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SUSTAINABLE ENGINEERING DEVELOPMENT (ICSED-2023)

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JUNE 2023

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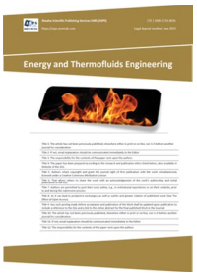

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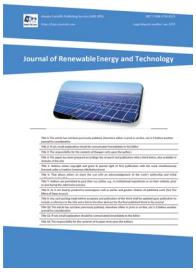

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Md Raisuddin Khan, PhD
Professor
Department of Mechatronics Engineering
International Islamic University Malaysia,
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Professor
Department of Civil Engineering
Indian Institute of Technology Delhi
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Cristian Birzer, PhD
Senior Lecturer
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Professor Md Raisuddin Khan received his B.Sc. degree in Mechanical Engineering from RUET in 1983. He received his M.Sc. and Ph.D. degrees in Mechanical Engineering from BUET in 1988 and 1996 respectively. More than twenty years, he is serving as a professor in the Department of Mechatronics Engineering at the International Islamic University Malaysia (IIUM). He has wide experience in designing and reviewing Mechatronics Engineering curricula of different universities in Malaysia and overseas. He had been the coordinator of the Autonomous Systems and Robotics Research Unit (ASRRU) of IIUM for more than five years. He also served as a member of the executive committee of the IEEE Robotic Automation Society (RAS) Malaysia chapter for several terms. His research interest covers robotics, smart devices, vibration, and stress analyses of structures. He received several awards from different national and international exhibitions for innovating different Mechatronics products. He has so far published more than seventy papers in different international journals and conferences. He is a life fellow of IEB and BSME and a Senior member of IEEE.

Prof Mittal has more than 30-Years leadership in education and research experience at the top national institutes like IIT Bombay, IIT Kanpur and IIT Delhi, and international universities like National University Singapore, INSA de Lyon France, Drexel University, USA, and ENPC Paris.

Led international projects in different broad areas of Environment and Climate involving partners from Europe, USA and Japan funded by international agencies European Commission, US Government, and Ministry of Education France government etc

Dr Cris Birzer is the Discipline Lead of Mechanical Engineering at the University of Adelaide and a Senior Lecturer in Sustainable Energy Engineering and Humanitarian Engineering within the School of Electrical and Mechanical Engineering.
He is a Chartered Professional Engineer, and former consultant engineer. Within the humanitarian/emergency sectors, Cris has worked in Australia for flood and bushfire response, as well as East Timor, Solomon Islands and Nepal in UN and UN-related operations.
Cris was a member of the Sustainability Strategy Steering Committee which recently launched the University of Adelaide Sustainability Strategy.

Invited Speakers



Hossein Ganjidoust, PhD
Professor
Faculty of Civil & Environmental Engineering
Tarbiat Modares University, Iran



Md Mahfujur Rahman, PhD
Senior Lecturer
Department of Muamalat and Halal Management
Islamic Businesses School
Universiti Utara Malaysia
Changloon, Kedah, Malaysia

Chief Patron's MESSAGE



It gives me immense pleasure and honour to act as the chief patron of the International Conference on Sustainable Engineering Development (ICSED-2023) organized by office of the Project Director, Further Development of Dhaka University of Engineering & Technology, Gazipur.

Sustainable engineering development is essential for the advancement of our global and local communities. It is expected that ICSED-2023 provides an ideal platform for engineering experts, researchers, students, and industry professionals to come together and share their expertise and insights.

The conference serves as a means to build a bridge between theory and practice by providing an interdisciplinary approach to advancing state-of-the-art technologies, educating practitioners and researchers on the latest techniques and developments, and ultimately pushing the boundaries of sustainable engineering for a better future.

We owe it to ourselves, to our planet, and to future generations to act responsibly and to strive towards developing emerging engineering systems that will help shape the future of our society. The conference will help us better understand the latest technologies and challenges, and bring together for collaboration of the many stakeholders across fields of research, industry, and policy. In my opinion, this conference will be crucial in addressing the many issues of the fourth industrial revolution, building a smart Bangladesh and implementing the Delta Plant.

All in all, the conference offered a truly comprehensive view while inspiring the attendees to come up with solid recommendations to tackle future challenges. I would like to take this opportunity to thank the keynote speakers; presenters and authors for their worthy contributions, and bless you all a fulfilling experience and very pleasant participation in ICSED-2023.

Prof. Dr. Md. Habibur Rahman
Vice Chancellor
Dhaka University of Engineering & Technology, Gazipur.

Patron's MESSAGE



It gives me great pleasure to be associated with the International Conference on Sustainable Engineering Development (ICSED-2023) organized by office of the Project Director, Further Development of Dhaka University of Engineering & Technology, Gazipur. Sustainability has become an important issue in the modern world and sustainable engineering solutions have become absolutely essential in order to address the challenges associated with sustainable development.

As a patron of the ICSED-2023, I am confident that the conference will serve as a valuable platform for researchers, academicians, industry professionals, and policymakers to come together, exchange ideas, insights, and experiences in the field of sustainable engineering, discuss the potential to innovate and leverage technology to promote sustainable engineering development. Through the collective efforts of all present, I aspire to see innovative solutions being developed that can lead to the sustainable development on a global level.

I wish for the success of this conference and I am excited to be part of the endeavor.

Prof. Dr. Mohammad Abdur Rashid
Pro-Vice-Chancellor
Professor, Department of Civil Engineering
Dhaka University of Engineering & Technology, Gazipur.

Conference Chair's MESSAGE



It is with great pleasure that I extend my warmest greetings and welcome you all to the International Conference on Sustainable Engineering Development (ICSED-2023). As the conference chair, I am honored to be part of this esteemed event and contribute to the advancement of sustainable engineering practices around the globe.

ICSED-2023 serves as a platform for researchers, academicians, industry professionals, and policymakers to come together and exchange ideas, insights, and experiences in the field of sustainable engineering. The conference aims to gather more than 50 researchers' in five research areas (but not limited to): Chemical Engineering, Food Engineering, Energy Engineering, Water & Environment Engineering, and Information & Communication Technology. The ICSED-2023 is a 2-day event intending to gather researchers, academics, scientists, students, industrial communities, and policymakers worldwide to present innovative research works and exchange ideas in their respective fields.

As the conference chair, my primary responsibility is to oversee the activities of the relevance committee and guide them properly to do it a successful event. I have overseen the submission and review process, working closely with our esteemed committee members and expert reviewers to ensure rigorous evaluation and selection of the papers. The conference has encompassed a wide range of topics related to sustainable engineering, including but not limited to renewable energy, environmental conservation, sustainable infrastructure, green technologies, and circular economy.

I encourage all authors/participants to actively engage in discussions, present their research findings, and contribute to the collective knowledge in sustainable engineering. Your valuable contributions will shape the future of our field and pave the way for a more sustainable and resilient world.

I would like to express my gratitude to the Ministry of Education, Bangladesh University Grant Commission, keynote speakers, invited speakers, organizing committee, different sub-committees, and sponsors for their support and dedication in making our conference, ICSED-2023, a successful event. Their unwavering commitment has been instrumental in bringing together this gathering of brilliant minds.

Lastly, I would like to thank all the authors/participants for their enthusiastic involvement and contribution to ICSED-2023. Together, let us embark on this intellectual journey, foster collaboration, and strive for a better future through sustainable engineering.

Wishing you all a fruitful and memorable conference.

Prof. Dr. Md. Showkat Osman
Project Director (FDDP)
Director, Planning & Development and Professor, Dept of Civil Engg
Dhaka University of Engineering & Technology, Gazipur.

Preface



It is with great pleasure and honour that I welcome you to the International Conference on Sustainable Engineering Development (ICSED-2023), organized by the Office of the Project Director "Further Development of Dhaka University of Engineering & Technology, Gazipur" Project DUET, Gazipur. This conference is aimed to bring together researchers, academics, scientists, students, industrial communities, and policymakers from around the world, mainly on five key research areas, namely Chemical Engineering, Food Engineering, Energy Engineering, Water and Environment Engineering, and Information & Communication Technology.

The primary objective of ICSED-2023 is to provide a dynamic platform for researchers and technical experts to share their recent ideas, innovations, and problem-solving techniques in the aforementioned areas. By gathering diverse perspectives, we aim to facilitate knowledge exchange, encourage collaboration, and drive advancements in sustainable engineering practices. I believe that sustainable development can only be achieved through the joint efforts of academia, industry, and policymakers, and ICSED-2023 serves as a catalyst for forging these crucial partnerships.

I extend my deepest welcome to all researchers and authors who have contributed to these proceedings. I genuinely believe that the research outputs presented here will undoubtedly contribute not only to the development of the scientific community but also to the wider public.

Prof. Dr. Mohammad Asaduzzaman Chowdhury
Chief Editor, Proceedings of ICSED-2023
Director, Research and Extension &
Professor, Department of Mechanical Engineering
Dhaka University of Engineering & Technology, Gazipur.

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Chemical Engineering

ICSED 2023

Paper ID: ICSED2023-002
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13-14 June 2023, DUET, Gazipur, Bangladesh

Removal of Toxic Methylene Blue from Aqueous Solution by Using High Performance Fish Scale Activated Carbon

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ABSTRACT

Methylene blue (MB) is a cationic dye that is commonly used in the food, textile, pharmaceutical, plastic, soap, cotton, and wool industries. These industries discharged the toxic dye-mixed wastewater throughout the production and processing stages at a high level, which has an adverse effect on the environment. In humans, long-term exposure to MB can result in vomiting, shock, abnormal body information, jaundice, and an elevated heart rate. For the removal of dyes from aquatic media, a variety of conventional techniques, including physical, chemical, and biological processes, have been employed. Adsorption is one of the physicochemical techniques that have been shown to be the easiest and most cost-effective for removing toxic dyes from effluents. The majority of recent studies have focused on agricultural byproducts such as fish scales, clay, agro-industrial biomass, and rice husks. Fish scales may be a nice contender. Every year throughout the world, large amounts of fish scales are thrown away as garbage. Fish scales mostly consist of protein and hydroxyapatite. Protein will act as the carbon supply during carbonization, and hydroxyapatite will act as a template to create a certain porosity shape. In this research, we utilized the porous carbon-based fish scale activated carbon as an adsorbent to remove the toxic organic dye MB and investigated its adsorption properties. Fish scale activated carbon (FSAC) was prepared from Hilsha hilsha fish scales by pyrolysis at 600 °C. The FSAC properties were characterized by FTIR, SEM, XRD, TGA, and DSC techniques. The adsorption experiments were conducted in batch mode. In this batch adsorption process, various experimental parameters such as dye concentration, pH, shaking time, and adsorbent doses were investigated. The adsorption of toxic MB on FSAC is pH-dependent and shows better results (almost 83% removal) at an acidic pH (pH-6). The MB adsorption process of FSAC was examined by the linear pseudo-first order (PFO), pseudo-second order (PSO), and intra-particle diffusion (IPD) models. Where the PSO model confirmed a better agreement with a high correlation coefficient ($R2 = 1$) for a 10 ppm MB solution. The Langmuir, Freundlich, and Temkin isotherm models were also investigated. A good enough correlation coefficient value ($R2 > 0.995$) proved that the isotherm parameters were perfectly fitted to the Langmuir and Freundlich model, and maximum multi-layer dye adsorption capacity (qmax) was obtained at 22.57 mg/g at 20°C, which is comparable with some other agriculture-based activated carbon absorbents reported before. The thermodynamic parameters revealed positive ($\Delta H°$) and negative ($\Delta G°$) values; which means the adsorption process is temperature-dependent and spontaneous in nature.

Keywords: Fish scale; Activated carbon; Adsorption; Isotherm; Kinetics.

ICSED 2023

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Study the Structural, Magnetic, and Electrical properties of nanocrystalline Mndoped Ni-Cu Ferrites

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ABSTRACT

In this research work, the Structural, Magnetic, and Electrical properties of nanocrystalline Mn-doped Ni-Cu ferrites (x = 0.0~0.4) have been investigated. With the rapid progress in science and technology, these types of materials are accepted as the most universal soft magnetic materials as it has interesting structural, electrical, and magnetic properties and their successful application in magnetic sensors, data storage, magnetic fluids, electronic communication, also in medical science: MRI cancer detection, and cancer therapy. Nanopowders are synthesized by the combustion method calcined at 950˚C. Compositions prepared from nanopowders are sintered at various temperatures. The Rietveld refinement of X-ray diffraction data confirms the single-phase formation with cubic spinel structure (Fd-3m space group). There is an increasing trend is observed in lattice parameters and crystallite size with Mn doping. The average crystallite size is calculated by W-H Equation (~8 to 66 nm). The optical microstructure stated that average grain size increases with Mn doping up to x=0.3, then it decreases. The initial permeability at 300 and 77 K with a high cut-off frequency (107 Hz) and relative quality factor increases with Mn doping and sintering temperature. On the other hand magnetic loss decreases with Mn doping and sintering temperature. The initial permeability and relative quality factor at 77 K are lower than 300 K. The observed variations in permeability and magnetic loss are accredited to the modification of density, porosity, grain size, and anisotropy contribution. The peak of Qmax and the cut-off frequency shift toward the lower frequency with sintering temperature and Mn doping. The Curie temperature decreases with the increase of Mn doping (maximum 858 K), due to the increase of lattice constant i.e., weakening of A-B interactions. The magnetization increases with the increase of Mn up to x = 0.3, then it decreases. It depends on cation redistributions, intragranular porosity, and the formation of spin canting at higher concentrations of Mn. The highest saturation magnetization value of 58 emu/g is obtained. The ac electrical conductivity embraced the universal law of Jonscher with large dispersion at higher frequencies and is regulated by the jumping of small polaron exchange interactions and charge transfer amid the nearest neighbor localized sites. The dielectric constant increases with Mn up to x = 0.3, then it decreases at 1MHz. The dielectric constant also increases with sintering temperature which is accounted for the partial reduction of Fe3+ to Fe2+ and exhibited dispersive behavior at low frequency as a result of Maxwell-Wagner-type interfacial polarization. Nyquist plot representation proclaims that the electrical conduction is ascribed to the contribution of
both grain and grain boundary effects. Finally, it is concluded that the Structural, Magnetic, and Electrical properties of these materials are appropriate for biomedical and different high-frequency electronic device applications.

Keywords: Nanocrystalline; Rietveld refinement; Nyquist plot; Curie temperature.

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Removal of Toxic Congo Red (CR) Dye by Sugarcane Bagasse Nanocellulose-TiO_2 Nanoparticles Composite from Aqueous Solution

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ABSTRACT

Globally, due to the rapid growth of urbanization, industrialization and population, there is an urgent need for clean water supplies. Enormous population expansion and the rapid development of industries, various pollutants, including heavy metals, organic/inorganic toxic dyes and chemicals are emitted into the air and water bodies. The presence of a small amount of dyes (< 1 ppm) is highly visible and needs to be removed before the wastewater is discharged into the environment. This study aims to synthesize and characterized a sugarcane bagasse-based composite material consisting of TiO_2 incorporated nano cellulose (TiO_2/NC) for effective degradation of an anionic dye congo red (CR) from wastewater. The process involved the extraction of nano cellulose (NC) from sugarcane bagasse (SB) and synthesizing TiO_2 nanoparticles (NP) from tetra isopropyl titanate (TIPT) via the reflux method. Subsequently, NC-NP composite material was produced by vigorously mixing NC and TiO_2 nanoparticles at room temperature for two hours. The morphology and surface chemistry of the adsorbent (SBNC-TiO_2 NPs composite) and the starting materials (NC and TiO_2 NPs) were analyzed using FTIR, SEM, TGA and XRD techniques while the adsorption was monitored by UV-visible spectroscopy. The feasibility of the adsorbent in the adsorption of congo red was also investigated by the impact of various factors including initial dye concentration, adsorbent dosage, contact time and pH. The results indicate that the optimal conditions for CR removal were achieved within 2 hours at 10 ppm initial dye concentration, 0.025 mg adsorbent dosage and at pH-2. It was found that the adsorption of CR dye on NC-NPs composites was considerably pH dependent. Nearly 98% elimination was found at highly acidic pH (pH-2) levels. The linear pseudo-first-order (PFO) and pseudo-second-order (PSO) models were used to investigate the CR dye adsorption process. The experimental data were fitted with Temkin isotherms with a correlation coefficient of (R^2 = 0.9108), followed by Freundlich and Langmuir isotherms with correlation coefficients of (R^2 = 0.9347) and (R^2 = 0.9958). By a sufficient correlation coefficient value (R^2> 0.9958) the isotherm parameters were definitively demonstrated to be completely suited to the Langmuir model. The existence of congo red monolayer adsorption on the homogeneous surface of nanocomposite is predicated by the superior fitting of Langmuir isotherms. The maximum adsorption capacity was found to be 88.49 mg/g at 20°C for NC-TiO_2 (NP) composite. According to the data, the pseudo-second-order (PSO) model's correlation coefficient (R^2 = 0.9999) is closer to unity (1.0) than the pseudo-first-order (PFO) model's correlation coefficient (R^2 = 0.9497). This suggests that congo red adsorption onto the surface of nanocomposite follows pseudo-second-order (PSO) kinetics models.

Keywords: Titanium oxide; Sugarcane bagasse; Photodegradation; Congo red dye; Kinetics; Isotherm.

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Performance Evaluation and Mechanism Analysis of Adsorption of MB Dye and Textile Wastewater by Powdered Activated Carbon

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ABSTRACT

The textile dyeing and washing industry plays an important role in the economical growth as well as the environmental sectors of Bangladesh. It has a high importance in terms of its environmental impact, since it consumes considerably high amounts of processed water and produces highly polluted discharge water in large amounts. Textile mills in Bangladesh are required to control their discharge and therefore have started treating textile wastewater. In this study, the treatment of dyeing wastewater by powdered activated carbon (PAC) was investigated to identify the suitable contact time and optimum dose. The wastewater samples were collected from a textile industry located in Gazipur. Wood based charcoal was used as activated carbon. From treatment of Methylene Blue (MB) Dye solution using different doses (0.01 to 0.025 g) of powdered activated carbon (PAC), 12 mg of PAC and 29 minute of contact time were determined for the decolorization of dye. In dose optimization analysis, from adsorption capacity versus dose graph we see that, when the doses of PAC was increased in MB Dye solution, removal of MB Dye also increases linearly up-to almost 12 mg of PAC. From 12 mg to 30 mg of PAC added in MB Dye solution, the graph is almost flat, that means, change of removal percentage is not significant. Because, PAC lost its efficiency due to pores of this PAC were blocked by MB dye. Also in contact time analysis, from removal efficiency versus dose graph we see that, when the contact time of PAC in MB Dye solution, removal of MB Dye also increases linearly up-to almost 29 minutes where a peak is observed. Because, PAC lost its efficiency due to pores of this PAC were blocked by MB dye. Maximum adsorption capacity found at 0.01 gm of PAC and 30 minutes contact time was 379.6 mg adsorbate/gm adsorbent. Also Maximum removal efficiency of MB dye solution found at 0.015 gm of PAC and at 30 minutes contact time was 96.95%. Then we performed a treatment of textile wastewater with the optimum doses of PAC and contact time found from the batch studies at different concentration to observe the removal efficiency of color, pH, turbidity, TDS and COD. The minimum and maximum removal efficiency were obtained 18.84% & 24.44% for Color, 9.68% & 17.11% for pH, 21.52% & 22.90% for Turbidity, 8.26% & 13.78% for Total dissolved solids (TDS), 18.66% & 33.33% for Total suspended solids (TSS) and 16.39% & 25.71% for Chemical Oxygen Demand (COD) respectively. It was observed that PAC has been quite effective to treat TSS, Turbidity, COD and Color. In adsorption isotherm & kinetics analysis, the R^2 values are considered as a measure of the goodness of fit of experimental data by isotherm models. Langmuir model usually means that the adsorption process may have a chemical character and Freundlich means it has a physical character. In adsorption isotherm analysis of the waste adsorption on the charcoal-based PAC analysis, the R^2 values were consistently > 0.8, with values of 0.9733 and 0.8899 for the Freundlich and Langmuir isotherms, respectively. From the R^2 values, the best fit is obtained using the Freundlich isotherm rather than the Langmuir isotherm. The value of R^2 obtained from the isotherm analysis is significant (0.9733) representing good fitness of this model for adsorption of MB dye onto PAC. In Adsorption kinetics analysis, the R^2 values were > 0.6, with values of 0.6851 and 0.6682 for the Adsorption Kinetics 1st order and 2nd order, respectively. From the R^2 values, the best fit is obtained using the Adsorption Kinetics 1st order rather than the adsorption kinetics 2nd order. Also the value of R^2 obtained from the kinetics analysis is significant (0.6851) representing good fitness of this model for adsorption of MB dye onto PAC.

Keywords: Adsorption; Powdered activated carbon; Wastewater; Isotherm; Kinetics.

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Synthesis of Schiff Base and Its Metal Complex for Biological Applications

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ABSTRACT

A Schiff base is a class of organic compounds that are widely used in the synthesis of metal complexes due to their unique properties, including their ability to coordinate with metal ions. Schiff bases are formed by the condensation of an aldehyde or ketone with a primary amine. The resulting compounds have a wide range of applications in fields such as catalysis, drug design, and material science. Metal complexes of Schiff bases are particularly interesting due to their potential as catalysts, sensors, and therapeutic agents. The metal ions in these complexes can influence the electronic and structural properties of the Schiff base ligand, leading to enhanced reactivity and selectivity in chemical reactions. In addition, metal complexes of Schiff bases can exhibit unique spectroscopic and magnetic properties, making them useful for a variety of analytical and diagnostic applications. The objective of this study was to synthesize a noble Schiff base metal complex and characterize its structure and properties. The Schiff base ligand was prepared by the condensation of 4-methoxyaniline with 4-(dimethylamino)benzaldehyde, and the resulting ligand was coordinated with lead (II) ion to form the metal complex. The synthesized complex was characterized using the analytical technique UV-Vis spectroscopy and Fourier transformed infrared (FTIR) spectroscopy. The results showed that the Schiff base ligand and the metal complex were successfully synthesized with a yield of 94.99% and 15.49%. The UV-Vis spectrum of the complex exhibited characteristic absorption peaks in the visible region, indicating the formation of a metal-ligand complex. FTIR analysis indicated that the Schiff base and coordination reaction takes place in the Schiff base skeleton. Moreover, with the difference in substituent groups and spacer, FTIR spectra showed a clear variety. Overall, the synthesis and characterization of this Schiff base metal complex represent an important step toward the design and synthesis of noble materials with unique properties and applications.

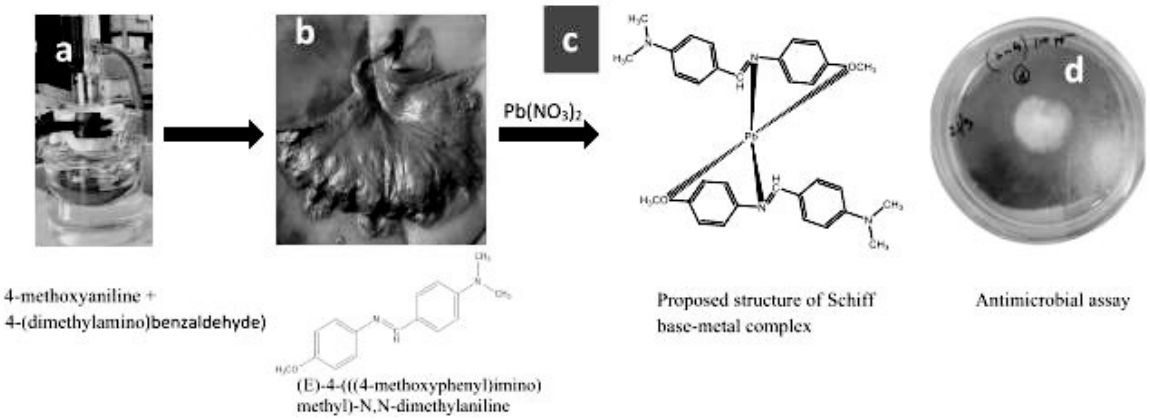

Fig. 1: Schiff base and it's metal complex

Synthesis of Schiff base ligand: A 25-mL ethanolic solution of 4-(dimethylamino)benzaldehyde (10 mmol) in a 100-mL two-neck round bottom flask was stirred for 20–30 min. 10–12 drops of sulfuric acid were added as a condensing agent. 10 mmol of 4-methoxyaniline (0.1091 g) dissolved in ethanol was added dropwise. The mixture was stirred for 6 h at 70–80°C. An orange precipitate (Fig. 1b) was generated in the solution. The precipitated ligand was filtered off, recrystallized from ethanol, and dried overnight at 60°C.

Synthesis of the Metal complex: The appropriate quantity of Schiff base ligand (0.197 mmol) was dissolved in 15 mL water and stirred for 15 min. To this solution was added dropwise a solution of $Pb(NO3)_2$ (0.394 mmol) dissolved in 10 mL distilled water. The mixture was refluxed for 6 h at 90–100°C. The reaction produced a white precipitate. The precipitated complex was then filtered off, washed with distilled water, and dried in the oven at 80°C for 4 h. For both reactions, TLC purity was tested, and reaction completeness was confirmed.

The well-known agar well diffusion method was employed for antimicrobial screening. The fungus *Sclerotium rolfsii* had been used for antimicrobial testing by well diffusion method in which potato dextrose agar (PDA) was the culture medium. Lactic acid incorporated PDA media was used as control. Each sample solution was mixed with sterile agar media before being placed into Petri-plates and allowed to solidify. The test solution was made by dissolving the compounds in water and KOH. The final concentration of samples in each petri-plate was 2.5 ppm for metal complex and 5.0 ppm for Schiff base. In each plate, a small circular piece of fungus was placed in the center of the plate by cutting with a sterile metallic borer as shown in the Fig. 1(d). The plates were incubated at 25°C for 72 hours to observe the growth of the fungus. Activity was determined by measuring the diameter of the zone showing inhibition (in mm). Growth of inhibition was compared with the control. The results showed that the metal complex exhibited enhanced antimicrobial activity compared to the free ligand.

The synthesized Schiff base and its metal complex were characterized using FTIR and UV-visible spectroscopic techniques. Water and KOH might dissolve the Schiff base chemical and its metal complex, respectively. The Schiff base produced a peak at 351.5 nm in UV-visible spectroscopy. To establish the involvement of functional groups in the generated Schiff base, FTIR spectra for Schiff base in the 4000-400 cm^{-1} wavenumber region were obtained. The distinctive peak of azomethine nitrogen (-CH = N-) was appear in the ligand's IR spectra at 1606.41 cm^{-1}. The Schiff base ligand also has visible IR peaks at 3380.6, 3276.47, 1507.1, 1264.11, and 1079.94 cm^{-1}. These peaks correspond to the -O-H, =N-H, C=C, and -N=O bands in the Schiff base ligand's phenolic, secondary amine, aromatic, and nitro groups.

In conclusion, the Schiff base ligand and its corresponding metal complex exhibited promising biological activities and can be further studied for their potential applications in medicinal and industrial fields. Further studies can also focus on improving the efficiency and selectivity of these compounds toward specific targets.

Keywords: Schiff base; Metal complex; Synthesis; Antimicrobial activity.

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Imine Synthesis and Its Metal Complex: An Application as Antimicrobial Agent

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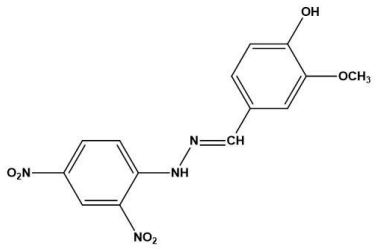
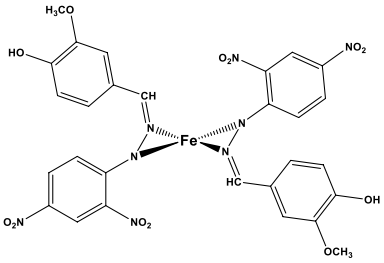
ABSTRACT

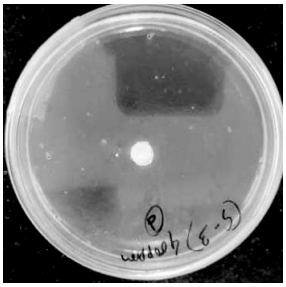
Imines are incredibly important to both humans and the environment due to their diverse range of biological and chemical properties. The general structural features of Imines comprise a carbon-nitrogen double bond (>C=N-) in their structure. Imines can be synthesized from the condensation reaction of carbonyl compounds with primary amines. Imines can also act as ligands which are called chelating agents in coordination complexes, forming stable chelates with transition metal ions. Imines play a significant role in the synthesis of organic compounds due to their widespread use (As a precursor in organic synthesis). It is also being utilized as pigment, dye, catalyst, and supercapacitor. One of the important properties of imines and their metal complexes is antimicrobial activity. They show anti-viral activity as well. An imine ligand named (E)-4-((2-(2,4-dinitrophenyl)hydrazineylidene)methyl)-2-methoxyphenol was prepared by the condensation reaction of (2,4-dinitrophenyl)hydrazine as an amine and 4-hydroxy-3-methoxybenzaldehyde as an aldehyde. Iron (II) ion and ligand were coordinated to create its metal complex. Spectroscopic and chromatographic techniques were used to characterize the synthesized imine and the metal complex. The yield of this imine and its metal complex is 31.05% & 31.97%. The synthesized ligand and the complex were shown to have antimicrobial activities against a fungal species (*Sclerotium rolfsii*).



Scheme 1 (a). Imine (E)-4-((2-(2,4-dinitrophenyl) hydrazineylidene)methyl)-2-methoxyphenol



Scheme 1 (b). Proposed structure of Imine-metal complex



Scheme 1(c). Antifungal activity assay (growth after 72 hours)

Synthesis of 1(a): In a 100 mL 2-neck round-bottom (RB) flask, 2,4-dinitrophenyl hydrazine (0.3 mmol, 0.0594 g, 1.0 eqv.) was dissolved in 60 mL ethanol solvent and stir for 1h. Hydrochloric acid (2-3 mL) was used as catalyst. 4-hydroxy-3-methoxybenzaldehyde (0.3 mmol; 0.456g, 1.0 eqv.) was mixed to the mixture. Then the resultant mixture was stirred for 45 minutes at room temperature. A red color precipitate (ppt) was obtained which was checked on Thin Layer Chromatographic (TLC) plate. TLC analysis showed the presence of one spot (1(a), R_f = 0.49, in solvent mixture ratio of n-Hexane/AcOEt = 3:2). The ppt was filtered and washed with ethanol solvent several times to remove the impurities. The red color ppt was dried at 60°C for over night.

Synthesis of 1(b): To form complex of the ligand with transition metal, 0.09 mmol, 0.0300g, 1.0 eqv. of the ligand 1(a) was dissolved in a 100 mL 2-neck RB flask in 50 mL ethanol solvent with the aid of a stirrer for 45 minutes at a temperature of 70°C. Freshly prepared aqueous $FeSO_4$ solution (dissolved in 15 mL of distilled water (0.18 mmol, 0.0279 g, 2 eqv.) was then gradually added to the RB flask. The resulting mixture was refluxed for 6 hours at 70–80°C temperature. The precipitate in red hue was achieved and was examined by TLC. One of the two spots identified by the TLC study was visible to the unassisted eye (1b, R_f = 0; 1a, R_f = 0.49, n-Hexane/AcOEt = 3:2). The reaction mixture was filtered and cleaned multiple times with ethanol solvent. Finally, red color precipitate on filter paper after wash was dried into an oven at 60°C, overnight.

Antifungal assay 1(c): Antifungal activity was demonstrated by *in vitro* agar well diffusion method. *Sclerotium rolfsii*, a fungus isolated from barley roots was imployed to evaluate anti-fungal activity. In this method, potato dextrose agar (PDA) was used as culture medium. All media and reagents were sterilize by autoclave before inclusion of microbe.

Final concentration of each sample in the PDA media would be 5.0 ppm and 10.0 ppm (0.5 mL of 200 ppm & 400 ppm sample added into 20.0 mL PDA media in each petridish). And, control petridish contained PDA media with lactic acid. The fungus retained in the center of each petridish (Scheme 1(c)) for culture in the incubator at 25°C for 72 hours until the control petridish was fully covered by the fungus. The diameter of the petridish is 90 mm. The growth was observed and measured in millimeter scale on 24 hours interval.

FTIR and UV-visible spectroscopy methods were used to characterize the produced imine ligand and its metal complex. Dichloromethane was capable of dissolving the imine compound and its metal complex. Under UV-visible spectroscopy, the Imine molecule showed a λ_{max} of 392.5 nm. To determine the role of functional groups in the produced imine, FTIR spectra for imines in the wavenumber range of 4000-400 cm^{-1} were taken. In the IR spectra of the imine ligand, the characteristic peak of azomethine nitrogen (-CH = N-) was discernible at 1603.52 cm^{-1}. There were also noticeable IR peaks for the imine ligand at 3374.82, 3275.5, 1505.17, and 1263.15 cm^{-1}. These peaks correlate to the phenolic -O-H, secondary amine =N-H, aromatic C=C, and nitro N=O groups in the imine ligand.

Finally, the synthesis and characterisation of the imine ligand and metal complex have yielded promising results in terms of antifungal activity. UV spectra of ligand and metal complex show distinctive absorption bands indicating the existence of metal -ligand coordination. The existence of new bands corresponding to metal-ligand vibrations in the FTIR spectrum also gives evidence for ligand coordination to the metal ion. These findings suggest that the imine ligand and its metal complex could be used as antibacterial agents in the future. Last but not least, NMR spectroscopy and biological testing are required to properly grasp their structure and potential as medications.

Keywords: Imine; Metal complex; Spectroscopy; Antifungal activity.

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Waterless Chemical Effect on Indigo Dyeing with Cost Saving

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ABSTRACT

Life is dependent upon water. Several thousand liters of water are required to produce a single pair of jeans. Under the guise of "waterless dyeing" or "zero water denim," a number of compounds have been produced for indigo and sulfur dyeing. But for a variety of reasons, such as cost, shade, and colorfastness concerns, dyers are not implementing the new approach. In this study, the author used a waterless indigo/sulfur dyeing chemical called Premaclean WF-I to color a batch of cotton yarn into ropes. Following dyeing, colorfastness is evaluated, and the cost of dyeing is assessed. The outcome demonstrates that denim factories may conserve 60% freshwater during the indigo rope dyeing stage with just a 7.5% FOB negotiation. As a result, this study will serve as a guidance for dyers who are uncertain about implementing eco-friendly dyeing of denim warp yarn.

Keywords: Denim fabric; Rope dyeing; Indigo dyeing; Waterless dyeing; Eco-friendly dyeing; Sustainability.

1. INTRODUCTION

For Bangladesh, the most promising sector is ready-made clothing (RMG). Since 2009, the industry has ranked as the world's second-largest exporter of RMGs, just behind China [1]. Customers in exporting nations are responding favorably to Bangladeshi products, and as a result, they are becoming more likely to look for the "Made in Bangladesh" label. Now that there are over 3,000 RMG units, more than 100 nations and about 150 international apparel brands use knit and woven products that are labeled "Made in Bangladesh," generating export revenues of USD 32 billion [2].

A stylish woven unisex garment for all ages is denim. Because of their comfort, fashion, and functionality, jeans are becoming increasingly popular on a global scale. Global sales of jeans were estimated to be at USD 66.02 billion in 2018 and are projected to increase to USD 85.4 billion by 2025, with a CAGR of almost 3.7% between 2019 and 2025[3]. In the 2018–2019 fiscal year, Bangladesh alone exported denim goods worth USD 2.22 billion to the EU and the USA. (Data source: Eurostat and Otexa, compiled by TextileToday). In actuality, Bangladesh is the third-largest exporter of denim apparel to the USA and the primary supplier of denim apparel to the European market. Having a sizable denim market, there is a huge chance and potential to receive a good order from customers in the United States.

A cotton warp prominent twill fabric called denim has weft threads that are positioned below two or more warp strands [4]. Warping, dyeing, sizing, weaving, finishing, and inspection are typical processes used in the manufacture of denim fabrics. In contrast to denim and other woven fabrics, warp yarns are coloured when warping completed. At first, ring-spun (RS) yarns were used for all types of denim, but in the 1970s, open-end (OE) yarn, produced quickly and at a lower cost, supplanted ring yarns for denim [5]. The warp yarns for denim fabrics are typically thicker than other woven fabrics and made of 100% cotton. Depending on the dyeing machine or procedure, there are two forms of warping: ball with beam warping. Then it is ready for dyed, whether in sheet or rope form, using indigo or sulfur dyes. After that, sizing, weaving, and finishing are completed.

In an appropriate dyeing machine, color is absorbed into fibrous goods in various forms, such as loose fiber, yarn, fabric, and nonwoven, during the wet textile processing process known as dyeing [6]. There are two sorts of coloring materials: dyes and pigments. Seven different types of dyes can be categorized based on how they are used: direct, acid, basic, reactive, vat, disperse, and azoic dyes. Pigments are insoluble coloring materials that are often affixed to the fabric during the printing process with the aid of a binder. A textile that has been dyed or printed must maintain sufficient color fastness while being used. Fiber, yarn, and solid fabric dyeing are all done in the textile industry of Bangladesh. Because reactive dyes have excellent colorfastness, non-denim cotton woven products are typically dyed with them here.

The name "vat dyes" refers to colored substances that are insoluble in water since historically, wooden pots or vats were used to dye textile materials with indigo, the first hue to be connected with this king of colors [7]. It takes two steps of reaction to make this dye soluble. First, use sodium hydrosulphide to convert vat dye into leuco vat dye. Leuco vat dye is then neutralized with caustic soda to produce a soluble sodium salt of the dye. After dying, oxidation is required to transform the sodium salt of leuco vat dye back into the original, water-insoluble vat dye. Alkali and unoxidized leuco chemicals can typically be removed following oxidation by rinsing at room temperature in 2/3 rinsing baths [5].

Because it technically requires a lot of water flow in wash tubs, dyeing traditional rope uses a lot of water. Caustic soda and other auxiliaries are entirely rinsed out of the substrate in pre-wash boxes. Continuous rinsing hastens the temperature decline and gets the substrate ready for room-temperature indigo dyeing. For the proper removal of unfix dyes and chemicals from the surface of dyed yarn, post-wash boxes need to have a continual flow of water.

All wash boxes (6) require a flow of water of approximately 75 L/min, therefore 450 L/min is required overall when dying. According to a Greenpeace estimate, it takes 1.7 million tons of chemicals and up to 7,000 liters of water to produce two billion pairs of jeans trousers annually [8]. Larger volumes of chemically loaded effluents, particularly excess sodium dithionite, unfixed indigo dye, and their byproducts, result from the consumption of huge amounts of chemicals and freshwater [9].

The attempts to lessen the impact of denim manufacturing on the environment have been important during the past fifteen years [10], since it is one of the most water-intensive processes in the world. There are numerous suggestions made to denim manufacturers today, including organic denim, less harmful indigo dyeing and washing, zero water methods, oxygen and ozone washing, reuse procedures, sustainable projects, and more [11]. The majority of earlier research has focused on denim finishing techniques that are applied to finished garments but have no real-world use. Among the famous waterless finishing techniques are ozone fading and laser fading in place of bleaching or pumice stone washing. In contrast to common procedures of fading based on stone, bleaching powder, and enzymes that cause a loss of ripping and tensile strength in thicker zones as well as visible stone spots [12], it (ozone) fades garments and offers enormous savings in water and chemicals. In comparison, laser technologies are quicker, simpler, more accurate, and nearly waterless [13].

Water conservation and recycling initiatives are likely to have a significant impact because they will lower the cost of water purchased and the cost of the effluent treatment plant, freeing up funds for plant expansion or process and equipment upgrades that will enable higher quality [14]. Additionally, many zero water enzymes, bleaching, and softening chemicals are produced by different chemical firms, but they are hardly ever used because of their prohibitive cost.

2. MATERIALS AND METHOD

2.1 Materials

From the creel, 320 ends of 6s Ne 100% cotton ring-spun yarn are taken to form rope or continuous strands. The Chinese Smartec rope dyeing machine dyes a group of 24 ropes in total. The material's estimated weight is 1530 kg, and the set length was 2000 meters.

2.2 Chemicals

Proser Chemicals, Adana, Turkey-based Proser WP (Surface active agent) and Premaclean WF-I (polymeric dye-fixing agent) chemicals are utilized in this investigation. In addition, acetic acid, caustic soda, hydrose, wetting agents, sequestering agents, and pure indigo dye are employed.

2.3 Traditional way of dyeing

There are primarily two types of continuous denim warp yarn dying machines in Bangladeshi denim industries: slasher and rope. Slasher or sheet dyeing is the term used when yarns are introduced into the dyeing vat in the form of sheets. Rope dyeing, on the other hand, refers to the device that feeds the yarn in rope form into the dye box. A rope dying machine is employed in this investigation. The following stages are used to continually color a rope made of 300 to 400 yarns: Pretreatment, prewashing, indigo dipping, and postwashing are the first four steps [9]. Materials are first fed into a pre-treatment bath where they are treated at 75–80°C with caustic soda, a wetting agent, and a sequestering agent.

Pre-wetting recipe:

NaOH -135g/L
Wetting Agent -15g/L
Seq. Agent -1.5g/L

The next three washes—cold wash, heated wash, and hot wash—follow by passing ropes through pre-wash boxes. The stock vat, Hydrose, Caustic Soda, Wetting agent, and Sequestering Agent are all included in the middle set of six to eight boxes containing dye liquor. The indigo dye is often combined with 0.7-0.8 times the amount of caustic soda (solid) and 0.8-0.9 times the amount of sodium hydrosulfite to make the stock vat [15]. Then, for 20 to 30 seconds, ropes are passed through a dye bath containing dye liquor at a speed of around 25 m/min.

Indigo dyeing recipe:

Indigo (6.21%) -4 g/L
NaOH -4g/L
Hydrose -1.6g/L
pH -11
Temp (°C) -26
Dip to Nip -32 sec
Oxidation -125 sec

Then, with the aid of skying rollers, compressed ropes are oxidized by ambient oxygen for around two minutes. For all dye boxes, this immersion-squeezing-skying remained constant. More leuco indigo is soaked into each box, followed by air oxidation, which builds up indigo color gradually on the fiber surfaces [5]. To maintain dye bath concentration, continuous feeding of the mother solution and automatic recirculation according to substrate weight are required. The dyed rope is then given three hot washes in a row to have it washed out and unfix the dyes.

2.4 Eco-friendly process of dyeing

In this works, two compounds from Proser compounds in Adana, Turkey, are utilized to create a novel coloring method. The goal of this experiment was to decrease number of wash boxes and stop the constant flow of water into wash boxes. This is accomplished through the pre-wetting at room temperature using only 6 g/L of the Prosind WP anionic surface-active agent.

Pre-wetting with prosind WP recipe:

Prosind WP - 6g/L
Temp (°C) - At room temp
Dip to Nip - 36 sec

Prosind WP guarantees quick de-aeration of yarns with Indigo dyeing at rope/ loop/ slasher system, with wound packages at lengthy dye liquors, and encourages penetration of the material by the liquor due to its low/zero foam production and good wetting action [16]. There is no need for a pre-wash because caustic soda is not utilized. The Premaclean WF-I reaction in an acidic bath is then performed after the Indigo penetration. Premaclean WF-I is a multipurpose polymeric product for sulfur and indigo dyeing. It physically takes the shape of a lengthy polymer shield or chain that produces a ring form of resin effects that inhibits numerous dyestuffs and speeds up the unique ring dyeing characteristics [17]. Without doing a post-wash, the colored substrate is collected.

Premaclean WF- I reaction recipe:

Premaclean WF- I - 16 g/L
Acetic acid - 11 g/L
Temp (°C) - 80°C

2.5 Dyed fabric colorfastness evaluation

2.5.1 Process of colorfastness to washing

The ISO 105 C06 technique is used to determine colorfastness to washing. A 10 cm × 4 cm piece of specimen and multifiber is cut out and stitched. Distilled water with sodium perborate, and ECE phosphate detergent are the ingredients used to make washing liquor. Then, according to the procedure, the sewed specimen is placed in a can along with 160mL of liquor and 26 steel balls and washed for 42 minutes at 55°C. After drying fastness is evaluated using greyscale.

2.5.2 Process of olorfastness to water

The ISO 105 E01 technique is used to assess colorfastness to water. A 10 cm × 4 cm piece of specimen and multifiber is cut out and stitched. The stitched specimen is placed into acrylic slides after being moistened with distilled water. Then, it is stored in a perspirometer with a dead load of 12.5 kpa. It is then stored for 4 hours at 37°C in the oven. Following drying, fastness is evaluated.

2.5.3 Process of colorfastness to perspiration

Using the ISO 105 E04 technique, colorfastness to perspiration (acid/alkali) is evaluated. Sodium dihydrogen phosphate, sodium chloride, L-Histidine monohydrochloride monohydrate and distilled water are used to create the acidic solution. Disodium hydrogen phosphate, L-Histidine monohydrochloride monohydrate, sodium chloride, and distilled water are used to create an alkaline solution. The solution is then applied to two specimens, each measuring 10 cm × 4 cm and wrapped with multifiber, and they are then placed into acrylic slides and subjected to a 12.5 kph load in the perspirometer. It is then stored for 3 hours at 36°C in the oven. After drying, the fastness of acidic and alkaline solutions is evaluated individually.

2.5.4 Process of colorfastness to rubbing

Using a common rubbing machine, the ISO 105 X12 technique evaluates colorfastness to water. The specimens are first cut. One is scrubbed for 10 strokes with a dry rubbing cloth, and the other for 10 strokes with a wet (100 percent water) rubbing cloth. The speed is then rated after being evaluated in greyscale.

3. RESULTS AND DISCUSSION

3.1 Comparison of color fastness

Table 1 below which is showing the results of the dyed sample colorfastness test.. All kinds of fastness tests have improved, it can be noticed. It unmistakably shows that the new dyeing procedure results in greater dye fixation to the substrate. While post-washing removes 16-20% of the colors used in conventional rope dyeing.

Table 1: Colorfastness test results of both dyed samples

SL. No.	Test for Colorfastness	Result			
		Conventional Dyeing		Eco-friendly Dyeing	
		Color Change	Color Staining	Color Change	Color Staining
1	Color Fastness to Washing	3/4	3	5	4/5
2	Color Fastness to Water	3	3/4	3.5/4	4/5
3	Color Fastness to Perspiration (Acid)	3	3	3.5/4	4/5
4	Color Fastness to Perspiration (Alkali)	3	3	4/5	4/5
5	Color Fastness to Rubbing (Dry)	2/3		3	
6	Color Fastness to Rubbing (Wet)	1/2		2/3	

3.2 Comparison of water consumption

As a result, during eco-friendly dyeing, six wash boxes were skipped, saving a sizable amount of water. The machine's set length was 2000 meters, and it ran at a speed of 25 meters per minute. 80 minutes of operation allowed the machine to save 6000 liters of water per rinse nozzle at the time of eco-friendly dyeing. Table 2 details how much water is used throughout each stage of the two forms of dyeing. After computation, it is discovered that the entire set of eco-friendly dyeing results in a 63% reduction in water usage.

Saving water in eco-friendly dyeing (refer Table 2):

$$(W_{Ct} - W_{Ce})/ W_{Ct} \times 100 = (72600-27400)/72600\times100= 63\%$$

where W_{Ct} water consumption in traditional dyeing and W_{Ce} water consumption in eco-friendly dyeing

Table 2: Water consumption of various steps Traditional and conventional dyeing

Process	Traditional Dyeing (Liter)	Ecofriendly Dyeing (Liter)
Pre-Wetting	2800	2800
Pre-Wash	22400	0
Dyeing	25000	23500
Post-Wash	22400	0
Premaclean Reaction	0	1100
Total	72600 Liter	27400 Liter

3.3 Comparison of ETP cost

Eco-friendly dyeing uses 60% less water, which also means that dyeing mills' effluent loads are 60% lower. (Table 3). As a result, denim fabric has a cost advantage per meter. (Table 3).

Table 3: Comparison of ETP cost per meter of fabric

Process	Total ETP cost (USD)	ETP cost per meter (USD)
Conventional	61.5	0.0308
Eco-friendly dyeing	24.5	0.0121

3.4 Comparison of chemical cost

There was a modest increase in chemical cost as a result of the addition of two additional chemicals to the environmentally friendly dyeing process. The breakdown of chemical use across the board is seen in Table 4. The new method of dyeing rope will result in a 22% increase in chemical cost, however when labor, time, and effluent treatment costs are taken into account, the overall dyeing cost increase is extremely little.

Table 4: Chemical cost of dyeing

Process are	Chemical Cost total (USD)	Chemical cost per meter (USD)
Traditional	597.36	0.29
Eco-friendly dyeing	731.567	0.36

4. CONCLUSION

The main purpose of this paper is to save the water and our environment both economically and environmentally. A standard indigo dyeing procedure uses about 150 liters of water per kg of fabric. A typical pair of men's pants weighs between 1.5 and 2 kilograms. The majority of Bangladeshi textile mills use drinkable subterranean water for dyeing. This study shows that a pair of jeans can save 135 to 180 liters of water. The colorfastness test results for fabric that has been colored sustainably are positive. Indigo and sulfur coloring both regularly cause colorfastness issues for denim manufacturers. Consequently, adopting innovative dyes will benefit dyers.

According to the calculations, using eco-friendly dyes will result in a 16% price rise for fabrics. However, the FOB price of a pair of jeans includes the costs of the shell fabric, pocketing fabric, trims and accessories, washing, CM, and other costs. Approximately 48% of the overall cost is made up of fabric costs .As a result, a pair of jeans with a FOB price of USD 8.00 will now cost USD 9.70, an increase of 8.6%.

Environmental risks, sustainability, a sustainable supply chain with corporate social responsibility are topics that the new generation of customers is well-aware of. Retailers are increasingly focusing on producing sustainable clothing as a result. Therefore, a sustainable apparel business could benefit from using an eco-friendly dyeing procedure.

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Evaluating the Concentration of a Solute in an Aquifer Using the Finite Element Technique

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ABSTRACT

The goal of this study is to establish the solute concentration in an aquifer with a lenticular form that is surrounded by porous material with a high fluid permeability. We obtain the Helmholtz equation by assuming appropriate change in the independent and dependent variables in the advective diffusive equation. We used the finite element approach to solve the Helmholtz equation and obtained the solute concentration at several fixed locations inside the aquifer domain. Finally, we obtain an approximate expression in terms of the independent variables using these values. We may determine the solute concentration at every location in the problem domain by using these functional approximations. We mostly employed eight and nine-noded quadrilateral elements while utilizing the finite element method. More nodal values of the solution are obtained in nine-noded elements than eight-noded elements and these approximate values are used to find the solution expression. We compared the results to the precise solution, we found that the nine-noded element produced better results than the eight-noded one.

Keywords: Fick's law; Helmholtz Equation; Convective-diffusive transport equation; Galerkin Equation; Finite Element Method.

1. INTRODUCTION

One of the most crucial elements in our ecosystem is ground water, which is extracted at a pace of roughly 600-700 km^3/year[1]. Globally, the dwindling aquifer water levels and salt intrusion in coastal aquifers are of great concern[2], [3]. Coastal aquifers is a transition zone where oceanic seawater and continental freshwater are able to combine. The position and stability of these transition zones are significantly impacted by the hydrogeological characteristics of the aquifer [4]. Salinity-rich groundwater has been utilized as an alternate source of saltwater for reverse osmosis desalination in Oman, Spain, Saudi Arabia, Turks and Caicos, and other countries[5]. Ground penetrating radar, hand samples, hydraulic parameters show us the great variety in the shallow aquifer's characteristics[6]. A. van Geen et al. [7] showed that the relation between the dissolved and P-extractable Arsenic concentration in Vietnam's and Nepal's shallow aquifers does not coincide with that of Bangladesh. Ayers et al.[8] took samples of ground water from tubewells in southwest Bangladesh to determine the sources of dissolved salt and arsenic. The water compositions of the tidal channel and the shrimp pond are identical throughout the dry season, however starting July, shrimp ponds are more salinated than tidal channels. So, Dietrich and Ayers [9] recommended restricting irrigation through tidal waterways in July. A range of simulation models for groundwater flow and transport have been used to build simulation-optimization models[10]. Har proposed several mathematical and physical models of groundwater, including Hele-shaw, sand tanks, analog electric models, and analytical and numerical models[11]. The Birma region's quaternary aquifer [12] is particularly sensitive to contamination and MODFLOW and MT3DMS algorithms based on finite difference method were used to determine the pollutants concentration in that region. In [13], it is assumed that the saturated aquifer has a consistent flow that is parallel to the x_*-axis. The fluid in the environment is represented by a fluid bath that contains different salt concentrations. This condition can arise close to a subterranean freshwater spring when clay-based soil is jammed between salt-containing gravely sand layers. The flow field is largely homogeneous in long, relatively thin aquifers that are situated deep underneath the partial saturation zone. The challenge is to calculate the equivalent solute distribution through the aquifer using the given quantities of solutes present in the immediate environment. On the assumption that Fick's law[14] holds true, the convective-diffusive transport equation regulates the steady solute concentration in the porous medium.

The advective diffusive transport equation is changed into a Helmholtz equation. Using the finite element approach[15], we resolve the Helmholtz problem. Lagrange's polynomial defines the aquifer boundary in the coordinate system. The top and bottom broders' concentration profiles range from zero to a maximum concentration of one. The lenticular-shaped domain is divided into a finite number of components. Each of them has a matching shape function and may contain several

nodes, such as three, four, eight, or nine. The estimated solution for each element is obtained by adding the product of the nodal values and the appropriate shape function. Each node has a global node number allocated to it, and we also give each node a local node number for each element. Using a modified Galerkin approach, we formulate the boundary value problem. We obtain an equation for each element by integrating the fundamental Galerkin equation over it. We establish relationships between the global and local node numbers for each element as well as between the roof function and the shape function. We define the approximation in terms of roof functions for the entire domain. Demonstrating the corresponding element matrix components we formulate the overall matrix components. Each integral is evaluated, and for this specific issue, this is often done numerically. We solve the resultant system of equations for the unidentified nodal values after imposing the boundary constraints. We obtain an expression for the solution using the nodal values. Every point's concentration may be obtained by entering its coordinates into the solution equation. By assuming a separable solution in the form of the product of two functions of x and y independently, this issue may also be resolved analytically. We have compared the analytical approach with our finite element solution. Essentially, the analytical solution is a series solution, and typically, the quality of the solution improves as the number of terms increases. We have only used six eight and nine-noded elements in our process, and we have demonstrated that the nine-noded element produces better results than the eight-noded ones. In the lenticular domain, we visually and mathematically compared the solution along a number of lines.

The goals and context of our effort have previously been stated. The exact translation of the advective diffusive equation to the Helmholtz equation will be demonstrated in the following section, together with a clear statement of the boundary value problem to be solved. Then, we will carry out the BVP's finite element formulation and display the decomposed domain figures. Finally the comparison of the exact and approximate solutions will be displayed visually and in tables.

2. FORMULATION

The steady convective-diffusive transport equation [13] is used to simulate the concentration of the solute $C(x_*, y_*)(0 \le C(x_*, y_*) \le 1)$ in the porous medium according to Fick's law:

$$\frac{\partial}{\partial x_*}\left[D_{x_*}\frac{\partial C}{\partial x_*}\right]+\frac{\partial}{\partial y_*}\left[D_{y_*}\frac{\partial C}{\partial y_*}\right]-u_*\frac{\partial C}{\partial x_*}=0 \quad (1)$$

where u_* represents the (constant) pore velocity, and the dispersivities D_{x_*}, D_{y_*} are defined as

$$D_{x_*}=d_{x_*}u_*,\ D_{y_*}=d_{y_*}u_* \quad (2)$$

The constant terms d_{x_*} and d_{y_*} rely on the properties of the soil. Along the top boundary $y_* = f_*^t(x_*)$ the concentration of the solute is given by

$$C(x_*, f_*^t(x_*)) = h_*^t(x_*) \quad (3)$$

Along the bottom boundary $y_* = f_*^b(x_*)$ the concentration of the solute is given by

$$C(x_*, f_*^b(x_*)) = h_*^b(x_*) \quad (4)$$

Independent variables are transformed as follows to get a Helmholtz equation:

$$x_* = \sqrt{D_{x_*}}(x-r), y_* = \sqrt{D_{y_*}}y \quad (5)$$

this results in the transformation of the dependent variable: $C(x,y) = e^{\frac{1}{2\sqrt{D_{x_*}}}u_*(x-\bar{x})}u(x,y)$ (6)

where $\bar{x}$ is an unspecified constant. As a result of these modifications, the controlling PDE becomes,

$$\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}-k^2u=0 \quad (7)$$

Where $k=\frac{1}{2\sqrt{D_{x_*}}}$. The boundary conditions become

$$u\left(x, f^t(x,y)\right) = e^{-k(x-\bar{x})}h_*^t(x_*) = h^t(x) \quad (8)$$

$$u\left(x, f^b(x,y)\right) = e^{-k(x-\bar{x})}h_*^b(x_*) = h^b(x) \quad (9)$$

Where $f_*^t(x_*) = \sqrt{D_{y_*}}f^t(x)$, $f_*^b(x_*) = \sqrt{D_{y_*}}f^b(x)$

The boundary of the aquifer in the (x,y) coordinate system is defined by Lagrange interpolation. We have used three points (2, 0), (4.5, 0.5), (5, 0) to determine the upper curve $f^t(x)$ another three points (2, 0), (2.5,1), (5, 0) to determine the lower curve $f^b(x)$. It is advised in [13] to use $r = 2.0$ and $l = 7 (= r + s)$ to get decent results. We used exponential term to transform the dependent variable and $\bar{x}$ was chosen as $\frac{1}{2}(r+s)$ to reduce the error. The solute concentration along the upper and lower boundaries changes from zero at $x = r$, up to one at $x = s$ and are defined as

$$C\left(x, f^t(x)\right) = \left(\frac{x-r}{s-r}\right)^3,\ C\left(x, f^b(x)\right) = \frac{x-r}{s-r} \quad (10)$$

Lagrange interpolation gives the top and the bottom boundary as

$$f^t(x) = -\frac{1}{5}(2x-4)(x-5),\ f^b(x) = \frac{2}{5}(2x-4)(x-5) \quad (11)$$

In [13], the problem was analytically solved for k=0.5, 1, and 2, and in this study, we use the wave number k = 1 to solve the problem numerically. Then we have to solve the following boundary value problem

$$\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}-u=0 \qquad (12)$$

with respect to the boundary conditions

$$u\left(x, f^t(x)\right)=e^{-(x-3.5)}\left(\frac{x-2}{3}\right)^3$$

$$(13)\, u\left(x, f^b(x)\right)=e^{-(x-3.5)}\,\frac{x-2}{3} \qquad (14)$$

over the domain of the following Fig.1.

The true solution $u(x,y)$ will be approximated by

$$\tilde{u}(x,y)=\sum_{i=1}^{n}\tilde{u}_i^{[e]}L_i(\xi,\eta) \qquad (15)$$

in which $x=\sum_{i=1}^{n}\tilde{x}_i^{[e]}L_i(\xi,\eta)$, $y=\sum_{i=1}^{n}\tilde{y}_i^{[e]}L_i(\xi,\eta)$ where $L_i(\xi,\eta)$ are the shape functions for standard element.

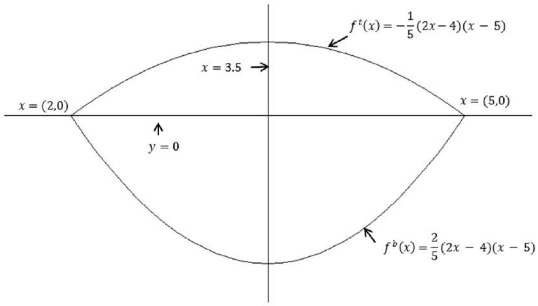

Fig. 1: Cross section of the aquifer

Putting equation (15) in equation (12) we get from Galerkin standard equation

$$\sum_{i=1}^{n}\tilde{u}_i^{[e]}\iint_A\left\{\frac{\partial L_i}{\partial x}\frac{\partial L_j}{\partial x}+\frac{\partial L_i}{\partial y}\frac{\partial L_j}{\partial y}+L_iL_j\right\}dxdy=0$$

$$j=1,2,\ldots,m \qquad (16)$$

Here we imagined that we have m standard n-noded elements. For each element we have an n linear equations in n unknowns and have m such system of equations. Let there are p nodes in the entire domain then after assembling the m systems we have a system of p equations in p unknowns. Solving this system we get the nodal values of the solution and using these in the expression we can get the approximate solution values at any point in the aquifer geometry.

3. NUMERICAL RESULTS

We have decomposed the domain into eight-noded and nine-noded quadrilateral elements as shown in the following Fig.2 and Fig.3. We have shown the graphs of the solution along a straight line at $y=0$ for $3.5\le x\le 5$ as in Figs. 4, 5 and 6. In this case, the exact solution is shown by the solid curve and the dashed curve with point markers and dashed dot curve with asterisk markers represent the approximate solutions for eight and nine-noded quadrilateral elements respectively. The graphs demonstrate that the finite element solutions match the exact solutions at a number of places and

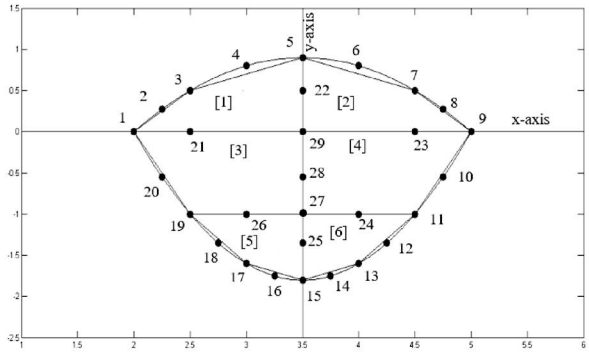

Fig. 2: Partitioned with eight-noded quadrilateral elements

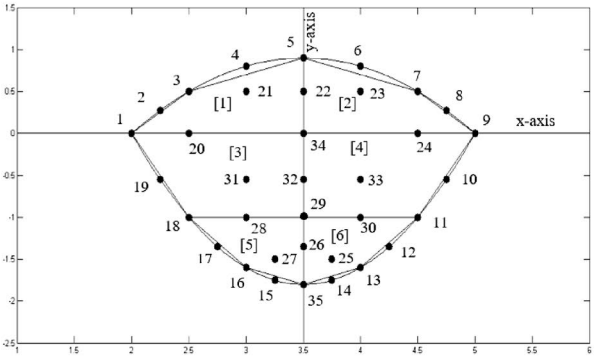

Fig. 3: Partitioned with nine-noded quadrilateral elements

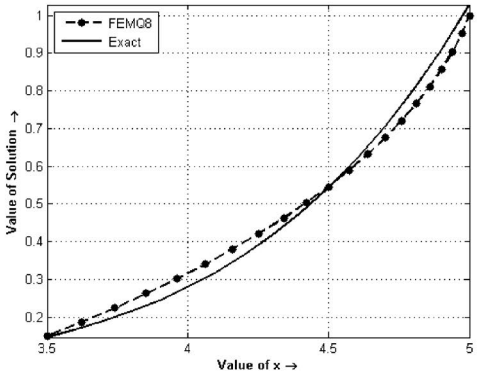

Fig. 4: Exact and approximate solutions at $y=0.3.5\le x\le 5$ for eight-noded quadrilateral elements

they are very close to the exact solutions for other points. Tables 1 and 2 include various approximations of the solution at the nodal sites shown in Figures 2 and 3 for quadrilateral elements with eight and nine nodes, respectively. For eight-noded elements, the absolute

minimum difference is 2.00×10^{-4} while for nine-noded elements, it is 1.00×10^{-5}. There are mainly two facilities in nine-noded element. We acquire more nodal values of the solution with higher precision when using a nine-noded approach as opposed to an eight-noded strategy

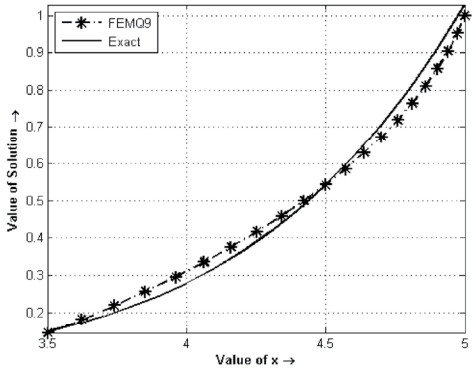

Fig. 5: Exact and approximate solutions at $y = 0, 3.5 \leq x \leq 5$ for nine noded quadrilateral elements

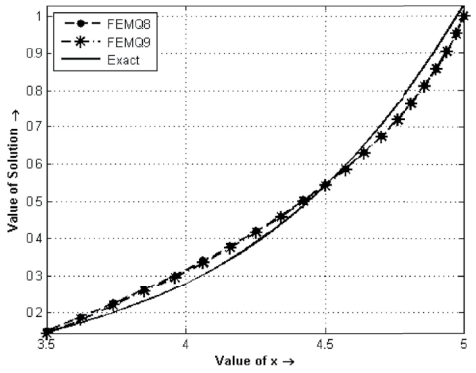

Fig. 6: Exact and approximate solutions at $y = 0, 3.5 \leq x \leq 5$ for eight and nine noded quadrilateral elements

Table 1: Absolute between the exact and approximate solutions at the nodal points for eight noded elements

Node number(Fig. 2)	Points	Analytical solution u [13]	Approximate solution $\tilde{u}$	Absolute difference Δu_{ij}
21	(2.5,0)	0.035351	0.032198	3.20×10^{-3}
22	(3.5,0.5)	0.121371	0.116803	4.60×10^{-3}
23	(4.5,0)	0.542228	0.545685	3.50×10^{-3}
24	(4.0, −1.0)	0.460178	0.457488	2.70×10^{-3}
25	(3.5, −1.35)	0.372115	0.371743	4.00×10^{-4}
26	(3.0, −1.0)	0.210133	0.209915	2.00×10^{-4}
27	(3.5, −1.0)	0.291637	0.295851	4.20×10^{-3}
28	(3.5, −0.55)	0.210691	0.207696	3.00×10^{-3}
29	(3.5,0)	0.146214	0.149983	3.80×10^{-3}

Table 2: Absolute between the exact and approximate solutions at the nodal points for nine noded elements

Node number(Fig. 3)	Points	Analytical solution u [13]	Approximate solution $\tilde{u}$	Absolute difference Δu_{ij}
20	(2.5,0)	0.035351	0.034507	8.00×10^{-4}
21	(3,0.5)	0.045485	0.046573	1.10×10^{-3}
22	(3.5,0.5)	0.121371	0.118758	2.00×10^{-3}
23	(4,0.5)	0.271689	0.272686	1.00×10^{-3}
24	(4.5,0)	0.542228	0.542735	5.00×10^{-4}
25	(3.75, −1.35)	0.452227	0.453731	1.50×10^{-3}
26	(3.5, −1.35)	0.372115	0.372104	1.00×10^{-5}
27	(3.25, −1.35)	0.317036	0.317255	2.00×10^{-4}
28	(3, −1)	0.210133	0.210602	5.00×10^{-4}
29	(3.5, −1)	0.291637	0.291980	3.00×10^{-4}
30	(4, −1)	0.460178	0.464553	4.40×10^{-3}
31	(3, −0.55)	0.138689	0.140649	2.00×10^{-3}
32	(3.5, −0.55)	0.210691	0.212841	2.10×10^{-3}
33	(4, −0.55)	0.353017	0.355819	2.80×10^{-3}
34	(3.5,0)	0.146214	0.143694	2.50×10^{-3}

4. CONCLUSION

The concentration of a liquid material is one of the most important aspects to take into account while analyzing its properties. In this study, we used the finite element method to determine the concentration profile of a solute in an aquifer. Additionally, there are certain methods like the Galerkin method, the finite difference method, etc. In the finite element approach, we have a functional expression, but in the finite difference method, we have numerical values of the solution at certain locations. We must select some coordinate functions in Galerkin method and there are no fixed ones which depend on our choice. But in finite element technique we have some predefined shape function for particular elements. Additionally, we have contrasted our approach with the precise solution and observed that the finite element approximation produces better outcomes. There are also more areas where we might work, such as using the approximation to create an error differential equation, which we could then solve to adjust our original solution slightly.

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Experimental Study on Treatment of Unconfined Aquifer to Recycle by Using Eco-friendly Natural Adsorbent

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ABSTRACT

Water treatment is any procedure that improves the nature of water to make it suitable for a specific end-use. Drinking water, water supply for business and agriculture, river flow maintenance, water enjoyment, and a range of other uses are all conceivable, as well as suitable environmental returns. The phreatic surface, or upper border of an unconfined aquifer, is exposed to the open air (atmospheric pressure). Adsorption treatment of wastewater is a great way to get rid of organic pollutants. The impact of adsorbents on wastewater characteristics and their application in the multimedia filter is the subject of this study. The goal of this research is to use natural adsorbents to recycle an unconfined aquifer. Instead of Activated Carbon Filter (ACF), Multi-Grade Filter (MGF), Submerged Aerated Filter (SAF), and other natural adsorbents, coarse sand, fine sand, coal, gravel stone, and filter paper were employed. The authors determined which water is purer after going through the model and prototype filtering systems by calculating pH, TDS, TH, and TSS. The main goal of this research is to keep the pH of the water at 7. This filtrated water must be recycled primarily for use in raw water, soft water (WTP), boiler feed water, boiler blowdown water, and hot water.

Keywords: Unconfined aquifer; Water treatment; Filtration; Natural adsorbent; pH, Total dissolved solids.

1. INTRODUCTION

According to estimates, approximately 2 billion people lack access to safe drinking water, nearly 2.5 billion lack proper disinfection, and three out of every five people lack access to clean water. Water continues to be an important resource for harmonizing monetary, social, and environmental challenges, as well as a critical component of long-term development. It keeps human usefulness and jobs above water while also assisting the world's biological processes in their cooperation. Due to increasing and competing demands from horticulture, urban, and home use, as well as increased contamination, water is becoming more difficult to find. Although the overall volume of study fields: wastewater treatment, microalgae design, and water handling, as defined by hydrology, remains continuous, water contamination from land, modern, and anthropogenic sources remains constant the biggest obstruction to Man's utilization. Around 1.6 million individuals all over the planet are compelled to drink dirtied water.

A water treatment plant is a building that processes untreated water from lakes, rivers, or other natural sources to satisfy the criteria needed for safe use. To get rid of impurities including silt, bacteria, viruses, and chemicals, the treatment process combines physical, chemical, and biological processes. After being cleaned, the purified water is dispersed to homes, businesses, and other locations via a system of pipelines. Water treatment facilities are crucial for enhancing public health and environmental sustainability as well as ensuring that communities have access to clean, safe drinking water.

The filter is a piece of domestic drinking water filtering equipment designed for use in rural areas. It helps to lessen disease risk by minimizing the number of germs in the water. Simply pour wastewater from above into the filter and let gravity carry it to the bottom. The biological layer's higher layer is assumed to be where pathogens are eradicated. Traditional wastewater treatment plants require a significant amount of land, high initial investment and continuing running costs, technically qualified employees, and a lengthy design and implementation process. Sanitation will inevitably be a huge challenge given the unclean surfaces and groundwater. Using demineralization water treatment plants, this raw water must be filtered (Fig. 1).

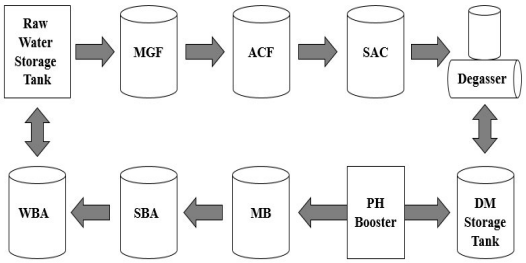

Fig. 1: Water treatment plant diagram [14]



Fig. 2: Mass size water filtration system in Bangladesh [15]

About 60 to 70% of infections in Bangladesh are caused by water, and the most worrying issue is that because Bangladesh lacks a water purification system, roughly 35 percent of people die each year from water-borne diseases. When done correctly, water can be purified. In Bangladesh, there are a few typical water purifying methods. For example, in Fig. 2 a mass-size water filtration system has been pictured by the authors in a renowned water treatment plant situated in Dhaka city.

Boiling water is the most popular and primary method of water purification in Bangladesh. However, this is not the correct approach. Some bacteria and viruses can be killed by boiling water at a specific temperature, but many organic and inorganic elements, such as arsenic, mercury, lead, chlorine, and a variety of inorganic sales, as well as foul odors, cannot.

Normal filters can only remove some solid radicals and do not prevent germ formation. Because the smallest bacteria or other microbes are 0.002 microns, this type of filter has a diameter of 5 microns [1]. According to studies, persons who drink this type of chlorinated water have a 93 percent higher risk of cancer than others. As a result, this approach is ineffective for water purification in Bangladesh. Tube wells were once a common source of fresh water in Bangladesh. However, arsenic, excess iron, lead, mercury, and certain inorganic salts were later discovered in tube well water.

The objective of this paper is to use natural adsorbents to recycle an unconfined aquifer. Coarse sand, fine sand, coal, gravel stone, and filter paper were employed instead of ACF, MGF, SAF, and other natural adsorbents. Basically, which type of water is purer after going through the model and prototype filtering systems is determined by the authors just to keep the pH of the water at 7.

K.A. Yongabi et al. [2] investigated that 100 liters of exceptionally grimy/turbid water (130.3 NTU) were ready with 100 drumstick tree seeds before being sifted through a 120-liter sand channel drum containing fine, coarse, and charcoal sand, charcoal, and rock. The mean upsides of similar boundaries for sand-sifted lake water alone were considerably lower than the same mean qualities for this tree-treated lake water, as indicated by the discoveries.

Chandra Kumar J et al. [3] studied that a Membrane bio-sand filter is a filter that has a RO membrane layer and forms a biological zone to completely remove trash and germs from the water. It's designed for ease of use and simplicity.

S. Qomariyah et al. [4] showed that greywater delivered into seepage channels or normal water bodies without treatment will corrupt the biological system and give a well-being concern. The investigations show that engineered wetland systems are effective at eliminating BOD, COD, TSS, pathogens, and detergent pollutants.

Mama Li-Qiang et al. [5] picked an OK golf as the site for making a groundwater repository in light of the suspicion of safe creation and utilized my water re-energized innovation in the mix with other related approaches for powerful water protection.

Axial dispersion was examined by Martina Matejkova et al. [6] in three pilot channel sites filled with gravel, sand, and sand with stones. Both activated carbons showed the best sorption effectiveness for organic and inorganic pollutants in laboratory and pilot trials.

Fluoride, arsenic, and coliform were eliminated from drinking water using an environmentally friendly handmade bio-sand filter studied by Sudhanshu Kanaujia et al. [7]. This technology has several advantages, including a quick workup procedure, the avoidance of organic solvents, and extremely advanced equipment, all of which help to make this a green process.

R.S. Wotton et al. [8] showed that drinking water is purified using slow sand filters. Each filter is made out of a huge tank with a sand bed through which water flows at a velocity of 0.1–0.3 m h-1. Physicochemical and biological activity clean the water at the air-water interface within the bulk water across the surface of the sand and within the sand bed.

Under the presumption that N03-N tainting of groundwater won't be critical, the USEPA 503 bio-solids use rules perceive the need for more prominent W Lee Daniels et al. [9] examined agronomic rate applications to mined areas. Leachates from the root zone were gathered in zero-strain lysimeters underneath adjoining miniature plots.

Similarly using some indigenous material Alam et al. [10] show that there may be some improvement in water quality. Because there needs some development of a low-cost indigenous sullage filtration system.

While activated maize cob is effective in removing some physical qualities, activated born char is effective in removing some chemical properties, such as chloride ion and alkalinity, and activated charcoal was effective in reducing ammonia nitrogen concentration studied by Adie D.B et al. [11]. Therefore, for good outcome penetration activities, it is suggested that a blend of the three wellsprings of enacted carbons be utilized.

A good rule of thumb is to filter the full volume of a closed cooling water system in a refrigerated vehicle two to three times per day. About 35% more stored goods were found to remain at normal temperature compared to the cooling water system design. [12]

This study also compares and examines the performance improvement potential if standard procedures from an earlier study are used. With the ultimate goal of creating a standard product-loading pattern acceptable and implementable in the local context, the first findings are described. [13].

2. METHODOLOGY

In natural filtration system, Submerged Aerated Filter (SAF), Activated Carbon Filter (ACF), Multi-Grade Filter (MGF), etc. filter has been used in available water treatment plant as shown in Fig. 1. In this study, the authors have tried to add some natural adsorbents instead of MGF, ACF, and SAF. In this experiment, unconfined aquifer water has been filtered by Eco-friendly Natural Adsorbent to check the filtering system and recycled water.

2.1 Prototype setup

Before the test of the model, the prototype needs to be set up so that anyone can understand that these natural adsorbents are effective.

At first, a PET bottle was chosen to filter. Then the top and bottom part was drilled (see Fig. 3) so that the water can go through this pet bottle easily. After that, the bottle was filled using multiple natural adsorbents to test. (See Fig. 4)

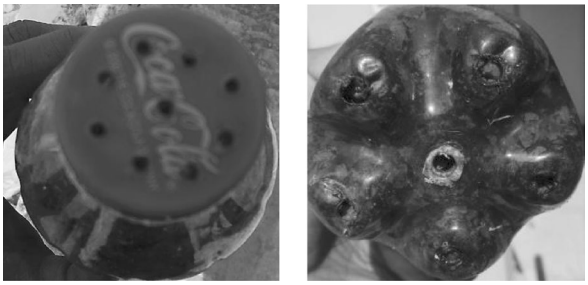

Fig. 3: Photograph of top and bottom view of prototype setup



Fig. 4: Photograph of prototype setup

2.2 Model setup

At first, a tentative drawing was done using SolidWorks. This model has been drawn step by step according to its layer. A total of six layers were drawn in all five have the same dimension. After some trial and error, the authors concluded a final design that contains six layers where per layer dimensions are 24 inch × 14 inch × 8 inch (60.96 cm × 36 cm × 20.32 cm). The top view of this drawing is shown in Fig. 5 And also, Fig. 6 shows the scenario of the top view after the drilling has been done. After completing the software drawing real design has been done. Fig. 8 shows the photograph of the single layer before drilling and Fig. 9 shows after drilling. Then each layer cut from an aluminum sheet was drilled a 1mm hole in every joining point in Fig. 9 and then welded using 4 angle bars in four directions and 24 solid shafts which were made of mild steel to connect the whole six-layer and made the real setup (Fig. 10) from the drawing of Fig. 7.

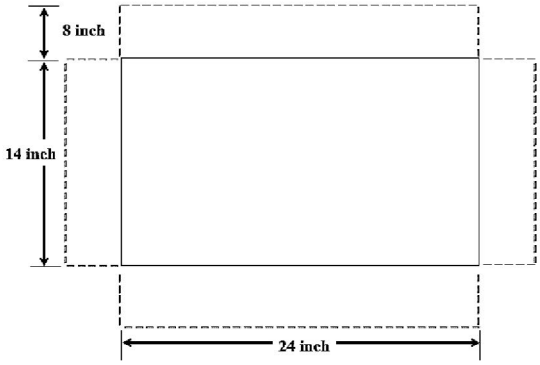

Fig. 5: Top view of the experimental setup

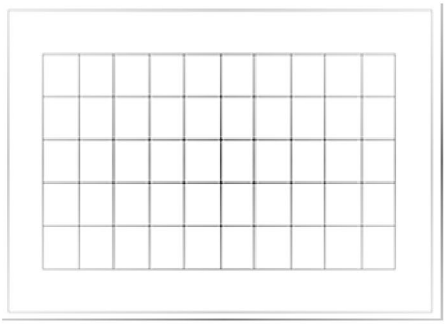

Fig. 6: Top view of single layer after drilling

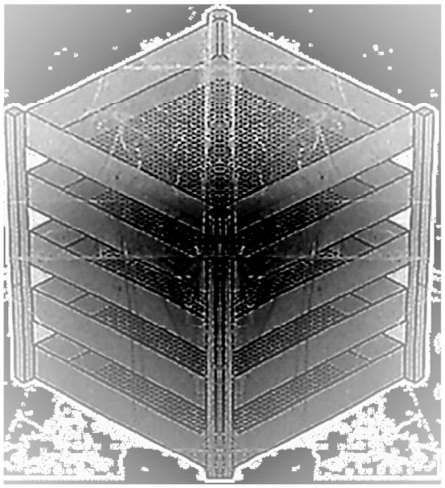

Fig. 7: Isometric view of the experimental setup

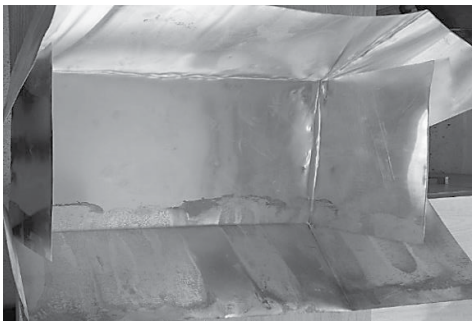

Fig. 8: Photograph of the single layer before drilling

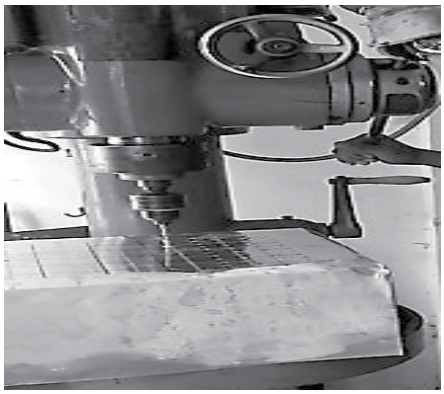

Fig. 9: Photograph of the single layer while drilling



Fig. 10: Photograph of the actual setup



Fig. 11: Photograph of actual setup using natural adsorbent

In this six-layer, there are five types of filling filtration Materials. From Fig. 12 we can easily understand why we need to use this natural adsorbent. In Fig. 11 a single layer of actual setup using natural adsorbent has been shown.

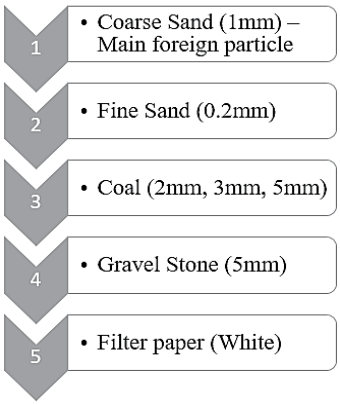

Fig. 12: Filling filtration materials

3. RESULTS AND DISCUSSION

The result has been collected for both types of prototypes and models. Both results show significant changes in pH, TDS, TH, TSS, etc.

3.1 Prototype results

An unconfined aquifer was used to gather raw water. Before entering and after leaving, the unconfined aquifer was tested. The pH, TDS, TH, and TSS of the water were then determined to determine its correctness.

The experiment was used to determine the accuracy of an unconfined aquifer. Three types of data were observed in this investigation. The prototype's first attempt was to compute the pH for both incoming and exit water. The pH measurement in experiment number two is more accurate than the others.

Table 1: Water quality data for prototype

Parameter	Exp. No	Value (In)	Value (Out)	Accuracy (Percent of removal)
pH	1	6.96	6.94	0.28
	2	6.96	6.93	0.43
	3	6.95	6.93	0.28
TDS (mg/l)	1	80	75	6.25
	2	78	74	5.12
	3	80	76	5
TH (mg/l)	1	22.05	20.7	6.12
	2	22.11	20.5	7.28
	3	22.09	20.5	7.19
TSS (mg/l)	1	12	7	41.66
	2	11.8	6.9	41.52
	3	12	6.9	42.5

TDS, TH, and TSS data are also measured with a machine. The highest accuracy for TDS was 6.25 percent, and the lowest was 5 percent. The greatest and minimum accuracy for TH was 7.28 percent and 6.12 percent, respectively. TSS was calculated with the highest accuracy of 42.5 percent.

The water must be pure to achieve a pH of 7. There are a variety of TDS (mg/l) levels that can be used to determine the accuracy of water. This range is depicted below.

Table 2: Taste of Water with Different TDS

Level of TDS (milligrams per liter)	Rating
Less than 300	Excellent
300 -600	Good
600 -900	Fair
900 – 1200	Poor
Above 1200	Unacceptable

3.2 Model results

In this model test, several types of samples are employed depending on the context of the model. For instance, raw water, soft water obtained from a water treatment plant, feed water, blowdown water, hot water, etc. are all examples of water that is obtained from a boiler. For this sample, different parameters were examined. These factors consist of pH, TDS, TH, and other things. These parameters also have their range to support the data in situations where the collected data and the standard parameter are crucial to one another. The data was collected three times, with the average data being reported on the table.

The filtering process of this adsorbent is calculated in the model using several sorts of data. Vital information like as pH, TDS, TH, and other values vary with each stratum. This data was measured twice, independently, to ensure its accuracy. So, using this data, we can extrapolate a number of parameters and compare them to decide what kind of water to use for various industrial applications.

The entire water treatment plant was used for the experiments. The information was initially gathered from the raw water section (Table 3). This information was compiled from two different sources. As a result, there must be a distinction between these two locations. Because the pH value at the first site was 7.69 while it was 7.49 in the second, there is a 0.2-point difference between the two. TDS and TH are different for two separate locations. Particularly, the TDS value differs significantly by around 16.2. Therefore, it is obvious that site 2's raw water is more treatable than position 1's. This notion is also applied to TH.

Table 3: Test report of raw water

Location	Para meter	Exp. No	Value	Average
1	pH	1	7.69	7.69
		2	7.67	
		3	7.71	
	TDS (ppm)	1	93.7	93.9
		2	94.1	
		3	93.9	
	TH (ppm)	1	57.5	57
		2	56.5	
		3	57	
2	pH	1	7.51	7.49
		2	7.47	
		3	7.49	
	TDS (ppm)	1	77.8	77.7
		2	77.7	
		3	77.7	
	TH (ppm)	1	47.5	48
		2	48	
		3	485	

Table 4: Test report of soft water (WTP)

Location	pH (5.5-7.5)	TDS (<500) ppm	TH (<10) ppm
1	7.40	75.0	0.3
2	7.55	63.3	0.3
3	7.60	75.8	0.3
4	7.51	81.6	1.5

Table 5: Test report of feed water (Boiler)

Location	pH (8.5-9.5)	TDS (<200) ppm	TH (0-5) ppm
1	7.50	64.1	0.3
2	9.27	267	0.3

Table 6: Test report of blowdown water (Boiler)

Location	pH (10.5-11.5)	TDS (2500-3500) ppm	TH (<10) ppm
1	11.05	1328	0.6
2	11.04	1392	0.9
3	11.16	2410	1.2
4	11.19	2730	1.0
5	10.90	1486	1.0

Table 7: Test report of hot water

Location	pH	TDS (ppm)	TH (ppm)
1	7.69	50.8	0.9
2	7.66	52	0.8

Then, data was gathered using soft water from a water treatment plant (Table 4). Four locations were chosen for the experiment in order to determine the filtering parameter. Similar to how there were some differences in the previous location, there were some in these next four. Despite the fact that TH at position 4 is greater than at the other locations, pH values vary less significantly between locations. The soft water from this water treatment facility also has bigger fluctuating TDS.

The sample was then taken from the boiler's feed water section (Table 5). In this case, the TH is the same, but the pH value is too different, being approximately 1.77. These two places' TDS values varied by an excessive amount (203.1), as well. This indicates that treating the feed water (boiler) section at site 2 will be challenging.

Following that, a sample was taken from the boiler's blowdown (Table 6). This time, data were collected from the first four separate sources to properly specify the filtering possibilities. In this case, the pH at the four different locations was very similar and TH followed a common gap. TDS shows no significant following curve and no trend despite reaming values ranging from 2500 to 3500.

Not to mention, two samples were taken from the hot water part (Table 7). There is a little change in pH value. Although hot water has no effect on the TDS in water, there is a slight variance in the TDS value as well. The TH value also differs by 0.1 ppm.

4. CONCLUSION

The biology of slow sand filters is compared to that of other sandy environments in this study. Even though slow sand filtration is based on natural processes and shares many characteristics with sandbanks and sandy beaches, there are some major differences. These issues are mostly due to the design and operation of filter beds, which are required to produce extremely high-quality drinking water that is practically free of pathogens, particles, and organic matter. Slow sand filtration has the advantage of requiring little maintenance or monitoring, except for keeping track of when the filter needs to be cleaned. Besides this sand filters also have some environmental benefits.

The advantages of cleaning water with plant materials and sifting it with a slow sand channel drum are enormous: the two frameworks' deficiencies are split up, a larger volume of treated water can be stored for longer, and any kind of filthy or wastewater may be dealt with and polished off in a generally short time frame. The systems are adaptable, and the materials required are inexpensive and widely available. Bangladesh is looking on expanding its methods for treating vast amounts of water.

These data indicate that a better filtration system is needed to reduce total dissolved solids (TDS). This chemical-based natural adsorbent is reasonably priced. These adsorbents, on the other hand, are less effective than chemical adsorbents utilized in industrial water treatment plants recently. After filtering, our goal was to get the water to a pH of 7, which we most certainly did. We also wanted to reduce the amount of harshness.

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Energy Engineering

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Effect of Sulfonation on Polystyrene based Proton Conductive Membrane Doped with Phosphorous Pentoxide

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ABSTRACT

Recently, proton conducting membrane fuel cells (PCMFCs) have been recognized as a potential future and excellent medium for efficient power sources. In the present work, polystyrene has been used to make a proton conductive membrane, mixing with phosphorus pentoxide (P_2O_5) targeting to achieve low cost and high proton conductivity under low humidity conditions. Several membranes are studied with varying amounts (three compositions: 5 wt.%, 10 wt.%, and 20 wt.%) of P_2O_5 concerning polystyrene weight and doped in 20% diluted sulfuric acid. It is expected that a new proton transport pathway is provided between the phosphoric acid and sulfuric acid in dry conditions. Results of conductivity, obtained by Electrochemical Impedance Spectroscopy (EIS) have shown excellent proton conductivity at room temperature. The 10 wt.% modified P_2O_5 membrane exhibited higher order of proton conductivity approximately two orders of magnitude compared to neat PS membrane at dry conditions (approximately 10^{-2} S/cm), which is the highest value among the fabricated membranes. The Fourier Transform Infrared Spectrometer (FTIR) analysis confirmed the sulfonation of the modified membranes. These membranes are also characterized by Scanning Electron Microscopy (SEM) and tensile test. The tensile test showed the highest strength 2 MPa while the SEM images proved the porous structure of the membranes, which is helpful to improve the proton conducting membrane (PEM) structure. So, the 10 wt.% modified membranes are a good promising candidate as a novel PEM and have potential applications for use in fuel cells.

Keywords: Proton conductive membrane; Polystyrene; Phosphorous pentoxide; Electrochemical impedance spectroscopy.

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Comparison of AC Breakdown Properties of Kraft Paper Impregnated with Shea Nut Oil and Mineral Oil for Transformer use

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ABSTRACT

The increasing demand for sustainable and efficient insulation materials in power transformers has led to the exploration of alternative solutions. Traditional insulation systems, such as oil-impregnated paper (OIP) with mineral oil, have been effective but pose environmental and flammability concerns. As a result natural ester oils like shea nut oil, have emerged as a potential alternative due to their biodegradable, non-toxic, and renewable properties. The research focuses on the effects of thermal aging on the dielectric strength, dielectric loss (tan δ), and dielectric constant (relative permittivity) of the shea nut oil-impregnated kraft paper insulation. Employing accelerated aging procedures and various measurement techniques, the study reveals that this alternative insulation demonstrates suitable dielectric properties for application in power transformers, with notable resistance to thermal aging. The objective of the research is to compare the AC breakdown properties of kraft paper impregnated with shea nut oil and mineral oil for transformer use and also to investigate the performance of shea nut oil as a dielectric fluid for its feasibility and identifying any potential limitations. The study also examines the use of kraft paper as an insulation material, given its widespread use in transformer insulation systems. The comparison of the AC breakdown properties of kraft paper impregnated with shea nut oil and mineral oil offers a comprehensive assessment of the potential for shea nut oil to replace mineral oil in transformer insulation systems. In conclusion, this research significantly contributes to the development of more sustainable and environmentally friendly transformer insulation systems, supporting the transition towards a greener and more sustainable energy sector. The findings reveal that thermally aged shea nut oil-impregnated kraft paper insulation demonstrates promising dielectric properties for application in power transformers highlighting its potential as a viable alternative to traditional mineral oil-based insulation systems.

Keywords: AC breakdown properties; Accelerated thermal ageing; Kraft paper; Mineral oil; Shea nut oil.

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A Critical Analysis of Microgrid Performance for Renewable and Conventional Energy Sources with Economic and Environmental Impacts

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ABSTRACT

In recent years, the development of microgrids that employ renewable energy sources has gained traction to address the issues that conventional sources of energy face. Microgrids are self-contained energy systems that can operate independently of the central grid and can be designed to use renewable or conventional energy sources. The deployment of microgrids powered by renewable energy sources has the potential to address the challenges that conventional energy sources encountered while minimizing the environmental impact of energy production. In a study, authors analyzed the feasibility of a grid-connected photovoltaic system for a residential building in Saudi Arabia. The authors used Homer Pro to model and simulate the system and found that a 5 kW photovoltaic system could meet the energy demands of the building. They also found that the system could generate excess energy that could be sold back to the grid, resulting in a lower payback period for the investment. In another study, authors used Homer Pro to design and optimize a solar-wind hybrid renewable energy system for a remote area in Jordan. The authors considered different system configurations and found that a system consisting of a wind turbine, solar panels, and batteries was the most effective. The study also highlighted the importance of conducting sensitivity analysis to evaluate the impact of different variables on the system's performance. In conclusion, the literature shows that Homer Pro software is an effective tool for designing, simulating, and optimizing renewable energy systems. The studies examined in this review demonstrate the software's usefulness in identifying the optimal configuration of renewable energy sources, sizing components, and evaluating system performance. The studies also highlight the importance of considering the environmental and economic factors when designing renewable energy systems. This paper investigates the efficiency of microgrids utilizing renewable and conventional energy sources, with an emphasis on the economic and environmental effects. The analysis includes conducting operational, technical, and economic evaluations on the microgrid using specialist tools. The analysis includes evaluating the performance of the microgrid using HOMER Energy Pro software. However, a solar system, a wind system, and a diesel system constitute the microgrid. The parameters of the energy system are based on data from databases on local meteorological conditions. The analysis is carried out in two modes: off-grid and on-grid. The off-grid system consists of PV, a wind turbine, batteries, and a diesel generator, whereas the on-grid system uses the same configuration to analyze the optimization result, cost summary, carbon emission, and sensitivity analysis. Along with NPC and COE, the combination of PV, wind turbines, and batteries considerably reduces carbon emissions. The study found that microgrids powered by renewable energy sources provide large economic benefits while minimizing environmental consequences. According to the findings, renewable energy sources such as solar and wind, when integrated with energy storage technology, offer an effective response to the issues that traditional energy sources face. Furthermore, the study discovers that the deployment of microgrids powered by renewable energy sources may effectively minimize emissions of greenhouse gases, resulting in a cleaner and healthier ecosystem. Overall, the study's results provide clarity on the advantages of using renewable energy sources in microgrids, as well as their potential to alleviate the issues that traditional energy sources face.

Keywords: Microgrids; Renewable energy; Homer software; Greenhouse gases; Off-Grid mode; On-Grid mode.

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SMR Reactors and the Future of Nuclear Energy: A Critical Review of Prospects and Challenges

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ABSTRACT

As the energy demand continues to increase worldwide, developing small modular reactors (SMRs) has become a promising solution to provide clean, reliable, and affordable power. This study provides a comprehensive overview of the current state of SMR technology, including a discussion of various reactor types, their designs, and deployment plans. This article evaluates the prospects and challenges of small modular reactors in the context of nuclear energy. It provides a comprehensive overview of the current state of SMR technology, analyzes the benefits and drawbacks, highlights regulatory hurdles, public perception, and lack of infrastructure, and explores the potential of SMRs to complement renewable energy sources and mitigate greenhouse gas emissions. It also highlights the importance of continued research and development in the SMR industry.

Keywords: SMR technology; Nuclear energy; Future energy; Renewable energy; Environmental impact; Challenges.

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Fabrication of Lanthanum Doped Calcium Copper Titanate (CCTO) Electroceramic for Energy Storage Application

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ABSTRACT

Calcium copper titanate electroceramic (abbreviated as CCTO, formula CaCu3Ti4O12) is a newly developed substance with a giant dielectric permittivity and a little dielectric loss factor. In this work, a facile solid state manufacturing process was employed to fabricate Ca1-3x/2LaxCu3Ti4O12 where x = 0.05. The structural and optical properties of the prepared samples were investigated by XRD and UV-visible spectroscopy. The sintered pellets exhibits a single-phase cubic structure as confirmed by the X-ray diffraction analysis. The crystallite size determined by using the Scherrer formula was found to be 27 nm. The peak positions for La-doped specimens revealed a slight shift towards lower 2θ, which is explained by the lattice distortion. Rietveld refinement of the XRD data was also performed which showed the goodness of fit (GOF) below 2. The spectrophotometer analysis confirmed that the absorption is greater at shorter wavelengths.

Keywords: CLCTO; XRD; Rietveld refinement; UV-visible Spectroscopy; Band gap.

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A Numerical Analysis on Enhance Heat Transfer and Fluid flow in Double U-Shape Geothermal Heat Exchanger using Nano-fluid

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ABSTRACT

A quarter percentage of the total world's energy is consumed for making comfortable living spaces. The researchers have been working for years to reduce the energy consumed in a building using conventional mechanical technology. In these circumstances, the Earth-heat exchanger can play a significant role in the decline of power expenditure. In this research work, the fluid flow and the heat transfer through a double U-shape vertical buried pipe into soil has been simulated using CuO/water nanofluid along with air flow considering geothermal heat energy. The cooling performmence has been investigated with a double U-shape vertical heat exchanger numericaly. ANSYS Fluent 17.0 solver package has been used to make the thermal transient representation to analyze the recital of warmth transfer. The impact of some potential variables like wind speed, pipe's width, length, thickness, and depth of buried pipe into the earth have been discussed. This paper studies the influence of these variables on thermal recital of the verticle buried pipe cooling/heating arrangement in a humid/cold dry semitropical weather. The results show that soil absorb much warmth in the summer time and discharge much warmth in the winter time in the presence of CuO-nanofluid when air flow through the inner pipe. This research would be a new window about cooling performance that is hardly found in literatures. The outcome of this work will offer a intensive thoughtful of the cooling arrangement.

Keywords: Geothermal heat exchanger; Computational fluid dynamics; ANSYS Fluent; Nanofluid; RANS.

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Design and Development of Lightweight Motorcycle Swing Arm to Improve Fuel Economy

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ABSTRACT

In this study, a motorcycle swingarm has been developed by using aluminum alloy instead of stainless steel. The goal of this project is to reduce the weight of the component, which will increase the fuel economy of the motorcycle and reduce the emissions and primary investment cost of the manufacturing process. For this project and analysis, a well-reported general class 150 CC SUZUKI GIXXER motorcycle swingarm was selected. The swingarm has been manufactured by wood pattern making, casting, machining, and painting. The modified swingarm manufacturing process has been easy and cheaper than the existing process. It is suitable for small capacity production and for better quality of the product. The weight of the swingarm decreases 27% compared to the existing one. Due to weight reduction fuel economy of motorcycle increased 0.19 ml per KM. The modified swingarm was assembled to the motorcycle as per SUZUKI assembly standards. The motorcycle has been tested as per SIS (SUZUKI Inspection Standard) and it was passed all the quality requirements and tests. So, the motorcycle swing arm can be manufactured by aluminum alloy instead of Alloy steel.

Keywords: Motorcycle; Swingarm; Stainless steel; Aluminum alloy; Fuel economy.

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Performance Evaluation of a Hybrid Solar Cabinet Dryer for Fish Drying

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ABSTRACT

In this project, a hybrid solar cabinet dryer is designed, fabricated and tested in case of drying fish. The dryer consists of a drying chamber, solar collector and two trays of dimensions 60 cm × 60 cm and paraffin wax. It also consists of photovoltaic cell modules that power the heating element, charge the battery and operate the other electric equipment. The dryer has been operated as both a solar energy dryer during normal sunny days and a hybrid solar dryer during cloudy days. The drying rate of hybrid solar dryers is evaluated on fresh fish and compared with solar dryers and sun drying under the same climatic conditions. The fish products can be stored for longer periods of time in dry conditions, but most of the fresh fish in remote areas of our country are spoils due to a lack of proper preservation. Due to this total fungal count and total microbes count increase. To overcome this problem, a hybrid solar dryer can play an important role to make drying continuous during night and day time and also off sunshine hours. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof simultaneously paraffin wax system inside the drying chamber absorbed the heat energy in the day time. At the same time, the battery is charged by the solar system and therefore the water kept in the tank reaches a certain temperature by absorbing heat from nature, which provides heat by circulating the water inside the drying chamber during inclement weather. Electric fans are used at the inlet of the solar collector and outlet of the dryer to maintain adequate airflow inside the drying chamber. During the night and cloudy weather paraffin wax and heater system deliver heat to maintain the set temperature in the drying chamber. The dryer exhibited sufficient ability to dry fish rapidly to a safe moisture level and simultaneously it ensures a good quality of that. The moisture can be removed by the present dryer 1.75 times faster than the open sun drying system.

Keywords: Dryer; Drying chamber; Solar collector; Paraffin wax; Battery.

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Design and Construction of a Solar Base Home Automation System with Bluetooth Module

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ABSTRACT

The design and construction of a solar-powered home automation system with a Bluetooth module are discussed in this paper to address the demand for alternative energy sources among Bangladesh's homes and small businesses. The market study results from the research are included, along with the design, analysis, and research methodology. A specially created inverter circuit and a solar panel are the first two components of the solar UPS's architecture. According to the specifications and requirements of the solar panel, the inverter circuit has been created. To improve the current circuit, many example circuits have been examined. To consider potential replacements if a component fails or is unavailable, assistance has also been obtained from the design engineers of existing UPSs on the market. The examination of the design and functionality options for a solar-powered UPS is presented in the article. It implies that solar UPSs could be a competitive and highly effective replacement for electrical UPSs on the market. The design consists of two primary parts: an exterior solar panel with solar cells that will transform solar energy into electrical energy and an inverter circuit that will transform that energy into alternating current for use in home appliances. The design and prototype implementation of the automation system that uses two Energy throw electronics components and one Arduino Nano with sensors. The automation system has been combined with devices like LDR, temperature sensors, and motion sensors to show how effective the system is. Additionally, security systems also use GSM modules. The sensors' duties include keeping an eye on and managing the temperature and light in the space. GSM, which is utilized to send SMS alerts to the owner, is the primary objective of the security system. A specific location is monitored by sensors and relays under the direction of an Arduino Nano, which also controls other devices that respond to conditions like temperature and light levels. If any irregularity is detected by the sensors, the microcontroller will SMS the owner. Door locks are also included. An infrared sensor creates security. The GSM module also used in this research which is more trustworthy and safer thanks to security systems.

Keywords: Solar based system; Bluetooth module; Alternate energy source; UPS; Security system; GSM.

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Vibration of an Aircraft Wing Due to Rotating Unbalance in the Gas Turbine Propulsion Engine

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ABSTRACT

This study reports how an aircraft wing vibrates once it is under the action of rotating unbalance in the gas turbine engines integrated into it. Aircraft model Boeing 767-200 and NACA 4424 airfoil is taken as reference for calculation. The area moment of inertia of the airfoil cross section is calculated with known techniques and the variation of the area moment of inertia along the length of the wing is found to be non-linear. The stiffness matrix of the complex aircraft wing is found by assuming it to be similar to a cantilever beam with two degrees of freedom and then inversing the flexibility matrix obtained by employing the area moment method. Solving the second-order linear differential equation of motion gives the amplitudes of vibration. Realistic values were used throughout the study. Investigation is then done on the effect of stiffness on the amplitudes of vibration and it is found that this effect of stiffness is negligible compared to the effect of mass/inertia force and applied external harmonic frequency.

Keywords: NACA airfoil; Natural frequency; Eccentricity; Flexibility matrix.

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Analysis of Heat Transfer Performance through Inline and Staggered Grooved Microchannel using Lattice Boltzmann Method

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ABSTRACT

The article represents a numerical study on heat transfer through inline and staggered grooved microchannels using the Thermal Lattice Boltzmann Method (TLBM). A two-dimensional (D2Q9) Bhatnagar-Gross-Krook (BGK) model is used to simulate this problem. The conditions are (a) inlet fluid is cold, (b) walls are heated (c) relative roughness height is rh=4%, 8% and 12% according to channel height and (d) different Knudsen numbers are Kn=0.02, 0.05 and 0.10 which represent the slip flow regime. The friction coefficient is consistent with the Poiseuille number (Pn) and the dimensionless heat transfer rate in terms of the Nusselt number (Nu) has been discussed in order to analyze the roughness effects. The result represents the average friction increased linearly with the increase of relative roughness height that decreased significantly with increasing the Knudsen numbers (Kn) for both inline and staggered grooved channels. In addition, compared to smooth, inline and staggered channels, the lowest friction happened for smooth and the highest friction for inline grooved channels. In the case of a staggered grooved channel, it is represented a greater heat transfer rate compared to the inline case. It is concluded that the maximum performances are displayed for smooth microchannel. But, compared to the inline grooved channel, the staggered grooved microchannel has shown better performance.

Keywords: Heat transfer; Inline and staggered; Knudsen number; Roughness height; Grooved microchannel.

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Characterization of Biocrude Oil Produced from Hydrothermal Liquefaction of Water Hyacinth

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ABSTRACT

Water hyacinth (Eichhornia crassipes) is an invasive aquatic plant species that can quickly form dense mats on the surface of bodies. Due to its propensity to poliferate swiftly, It can obstract waterways and degrade water resources causing detrimental effects on aquatic ecosystems. This issue can be solved by converting water hyacinth into biocrude by Hydrothermal Liquefaction (HTL). In this study, root, leaf stalks, and leaves of Water Hyacinth (WH) were converted to bio-crude oil by HTL. The HTL of WH was evaluated in a 25 cc HTL reactor under 10% solid loading, 300^0C temperature and 60-minute operating conditions. The yield of biocrude was 28.2%. However, the higher heating value (HHV) of 33.02 MJ/Kg was obtained for HTL biocrude. By elemental analysis, biocrude was found to have 68.8% carbon, and 9.1% hydrogen, with the potential to resemble petrocrude. The FTIR analysis confirmed the presence of ester, alcohol and Carboxylic acid at biocrude. The GC-MS fractionation analysis of HTL biocrude revealed the maximum heavier fraction fuel oil (72.93%). The findings of this study suggest that the HTL of root, leaf stalks, and leaves of Water could be a comprehensive approach to converting waste to bioenergy products.

Keywords: Water hyacinth; Hydrothermal liquefaction; Biocrude; Biochar; GC-MS; FTIR.

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Financial Analysis of Grid-Tied Solar Park's Feasibility in Coastal Area

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ABSTRACT

This project work focuses on energy yield assessment and feasibility analysis of a grid-tied solar photovoltaic power plant in the coastal region of Bangladesh. Bangladesh is experiencing a gradual depletion of its primary energy resource such as natural gas and the time has come to explore and harness the full potential of alternative energy sources to ensure our long-term energy security as well as sustainable economic development. Realizing the importance, Bangladesh Government attaches due importance to renewable energy. One of the most common sources of renewable energy now a day is solar and its production over other energy sources rising globally. With the advancement in carbon emission reduction and the development of low-carbon power systems, solar power technology has become a new hot issue of renewable energy and it is of crucial importance to solve the interlinked global challenges of climate change and energy security. The selected site is located at Sabrang, Teknaf, Cox's Bazar near BREB substation Teknaf-4 (Proposed), latitude is 20.83º N and longitude is 92.31º E. Global Horizontal Irradiation (GHI) at sabrang is 1863 kWh/m^2 per year. To assess solar irradiation and estimate annual energy yield for this location, a simulation has been conducted with photovoltaic simulation software PVsyst version 7.1.2. This project work also took into account all measurable loss factors such as optical losses, PV array losses, DC to AC conversion losses, and other system losses. Finally, financial analysis has been done by calculating the key financial profitability indicators such as levelized cost of electricity (LCOE), net present value (NPV), internal rate of return (IRR), Payback period (PBP) benefit-to-cost ratio (B/C) or profitability index (PI). Project work also assessed the measurable risk for this selected project. To effectively utilization of unlimited solar potential, more research is required to analyze the feasibility of utility-scale floating solar power plants and rooftop solar on industry roofs, railway stations, and residential building roofs.

Keywords: Solar park; Power plant; Alternate energy source; GHI; System loss; Risk**.**

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Selecting Optimal Sites for Solar Power Plants in Bangladesh Using a GIS And AHP-based Multi-Criteria Decision Analysis (MCDA)

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ABSTRACT

Choosing a suitable location for a solar power plant is an extremely challenging undertaking because there are so many things to think about, such as the environment, the economy, and the weather. This study used geographic information systems and a multi-criteria decision-making (MCDA) method to analyze and choose the best site for utility-scale solar power site selection. The model takes into account both scientific and economic factors to make sure that the most power is produced with the least amount of money spent on the project. An analytical hierarchy process (AHP) is used to weigh the factors and come up with a land suitability index (L.SI) that can be used to evaluate possible sites. Based on how likely and predictable they are, the L.S.l. classification breaks places into five groups: "least suitable," "marginally suitable," "moderately suitable," "very suitable," and "very highly appropriate." The model uses data from real climate researchers and law information about things like roads, slopes, mountains, and protected areas. The solar analyzer tool in ArcGIS software uses real weather conditions to determine the solar irradiance for the whole study area. The model of air temperature was made by interpolating data from the Bangladesh Meteorological Department's devices for monitoring that was spread out all over Bangladesh. The analysis's overlay map showed that 31% (46311 km^2) of the study area is great for the construction of solar power plants, with the best places being in the south and southwest of Bangladesh. It has been shown that possible land follows a pattern that depends on how far it is from big roads, power lines, and cities. In this study, we found that the L.Sl was very high in more than 57.6% of the right places. with the installation of solar power plants in the best place for it. The mix of multi-criteria decision-making (MCDM) and geographic information system methods has proven to be a very effective way to deal with large areas, large amounts of geographic information data, and the manipulation of key criteria.

Keywords: Solar energy; MCDA; GIS and AHP; Site selection.

1. INTRODUCTION

Renewable energy sources like the sun, wind, biogas, and geothermal are perfect for a safe, stable, and low-carbon future because they are natural, free, and easy to absorb. One of the green energy sources that are growing the fastest is solar power plants [1]. PV module prices have recently dropped by 80%, and it is expected that they will continue to fall in the coming years, as long as past factors like slowly falling production costs and the effect of a growing market keep pushing prices down. Solar photovoltaic (PV) technology can be used in large places that get a lot of sun. But radioactivity that is different in different places is a problem[2]. When choosing a site for solar panels, location and cost should be taken into account to get the most out of them. A thorough assessment of the solar site is a key part of making sure that a solar project is good and saves money[3, 4]. Given that many things could affect the choice of place. MCDM methods have been used in a lot of successful energy planning projects. Both Ramachandran and Pohekar[5], Mateo [6], and Wang et al [7]. do a good job of evaluating the literature on how MCDM methods can be used to plan renewable energy sources.

In recent years, the Geographical Information System, or GIS, has become more popular for use in site selection studies, especially those related to energy planning [8-22]. Several study and strategy firms, such as the National Renewable Energy Laboratory, suggest that figuring out where possible PV projects could go is the first step in any planning process [4, 21-25].

The process of determining a place can be divided into several of the following general steps: [14]

- Making a list of things that could go wrong and guidelines for making decisions for the site selection study;
- Model-based site selection and site prioritization;
- Using sensitivity analysis, you can learn more about how relevant choice criteria are.

Taking 14 variables to consideration, solar PV technology is the best choice. Based on a review of Bangladesh's renewable sources, [26] The study offers a decision model that uses GIS data and AHP as an MCDM method to make it easy to choose an appropriate location for utility-scale solar PV installations that are connected to the grid. With this method, DMs can better understand factors that are hard to explain and depend on the person.

Solar energy is important for Bangladesh because it can help improve access to energy, slow down the effects of climate change, improve energy security, boost the

economy, protect the environment, and contribute to long-term growth. Bangladesh can get many benefits from usingsolar energy, which makes it a valuable and strategic choice for the country's energy transition.

2. MATERIALS AND METHODS

The goal of this study is to come up with a way to separate land that could be used for solar farm projects into different levels based on how well it seems to fit such projects. Figure 1 shows the different steps that have been planned to reach the goal. The first step in the research process is to choose a case study. Next, a book review is done to figure out how much demand there is for projects like this and if the recommended site is right for these kinds of projects. Next, decide which parts of the land's suitability for solar farms are most important, keeping in mind the details of the case study and the technical problems it presents. As a result of this study, each factor is given a certain amount of weight to create a measure that can be used to judge how suitable a piece of land is. The AHP [27-36] was used to figure out these total weights. Then, the final suitability map is made with GIS, a map that lets you do spatial analysis and add a number of factors to the recommended index to find places that aren't good.

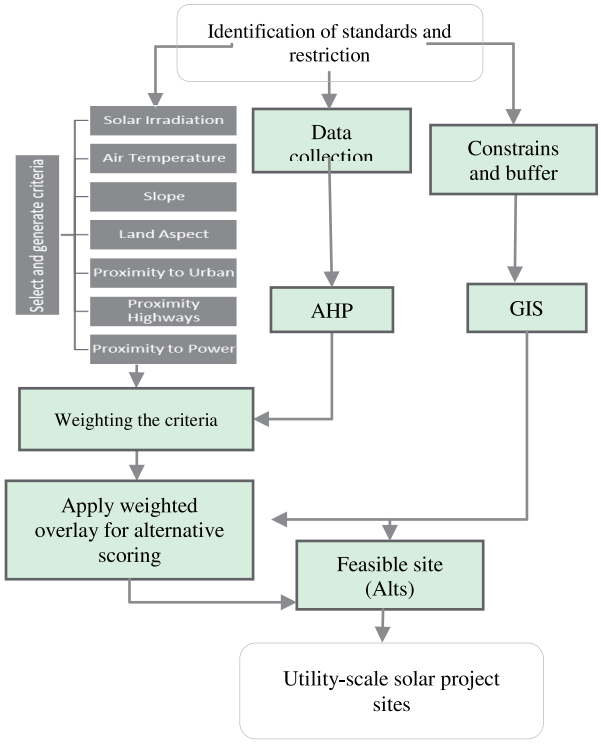

Fig. 1: Flow chart of the proposed method

2.1 Data used

The criteria came from different places, and then the reclassification criteria were worked out. The digital elevation model was used to make the slope and land aspect maps after solar energy data were pulled from the NASA website. The Bangladesh Meteorological Department gave us information about the temperature of the air. The 1320 MW coal-based power plant at Gaibandha-Dinajpur was used to digitize the map of the energy supply lines. Banglapedia was used to get the map of the roads.

2.2 Study area

The study area of Bangladesh defined by the coordinates 20°340′N to 88°0′E and 26°380′N to 92°410′E. This country is geographically unique in that it is almost entirely surrounded by India, sharing borders on its west, north, and northeast sides. To the southeast, Bangladesh shares a border with Myanmar. The country is also home to a distributed coastline that stretches along the Bay of Bengal, with the Sundarbans, the world's largest mangrove forest, located on the southwestern coast. (Fig. 2).

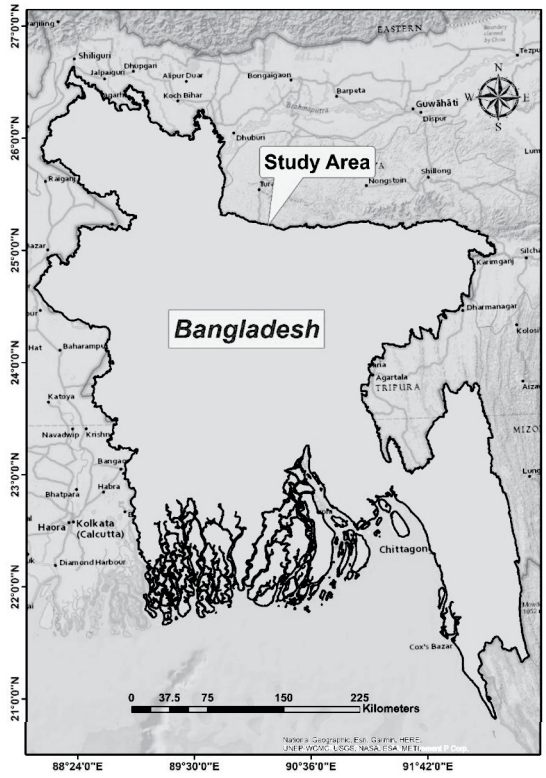

Fig. 2: Study area map of Bangladesh (Source: author)

2.3 Land suitability evaluation factors

Large-scale power plant projects are located at sites that take into consideration technical factors that have a direct effect on how well the plant works [11]. Two examples are the amount of radiation and the norm for air temperature. How the location of solar farms changes the cost of a project is determined by economic factors[9]. These include slope, proximity to the land's orientation, closeness to roads, closeness to power lines, and proximity to cities (Fig. 3). Here is a full description of the two factors for technical and economic feasibility:

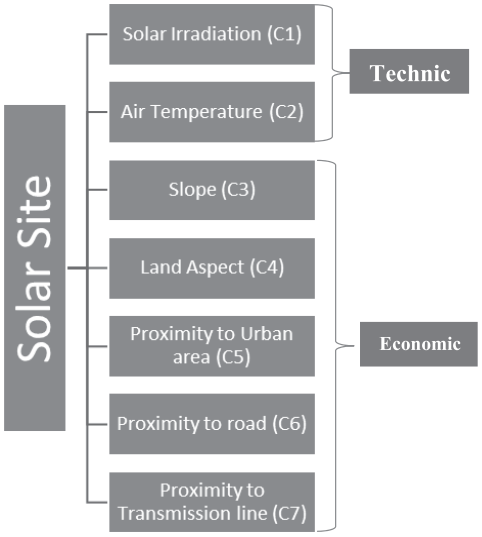

Fig. 3: Decision criteria considered in solar site selection

- **Solar irradiation (C1) (kWh/m^d):** The solar analyzer feature of the ArcGIS software maps and analyzes solar energy for certain places or points at a certain time. It is good for modeling sun irradiation for an area with different topography because it takes into account local factors like direction, slope, and temperature.

Table 1: ArcGIS solar analyst tool parameters

ArcGIS solar analyzer tool parameters			
Parameter	**Value**	**Parameter**	**Value**
DEM	Resolution of 90m	Slope Aspect Input Type	DEM
Latitude	24.1 (Auto)	calculations Directions	32
Sky size	200 (Default)	Zenith Divisions	8
Time Configuration	Whole Year (2022)	Azimuth Number	8
Day interval hour	14 (Default)	Diffuse Model Type	Uniform sky
Hou r interval	0.5 (Default)	Diffuse Proportion	0.36
Z units	1	Transmissivity	0.65

- **Average temperature (C2) (°C):** The From 2010 to 2019, the Bangladesh Meteorological Department (BMD) collected data on the average temperature. These observations showed that the average temperature had changed. A study [37] is a summary of an analysis of the measurement data used at 35 places across the country. During the study period, each place keeps track of the average temperature for the year based on 24 hours of data for each day. When we used the weight parameter , we got higher values for the weight parameter, which made the surface harder (weight = 10, no. of points = 4).
- **Slope (C3):** Avoiding the high building costs needed in high slope locations will be possible by using flat terrain or somewhat steep slopes[35]. Large-scale PV farms require level topography; As a consequence of their limited economic feasibility, high-slope locations are rarely selected for such projects.
- **land aspects (C4):** The land aspect is a topographical characteristic that refers to the direction of the land slope. The angle of azimuth, which runs from 0 to 360 degrees, is used to indicate it. 0 or 360 represents the north, 90 represents the east, 180 represents the south, and 270 represents the west. Slopes that face south are the best orientation for solar farm locations in nations in the Northern Hemisphere[32].
- **Proximity to urban areas (C5):** Several studies indicate that locations farther from metropolitan centers are better suited for the development of renewable energy. In order to reduce the adverse environmental effects of urban growth and overcome NIMBY (not in my back yard) resistance[5, 9, 38]. On the other hand, according to some research, locations close to cities offer larger economic benefits[4, 22].
- **proximity to highways (C6):** Better accessibility will result from being near highways, and this closeness also helps to minimize the expense and negative environmental effects of building new infrastructure[39]. In terms of building expenses, proximity to major roadways is crucial.
- **proximity to power lines (C7) (m):** Power loss in distribution and transmission networks is significant. Keeping solar photovoltaic (PV) facilities close to existing power lines would reduce transmission loss and eliminate the need to build costly new power infrastructure[40]. The solar power plants' close proximity to the energy transmission line offers a benefit in terms of efficiency.

2.4 Procedure for multi-criteria determination using the analytical hierarchy process (AHP)

Due to its broad application and the universal acceptance of the veracity of its widely believed claims of rigorous mathematical properties, the Analytic Hierarchy Process (AHP) has attracted a lot of attention [1]. AHP has been used by academics from many different sectors for a number of objectives since it can solve issues by weighing a range of elements. The AHP helps users get closer to the ideal address by allowing them to precisely weight the factors that are most important in a multi-criteria decision-making problem. A pairwise comparison matrix based on the preference scale is constructed in order to compare the criteria at one hierarchy level with the criteria at the next hierarchy level. (Table 2) [25]. The pairwise comparison matrix has n (n-1)/2 comparisons for an n-entry matrix like n-number.

Table 2: Fundamental scale for pairwise comparison [25]

SN	Intensity of Importance	Definition	Explanation
1	1	Equal importance	Two activities contribute equally to the objective
2	3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
3	5	Essential or strong importance	Experience and judgment strongly favor one activity over another
4	7	Demonstrated importance	Activity is strongly favored and its dominance demonstrated in practice
5	9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
6	2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed the
7	Reciprocals	If activity *I* have one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

The AHP method sets relative weights to each criterion to be taken into consideration throughout the problem-solving phase through a pairwise comparison procedure. Consistency ratios, which evaluate the percentage of pairwise comparisons that produce inconsistencies and are less than a threshold value (CR = 0.1), are used to quantify matrix consistency [26]. We will have to modify the DM scores in this situation. Use equation (1), which comprises the consistency index (CI), the principal eigenvalue (m) of the comparison matrix, and the random index (RI), which is dependent on the size (n) of the matrix, to obtain the correlation coefficient.

Saaty proposes selecting a maximum value of "0.10" for this ratio. If the consistency ratio is less than 0.10, it is considered that the evaluations are adequately consistent. Over a 0.10 threshold, it is assumed that the judgment is contradictory. Here, a higher standard of judgment is required. Analyzing the judgments could help lower the consistency rate [26]. To determine which locations would be suitable for solar photovoltaic (PV) installations, we employed eight thematic layers that were incorporated into the GIS platform. The weighted overlay approach of Equation (2) was used for this.

The parameters X_i and W_j represent the normalized weights for the ith feature and the jth class in the thematic layer, respectively. SI represents the suitability index for solar (PV) farm locations; m represents the total number of themes; and n represents the total number of classes inside a theme.

2.5 Restrictions for site selection

Research into what is and isn't acceptable has selected as limiting criteria urban areas, protected land, large transportation networks, and water bodies [21]. These four constraints are typically used in solar site suitability analyses and are equivalent to this one. At the moment, about 17.08% of the country is set aside for parks and reserves. The map is given in Fig. 4.

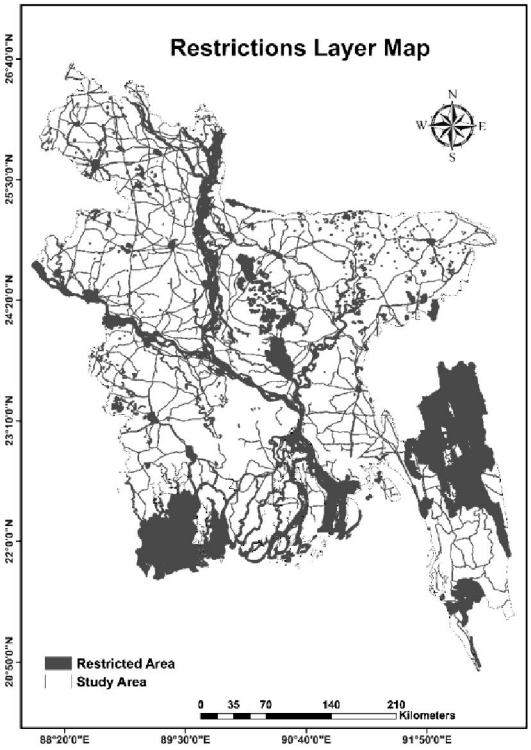

Fig. 4: Restrictions layer map

2.6 GIS processing

This research is the first AHP-GIS analysis of solar power plant allocation in Bangladesh. Figure 1 demonstrates how the suitability map was made using ArcGIS Desktop 10.8, whereas all of the geo-information used came from open internet databases. To find the best and worst places for solar farms, this study employs eleven constraints to establish seven assessment criteria. All parameters for the geospatial analysis models were chosen after taking into account the specifics of the study area, expert opinion, and a comprehensive analysis [6-16].

2.7 Preparing the standardized suitability maps

All the criteria in the suitability map were mapped out and organized using GIS software. The resulting maps show how various factors were prioritized and evaluated. After being drawn, processed in a raster format with 90 by

90 m pixels, and sorted, each map was unique. The distribution of each criteria on the map has been analyzed and decided. The digital elevation model was used to generate the specifications for the slope as well as the height. With ArcGIS's "Slope" tool, we can create the slope map. Next, the map is reorganized using the classification program. To complete the overall flash density map, a land aspect distribution map was made using the reclassification tool in ArcMap 10.8. The whole map was then reclassified.

3. RESULTS AND DISCUSSION

Using AHP-GIS, the results of a geographical study of where solar energy systems are located in Bangladesh are given and thoroughly looked into.Here is the final map of a site's suitability and the numbers that give it the best possible evaluation weighting.

There are numerous benefits of solar energy, which is energy derived from the sun's radiation. Some of the key benefits in Bangladesh Perspectives is given below include:

1. Renewable and Sustainable: Solar energy is a renewable and sustainable source of energy, as it is derived from the sun, which is a virtually limitless resource [36]. As long as the sun continues to shine, solar energy can be harnessed for power generation, making it a reliable and long-term solution to meet our energy needs.

2. Environmentally Friendly: Solar energy is a clean source of energy that produces no harmful greenhouse gas emissions, air pollution, or water pollution during its operation. It helps to reduce our dependence on fossil fuels, which are major contributors to climate change, and helps to mitigate the negative impacts of burning fossil fuels, such as air pollution and environmental degradation[40].

3. Energy Independence: Solar energy allows for greater energy independence, as it reduces reliance on fossil fuels, which are often imported and subject to price fluctuations. By generating electricity from solar panels on-site, homes, businesses, and communities can reduce their dependence on external energy sources, increase energy security, and have greater control over their energy costs [41].

4. Cost-effective: While the upfront costs of installing solar panels may be higher, solar energy can be cost-effective in the long run. Once installed, solar panels require minimal maintenance and have a lifespan of 25-30 years or more, making them a cost-effective solution for electricity generation over their lifetime. Solar energy can also provide savings on electricity bills, as excess electricity generated by solar panels can be fed back into the grid or stored in batteries for later use, offsetting the need to purchase electricity from the utility[42].

5. Job Creation and Economic Benefits: Solar energy has the potential to create jobs and stimulate economic growth. The installation, manufacturing, and maintenance of solar panels require skilled labor, creating job opportunities in the renewable energy sector. Additionally, by reducing dependence on fossil fuels and promoting local energy generation, solar energy can contribute to local economic development and energy resilience [43].

6. Scalable and Versatile: Solar energy can be used in a wide range of applications, from powering homes and businesses to providing electricity for remote areas and powering transportation. Solar panels can be installed on rooftops, ground-mounted in solar farms, integrated into buildings, and even used in portable devices, making solar energy a versatile and scalable source of power.

7. Sustainable Development: Solar energy can contribute to sustainable development by providing access to clean and affordable electricity in rural and remote areas without access to traditional power grids. Solar-powered electricity can be used for lighting, cooking, heating, powering water pumps for irrigation, and other essential services, improving living standards, education, healthcare, and economic opportunities in underserved communities [44].

Solar energy can benefit a wide range of communities, including residential, commercial, industrial, rural, remote, developing, educational, healthcare, community, and non-profit organizations. Solar energy has the potential to provide clean, affordable, and sustainable electricity, contributing to economic, social, and environmental well-being in diverse communities around the world.

3.1. AHP results

The AHP-based MCDM method was applied in this research to analyse weights for each of the seven criteria that influenced the factors (C1: solar irradiation; C2: air temperature; C3: slope; C4: land aspects; C5: proximity to urban areas; C6: distance from highways; C7: proximity to transmission lines). It was determined that factor C1 of the criteria carried the highest weight when deciding where in the study region photovoltaic (PV) plants should be constructed (35.4%). The study found that a CR ratio of 0.025 is optimal.

3.2. Solar PV site suitability categories

Figure 5 shows the final result, a map showing the viability of various photovoltaic (PV) site locations. Table 3 displays the total area corresponding to each suitability class as well as the numerical results for that class. The

research indicates that 32.05% (46,311.61 km^2) of the land is very high suitable, 26.55% (39,616.19 km^2) is high suitable, 29.83% (44,4886 km^2) is moderately suitable. The high and ideal locations, which account for 57.61 % of the land, would be designated as optimal locations, requiring investment development and laws specific to solar (PV) energy projects.

According to the suitability map, the best landscape is in the western and central southern regions. Also, it is generally agreed that coastal regions are ideal locations for photovoltaic (PV) installations. Each of these areas meets a set of requirements that makes the installation of solar photovoltaic (PV) sites feasible, making them prime candidates. An optimal land slope and elevation, strong solar (PV) activity, near proximity to grid TLs and northern airports, isolation from urban and rural regions, and low vulnerability to lightning strikes are all important factors.

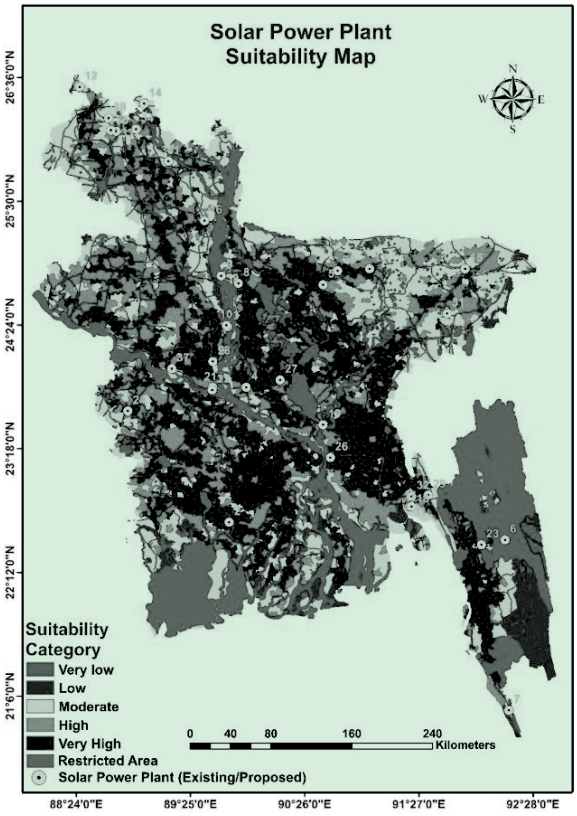

Fig. 5: Suitability map for solar power plant locations

Table 3 : Areas of each suitability class and their percentage to Bangladesh's total land area.

SN	Class	Map Color	Name	Area (SKM)	Percentage (%)
1	Very low	Green	Very low	3869.47	2.59
2	Low	Antique Gold	Low	14849.50	9.96
3	Moderate	Yellow	Moderate	44488.00	29.83
4	High	Cerulean	High	39616.19	26.56
5	Very high	Blue	Very high	46311.61	31.05

3.3. Validation and comparison

The SREDA is now working on 37 photovoltaic (PV) site projects around Bangladesh. However, the sites of these projects have been marked on the suitability map produced by this study, allowing for an examination of the study's possibilities. It was found that eight projects whose construction is complete and running are situated in places with very high and high suitability, while eight projects for which planning is currently underway are placed in regions with moderate and high appropriateness. Twenty more projects have had their feasibility studies completed, and construction will shortly begin. Two of these projects are in areas with high suitability.

Table 4. Previous Solar power plant position according to our research

SN	Suitibility Area	Total Plant
1	Very low	3
2	Low	7
3	Moderate	9
4	High	14
5	Very high	4

4. CONCLUSIONS

This This study provides an approach for locating feasible solar farm installation locations in Bangladesh based on GIS and AHP. It is strongly advised to choose the best site for solar firms before moving on with the installation of the equipment that produces power, despite the difficulties in locating an acceptable place. This needs to be finished before continuing with the installation. The MCDM approach successfully handles complex decision-making issues by utilizing the GIS platform. In this study, decision-supporting characteristics were evaluated using expert judgment and evidence from prior investigations. AHP was used to evaluate the significance and weight of the selected elements in the decision to grant assistance. The final solar suitability map was produced by combining all of the weight-based raster criteria specified by the AHP. According to this analysis, Bangladesh has a great chance of using solar energy because of its enormous land area. It is found that the "extremely high-suited sites are spread out across the country rather than being concentrated in a single area. As a result, any region may build utility-scale solar farms to make the switch to renewable energy. There will be a significant decrease in expenditure on roads and transmission lines as a result of the scattered nature of solar farm-appropriate locations. Additionally, because of this, beginning costs will be less expensive. The complicated renewable energy decision-making process in Bangladesh has been solved as a result of this study.

Despite the removal of a number of important geological aspects of the study region that have a significant impact on site selection, this research will serve as a strong basis for the growth of renewable energy. The complexity of site planning and construction for the proposed solar farms, as well as their post-construction

safety and resilience, are all significant considerations. Therefore, our work recommends further investigation while taking into account the unique geological characteristics. As a consequence, the results of the current state of the art might persuade decision-makers to invest in power generation with a higher likelihood, which would be advantageous for Bangladesh's efforts to reduce its carbon emissions.

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Food Engineering

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Physicochemical and Antioxidant Properties of Fresh and Boiled Onion Flower Stalk

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ABSTRACT

Cooking induces significant changes in chemical compositions, affecting bioavailability and the content of antioxidant compounds, in vegetables. To investigate the effects of boiling time on physicochemical properties, and to identify the changes in antioxidant activity onion flower was boiled at 100°C for 5, 10, 15 and 20 min. Physicochemical properties were determined by following AOAC methods. The total phenolics were determined using the modified Folin-Ciocalteu method, flavonoid content in the vegetable extracts was determined by Aluminum chloride colorimetric method, tannins were determined using the Folin-Ciocalteu Phenol reagent. Antioxidant activity was evaluated by DPPH radical scavenging activity assay. From the physicochemical analysis, it was found that the moisture content and pH increased with the increase in boiling time, whereas ash content, total soluble solids, water activity, titrable acidity and ascorbic acid (vitamin C) decreased gradually. The ascorbic acid content of fresh onion flower stalk was 20.59 mg/100g f.w. which decreased by 71.45% after 20 minutes of boiling. The total phenolic compounds, total flavonoids and total tannin content in fresh onion flower stalk was 200.34±2.89 mg GAE/kg f.w., 175.64±0.505 mg QE/kg f.w. and 197.44±1.15 mg TAE/kg f.w., respectively. However, prolonged boiling caused a detrimental effect on these bioactive compounds and it was observed that 20 min of boiling caused about 48.84% loss in total phenolic, 27.39% loss in total flavonoids and 48.62% loss in total tannin. The results also showed that the ethanolic extract of onion flower stalk possesses DPPH free radical scavenging activity. IC50 values increased gradually which indicates a decreased antioxidant activity. The results of our investigation suggested that reducing cooking time would minimize the loss of ascorbic acid, polyphenols, flavonoids, tannin and preserve the antioxidant activity.

Keywords: Onion flower; Flavonoids; Polyphenols.

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Development of Instant Green Tea by Foam Mat Drying Technique and Their Quality Evaluation for Commercial Application

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ABSTRACT

Foam mat drying is an economical alternative to drum, spray, and freeze-drying, where a liquid is turned into a stable foam, and then it goes through air drying. A high-quality food powder can be obtained by a proper selection of foaming methods, foaming agents, foam stabilizers, and the time taken for foaming. This study aimed at developing instant green tea powder through foam mat drying from green tea extracts and focused on investigating the antioxidant levels in both green tea and made instant green tea powder. For making instant green tea, 1.0% Carboxymethyl cellulose (CMC) as emulsifiers and 5% egg albumin as foaming agents were incorporated into green tea extracts, whipped for 5 minutes, and dried at 40ºC temperature until gaining a consistent weight. Thereafter both green tea and instant-made green tea samples were prepared using methanolic extraction. Then, the total phenolic content (TPC), total antioxidant activity (TAC), and diphenyl-picrylhydrazyl (DPPH) scavenging activity of both samples were determined by spectrophotometer at 765nm, 695nm, and 517nm, respectively. In making instant green tea powder by foam mat drying process, total antioxidant capacity was reduced by 0.406 mg AAE/g (from 0.809 mg AAE/g to 0.403 mgAAE/g), and total phenolic content was decreased by 7.79 mg GAE/g (from 10.45 mg GAE/g to 2.66 mg GAE/g) and DPPH radical scavenging activity percentage reduced by 33.9% (from 62.20% to 28.3%) from green tea extracts.

Keywords: Foam mat drying; Instant green tea**;** Carboxymethyl cellulose; Total antioxidant activity; DPPH radical scavenging activity.

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Extraction of High-value Collagen from Fish Waste

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ABSTRACT

According to pevious study, there was no technology for the fish waste produced by Bangladeshi local fish markets. Objective of this study was to utilize local fish waste as to collecting/extracting high –value protein (Collagen) by pH shifting protein isolation technology. Protein isolates from different types of fish scale powder were extracted using pH shift processing at different pH levels, and acid-soluble collagen was also extracted from the insoluble residue of fish scale powder after the extraction of protein isolate. Protein solubility, yield percentage of precipitated freeze-dried protein isolate powder, and extracted collagen were studied. The maximum average protein solubility of fish scale powder was observed at pH 2 (99.218%) in an acidic condition and at pH 8 (58.436%) in an alkaline condition. The maximum yield percentage of precipitated freeze-dried protein isolate powder was found at pH 2 (71.75±0.66%) in an acidic condition, but precipitation of protein isolate was very little or not found in an alkaline condition. The maximum amount of extracted acid-soluble collagen (ASC) was found in the pH 2 treated insoluble fish scale residue and the pH 12 treated insoluble fish scale residue samples. The maximum amount of extracted acid soluble collagen from pH 2 and pH 12 treated insoluble fish scale residue were found 0.3816 % and 0.3032 % respectively. The whiteness of the extracted protein isolate that was treated only at pH 2, 3, and 4 in an acidic condition was also observed. The maximum whiteness of protein isolate was found at pH 3 (91.87±2.75) and then at pH 4 (85.98±1.86) ($P< 0.05$). The scanning electron microscope (SEM) test of precipitated freeze-dried protein isolate and freeze-dried ASC was performed to observe the microstructure of extracted ASC and protein isolate powder at different pH levels in an acidic and alkaline condition. Microstructural differences between ASC samples and protein isolates were observed when they were treated at pH 2, 3, 4, 6, 10, and 12 for the ASC sample in both acidic and alkaline conditions, and at pH 2, 3, and 4 for the protein isolate in an acidic condition. So, it was concluded that a lower pH level in an acidic condition affected the microstructure of the ASC sample but was not affected in an alkaline condition because the same microstructure was found on the alkaline side and extracted protein isolate at pH 2, 3, and 4 SEM image was observed different microstructure. Water solubility of freeze-dried protein isolates from two samples treated with pH 2 and 3 was also determined at pH 2, 3, and 4 in an acidic condition and at pH 8, 10, and 12 in an alkaline condition. The maximum water solubility of the pH 2-treated sample was found at pH 3 (2.816%) in an acidic condition and at pH 12 (2.082%) in an alkaline condition. The maximum water solubility of the pH 3-treated sample was observed at pH 2 (4.415%) in an acidic condition and at pH 12 (1.618%). The purity of the collagen samples, which were extracted from insoluble residues of fish scales, was determined by a UV-Vis spectrophotometer, which was treated at pH 2, 3, 4, and 6 in an acidic condition and at pH 10 and 12 in an alkaline condition. The absorption peaks of collagen samples were measured at wavelengths ranging from 230.4 to 230.8 nm. These wavelengths were similar to the pure collagen absorption peak at 230 nm. So, it indicates the extracted collagen was pure. Final product of the study could be use as a cosmetics raw materials and protein supliments.

Keywords: Protein isolate; Collagen; pH-shift method; Fish scale; Protein solubility.

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Impact of Slightly Acidic Electrolyzed Water in Combination with Ultrasound and Mild Heat on Safety and Quality of Freshcut Cauliflower

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ABSTRACT

Slightly acidic electrolyzed water (SAEW) has recently gained popularity as a chlorine sanitizer because it provides greater decontamination efficacy while using less available chlorine. However, microbial reductions achieved literally through SAEW treatment are insufficient to ensure safety. Combining SAEW with other compatible techniques can improve its disinfection efficacy. As a result, this study was carried out to assess the decontamination efficacy of SAEW alone and in combination with ultrasonic treatment and moderate heat on cauliflower. SAEW with a pH of 5.5-5.6, an available chlorine content (AAC) of 20-22 mg L^{-1}, and an oxidation-reduction potential (ORP) of 900-950 mV was applied to fresh-cut cauliflower to determine disinfection activity. SAEW was produced in an electrolysis unit without a membrane by electrolysis of a dilute NaCl solution (5 g/100 mL). To improve the bactericidal efficacy of SAEW, it was combined with ultrasound treatment (US) at 40 kHz frequency and moderate heat (45°C) for 10 minutes. Individual (SAEW) and combined treatments such as (SAEW + US), (SAEW + US + mild heat 45°C) were evaluated for their effects on the microbial population, physicochemical properties, and antioxidant activity of fresh-cut cauliflower. When compared to the control, SAEW treatment reduced total aerobic bacterial population by 2.21 log CFU g^{-1} and yeasts and molds by 1.17 log CFU g^{-1} of cauliflower. After combined treatment of SAEW and ultrasound, total aerobic bacteria on cauliflower were reduced by 3.05 log CFU g^{-1}, while molds and yeasts were eliminated by 2.16 log CFU g^{-1}. When compared to the effects of SAEW treatment alone, the combined treatment of SAEW with ultrasound reduced total aerobic bacteria by 0.84 log CFU g^{-1} and yeasts and molds by 0.99 log CFU g^{-1} on cauliflower. In this study, mildly heated SAEW with ultrasound treatment significantly reduced total aerobic bacterial population by about 4.14 log CFU g^{-1}, and molds and yeasts population by 3.46 log CFU g^{-1} compared to control. The combined treatment with mild heat was more effective at microbial decontamination than the other treatments, but it significantly reduced the antioxidant and physicochemical properties of fresh cauliflower. Untreated (control) and treated samples (SAEW, SAEW + US, SAEW + US + 45°C) contained 54.64, 54.03, 54.42, and 51.51 mg/100 g of vitamin C, respectively. Vitamin C was significantly decreased in SAEW + US + 45 °C heat treatment than other treatments. Total phenolics, flavonoids, tannin content and antioxidant activity were unchanged in the treated samples compared with untreated samples except for SAEW + US + 45°C heat treatment. In contrast to the untreated sample, reduction in total phenolics, flavonoids and tannin content of cauliflower treated with mildly heated SAEW with US treatment were 51.35%, 33.60%, and 37.70%, respectively. The antioxidant activity of SAEW with ultrasound-treated samples was higher than that of other treated samples and the standard (ascorbic acid). The SAEW treated sample had the lowest IC_{50} value (19.94), which corresponded to the highest antioxidant activity, followed by the control (20.42), combination of SAEW and US treated sample (20.43), and mildly heated SAEW with ultrasonically treated sample (71.44). However, SAEW with US treatment preserved bioactive compounds and antioxidant activity while significantly reducing microbial load. According to the findings of this study, SAEW with US treatment could be a promising decontamination technique for improving postharvest quality and reducing postharvest losses in fresh produce. Therefore, SAEW and its combination with ultrasound treatment would be a promising alternative decontamination technique for minimally processed vegetables. More study should be done to select the optimum and effective combination of SAEW and ultrasound for inactivating pathogenic microorganisms in fresh produce.

Keywords: Electrolyzed water; Ultrasound treatment; Cauliflower; Microbial reduction; Antioxidant activity.

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Formulation and Quality Evaluation of Plain Muffins Using Red Gram and Cabbage Powders as Nutritional Supplements

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ABSTRACT

Since the dawn of civilization, nutritional supplements have grown in popularity as a way to improve the functionality of food products. In Bangladesh, protein rich red gram is mostly consumed as a popular side dish or soup. On the other hand, cabbage is abundant during winter and somewhat an underutilized source of nutrient. Expectantly, the combination of these two might have the potential as an economical supplementation with appropriate nutritional profiles. Cabbage powder (CP) and Red Gram powder (RGP) were used in this study to fortify a popular bakery product like muffin cake and study the effects of this fortification on the composition, nutritional quality, sensory attributes and shelf life of the formulated products. Locally sourced Cabbage and Red Gram were dried in hot air drier and ground afterwards to obtain CP and RGP. Four cake samples were formulated using different proportions of composite flour: the control S_4 (100% wheat flour), S_3 (86% wheat flour, 10% CP and 4% RGP), S_2 (86% wheat flour, 7% CP and 7% RGP) and S_1 (86% wheat flour, 4% CP and 10% RGP). Results of proximate analysis showed that the increase of RGP and decrease of CP in cakes gradually increased the moisture content (10.62-27.55%, db.), protein (12.04-14.29% db), fat (25.71-30.68% db.), ash (1.49-1.85%, db.), carbohydrates (73.82-120.60%), energy (417-480.25 Kcal/100g) and lowered vitamin C (17.72-5.36 mg/100g) contents. Supplemented cakes had higher amounts of calcium (Ca), Zinc (Zn), Iron (Fe) and lower amounts of phosphorus (P) than control sample (13.85-19.10 mg/100g, 0.14-0.26 mg/100g, 0.80-1.20 mg/100g and 9.29-9.24 mg/100g respectively). Concerning to physical properties, increasing the percentage of RGP with decreasing percentage of CP increased the volume (48-59 cm^3), the specific volume (1.79-1.91 cm^3/gm), height (1.83-2.50 cm), weight (26.84-31.42 gm) and baking loss (8.11-8.58%) of cakes. Considering color, lightness (L*) of crumb increased (61.54-62.66), the redness (a*) of crumb increased (8.59 -13.48) and the yellowness (b*) of crumb increased (34.06-38.05) with increasing RGP and decreasing CP addition. For Microbial studies, cakes were nitrogen packed in single layer polythene. The examination revealed that the total viable count expressed as Colony Forming Units (CFU) for cakes ranged from 3.1×10^3 to 4.5×10^3 CFU/g after 6 days of storage. The sensory analysis with respect to color, flavor, texture and overall acceptability was carried out using a 9-point hedonic scale and a panel of 20 tasters. The sample S_3 (86% wheat flour, 10% CP, and 4% RGP) was found to be more acceptable than others in terms of flavor, texture, and overall acceptability, while the control S_4 (with only wheat flour) was found to be more acceptable in terms of color. Thus, it can be inferred that, employing CP and RGP as supplements may upgrade the nutritional profiles of the targeted bakery items, but further extensive research must be carried out to improve the sensory and physical attributes.

Keywords: Bakery products; Composite flour; Supplementation; Microbial load; Nutrition.

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A Brief Analysis of the Manufacturing Process for Two Antibiotics in a Multinational Pharmaceutical Company in Bangladesh

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ABSTRACT

Antibiotics are the most powerful and widely given antibiotics for bacterial illness prevention. It is primarily used to treat a wide range of bacterial infections, including stomach, bone, and joint infections, by inhibiting bacterial cell wall formation. The penicillin and cephalosporin antibiotic groups are particularly adept at this mechanism. Penicillin and cephalosporin have comparable manufacturing processes, but for various reasons, they cannot be produced in the same facility. One reason is that if both of these groups are manufactured in the same facility, cross-contamination occurs. Cross-contamination is the transfer of harmful germs or pollutants from one object or organism to another. As a result, certain patients may experience a hypersensitive reaction as a result of this contamination (an estimated 10% of the population). Another factor is that using various manufacturing facilities allows for smooth output. As a result, manufacturing penicillin and non-penicillin drugs requires fewer labor hours. Furthermore, the quality control processes for various dosage forms vary. Physical and laboratory tests are required for tablet and capsule manufacturing processes, whereas physical tests are not required for liquid or injectable products. Penicillin and non-penicillin goods should be manufactured in separate facility systems for patient safety and to preserve product quality.

Keywords: Antibiotic; Cephalosporin; Penicillin; Manufacturing process; Quality control; In-process control.

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Development and Quality Assessment of Composite Biscuits Fortified with Potato and Corn flour

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ABSTRACT

Applying composite flour in bread production could provide a healthier alternative to bread made with wheat flour. This study aimed to develop fortified wheat flour bread with improved nutritional properties, thereby enhancing the overall nutritional value of wheat flour bread. This study used potato and corn flour as supplementary components to produce fortified biscuits. Wheat flour contains optimum levels of moisture (13.10%) and protein (9.37%), while potato flour contains the highest levels of ash (1.6%) and total carbohydrates (82.39%). The result shows that corn flour had the maximum fat content at 2.54% and the highest energy content at 360 Kcal/100 g. As the level of supplementation increases, the diameter, thickness, and volume increase significantly while the weight, spread ratio, and density decrease. The chemical analysis revealed that the control biscuits made with 100% wheat flour had the highest moisture content (5.02%), while the sample containing 50% potato flour and 50% wheat flour had the highest ash content (1.11%). The fat content increased while the protein content decreased as the potato or corn flour percentage increased. Sensory analysis of biscuits revealed that a combination of 50% potato flour and 50% wheat flour (F2) was the most popular among consumers. Based on sensory evaluation and storage studies on the shelf-life of processed biscuits, it is recommended that up to 50% of the wheat flour in fortified biscuits may be replaced with potato flour on an industrial scale.

Keywords: Biscuit; Fortification; Quality; Physical properties; Composite flour; Shelflife.

Information & Communication Technology

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A Comprehensive Review of IoT-enabled Crop Yields and Sustainability Improvements in Bangladeshi Agriculture

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ABSTRACT

In the age of the fourth industrial revolution, the agriculture industry in Bangladesh plays an important part in the country's economy, accounting for around 15% of GDP and employing more than 45% of the workforce. To fulfill the rising demand for food of both quality as well as quantity, agricultural modernization and intensification are required. Therefore, IoT technology is providing novel solutions to upgrade and maintain the sector. This research offers a systematic literature review (SLR) that examines the current use of IoT technology in several agricultural application fields in Bangladesh. The analysis discovered that crop monitoring, irrigation management, and animal monitoring were the most prevalent IoT application domains in agriculture in Bangladesh. The bulk of the articles chosen (60%) were about crop monitoring, while 19% were about irrigation management and 13% were about animal monitoring. The primary purpose of this systematic study is to consolidate all relevant research on IoT agricultural applications, sensors or devices, communication protocols, and network types. The study also emphasizes the significant concerns and obstacles being investigated in agriculture, such as a lack of internet connectivity, limited power supply, and high implementation costs. Lastly, the research outlines critical challenges and bottlenecks, pointing academics in the direction of probable future approaches in the field of IoT agricultural production. According to the study, future research should focus on producing low-cost IoT devices and investigating alternate communication protocols suited for the agricultural setting in Bangladesh. Finally, this article provides a comprehensive analysis of the existing use of IoT technology in several application areas of Bangladesh's agriculture industry. According to the findings, IoT has the potential to substantially enhance agricultural yields and sustainability in Bangladeshi agriculture.

Keywords: Internet of Things; Low-cost IoT devices; Bangladeshi agricultural sector; Sensors; IoT based agriculture; Fourth industrial revolution.

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Comparative Study of Sparse Canonical Correlation Analysis (SCCA) on High-Dimensional Data

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ABSTRACT

Canonical Correlation Analysis (CCA) is one of the most powerful multivariate techniques that can be used to quantify the relationship between two sets of variables. It is appropriate in such case where the number of variable did not exceed the sample size for all the data sets. In many applications (for instance, genomic studies), the number of variable of the dataset exceeds sample size that is called high-dimensional data. However, it is big challenges in analyzing high-dimensional data with CCA. In order to analyze high-dimensional data some sparse canonical correlation analysis (SCCA) techniques are available in literature to identify linear combination of two set of variables with maximal correlation. The main focus of our thesis is to compare the performance of the four SCCA methods namely, SAR, Witten, Waaijenborg, and Parkhomenko in contamination and no contamination data. In this study, we consider two sparse High-dimensional Designs and repeated into 500 times for design 1 and 300 times for design 2. We generate non contaminated data from multivariate normal distribution and multivariate t-distribution for both designs. About 5%, 10% and 15% contaminated data generated from multivariate normal distribution. We compare SAR with Witten, Waaijenborg, and Parkhomenko SCCA methods based on estimation accuracy, TPR, and TNR. In sparse "High-dimensional Design 1"the estimation accuracy of SAR methods is better for no contamination data but in contamination data, the estimation accuracy of all methods is almost similar. In sparse "High dimensional Design 2" the estimation accuracy of SAR methods out spoken. For sparsity recognition performance SAR and Witten methods show the best performance, but SAR method is better than Witten method. Finally, we conclude that SAR method is better performer than the existing other three methods. There are very few comparative studies have been done to evaluate the some of the approaches to SCCA methods. But there is no experimental study (wet laboratory work) in literature to compare the different SCCA techniques in presence of contamination. In this study we compare the performance with four SCCA techniques in different simulation studies. Results of the simulation studies show that sparse alternating regression (SAR) is perform better in contaminated data as well as no contaminated data.

Keywords: Canonical correlation analysis; Sparse canonical correlation analysis; Sparse alternating regression (SAR); Witten; Waaijenborg; Parkhomenko.

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Factors of Failure by Using IoT in Project Management

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ABSTRACT

The internet is a relatively new project that has not been completed for a very long time; it has grown to capture the interest of people, businesses, and governments around the world; and it has given rise to a new concept, the Internet of Things (IoT), which integrates many forms of technology into nearly every aspect of modern life. Developers often release updated versions of existing IoT-related software and launch brand new services. With so much backing, it was inevitable that this program would eventually expand. There are a number of fundamental difficulties in implementing IoT in PM. The success or failure of IoT integration into project management hinges on these aspects. As well as discussing the major concerns and underlying aspects that underlie its adoption, we also examine the potential dangers of implementing IoT into project management.

Keywords: Internet of Things; Failure; Factors; Critical factors; Project management.

1. INTRODUCTION

It is hard to go a day without hearing the term "Internet of Things" (IoT) [1]. When he established the MIT Auto-ID Centre in 1999, British innovator Kevin Ashton was the first to employ it. Media outlets of all stripes have been giving IoT more attention as of late. This includes both mainstream publications and more technical publications like engineering journals. Many previously impossible kinds of networked devices, systems, and sensors are now within reach as a result of advancements in processing power, electronics miniaturization, and network connectivity. Conferences, papers, and news articles have all been devoted to discussing the potential consequences of the "IoT revolution," which have been variously cited as including new market prospects and business models as well as worries regarding security, privacy, and technical compatibility [2].

The "Internet of Things" (IoT) is a network in which ordinary objects like smartphones, refrigerators, washing machines, and even entire buildings are equipped with sensors and a network connection to automatically acquire, transmit, analyze, and act upon data [4].

The goal of this study is to identify the factors that have led to the success (or failure) of Internet of Things adoption and deployment in the information technology sector in Bahrain. This article investigates the factors that determine whether or not a roll out of an IoT system is successful. In order to better prepare for delivering IoT across different departments, businesses can use the study's findings to gain a better understanding of the features, functionality, and failure causes that need to be taken into account.

2. BACKGROUND OF THE PROBLEM

Many of today's most successful businesses recognize the importance of acquiring cutting-edge technology if they want to maintain their position in the market. Introducing an IoT software package can increase productivity in any organization. The corporation recognizes the Internet of Things as a key enabler in its quest to boost internal and external performance. It's possible that managers' reluctance to implement IoT stems from their unfamiliarity with the technology's back end and the ways in which an enterprise could benefit from implementing it. To continue, after Our analysis of the available literature allowed us to identify the key factors that have been shown to cause Internet of Things deployments to fail. My research aims to determine what factors are most indicative of success or failure for businesses implementing IoT solutions.

3. IoT IN PROJECT MANAGEMENT ROLE

Over the course of a project's lifespan, the pressures placed on management will decrease. Before deciding whether to adopt or reject a potentially disruptive technology, it is crucial to weigh its benefits and drawbacks. Project management is not immune to the ripple effects of the Internet of Things on other sectors. In the end, everyone in the focus group seemed to agree on two primary points: (a) technology has had a hugely positive impact on the project manager's job, and (b) technology's duty is to complement humans, not to replace them. Improvements were made in the areas of streamlining essential procedures, fostering open lines of communication with stakeholders and, most importantly, within the team itself, and achieving broader acceptance of the group's findings and conclusions. Problems like bureaucratic red tape, a lack of information that prevents thorough analysis and formulation, and an inability to bring about meaningful cooperation and communication among interested parties are common causes of the decision-making and procedure-carrying out processes taking too much time. But with today's technological advancements, the project manager

can lessen the risks and increase his productivity, guaranteeing that all projects will be finished on time and successfully. Having easy access to a large amount of data may be both a boon and a bane if you don't know how to utilize it effectively. It was agreed that the team would have more say in project decisions and access to more data than upper management. IoT project managers need to be cautious when dealing with the potentially disastrous data glut. Finally, it is important to note that respondents emphasized the importance of having the correct skill set, which should include both innovative and creative enabling technologies linked with IoT applications and the IT ecosystem in general, as well as more traditional approaches. You'll need to learn something new to successfully set up Internet of Things apps that make the most of your network's features. In addition to maintaining your formidable set of soft skills, you'll need to master the new IT infrastructure [12]. Because of its potential to reduce costs, increase uptime, decrease waste, boost productivity, and better predict human resource needs, the IoT will have far-reaching effects on project management. Due to the growing importance of maintaining, securing, and keeping tabs on such efforts over time, project managers should expect in-person meetings to last for longer and be more in-depth. If you want your Internet of Things project to be a success, you need to give equal weight to the business and technology considerations, pay close attention to security and privacy threats, always have an exit strategy or plan B, plan better risk management (including vendor risk), make it easy to replace or update the IoT components, and get buy-in from across the organization. A manager working on an IoT project must always keep these in mind [8].

4. FACTORS OF FAILURE OF IoT

On the occasion of that IoT World Forum 2017, the company also released data from a survey examining the success and failure rate of Internet of Things projects and initiatives, as well as the conditions for IoT success in times that IoT is increasingly present in the digital transformation strategy journeys of ample organizations. According to Cisco's survey, 74% of the companies interviewed had Internet of Things initiatives that failed. This is because putting the Internet of Things into action requires considering not only the technical aspects of sensors and networks, but also a wide range of human variables. Building a culture around technology and making sure everything communicates well is essential for your company's success in the Internet of Things [6]. The factors that can make or break the Internet of Things are laid forth in

Table 1. Factors that cause failure of IoT

No.	Factors that cause failure
1	Regulatory support
2	Managing the data flow
3	Billing
4	Power consumption
5	Scalability
6	Security concerns
7	Missing the right people and mindset
8	Compatibility
9	Organizational culture
10	Lack of readiness
11	Lack of clear planning and strategy
12	Cybersecurity
13	Ignorance of the latest technologies
14	Lack of skilled professionals
15	Limited guidance for maintaining IoT devices
16	Non-authentication and authorization of IoT devices
17	Lack of knowledge and staff resources
18	The “high” investment cost
19	No clear definition of IoT
20	Lack of a strong project roadmap

5. METHODOLOGY

The flowchart in Fig. 1 shows the study flowchart, which demonstrates the sequential phases used to carry out this study.

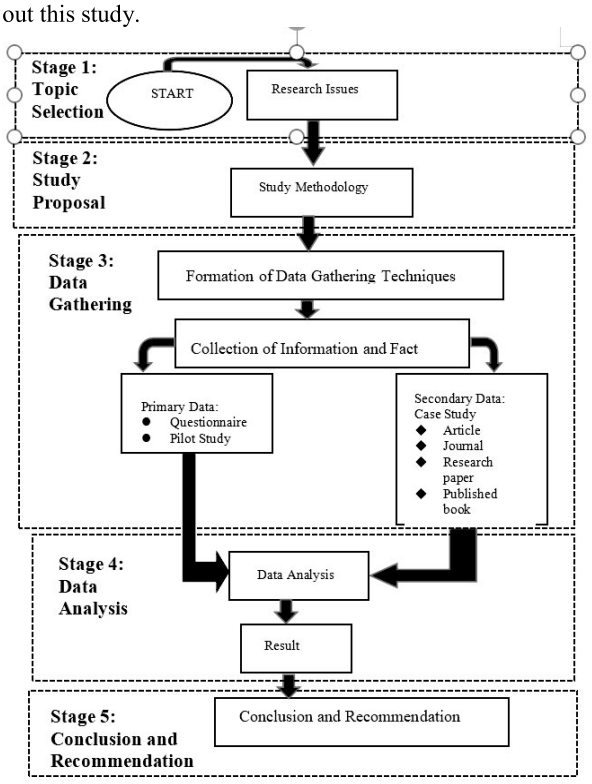

Fig. 1: Flow chart of methodology

6. DATA ANALYSIS

In order to analyze the data, SPSS was employed (Statistical Package for Social Software). Additionally, Microsoft Excel was used to make visually appealing tables and charts to display the findings.

7. QUANTITATIVE DATA ANALYSIS

SPSS is used to analyze data gathered via questionnaire. The information was analyzed using a variety of quantitative techniques, including the T-test, descriptive mean, frequencies, and the ANOVA (Analysis of Variance) test. In order to validate the survey results, they were compared to established data and theory.

8. DISCUSSION

Results from studies analyzed using information gleaned from various kinds of testing were dissected in further depth in the debate that followed.

9. RESULTS

In this section, we discuss the study's data analysis and the results, based on a survey sent to 439 respondents randomly selected from among Bahrain residents. In order to identify the main factors using the Internet of Things in project management and to assess the level of importance of each element, this study collected responses from 439 sets of questionnaires.

Table 2 displays the distribution and breakdown of respondents by gender and Fig. 2 shows that out of a total of 439 respondents, 185 were female and 254 were male.

Table 2: Respondent gender information

Personal Information	Detail	Frequency	Percentage (%)
Gender	Male	254	57.9
	Female	185	42.1
	Total	**439**	**100**

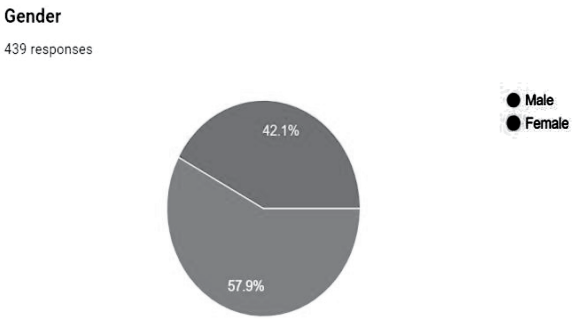

Fig. 2: Percentage of respondent categorized by gender

10. ANALYSIS ON FAILURE FACTORS OF USING IoT ON PROJECT MANAGEMENT

In this section, we'll examine the reasons why Internet of Things (IoT) project management approaches often fail. Inadequate management of data flow and lack of regulatory support are the two main reasons why Internet of Things projects fail. The second concern is whether or not the cost of the energy required to rewire or maintain the system is a factor in people's reluctance to adopt IoT. The third concern is whether or not the data generated by my present and projected customer base can be effectively processed by the system in issue; if it cannot, then the use of IoT will be unsuccessful. Many Internet of Things projects fail because their leaders don't have a clear, business-focused vision for the end result. As said in the fifth question, the failure rate of IoT projects is high because no one is flawless (including IoT experts) and because the initiatives need a solid road-map. The sixth question If the business does not make the necessary changes to its processes, culture, and management structures to completely integrate its workings, then the use of IoT will be unsuccessful. The seventh inquiry pondered whether or not organizations' failure to implement IoT is caused by an overestimation of existing technical capabilities, team member dedication, and available funding [3]. The eighth hypothesis is that preparation for the safety of data, devices, web servers, and communication networks was overlooked, leading to a failure to implement IoT. The ninth question posed the hypothesis that businesses without a comprehensive list of use cases, customer criteria, and market demand are doomed to fail. The tenth and final question asks if a company is missing out on opportunities to improve productivity and efficiency by not using cutting-edge tools. The final issue cited as a reason for IoT's failure is the scarcity of trained personnel, the absence of qualified professionals, and the absence of clear guidelines for the upkeep and control of IoT devices throughout their useful lifetimes [7].

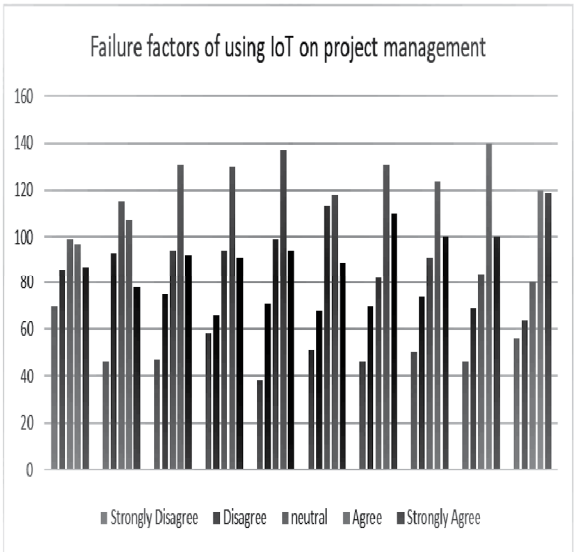

Fig. 3: Ranking distribution of failure factors of using IoT on project management

Figure 3 shows that respondents believed there were factors contributing to the failure of using IoT in project management, with the highest ratings given to the statement "Using IoT failed because the security of data, devices, web servers, and communication networks was not taken into account in the planning phase (3.43 means failure, while the standard deviation adds 0.17), suggesting that this factor was most responsible for the failure.

If the company's processes, culture, and management structures are not adjusted over time to fully integrate the

IoT's workings, then the project will fail, ranking second highest in both mean (3.41) and standard deviation (7.12). Companies often fail to take advantage of the latest technology to obtain better outcomes at a reduced cost ranks third in both the mean (3.41 points) and the standard deviation (7.1 percentage points) of factors that contribute to the failure of employing IoT in project management (1.28).

Regulatory support and not managing the data flow are the keys to failure when using IoT for project management, according to both the mean (3.10) and the standard deviation (SD) of these parameters (1.36). According to the evidence presented in the analysis of the fourth hypothesis, "Previous knowledge of the factors affecting the success or failure of the use of the Internet of things helps to MIS (Management Information Systems) department to avoid the factors causing failure to use IoT," the factors of failure can be placed in order as shown in Table 3.

Table 3: Factors of failure placed on order

No.	Factors of Failure
1	Cybersecurity
2	lack of standards for authentication and authorization of IoT edge devices
3	Organizational culture
4	No clear definition of IoT
5	Ignorance of the latest technologies
6	The “high” investment cost
7	Lack of skilled professionals
8	Limited guidance for life cycle maintenance and management of IoT devices
9	Lack of clear planning and strategy
10	Security concerns
11	Compatibility
12	Missing the right people and mindset
13	Lack of a strong project roadmap
14	Lack of readiness
15	Lack of knowledge and staff resources
16	Scalability
17	Billing
18	Power consumption
19	Regulatory support
20	Managing the data flow

11. CONCLUSION

We analyze project management's part in launching an IoT project and pinpoint the most important criteria and potential failure points. There are a number of potential stumbling blocks that must be overcome before an Internet of Things project can be successful, and if the project's management or end users don't take care of these, the project will inevitably fail. We also discuss strategies for deciding how many people and what demographics to survey anonymously. The study's results should be used as cautionary tales by those who are thinking about using IoT in the most important aspects of project management. After that, an abbreviated summary of the entire study is offered.

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An Experimental Analysis of Empirical Mode Decomposition to Recognize Similarity and Dissimilarity Species According to their Mitochondrial DNA

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ABSTRACT

As DNA holds the characteristics and features of organisms, it is important to numerically characterize the DNA sequences and analyze their similarities and dissimilarities. The goal is to classify different species using their mitochondrial DNA (mtDNA). This analysis will also help medical science to analyze different types of diseases and find their cure and also predict any future diseases. This analysis can assist the biotechnologist to build any machine which can be a revolution to medical science. That is why different schemes are needed to analyze the DNA similarity. To perform DNA similarity analysis, the mitochondrial DNA sequence has been converted into a time series. Then, two methods, such as Empirical Mode Decomposition (EMD) based filtering of the gene sequence and Cross-correlation based similarity analysis have been used to analyze similarities and dissimilarities of different species. These methods show the similarity or dissimilarity of DNA sequences graphically. So from the result, different types of species can be classified graphically.

Keywords: DNA sequences; Mitochondrial DNA; Species categorization; Empirical mode decomposition; Cross-correlation.

1. INTRODUCTION

Evolutionists often argue that the similarity of DNA sequences among different organisms, including humans and chimpanzees, supports the theory of common ancestry. However, it is also possible to interpret DNA similarity as evidence of a common Creator. A genome refers to the complete set of genetic instructions that an organism possesses. These instructions are encoded in DNA, which is organized into chromosomes and genes. Mitochondrial DNA sequences are particularly useful for studying relationships among different species, as they are influenced only by mutations. To investigate these relationships, we selected 56 species and analyzed their mitochondrial DNA sequences. By comparing the similarities and differences between these sequences, we can gain insights into the evolutionary history of these organisms. However, we should also consider alternative explanations for the observed patterns of DNA similarity.

The field of biotechnology has witnessed rapid advancement, resulting in a significant surge in biological sequence data. Exploring biological sequences, which represent essential aspects of life processes, constitutes a fundamental and critical aspect of scientific inquiry. Numerous challenges exist in studying biological sequences, with the primary objective being identifying and characterizing stability patterns and variations that can be utilized to delineate functional attributes and differences. To cater to the escalating requirements, a multitude of similarity analysis techniques for DNA sequences have been put forth over the preceding decades.

1.1 Objectives of the study

This approach involves the followings steps:

- Transforming DNA sequences into 2D nonlinear signal sequences utilizing 2D graphs.
- Then, the Empirical Mode Decomposition (EMD) method is applied to each DNA sequence to extract the Intrinsic Mode Functions (IMFs). And the latest five IMFs are combined to create a residue.
- A comparison of corresponding residues in each DNA sequence is conducted to showcase similarities or differences between different species.
- The correlation method is utilized to better comprehend the results, which calculates the correlation coefficient between different DNA sequences.
- Based on the results of the correlation, it is possible to determine the degree of similarity or dissimilarity between different species.

2. LITERATURE REVIEW

According to G. Liu and Y. Luan [1], various methods, such as the discrete Fourier transform (DFT) based techniques, had been employed for DNA sequencing. However, these methods had proved to be less effective when dealing with short DNA sequences.

Consequently, the authors proposed an alternative, integrated algorithm that utilizes autoregressive spectrumanalysis and wavelet packet transform. This novel approach enhances both the efficiency and accuracy of identifying coding regions in DNA sequences.

In their study, T. M. Inbamalar and R. Sivakumar [2] proposed a novel DSP-based approach for identifying protein-coding regions in DNA sequences that is less complicated and had minimal background noise. The method involves the conversion of DNA sequences into numerical sequences using electron-ion interaction potential (EIIP) representation. This was followed by discrete wavelet transformation to obtain the absolute value of the energy, which was then subjected to appropriate thresholding to enable the effective identification of protein-coding regions.

In their paper, Lin et al. [3] introduced a technique for analyzing sequence similarity known as SSAW (Stationary Discrete Wavelet Transform). This method involved extracting k-mers from a sequence and associating each k-mer with a complex number field. The resulting sequence of complex numbers was then subjected to the stationary discrete wavelet transform to generate feature vectors. These feature vectors encode the original sequence as a numeric value, enabling it to be used for various applications such as clustering and classification.

Qi [4] proposed a graph theory-based approach for comparing DNA sequences. They construct a weighted directed graph and use its adjacency matrix to create a representative vector. Two distance metrics were employed to evaluate the similarity or dissimilarity between different DNA sequences using their representative vectors. Maintaining a one-to-one mapping between a DNA sequence and its corresponding weighted directed multigraph requires retaining a significant number of digits in the arc weights between two nucleotides for large DNA sequences, which increases computational complexity.

In their study, Pianyu [11] suggested a straightforward mathematical descriptor for characterizing cis-sequence complex DNA networks. This method was based on a gene's code of three cis nucleotides, which can encode an amino acid in each DNA sequence. They established a cis sequence complex network, which generates a 60-dimensional characterization vector that could be used to analyze mitochondrial DNA sequences and identify similarities among different species.

Previous research on DNA sequencing or similarity primarily utilized complex methods. However, this paper employs less complex but more effective approaches. Firstly, DNA sequences are transformed into nonlinear signal sequences based on 2D graphs. Next, the EMD method is employed to extract the IMFs of each DNA sequence and compare the corresponding residues, thus demonstrating the similarity or dissimilarity among different species. To better comprehend the results, the correlation method is utilized. The degree of similarity or dissimilarity among different species can be readily determined based on the results of the correlation.

3. METHODOLOGY

Genome sequencing is a method used to decipher the DNA sequence by "reading" it. It involves determining the order of DNA nucleotides or bases (As, Cs, Gs, and Ts) that make up an organism's DNA [8]. This process can be thought of as translating a DNA sequence from the chemical language of life into the written language of our alphabet as in Figure 2. For example, a DNA sequence may be represented in our alphabet as follows: AGTCCGCGAATACAGGCTCGGT

3.1 Mathematical representation of DNA sequence

To utilize appropriate digital signal processing techniques on DNA sequences, it is necessary to convert the character string of these sequences into numerical sequences as in Fig. 1.

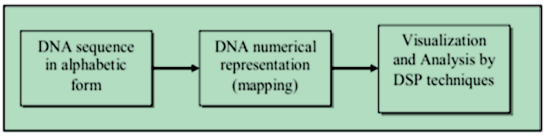

Fig. 1: Block diagram of DNA conversion

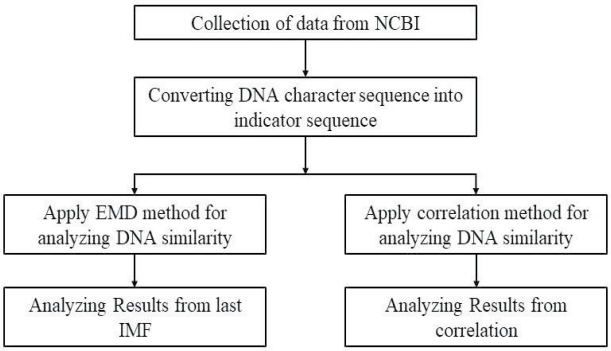

Fig. 2: Steps for DNA similarity analysis

3.2 Binary indicator sequences or voss representation

In 1992, Voss initially proposed mapping genomic sequences into numerals using binary indicator sequences. In this approach, the A-sequence is substituted with 1 wherever it occurs and with '0' elsewhere. Similar techniques are adopted for the other nucleotides G, T, and C. For instance, given a DNA sequence ATGCAAATG, it would be transformed into its binary equivalent 100001110.

EMD: Empirical Mode Decomposition (EMD) is a signal decomposition method that breaks down any signal into Intrinsic Mode Functions (IMFs) [7]. An IMF represents a simple oscillatory mode, analogous to a simple harmonic function, but with variable amplitude and frequency along the time axis. The process of extracting an IMF is called sifting, which aims to make the remaining signal more symmetric with a local mean

close to zero. This is achieved by sifting the signal until the maximum positive and minimum negative values are centered around the zero mean envelope. This ensures thaan IMF is a nearly periodic function with a mean close to zero. The EMD algorithm [7–9] follows a sifting process that can be summarized as follows:

Step 1. First, consider a signal *x(t)*.

Step 2. Identify all extrema of *x(t)*. (Fig.3 1-2)

Step 3. Determine upper envelopes $e_{max}(t)$ by connecting all the local maxima by a cubic spline line interpolation.

Step 4. Also, determine lower envelopes $e_{min}(t)$ by connecting all the local minima by a cubic spline line interpolation.(Fig. 3. 1-2)
The upper and lower envelopes should cover all the data between them.

Step 5. Determine the mean of its upper and lower envelopes. (Fig. 3. 1-3)
Let, m_1 = mean of upper and lower envelopes.
The average, envelop mean is lower frequency component than the original signal.

$$m_1 = \frac{(e_{min}(t) + e_{max}(t))}{2}$$

Step 6. By subtracting envelop mean, from the original signal *x(t)*, the first component h_1 can be found. Which is a highly oscillated component.(Fig.3. 1-4)

$$x(t) - m_1 = h_1$$

Actually, h_1 should satisfy the condition of the IMF. If h_1 should not satisfy the condition of IMF the same procedure of sifting is applied to h_1. Now In the second sifting process, h_1 will be the data, and m_{11} is the mean of h_1's upper and lower envelopes.

$$h_1 - m_{11} = h_{11}$$

This sifting procedure is repeated k times until h_{1k} satisfies the condition of IMF.

$$h_{1(k-1)} - m_{1k} = h_{1k}$$

Now consider, the first IMF component.

$$c_1 = h_{1k}$$

Step 7. Now separate the first IMF from the rest of the data.

$$x(t) - c_1 = r_1$$

r_1 treated as the new data and 2nd IMF will be found from it by again doing the shifting process.

This procedure can be repeated on all the subsequent r_j s and the result will be as below.

$$r_1 - c_2 = r_2, \dots\dots, r_{n-1} - c_n = r_n$$

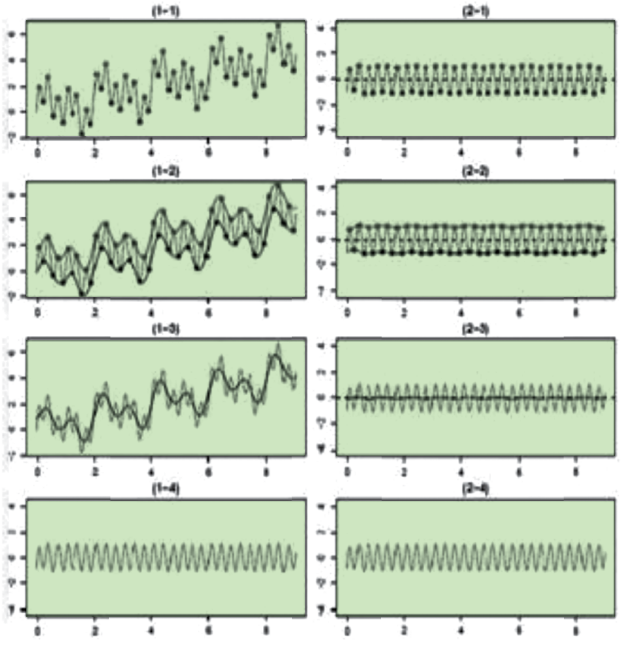

Fig. 3: Process of EMD
(Courtesy: Introduction to EMD (Empirical Mode Decomposition) with application to a scientific data)

The stopping criterion for the sifting process determines the number of sifting iterations required to obtain an IMF. One commonly used criterion is based on the standard deviation of the residue. This criterion was proposed by Huang et al. (1998) [16] and is similar to the Cauchy convergence test. The standard deviation (SD) is calculated as the sum of the differences:

$$SD = \sum_{t=0}^{T} \left[\frac{|(h_{k-1}(t) - h_k(t))|^2}{h_{k-1}^2(t)} \right]$$

Typically, an SD value of 0.2-0.3 is deemed suitable for the sifting process. For comparison, two Fourier spectra obtained by shifting only five out of 1024 points from the same data can yield an equivalent SD of 0.2-0.3 computed point-by-point. Therefore, an SD value of 0.2-0.3 is an appropriate threshold for stopping the sifting process when the difference between siftings is sufficiently small. This criterion was proposed by Huang et al. (1998) and is widely used in practice [10].

3.2 Correlation

Correlation is a statistical method used to determine the degree and direction of the relationship between pairs of variables [9]. Cross-correlation is a measure of the similarity between two different signals. Suppose we have two signals, $x1(t)$ and $x2(t)$. The cross-correlation

between these two signals, denoted by w(τ), is defined as [10]:

$$w(\tau) = \int_{-\infty}^{\infty} x_1(t)x_2(t-\tau)\,dt \qquad [+ve\ shift]$$

$$= \int_{-\infty}^{\infty} x_1(t)x_2(t+\tau)\,dt \qquad [-ve\ shift]$$

Cross-correlation is a technique used to determine the degree to which one signal, represented by function $x1(t)$, is similar to a second signal, represented by function $x2(t)$, when $x2$ is shifted along the x-axis. The cross-correlation function, represented by w(τ), is obtained by integrating the product of the two signals overall values of τ. As $x2$ is shifted along the x-axis, the value of the cross-correlation function varies. When the two signals are maximally aligned, the value of the cross-correlation function is maximized. Positive areas of the signals that align contribute positively to the integral, as do negative areas that align.

$$w(\tau) = x_1(\tau) \otimes x_2(\tau)$$

$$= \int_{-\infty}^{\infty} x_1(t)x_2(t-\tau)\,dt$$

w(τ) gives a peak at the time lag where $x_2(t-\tau)$ best matches $x_1(t)$.

4. RESULTS AND DISCUSSION

This paper utilized the Empirical Mode Decomposition (EMD) method to analyze the similarity or dissimilarity of different species, including two bird species (Acanthis flammea and Accipiter virgatus), two fish species (Labiobarbus leptocheilus and Leptobotia pellegrini), two frog species (Babina subaspera and Bufo japonicas), and two elephant species (Elephas antiquus and Elephas maximus). Firstly, the DNA sequences of these species were converted into numerical sequences to obtain the graphical representation of the DNA sequence. Then, the signals were decomposed into several functions through EMD, resulting in Intrinsic Mode Functions (IMFs). Finally, the last two, three, or four IMFs were added to obtain a perfect signal for each DNA sequence, depending on the requirement.

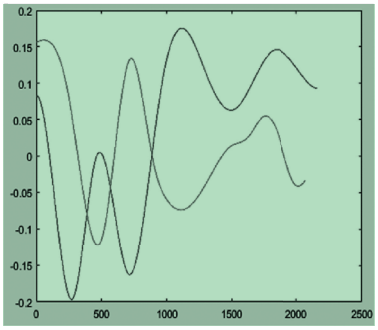

Fig. 4: Similarity between two birds

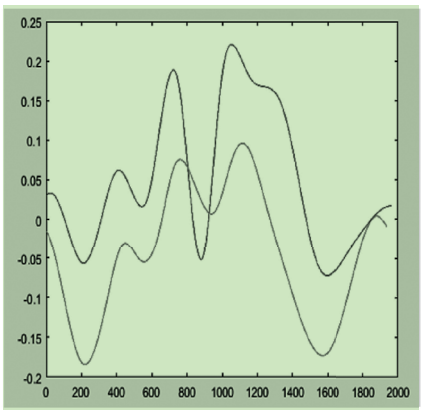

Fig. 5: Similarity between two fishes

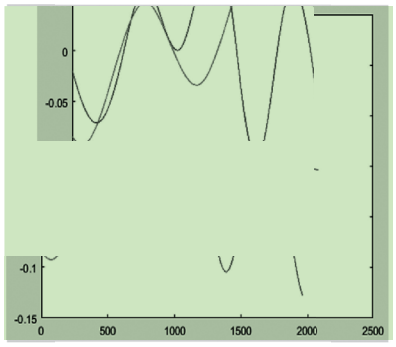

Fig. 6: Similarity between two frogs

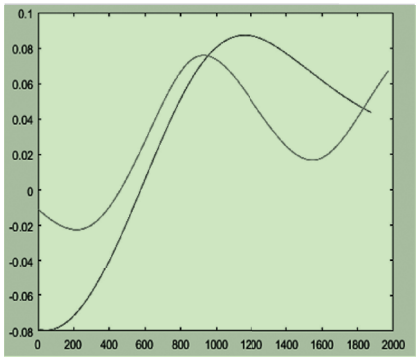

Fig. 7: Similarity between two elephants

The study analyzed the similarity or dissimilarity between different species using the Empirical Mode Decomposition (EMD) method. The DNA sequence of two birds (Acanthis flammea and Accipiter virgatus), two fish (Labiobarbus leptocheilus and Leptobotia pellegrini), two frogs (Babina subaspera and Bufo japonicas), and two elephants (Elephas antiquus and Elephas maximus) were converted into numerical sequences to find their graphical representations. The signals were decomposed into several functions or IMFs using EMD, and the last few IMFs were added to find a perfect signal for each DNA sequence.

The final signal for each species was obtained from a suitable sum of the last few IMFs. The analysis showed that the signals of the same species were almost the same. Fig. 4 shows that the signals of Acanthis flammea and Accipiter virgatus are close and behave in the same pattern. Similarly, Fig. 5 shows that the signals of Labiobarbus leptocheilus and Leptobotia pellegrini, Fig. 6 shows that the signals of Babina subaspera and Bufo japonicas, and Fig. 7 shows that the signals of Elephas antiquus and Elephas maximus behave in a similar pattern. The similarity between signals of the same species can be easily observed from these figures.

The purpose of this study was to use correlation to determine the similarity or dissimilarity between different species based on their mitochondrial DNA sequences. Various types of mitochondrial DNA sequences from different species were collected and expressed as signals. The correlation between the signals was then observed. For instance, the study looked at two types of birds, Acanthis flammea and Accipiter virgatus, two types of frogs, Babina subaspera and Bufo japonicus, and two types of fish, Abalistes stellaris and Leptobotia pellegrini. The Empirical Mode Decomposition (EMD) method was employed on these DNA sequences to obtain the Intrinsic Mode Functions (IMFs) of each DNA sequence. The sum of the first eight IMFs was then used to find suitable signals for each species to apply correlation. The signals for the mitochondrial DNA sequences of these species are shown in the figure.

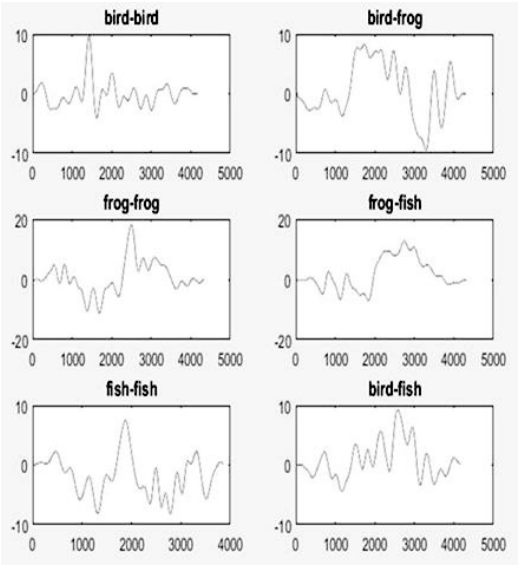

Fig. 8: Similarity and dissimilarity analysis

Figure 8 illustrates the changes in signal behavior when the correlation is applied to determine the similarity or dissimilarity between different species. When the correlation was applied to the two types of bird, Acanthis flammea and Accipiter virgatus, a large peak was observed on its amplitude compared to the other peak which was much smaller, indicating that the two signals were almost identical and were of the same species. The same result was observed for the two types of frog, Babina subaspera and Bufo japonicus, and two types of fish, Abalistes stellaris and Leptobotia pellegrini. However, when correlation was applied between bird and frog, frog and fish, and bird and fish, there were no significant differences between the peak amplitude and other amplitudes. According to the correlation method, it was proven that there was no relationship between them, indicating that the signals were different from one another and that they were of different species.

5. CONCLUSION

The aim of this research is to explore the conversion of DNA sequences into 2D graphs and nonlinear signal sequences. The Empirical Mode Decomposition (EMD) method is utilized to break down the nonlinear signal sequence into IMFs and a residue. This enables a straightforward comparison of the corresponding residues to establish the similarity of different DNA sequences. Correlation analysis is also applied to demonstrate the similarity between the same species and the dissimilarity of different species. The method is shown to be well-suited to examining long DNA sequences, which is vital for enhancing the accuracy and efficiency of investigating, searching, and sorting repeated subsequences in the sequence, as well as discussing evolutionary relationships and processes across various species. Overall, this research establishes a robust method that has significant implications for further scientific inquiry in the field.

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Agribot: A Multipurpose Intelligent Robotic solution for Maximizing Crop Yields in Large Agricultural Projects

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ABSTRACT

In this research, an efficient multifunctional intelligent agricultural robot is proposed to ease the operations of sowing, pesticide spraying, and weather-based watering in to optimize crop production. The agricultural business now employs roughly 23.4% of all workers worldwide and has developed into a sizable high-tech industry. However, manual labor is time-consuming and inefficient in tasks including as seeding, pesticide spraying, and watering in large agricultural fields. To address this issue, we developed a comprehensive robotic system that includes a rover for mobility, a seeding and pesticide spraying component, and an integrated weather station for precise forecasting. By providing a weather-aware, intelligent robot that optimizes planting and pesticide spraying based on real-time weather data, the proposed solution simplifies the complex tasks of farming. The proposed approach is considered to be especially beneficial to farmers and rural workers who engage in hot weather, rough terrain, and high humidity levels. Our testing shows that the proposed robotic solution is capable of performing these tasks and has the potential to revolutionize modern agriculture. Finally, this multipurpose intelligent robotic system is predicted to increase production, optimize crop productivity, and minimize the wastage of resources, making it an important part of the agricultural industry.

Keywords: Agricultural robot; Water spraying; Seeding; Developing countries; Weather forecast.

1. INTRODUCTION

In the Fourth Industrial Revolution (4IR), Agricultural robots are a rising trend because they provide major benefits to the agriculture industry. These robots are intended to do a wide range of tasks, including planting, weeding, harvesting, and spraying crops, all while lowering labor costs and increasing efficiency. One of the most significant advantages of agricultural robots is their ability to work around the clock, regardless of weather conditions, decreasing downtime and increasing productivity. As they are able to accurately target specific portions of the field, they have the potential to increase crop yields while reducing the need for harmful pesticides and herbicides. In recent years, villages are being transferred and manual labor is being reduced with the growth of technology [1]. Demand for meteorological data is rising in nearby agricultural areas like rice fields and greenhouse, among other places. Robotic technology can make the activities of spraying, plowing and other tasks easier. Local weather stations have been the subject of intense conventional research. However, weather stations with low cost, high accuracy and steady observations both indoors and outdoors for extended periods of time are rarely recorded. Farm machinery like water sprinklers (WS) and pesticide sprayers (PS) are becoming quite popular in the agricultural sector [2].Additionally, there is a dearth of research that simultaneously collects and retains weather data, and provides weather information to farmers. Moreover, the existing technology for this is costly. With our prototype, we sought to find a solution to this issue. Robotics for farming is a promising technology which provides efficient and reliable solutions for the modernization of several domains. Farming today is done by machines in a lot of countries. As the world population is increasing, it will reach 10 billion within 2050 [19] according to the statistics of the United Nations' (UN 2019). This will lead to an ever-increasing demand for food crops for consumption. Therefore, multipurpose agricultural robots with smart phone systems will be more effective in making farming more efficient, sustainable, and profitable. Agricultural robots are typically equipped with a range of sensors and cameras that allow them to gather data on soil conditions, crop health, and other important parameters as in Figure 1. This data can then be analyzed by farmers to make informed decisions about planting, fertilization, and irrigation. As a result, the significance of agricultural robots in maximizing the production of crops in large agricultural sectors is far too considerable.

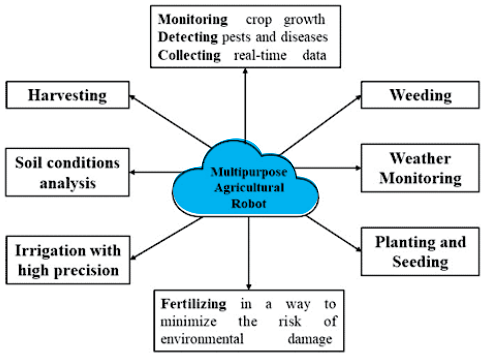

Fig. 1: Application of multipurpose robotics solution in agriculture

1.1 Importance of agriculture robot in 4IR

The Fourth Industrial Revolution (4IR) is characterised by the technological integration that reveals the boundaries between the physical, digital, and biological sectors. 4IR technologies, particularly the utilization of agricultural robots, have the potential to considerably improve the agriculture sector.

Agricultural robots have the following significant impacts:

Precision farming: Sensors and cameras on agricultural robots collect data on soil moisture, nutrient levels, and crop health, which can then be analyzed to optimize farming practices. Precision farming allows farmers to save waste, enhance efficiency, and maximize yields.

Labor shortage: Several nations are facing a labor shortfall in the agriculture industry, which can be handled by using robots. Planting, harvesting, and weeding duties may be performed by agricultural robots, freeing up human work. Planting, harvesting, and weed management duties can be performed by agricultural robots, freeing up human labor for other activities.

Sustainability: Agricultural robots can assist farmers in adopting more sustainable farming techniques. Robots, for example, could be utilized to precisely apply fertilizers and insecticides, eliminating waste and minimizing environmental effect.

Cost savings: Farmers may cut labor expenses and boost production by deploying robots, which can result in considerable cost savings.

Safety: Farm robots may undertake activities that humans find unsafe, such as working in adverse weather or handling hazardous products.

Overall, the deployment of agricultural robots in the 4IR can improve agricultural efficiency, production, sustainability, and safety.

This paper presents many aspects of technologies involved in the domain of Robotics and Earth Observation. A rigorous discussion of the apparatus used for agriculture has been presented, involving features, specifications, and applications. Smart Phone- based and Sensor-based applications have been developed for different aspects of farm management with diverse success stories. We have tested our robot. It can successfully evade obstacles like people, agricultural tools, animals and machines. However, we have a limitation of the robot being moderately water-proof. We are also working to make it IOT-based as it takes the data from local server currently.Wireless monitoring equipment for farmlands are produced using developed technology and M2M-based machinery to control processes [12]. This study have the following objectives:

- To enable farmers to monitor the weather and make decision of precipitation accordingly.
- To water/ provide pesticide/seeding as per our need
- To perform live streaming of the farming field.
- To measure the humidity of the environment and take steps.

Our system has three parts: 1. Rover part, 2. Seeding and pesticide section and 3. Built-in Weather station. In rover part we used ESP 32 CAM as the Brain of as our system and motherboard of the rover. L298D works as motor driver for the rover. In weather and multipurpose part, we used Node MCU as the brain of the seeding hopper, pump and direction of the system. Dht11 and Bmp180 sensors collect Temperature, Humidity, and Pressure of wind and based on these parameters they measure the possibility of rain thus the system can decide about seeding and spraying pesticide/water [11].

2. LITERATURE REVIEW

In this article[1], A crank-slider injection procedure was utilized for seeding of crops (Hussain Nor Azmi, 2021). This keeps on injecting seeds to the ground at a stretch precisely.Thus it manages to maintain a successful germination. In this article [2],the authors propose a brand-new, dual-function smart farming robot (MpSFR) that can spray both water and pesticides.In this article [3], the developed robotics methods are effective for completing duties like automatic cultivating, seed provision sprinkling, insecticide spraying using solar energy is represented. In this article [4], this project seeks to design, develop, and create a robot that can sow seeds, mow lawns, and spray pesticides. The robot and its entire system are powered by solar energy. In this article [5], the author serves as an example of the collection, transmission, storage, analysis, and application of appropriate answers. IoT connects sensor devices to carry out a variety of fundamental functions, making it one of the fundamental foundations of smart systems.

This article [6], the authors suggest the system that focuses on using microcontrollers, Bluetooth models HC-05 and H06, various sensors, etc. to execute all farming processes, particularly in the field of plowing and seeding. The author of article [7], describes how a farm robot that is currently in use can carry out simple tasks like planting, harvesting, and spreading pesticides. The suggested system seeks to create an autonomous, multipurpose agricultural robotic vehicle that can be operated via Bluetooth for irrigation, seeding, and plowing. This article [10], Arduino was used for sowing seeds in fields in the automated robot. Long Short Term Memory (LSTM) using system schedules from Central Weather Bureau has been used successfully for weather forecasts and watering accordingly (Chien-Hung Wu, Chun-Yi Lu, Jun-We Zhan, Hsin-Te Wu, 2020). Our weather forecasting station has been inspired by this

pattern of work. This article [11],By entering machine vision systems into this subject , they turned into a reliable ,low cost and real time technology.The existence of machine vision systems,in this process there are still major challenges in categorizing agricultural products quality,size,shape and examination of defects. In this article [12] the author describes the development of a low-cost agricultural robot for crop seeding.

3. METHODOLOGY

The proposed system emphasizes on controlling the movement of the robot from a distant place without any hassle. It can be controlled from a browser. Servomotors are utilized for managing the seeding and water spraying of the Agribot. There also plans for making the prototype dependent on solar energy. Thus running on renewable energy, it can be more cost efficient [14].

3.1 The prototype of AgriBot

The design concept of the proposed multipurpose agricultural robot has three sections as in Figure 2 and Figure 3. Firstly, rover part deals with the mobile base for robotic locomotion. A seeding mechanism and pesticide tank is linked to the mobile base for farming application. The mobile base and chassis has a four-wheel design. It is coordinated by an ESP32 Cam. The ESP32 cam is more of a low-cost onboard camera for IoT applications and prototype creations. It has two extremely powerful 32-bit LX6 CPUs. The ESP32 uses a 7 stage pipeline architecture in its construction. As it complies with Bluetooth 4.2 and WiFi 802.11b/g/n/e/I standards, it can be utilized as a master mode when creating a standalone network controller. The final section is the built-in Weather Station. This device is mounted on the Agribot's chassis. It uses sensors for measuring the precipitation, humidity and atmospheric temperature. Our Agribot prototype was outlined to be portable, compact and light in weight. This was done for easing maneuverability around crops in an agriculture field. It also adds the advantage of preventing damage to the crops and soil structure.GPS has been used successfully for directing an automated tractor [13] .

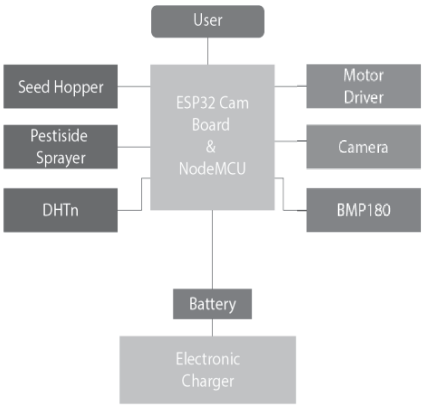

Fig. 2: Block diagram of the agricultural robot

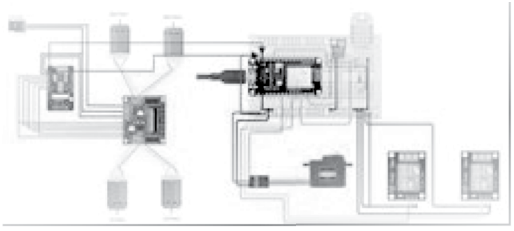

Fig. 3: Circuit diagram of the Agribot

For pesticides and seeding mechanism [8], the Agribot prototype uses a relay module and Node MCU. The relay module's primary function is managing the seeding and pesticide application [9]. L298D works as motor driver for the robot. It is a high voltage and current dual DC motor driver. Additionally, it can be managed by conventional logic systems .ESP8266 Node MCU is a convenient open-source firmware. The Node MCU has Lua as its embedded scripting language. Lua has the option of making a more powerful IoT based Agribot.

The components for system are ESP 32 cam, Node MCU (ESP8266), L298d dual DC motor driver, Temperature Sensor Dht11, Barometric Pressure sensor (BMP180), 2ch relay module, Water pump, Micro servo, Gear motor, Robot chassis, Vero board and bread board power supply. Figure 4 shows the hardware implementation of the proposed agribot.

3.2 DHT 11 module

A capacitive humidity sensing element is part of the DHT11 sensor type. A thermistor is also included for temperature sensing. The humidity sensing capacitor consists of two electrodes. A substrate that can hold moisture serves as a dielectric between the electrodes. Alternation in the capacitance value occurs when the humidity levels change. The IC measures, refines and rectifies this changed resistance values and transform them into a digital form. For assessing temperature, this sensor utilizes a Negative Temperature coefficient thermistor. This thermistor creates a decrease in its resistance value while increasing the temperature. This sensor's primary construction material is semiconductor ceramics, which allows it to provide a higher resistive value even for a small change in temperature.

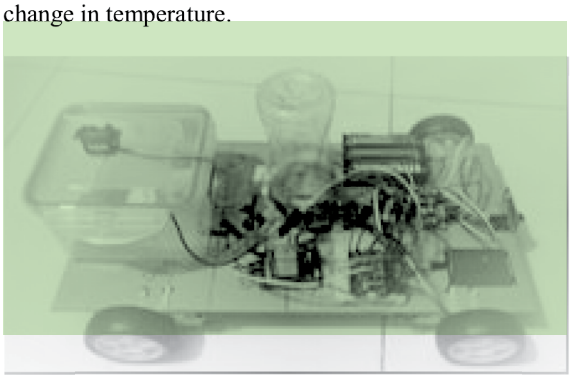

Fig. 4: Top view of the proposed Agribot

3.3 BMP180 module

The BMP180 has a piezo-resistive sensor. There is an analog to digital converter as well as a control unit with E2PROM. The BMP180 uses pressure and temperature as honorable values. A start sequence is delivered by the microcontroller to initiate a pressure or temperature measurement. The resultant value (here, pressure or temperature) can be examined using the I2C interface. By dint of assisting temperature, we can observe humidity and pressure and thus set a dew point. When cooling at a steady pressure, the air becomes saturated at the dew point temperature, Td. Td is the temperature at which the air's saturation pressure equals the vapor pressure (water vapor mixing ratio). The surface humidity's influence on convective activity can be verified using this model.

3.4 ESP32-CAM

A development board with an integrated camera actively is called the ESP32-CAM. It has a clock speed of 160MHz and a computing power up to 600 DMIPS. There is a Built-in 520KB SRAM and an external 4MPSRAM. It supports UART/SPI/I2C/PWM/ADC/DAC. There is also the advantage of multiple sleep modes. Wireless monitoring gets easier as its control interface can be perceived by pin header.

3.5 L298d dual DC motor driver

The motor driver can control 2 DC motors for various locations with required speeds. For using this, we connect the two terminals of the motors to the blue terminal block connectors. It gives the precise signals to the input pins. Red and Green LEDs are used for providing direction routes. There is an onboard voltage regulator. It supplies 5V to L298. There are also three distinct power rails to deploy Vin, GND and 5V to the miniature power supply board. The option to gauge how much current is flowing at any one time is also available. However, a reverse voltage polarity at Vin and GND will damage the motor perpetually.

4. COMPARATIVE ANALYSIS

We have tested our robot. It can successfully evade obstacles like people, agricultural tools, animals and machines. However, we have a limitation of the robot being moderately water-proof. We are also working to make it IOT-based as it takes the data from local server currently.Wireless monitoring equipment for farmlands are produced using developed technology and M2M-based machinery to control processes [12].

4.1 Proposed Agribot compared with other systems

Agribots [19], [20], [21], [22], [23] have been investigated and compared with the proposed agribot in Table 1 for price and technical functionality. Figure 5 demonstrates that the proposed agribot is less expensive and has good technical expertise. Therefore, the proposed robot is affordable and easy to use in agricultural fields.

Table 1: Evaluation of the proposed agribot in comparison to other reported robots' costs and technical expertise

Agricultural Robots (Agribots)	Cost of Robots (BDT) in Thousand Unit	Technical Expertise of Robots
Agribot#1 [19]	11.5	1.Waters the plants. 2.Senses the need of water. 3.Locates the plants.
Agribot#2 [20]	136.5	1.Plant identification. 2.Compromising temperature. 3.Sensing Module.
Agribot#3 [21]	23.7	1.Processes image in Agriculture. 2.Avoiding obstacles. 3.Implements crops.
Agribot#4 [22]	42.8	1.Environmental monitoring 2. Precision agriculture 3.facility automation
Agribot#5 [23]	107	1. Machine conversion 2.Navigation 3.Mission planning
Proposed Agribot	9.7	1.Performs all basic tasks in agriculture. 2.Controls weather station. 3.Ensures less human intervention.

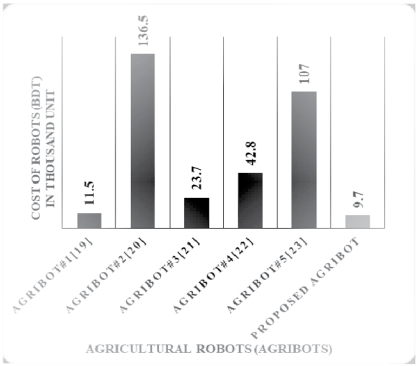

Fig. 5: Comparison of proposed agribot with other reported robots' costs

Currently, the commercial devices that are engaged in this sector have the working of all three functions separately set up. It requires exceeding hours for pesticide spraying the crops, watering them on the field. On the other hand, our Multipurpose Autonomou Agribot needs very less time for completing the whole process involving the cited basic functions. The item was trialed taking it to a defined region. The apparatus frames a way of being lightweight and compensates the expressed targets. The seeds are sown all the while in a user defined interim of time [9]. A battery life test was also conducted with a satisfactory result of 10 hours with three batteries. This provides about 12V power supply to Robot. This test was done by running the robot on farmland tracks. The seeding mechanism as well as pesticide usage was activated during this period. An acceptable battery life is necessary to make this prototype system a feasible solution for farmers. Thus, it will enable them to have a cost-effective solution to this tedious labor [7].

4. CONCLUSION

The primary goal of this research was to develop a low cost agricultural robot capable of performing basic functions inagricultural fields. More robots are needed in developing countries to meet the everincreasing demand for food. The agribot prototype created for this research will respond to the commands of an operator. Tests being performed on the agricultural robot prototype demonstrated that it could be used under real world usage scenarios. The crop seeding test demonstrates that the robot can sow seeds with a good accuracy. It is significantly higher when compared to human workers. Because of the use of sensors for obstacle detection, less human intervention has been possible. The weather station will also provide information on when seeding will take place.

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A Comprehensive Analysis of the Self-Balancing Characteristics of Long-Distance Jumping Robots

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ABSTRACT

This research provides a thorough investigation of the self-balancing capabilities of long-range jumping robots. The study focuses on the concepts underlying jumping robots' self-balancing mechanisms and their capacity to retain stability during lengthy jumps. The existing literature on self-balancing robots is reviewed, with an emphasis on the various ways utilized to accomplish self-balancing. The research looks at the dynamics of the jumping robot during take-off, flight, and landing, as well as the efficiency of the self-balancing system in maintaining stability. The findings show that the self-balancing mechanism greatly enhances the stability and accuracy of long-distance leaps and that it can be adjusted by modifying different design factors such as mass distribution and spring stiffness. The study's observations can be helpful for future generations of jumping robot designers and developers for tasks including search and rescue, surveillance, and exploration.

Keywords: Bioinspired robot; Jumping robots; Self-balancing; Stability, Mass distribution; Future generations.

1. INTRODUCTION

With the advent of technological advancement, the world is going to enter a new revolution named Industrial Revolution 4.0 (IR 4.0). This transformation is taking place very rapidly with every industry's greater collaboration with respect to research and development. By achieving the latest technological high-pace improvements like cloud computing, digitization, data science, artificial intelligence, machine learning, etc., the world is very close to upgrading into an IR 4.0 environment when it is feasible to meet the requirements for intelligent automation through cyber physical domain establishment. In an intelligently automated smart world, it would be possible to integrate the domain with the help of intelligent robotics and the Internet of Things (IoT) and secure cyberspace through the monitoring of these entities through innovation.

Intelligent robotics is playing a vital role in implementing the cyber physical systems with the superior innovation of each product. [1][2] 'TESLA' is deploying a large number of robots to speed up their production system and delivery in order to upgrade them to a new level of acceptance for IR 4.0 [3][4][5]. Also, in Australia, it has been found that they are utilizing the power of intelligent robotics for livestock farming and controlling these robots successfully without human interaction. However, a 'smart world' is going to be established through the finest innovation and technological development.

In order to build an intelligent automation world with the successful application of robotics, we can consider the jumping robot applications in various fields of innovation, such as the healthcare industry, the agricultural field, transportation systems, space exploration events, and so on. Actually, these jumping robots are being manufactured using biomimetic solutions that are obtained from the natural characteristics of different creatures in the world. The bioinspired jumping robots will have excellent characteristics to overcome obstacles in an irregular, unstructured environment where walking robots' performance is less and they cannot understand their direction of movement towards the destination. That's why scientists and researchers tried to bring innovative features from natural animals' locomotion properties and were successful in implementing those in robots. Applications of these jumping robots include rescue missions in any disaster ,livestock farming, underwater submarine cable maintenance, and military war field applications to save and protect soldiers' lives, etc.[6][7]. The importance of deploying these bioinspired jumping robots is actually to integrate the cyber physical systems with the required infrastructure in a smooth way so that intelligent automation features can be achieved to materialize the Industrial Revolution 4.0 with a higher degree of reliability. These types of control software had been engaged, but these were not actual AI or ML applications [8]. However, it can be suggested to use modern concepts for building the more possibility to accept the system design with innovative design plans. Though the researchers CELESTINE IWENDI and his team [9] showed their dedication to developing the PD-PI control algorithm, the control algorithm could bring robust performance through the feedback controller analysis and research. However, velocity enhancement and stability adjustment can be brought about through more system review, as it should be the ultimate goal to increase the speed of the designed jumping robot without losing stability. Another major importance of subject should be optimization of power sources. Though in the research [10], the Author Je-Sung Koh and his team proposed a solution of an embedded system for power that can be the best solution for making bioinspired jumping robots to

use solar power to identify it as an innovative solution. Following the biomimetic solution, the jumping robots can be deployed in the healthcare industry to show its amazing services during COVID-19 like pandemic situations around the world [11][12][13]. In pandemic situations, few jumping robots can show their relationship with infected patients handling, patients' medical facilities they ensure, and longtime monitoring and treatment[14][15]. To improve the scenario in a pandemic situation, jumping robots can play a vital role to ensure better quality support for the impacted community.

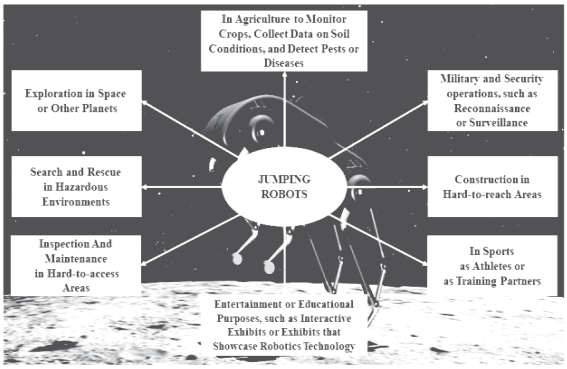

Fig. 1: The scope of jumping robots in dealing with real-world challenges [16]

Secondly, during the flood situation, jumping robots can show their excellent performance by delivering rescue services and protect people's lives from unexpected death poll increase in these days, even they can support to rescue the livestock from the specific flood affected area. In 2019 and 2020, different types of wildfire incidents around the world lost the biodiversity in Amazon Forest, Turkey and also in Australia [17][18][19][20]. During those incidents, we observed the worst impact of wildfire on valuable people's lives as well as the huge number of animals that lived in that region.

However, if jumping robots could be utilized in these emergencies, few lives would be saved and biodiversity could not be impacted, as biodiversity loss is the prime reason for the global warming and climate change issues. So, in order to build a smarter world with more innovative products, we should do more analysis in the case of effective and optimized system design that is forming complex cyber-physical systems.

2. LITERATURE REVIEW

In [21], the Author Jianguo Zhao et. al. used 2-RRR mechanism, One way bearing method and 'Four Bar mechanism' to deliver its capabilities but they didn't consider these several factors like air resistance, loss of energy during take-off and most significant robot's orientation as these are the essential parameters of stable operating environment. To bring stability for jumping robot, we need to consider these with greater importance.

In [22], a 'Biomimetic Design solution' have been developed by the author Armour and team adjusting the center of gravity of the robot for jumping and rolling movements where for JollBot robot, no locally available energy source used and jumping performance could be degraded if any payload is applied to robot. In comparison of both robots, it is observed that Glumper power and energy density are better than Jollbot. Weight could be reduced to a significant level by the application of new material. Undoubtedly this research can be considered as an extraordinary analysis for jumping robot but they should provide us the direction of analysis of factors those were limiting the robot's performance such as how we can reduce the mass of robot and which type of materials could be utilized for effective model. Here computational and power requirements also large compared to walking robots.

Scarfogliero et. al. [23] proposed a prototype by utilizing passive elastic forelegs and rare limbs not only for this research but also for future open –platform analysis. They had mentioned the necessity of impact analysis for the robot model during landing in order to gain the stability and also there is a requirement to use a small motor to balance the body orientation. Moreover, stiffness and damping properties need to be addressed during irregular terrain journey.

In article [24], the Author Dilip R et. al. showed their credibility in this research methodology to bring an innovative idea to overcome the obstacle ahead of its traversed path detected by the robot and deployed sensors will get real time information from environment. In this paper it is found that the researchers faced the difficulty of weight ratio of the system and they suggested to reduce the cylinder weight to get better performance for this jumping robot in a harsh environment.

In [8], authors discussed about the electro-mechanical arrangement of prototype model that contains few mechanical materials with embedded microcontroller and control software such as Solid Work, Cosmos motion software For the development of jumping robot analysis, This need to be careful for application software's authentic monitoring for the kinetic energy to potential energy transition so that during landing the robot will not face distracted landing or deformation .

In [10] the author Je-Sung Koh and his team introduced a 'Elastic Catapult Mechanism' (energy storage & release) to establish their prototype for this jumping robot and during fabrication they followed the process of 'Smart Composite Microstructures 'in order to get 2D pattern to 3D pattern of robot. But in result of testing, it was found that jumping height was degraded significantly with the increase of payload. The researchers commented that battery power source should be kept as embedded object to reduce the weight ratio otherwise the efficiency could be less and also need to address the structure design and power transition matters to make this robot effective for operation in unstructured environments.

Choudhari et. al. in [25], introduced a stair climbing robot utilizing the recognized 'Rocker Bogie

mechanism'. For a particular step length not more than 375mm and 45 degree inclination of surface had been considered only here. During the testing, they found that with the reduction of step length, the robot was unable to show its capability for ascending the stair. It is an essential drawback of the designed model in a rough terrain or irregular environment.

In [26] Akira UMEHARA et. al. proposed through a jumping pattern dynamic analysis for the exhaustion and supply of air in this paper. The jumping robot performance was limited to flat floor only, that means it is not having the expected stability in a rough or irregular surface. They found that the robot showed the vertical jump of 100mm. However it is very critical to stabilize continuous jumping for exhausting pattern and supply of air.

In [9], the researchers CELESTINE IWENDI and his team contributed to develop a Proportional-Derivative Proportional-Integral (PD-PI) dynamic control algorithm in this research activity that is more suitable than adaptive Fuzzy controller. In this paper it is found that the challenging thing is to control the feedback path of the used PID controller during the robot operation and this scenario had been confirmed by the researchers. Also, forward frame will be missed if the communication between the 2 frames occurred more than 1 ms. The performance got deteriorated when the velocity of the robot increased and stability lost, that's why they gave emphasis to strictly maintain the control algorithm.

In article [27], by combining a 'bionic symmetrical mechanism', 'Height-adjustable triggering mechanism' and a self-Righting mechanism, the Yunqian Ma and all team mates tried to develop a bioinspired multi-locomotion robot with the feature of route adjustability. For this biologically inspired robot, the performance could be improved by deploying the more elastic actuator components and powerful motor for its operation. It is praiseworthy that the researchers gave the emphasis to use the embedded sensors and cameras to operate this robot effectively.

In [28], the Author Jun Zhang, Kai Ding and his Team proposed a 3D model designed for a robot that had been simulated in 'Automatic Dynamic Analysis of Mechanical Systems (ADAMS)' under kinematic and dynamic solution ..For the research analysis, they mentioned that they did not perform optimization for the mechanism of jumping and steering during the flight of robot. It was noted that collision and damage of robot during landing need to be investigated properly before launch of this application.

In paper [29], the authors proposed the three (3) mechanisms to get their desired outcome. These mechanisms are a) passive recovery mechanism b) active recovery and c) air posture adjustment. They found that this robot could not lift it's body during take-off with perfect air posture as required by the system to stabilize from the operation point of view. That's why need more contribution to fix the appropriate jumping structure for this self-righting robot practically.

3. CHALLENGING ASPECTS OF JUMPING ROBOTS

3.1 Design choices

To prepare a smart design of a jumping robot, it is expected to categorize the planned jumping robot's usage considering its specific application area. Either it could be a non-bionic jumping robot or a bionic jumping robot. As it is found that the advancement of bioinspired jumping robots is increasing day by day, it is suggested that analyzing the design issues of bioinspired jumping robots is of greater importance in the robotics world, and obviously, this robot will have the capability to show long distance travel with continuous jumping ability. During the design phase, such a type of robot below the WBS can be maintained for the development and execution of this activity. In [30], the researcher Zhang et al. discussed the merits and demerits of various methods, including the demerits of doing hardware selection for the implementation of a mechanical setup. In some cases, it was found that, due to the use of springs, take-off will be quick and energy release will be faster. Again, a torsional spring can be a good fit for a few cases as it gives the gliding advantage necessary for stable operation after landing.

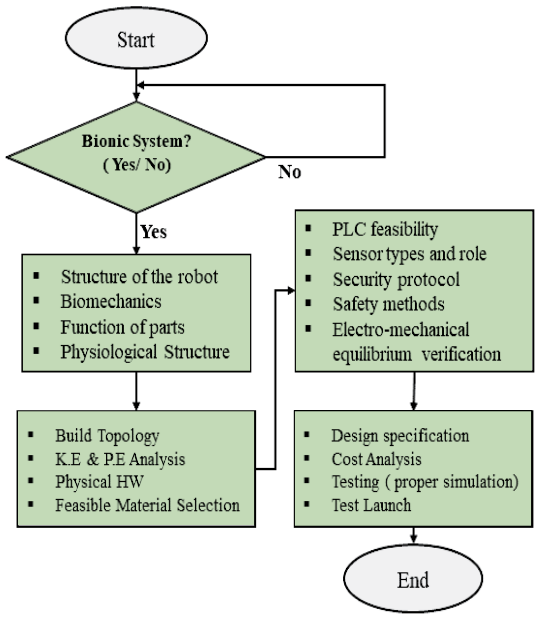

Fig. 2: Jumping mechanism selection workflow

However, to make the system design precise and effective, the designer needs to focus on the key factors: mass and stability to make his/her system feasible for the jumping process, and in the case of long distance jumping, this movement will have to be continuous for the model.

3.2 Air posture balancing for stability

To get adjustment in the air flight phase for a jumping robot, the design mechanism will be different as few creatures have air power support capability through the wings, and a few creatures have tail or abdomen support during landing to achieve the required air posture in the tough terrain comfortably. That's why the integration of different subsystems is a very vital task to ensure the best quality of air posture stability for the jumping robot as planned. A real-time control method should be developed during air posture adjustment as, on the basis of different variables, the prototype will be different for each design to achieve the expected adjustment of air posture stability.

3.3 Ensuring the reliable landing buffer mechanism

It is an essential characteristic of a long-distance jumping robot to ensure a smooth landing through the application of a proper landing buffer mechanism. In this mechanism, energy storage and energy release are the main subject matter to give a smooth landing, including the next jumping event. Also, it is vital to note that if a spring can have extra displacement, it will have more potential energy, which will result in a perfect landing in a rough terrain or unstructured environment. During landing, huge amounts of impulse energy and kinetic energy are converted into potential energy for the jumping robot. During the design of a long-distance jumping robot, we must keep in mind the possibility of colliding with the ground by selecting appropriate spring materials. In this landing buffer mechanism, we have to consider the stiffness of the proposed spring material, touchdown angle consideration, and touchdown velocity at which the jumping robot will touch the point of that terrain for a better landing. In [30], the researcher Zhang et al showed that multi-constrained buffer leg usage had the capability to store a higher amount of energy compared with the other 2 mechanisms (arc buffering, which has a simple structure, and bionic buffering, which has poor performance). So, finally, we can conclude that by designing the proper material selection and suitable leg mechanism, the landing buffer mechanism can bring excellent characteristics to this jumping robot, which can play a vital role in traversing long distances towards its destination.

3.4 Cost and security aspects of jumping robot

The cost and safety issues are the most vital concerns to take into account, as this intelligent system needs to be protected from external network attacks due to its vulnerability during manufacturing.

Table 1: The comparison data of popular jumping robots in terms of cost and capabilities

Jumping Robots	Estimated Cost In Thousands (BDT)	Functionalities of robots
Doggo [31]	300	a) Rescue operation b) Search operation c) Carry a package
TAUB [32]	100	a) Surveillance operation, oil spill to rescue b) Multiple jumping capability c) Locust muscle mechanism
RoboBee X-Wing [33]	500	a) Smart Agriculture b) Remote maintenance c) Inspection in restricted spaces
SpaceBok [34]	1000	a) Space exploration b) Low gravity environment c) Parallel motion mechanism d) non-flat rough terrain feasible
HAMR [35]	500	a) Water-strider like movement b) Object detection upon water body c) Information gathering in coastal areas d) Environment monitoring
Balancio-Kit [36]	40	a) It can serve educational purposes. b) Compatibility with Bluetooth applications and CAD files
Rocker-Bogie [37]	100	a) Stairs and rock climbing. b) Exploration of planets.
Ascento [38]	70	a) High speed operations. b) Outdoor navigation.
Salto-1P [39]	60	a) Saltatorial locomotion.
Sand Flea [40]	90	a) Special mid-air stabilization capability. b) Remote surveillance
JumpRoACH [41]	110	a) Autonomous control. b) Search and rescue operation.

As it will be operated under a smart infrastructure, this jumping robot should be protected by the efficient Wireless Sensor Network protocol, and for this purpose, software-defined network protocols can be applied for better handling to avoid the possibility of interruption or hacking. For cost issues, during the system design we need to emphasize the material selection, energy release timing, and battery specifications for a cost-effective solution instead of using the lithium-ion battery. To make it suitable for the smart world as an innovative product in Industrial Revolution 4.0, the control algorithm might be developed through artificial intelligence or machine learning methods so that it can have plenty of smart features to challenge the competitive world.

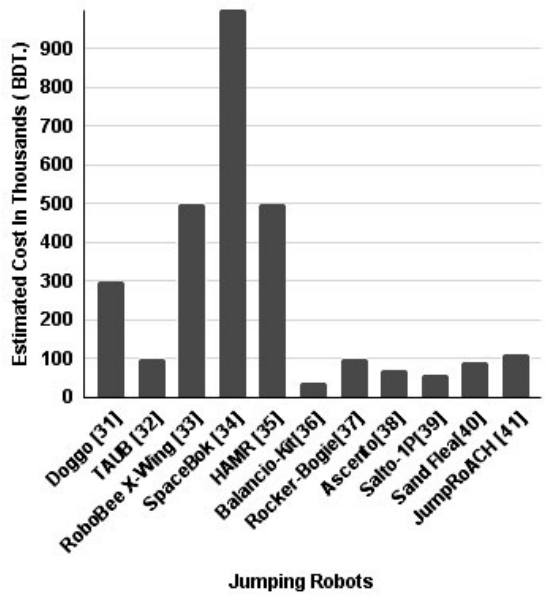

Fig. 3: Comparison of cost for reported jumping robots

Figure 3 depicts a cost comparison of several jumping robots presented by researchers in recent years. The figure above shows that jumping robots are often costly owing to the sophisticated design of the jumping mechanism and safety considerations.

4. CONCLUSION

By designing and implementing bio-inspired robots properly, we can utilize this type of robots in a harsh critical environment such as post disaster victim evacuation, military reconnaissance, rescue mission from devastated infrastructure. For this reason, we need to address and solve each and every issues found in Bioinspired Robotic research area on the basis of our study. We have already known that there are Three (3) major areas exist in bioinspired robot operation, they are a) lifting operation, b) air posture adjustment and c) smooth landing without any unexpected collision or damage occurred. Also, we need to bring solutions to provide reduced weight ratio, excellent motor characteristics, suitable elastic components with better material chosen as required for the system stabilization. As bio-inspired Robots will follow the characteristics of several creatures of nature, we will need to closely check their physiological structure and function how they are operating smoothly in any environment during their livelihood or life span. When we will be able to research and make understand ourselves actual bionic mechanism of these creatures, we can definitely solve the previous issues found in material selection, energy conversion process, landing time collision or damage, total system overweight related drawback. Finally, our research for the bioinspired jumping robots will be found as satisfactory to implement their operation practically in any difficult environmental situation as they are having wider application scope of opportunities.

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An Investigation and Critical Analysis of Common Replication Strategies in the Distributed Cloud Computing Storage Framework

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ABSTRACT

In this research, the standard replication strategies in the distributed cloud computing storage system are investigated and assessed. To guarantee data availability and dependability in cloud storage, replication is a fundamental strategy. Analyzing the effectiveness, scalability, and fault tolerance of different widely used replication strategies is the main goal of the research. The study is focused on how the particular needs of the cloud storage application affect the choice of replication approach. The study also identifies several challenges and restrictions related to replication in the distributed cloud storage system, including network congestion and data consistency. The findings from this study can be implemented to guide the design and deployment of cloud storage systems, especially in terms of choosing the most appropriate replication approach to satisfy the unique needs of a distributed cloud computing storage system.

Keywords: Replication strategies; Data consistency; Distributed cloud computing; Storage system; Data availability; Scalability; Fault tolerance.

1. INTRODUCTION

Replication [1,2] is the process of maintaining copies of data among different machines connected to a network. The benefits of replication for high system performance, scalability, and data availability in distributed environments. To increase performance, replication involves making multiple copies of data stored at various locations and retrieving data from the most nearby replica that is still accessible as in Figure 1. However, system designers face a challenge in ensuring consistency across replicas. Replication for availability, replication for performance, and replication for consistency are three crucial replication-related issues that are covered in the paper. It looks at well-known replication software for distributed storage platforms like Dynamo, Cassandra, Spanner, and Yahoo! PNUTS. Regarding replication strategies for large-scale distributed systems.

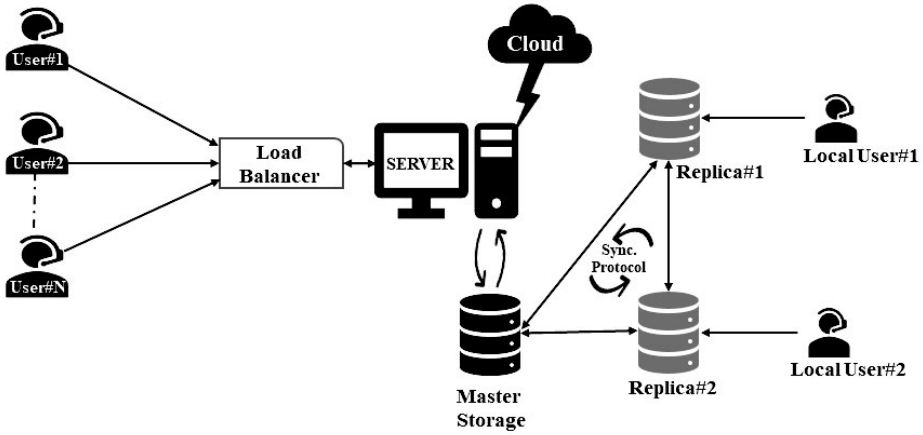

Fig. 1. Overview of replication facilities in distributed systems

1.1 Motivation

Due to their capacity to deliver high system efficiency, scalability, and data accessibility while minimizing the overhead of communication, distributed systems have gained popularity. Distributed systems have multiple LANs connected by a WAN, more data servers, and more applications than a conventional centralized business database system, which is under the control of the Information Systems division. Data requests are fulfilled on the local data server in a distributed replication system, which improves performance for local clients by lowerintraffic and locks contention and enabling faster data transfer rates.

2. REPLICATION IN DISTRIBUTED ENVIRONMENT

In distributed systems, the idea of data replication [1] is typically intended and put into practice to ensure the availability of data in the event of server breakdowns. It specifically makes multiple copies of similar data and spreads them across various servers, shelves, or data centers. Replicas are such data copies. Data can therefore be retrieved from various servers that have copies of the data in the event of a server crash. Maintaining consistency [2,3,4] among identical replicas located in various locations is the main difficulty of data replication.

2.1 Replication for data reliability

In modern distributed data storage systems, data replication has become the main method for assuring data reliability. ThriftStore, Total Recall, Farsite, Hadoop, Amazon S3, Distributed File System (HDFS), Parallel Virtual File System (PVFS), Freeloader, and Ceph Filesystem (Ceph FS) are some examples of distributed systems of storage that employ replication to ensure data reliability. The use of replication [5] and erasure coding by Windows Azure Storage for particular kinds of data is also mentioned in the piece, along with Total Recall. Here discusses optimistic replication methods and their main difficulties, including recognizing and resolving disputes, ordering activities, bounding copy divergence, and effectively propagating changes.

2.2 Replication to improve system scalability

In a distributed system, the application of replication to distributed systems boosts scalability and high availability[5]. To improve system efficiency and keep appropriate response times, replication is applied. It describes a scenario in which the workload is greater than the system's capacity, leading to decreased performance or system downtime. It lists two general remedies to this problem.

2.2.1 Vertical Scaling

Vertical scaling necessitates data division and distribution among numerous servers, each in charge of a specific portion of the data. Although this solution can handle heavier workloads, scalability requires an understanding of service logic. The system turns into more difficult to manage as it scales up, and the availability of data and reliability are not ensured.

2.2.2 Horizontal Scaling

Data from a single server is replicated across multiple servers during horizontal scaling, enabling a server to scale horizontally and accommodate more requests. Additionally, it increases the system's availability and robustness, but sustaining replica consistency is costly [5].

2.3 Replica management

The placement of replicas [6,7] has a significant impact on availability and scalability. Replication is the general solution for accessibility so developers and designers should avoid creating single points of collapse by placing replicas on similar hardware. This is determined by the geographical placement of replication servers and replica distribution.

2.3.1 Replica server and content placement

Each distributed system faces the critical problem of replica placement. Replica server placement and content placement [8] are the two sub-problems that make up the placement difficulty. The best places to host data stores are determined by replica-server placement, whereas the best servers for hosting content are determined by content placement. Before content placement can take place, replica servers must be employed.

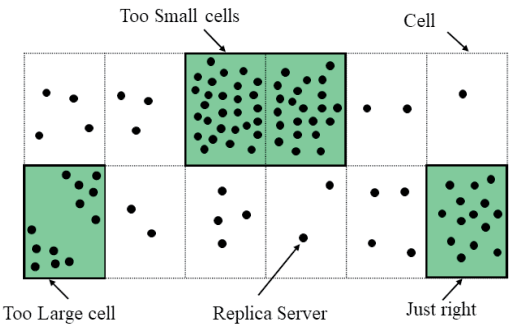

Fig.2: Choosing a appropriate cell size for server placement

Permanent replicas:

There is always a master copy in a permanent replica [9] to provide high availability, data durability, disaster recovery, load balancing, data integrity, and consistency. Organizations may guarantee that their data is always accessible and secure by utilizing permanent replicas, even

in the face of disasters or other events that may result in data loss.

Server-initiated replicas:

A replication technique called server-initiated replicas reduces latency and improves consistency by having the server start the replication process by pushing updates to the replicas.

Client- initiated replicas:

Client-initiated replicas are more commonly known as (client) caches [9]. Client-Initiated Replicas is a replication technique in which the client asks the server for updates, enhancing client autonomy and lowering server load.

3. CONSISTENCY CHALLENGES FOR REPLICA

High availability and scalability are two advantages of data replication, but it also presents difficulties in preserving data consistency. Shared databases and file systems have been used to discuss consistency. Since all replicas must behave synchronously, replica consistency can be challenging in distributed systems with concurrent client queries. There are numerous consistency models, and developers are looking into various solutions to handle this problem.

3.1 Atomic consistency

Strong consistency [5] in distributed systems is a complex and costly task, particularly when there is a possibility of network partitioning. As the system expands, ensuring high availability and strong consistency becomes even more difficult. Therefore, numerous production systems are currently opting for consistency models that offer weaker guarantees than strong consistency.

3.2 Sequential consistency

Compared to strict consistency, the sequential consistency model is less restrictive [5,7]. It makes sure that the results of any execution are the same as if every read and write function by every process in the data store had been completed in a timely manner. Each process's operations will appear in the order that its program specifies.

3.3 Client-centric consistency

In distributed systems, it is essential to maintain sequential consistency while managing concurrent operations on data that is shared. For the reason of performance, synchronization mechanisms like transactions or locks might be required to ensure sequential consistency. Client-centric consistency models offer guarantees of consistency for a single client's data storage. [8] Eventual Consistency, Monotonic Writes, Monotonic Reads, Writes Fellow Reads and Read Your Writes are a few well-known client-centric models.

4. COMPARATIVE ANALYSIS

4.1 Performance of replication techniques

The distributed cloud computing storage framework's replication approaches provide different levels of fault tolerance, data durability, disaster recovery, consistency guarantees, single point of failure, and processing overhead as in Table 1. A single-replica approach has little fault tolerance as well as limited data durability, whereas a multiple-replica strategy has high fault tolerance and medium data durability. The master-slave method has a single point of failure at the master node but provides high fault tolerance and good data durability. The multi-master technique has higher processing overhead but provides high fault tolerance and medium-high data durability. A quorum-based technique provides significant fault tolerance, data durability, and consistency, but at the cost of additional processing and storage overhead.

Table 1. The comparison among common replication strategies in the distributed cloud computing storage

Replication Strategy	Fault Tolerance	Data Durability	Disaster Recovery	Consistency Guarantees	Single Point of Failure	Processing Overhead
Single-Replica[7]	No	Low	No	No	Yes	Low
Multiple-Replica [8]	High	Medium	No	No	No	Medium-High
Master-Slave[10]	High	Medium	No	Low	Master node	Medium
Multi-Master [11]	High	Medium-High	No	Low	No	High
Quorum-Based [9]	High	High	No	High	No	Medium-High
Erasure Coding[12]	High	High	No	Low	No	High
Reed-Solomon Coding [13]	High	High	No	Low	No	High
RAID [14,15]	High	Medium-High	No	No	Node failure	Low
Backup and Restore[16]	High	High	Yes	No	No	Low
Hybrid [17,18]	High	High	Yes	High	Depends on implementation	Depends on implementation

Although erasure coding and Reed-Solomon coding schemes provide great fault tolerance and data durability, these have a higher computational overhead. RAID provides high fault tolerance and medium to high data durability, but it does not defend against node failures. The backup and restore technique is time-consuming and resource-intensive, but it enables great fault tolerance, data durability, and catastrophe recovery. A hybrid method, although providing a mix of fault tolerance, data durability, and network and storage overhead, can be complicated and difficult to execute. Overall, the replication technique used is determined by the application's unique needs, such as fault tolerance, data durability, and consistency agreements, as well as the available resources, such as processing power and storage space.

4.2 Potential guideline on replica management

Choose the optimal replication: Data availability, reliability, and performance requirements vary by application. It is essential to evaluate the application's requirements and select the replication technique that best meets those requirements.

Maintain data consistency: Ensuring data consistency in a distributed system can be challenging. Choose a replication strategy that guarantees data consistency across all replicas.

Employ a combination of replication techniques: To improve performance and availability, utilize a combination of replication mechanisms. Using mixed synchronous and asynchronous replication mechanisms, for example, can improve fault tolerance and efficiency.

Consider network congestion: Replication can place a significant pressure on the network, causing it to become congested. While choosing a replication strategy, keep congestion issues in mind.

Monitoring and maintain replicas regularly: Monitoring and managing replicas on a regular basis can assist identify problems early on and prevent data loss. To assure the health and performance of the replicas, a strong monitoring and management system must be in place.

Deploy load balancing: Load balancing can assist disperse load between replicas while also preventing any one replica from getting overburdened.

Ensure security: Replicas must be safe and secure from unauthorized access. To ensure the security of the replicas, use security protocols such as encryption and access controls.

Data replication in various locations: Data replication in different places can assist assure data availability in the event of a failure. To achieve maximum availability, data should be replicated in various geographically separated places.

Prepare a catastrophe recovery plan: Disaster recovery strategies must be in place to ensure data recovery in the event of a disaster. A solid disaster recovery strategy is essential for replica management in a distributed system.

Testing replica management system: Testing on a regular basis to confirm that it is functioning as planned. Testing can assist in the early detection of problems and the prevention of data loss.

5. CONCLUSION

Replication in distributed systems plays a vital role in providing Reliability, Fault tolerance, Accessibility, Performance, and Scalability which are essentials for a large-scale business system. However, Replication is not economical for small and medium organizations due to the extra cost of placing replica servers. Though Replication is economical for large-scale business systems, replication suffers from inconsistency among different replicas. Though there are several consistency controlling techniques, still, there are doors to further improvement to achieve strict consistency in distributed systems without synchronization problems.

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Analyzing the Effectiveness of Random Data Poisoning Attacks on Nonlinear Regression Learning Models: An Evaluation with Existing Defense

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ABSTRACT

Machine learning algorithms have produced excellent achievements in a variety of disciplines, including image identification, natural language processing, and regression analysis in recent years. These models, however, are vulnerable to malicious attacks, in which an attacker manipulates the input data to cause the model to give false results. Data poisoning is one type of attack in which the attacker inserts malicious data points into the training set in order to degrade the model's performance. This research focuses on unpredictable data poisoning threats for nonlinear regression learning and analyzes iTrim, an existing protection mechanism. The major purpose of this paper is to evaluate the iTrim protection mechanism against random data poisoning threats. Several more nonlinear regression datasets and common regression techniques were employed to carry out the experiment. The data poisoning attack was carried out by randomly regenerating data points with altered labels and inserting them into the training set. The iTrim defensive mechanism was then applied to the polluted dataset, and the model's performance on a test set was used to assess its effectiveness. The findings of the studies reveal that when the models are subjected to random data poisoning attacks, their performance suffers significantly. When malicious data points are introduced, the models overfit the training data, resulting in poor generalization to the test set. To some extent, the iTrim protection mechanism mitigated the consequences of data poisoning attacks, although its effectiveness varied depending on the dataset and regression technique utilized. Overall, the work emphasizes nonlinear regression models' sensitivity to random data poisoning threats and the necessity for adequate security mechanisms. The iTrim defensive mechanism offers some protection against data poisoning attack, but additional study is required to build more powerful defense systems capable of withstanding more complex attacks.

Keywords: Data poisoning; Non-linear regression; Randomization; Mean squared error (MSE); iTrim; Flip attack.

1. INTRODUCTION

Regression learning is a widely used machine learning technique that involves predicting a continuous output variable based on input data. It has been successfully applied in various systems, including mission-critical applications such as medical diagnosis, financial forecasting, and control of cyber-physical systems.These unavoidable systems are sensitive to malicious attacks. Two types of attacks are possible in these scenaio. Evasion works at test phase and poisioning works at training phase. we will walk through the poisioning attack. Data poisoning attack is an adversarial attack that involves the injection of malicious or corrupted data samples into the training set of a machine learning model. The goal of such an attack is to manipulate the learning process of the model and compromise its integrity and accuracy. The malicious data samples, also known as poisoning samples, are specifically designed to introduce bias into the model and steer it towards making incorrect decisions or predictions. The impact of such an attack can be severe, particularly in mission-critical applications such as healthcare, finance, and autonomous systems. For instance, Let's discuss a medical casestudy, we can find the accurate dosage where too high and too low dosage leads to bleeding and clotting for blood thinner warfarin having a very small therapeutic window. Several regressor learning techniques have already been applied to predict these kind of things. However, such predictions is sensitive to data poisoning attacks. A malicious input may generate tiny amount of poisoned samples into the dataset. The possible motives may be personal (a malignant doctor/nurse/psychopath), financial (business perspective from other company) or even terrorist or political. These kind of attack can be possible even by an individual. In realistic scenario, these are already being happening.

DePois has already shown that how small fraction of poisoned data can significatly affect the number of accepted dosages. The example shows us the drastical effect of data poisoning attacks.

2. RELATED WORKS

In this section, we presented an overview on recent literature on data poisoning. Basically there are two kind of poisoning attacks. Attacks in classifier and attacks in regressor.

Data poisoning has so far been examined almost exclusively for classification learning. For regression learning, there is work only by jagielski et. al. [1] previously. They build upon work by Xiao et. al. [2], who introduce a gradient-based optimisation attack for linear classifiers such as Lasso, Ridge Regression and Elastic

Net for feature selection. Jagielski et. Al [1] use the same approach for the same models, but interpret the model's decision surface as a predictor for the continuous target variable, yielding a poisoning attack for linear regression. Additionally, they introduce a non-gradient based attack, plus a defense called Trim and evaluate it on three datasets. Their approach in evaluating the defense is, however, not applicable in practice, since they use an oracle to determine the defense's hyper parameters. More specifically, they assume they know the fraction of poisoned samples in the dataset of size n, which is generally unknown. Nonlinear regressors such as Kernel Ridge, Kernel SVM and Neural Networks have, to the best of our knowledge, firstly have been examined in the context of adversarial poisoning by Muller et. al. [3]. This may be because the attack presented in [2] is not applicable to nonlinear learners. Muller et. al. [3] introduce an attack namely Flip attack that is evaluated through a large number of 26 datasets and they also propose a possible defense mechanism. Their iTrim defense mechanism is basically an iterative approach over Trim [1] which tries to find the poisoned fraction of dataset n. Then they try to identify subset of samples with the smallest residual as pristine through iteration. This approach initially try to predict the range of target variable, subsequently replace the target variable by either max of min value of the target variable decided by maximizing error. However, from attacker perspective, any value in between the range can produce more error. Eventually, the approach lack of pure randomization.

3. METHODOLOGY

The details of the proposed technique are covered in this part, including the Threat Model Flip Attack, the proposed Flip Attack and Randomization algorithms, and the results of the experiments.

3.1 Threat model

We considered a realistic attack scenario where the attacker has only limited capabilities, such as for example a malicious individual could have. Specifically, we considered black-box attacks where 1) the attacker knows nothing about the model (not even what kind of regressor is used), 2) the attacker does not have access to the training dataset (X, y), but only to a smaller substitute dataset (Xsub, ysub), and 3) where the attacker is capable of fully controlling the n data samples he contributes to the dataset. He is not able to manipulate the rest of the data.

3.6 Flip attack

Algorithm presents black-box attack called Flip. This algorithm computes a set of adversarial poisoning points for any degree of poisoning 0 < n < 1. The attack is completely independent of the regressor model and only requires a substitute dataset (Xsub, ysub) from the same domain as the training dataset Dtr and a feasibility domain of the target variables [γmin, γmax]. The feasibility domain is necessary because we usually assume that only certain target variables are valid. Other values are bound to raise suspicion, such as for example a room temperature of −400 degrees Celsius, or medical doses that are extremely high or low. After having initialised an empty set Δ in line 2, we populate it in the following for loop (line 3-6). For each instance in the substitute dataset, we find the maximum of the distance to the lower or upper end of the feasibility domain, and save the results to Δ. Then, in line 7 we find the ⌈n⌉-highest value t ∈ R in Δ. This is used in line 8 to compute the indices of those points for which there is most potential to disturb. Thus, the rational of line 7 8 is to find those points for which the target value is closest to either γmin or γmax. These values are the ones which can be maximally disturbed by shifting the target variable to the other side of the feasibility domain. This is implemented in line 10-19, where we compute the poison set by retaining the feature values and 'flipping' the target value to the other side of the feasibility domain for the appropriate candidates as specified by I. Finally, from line 20, we send poison data.

Algorithm 1 Flip attack

Require:
1: Substitute data $\mathbf{X}^{sub}, \mathbf{y}^{sub}$ of size m
2: Number of poison points $\lceil \epsilon n \rceil$ to compute
3: Feasibility domain $[\gamma_{min}, \gamma_{max}]$ of the target values
4: **function** Flip
5: $\quad \mathbf{\Delta} \leftarrow \emptyset$
6: $\quad$ **for** $i \in [1, ..., m]$ **do**
7: $\quad\quad \Delta_i \leftarrow \max(y_i^{sub} - \gamma_{min}, \gamma_{max} - y_i^{sub})$
8: $\quad\quad \mathbf{\Delta} \leftarrow \mathbf{\Delta} \cup \Delta_i$
9: $\quad$ **end for**
10: $\quad T_\epsilon \leftarrow t \in \mathbb{R}$ s.t. t is the $\lceil \epsilon n \rceil$-th highest value of $\mathbf{\Delta}$
11: $\quad I_\epsilon \leftarrow \{i \in [1, ..., m]$ s.t. $d_i >= T_\epsilon$ where $d_i \in \Delta\}$
12: $\quad \mathbf{X_p} \leftarrow \emptyset, \quad \mathbf{y_p} \leftarrow \emptyset$
13: $\quad$ **for** $i \in I_\epsilon$ **do**
14: $\quad\quad$ **if** $y_i > \frac{1}{2}(\gamma_{max} - \gamma_{min})$ **then**
15: $\quad\quad\quad y_{p,i} \leftarrow \gamma_{min}$ + random()
16: $\quad\quad\quad \mathbf{y_p} \leftarrow \mathbf{y_p} \cup y_{p,i}$
17: $\quad\quad$ **else**
18: $\quad\quad\quad y_{p,i} \leftarrow \gamma_{max}$ - random()
19: $\quad\quad\quad \mathbf{y_p} \leftarrow \mathbf{y_p} \cup y_{p,i}$
20: $\quad\quad$ **end if**
21: $\quad\quad \mathbf{X_p} \leftarrow \mathbf{X_p} \cup X_i^{sub}$
22: $\quad$ **end for**
23: $\quad$ **return** $\mathbf{X_p}, \mathbf{y_p}$
24: **end function**

3.7 Randomized flip attack

We introduced randomization from this intuition that not always min value or max value is most potential to disturb. If we change the value by randomization, from defender side, it will be tough to identify the random points.

3.8 Reversed flip attack

The way we think to change the target variable by reversing it. We make it from the intuition that it will lead us in a wrong direction. From the attacker side, the target is always increasing the error both in attack side and defense side.

3.9 Experiments

This subsection discussed about the experiments in a nutshell. The experiment done for the proposed approach aims to be as inclusive and realistic as possible. First, we split each of the 26 datasets into a randomly.drawn substitute set of size 0.25, a train set of size 0.75 × 0.8 and a test set of size 0.75 × 0.2. For each combination of the 26 substitute datasets and [0.00, 0.02, 0.04, 0.06, 0.08, 0.10], we create a poisoned dataset using the respective attack, which we append to the corresponding train set and shuffle. This results in 6 × 26 = 156 combinations of train dataset and poisoning rate. This step does not depend on the regressors. Then, for each regressor and each of the 156 poisoned train datasets, we perform Cross-Validated Grid Search to find suitable hyper parameters. Finally, for all 156 poisoned train datasets and both defenses (Trim and iTrim, we clean each of the 156 poisoned train datasets. We then train a regressor and measure test error on the test data sets and report below. Thus, in total we run 156 × 7 × 2 = 2184 experiments (7 being the number of different regressors evaluated).

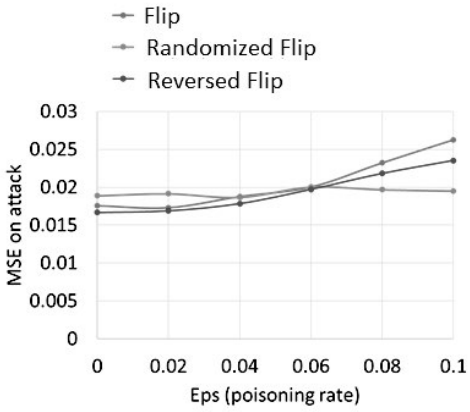

Fig. 1: Attack on concrete dataset

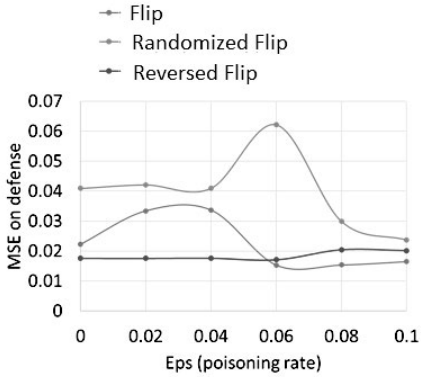

Fig. 2: iTrim defense on different attacks for concrete dataset

3.9.1 Regressors and datasets

For the experiments, we used 23 datasets: Eight datasets from the GitHub repository imbalanced dataset [5], and 15 datasets from the KEEL regression repository [4]. Each dataset contains at least 1000 data points. For datasets where n > 10000, we randomly sample a subset n = 10000. In keeping with [6], we scale features and targets to [0, 1]. We evaluate four linear models (HuberRegressor, Lasso, Ridge, Elastic Net) and three non-linear models (Neural Networks, Kernel Ridge with RBF kernel, and Support Vector Regressor with RBF kernel). To the best of our knowledge, we are the first to evaluate randomized poisoning attacks against non-linear regressors.

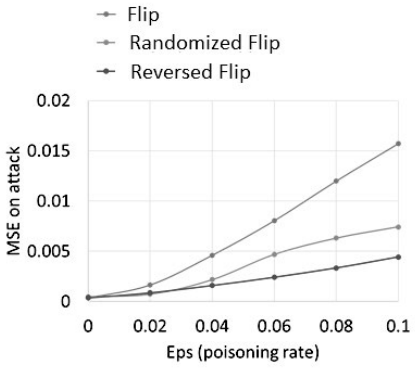

Fig. 3: Attack on Wizmir dataset

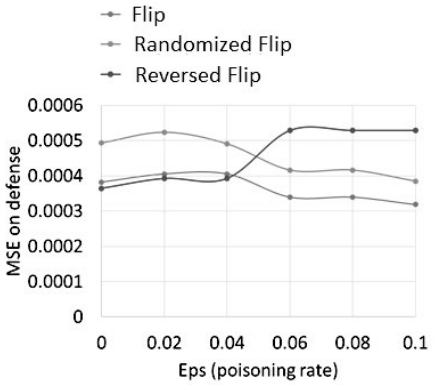

Fig. 4: iTrim defense on different attacks for Wizmir dataset

4. RESULTS AND COMPARATIVE ANALYSIS

In this section, we presented the details of experimental results for the proposed approach. The indicator of regression learning is none but errors like MSE(Mean Squared Error). Therefore, for different poisoning rate, we calculate the MSE of the Flip attack. For just an instance, in figure 1 we can see that for low poisoning rate, MSE on attack is better than previous work. On the other hand, existing defense fail to mitigate our randomized Flip in figure 2. From figure 5, we can conclude that Reversed Flip perform well for earthquake dataset and no approach perfoms well enogh for wizmir weather dataset. Moreover, from figure 6, we can conclude that existig defense iTrim fail for touples concrete dataset over Randomized Flip , earthquake dataset over Reversed Flip. These results show significant weakness in existing defense mechanism. Thus need a humble approach to mitigate Our proposed Randomized and Reversed Flip attack. From figure 7 to figure 14 show average MSE during attacks on individual regressors over all dataset. From figure 7 and 10 we see that error introduced for n = 0.08 is much higher than the others for Randomized Flip attack. For the rest of the regressor, Randomized and Reversed Flip attack are very near to Flip attack. The main concern about the randomized and reversed flip attack is that the existing defense like iTrim can't minimize error as Flip attack. In figure 14 we can see the error for Randomized Flip defense is almost double than flip defense.

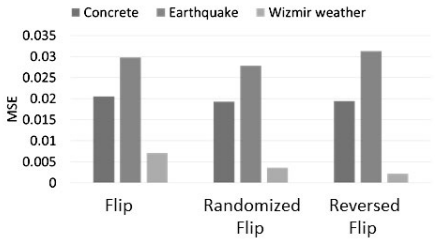

Fig. 5: Comparison of existing(flip) and new two (reversed flip and randomized flip) attacks over all dataset

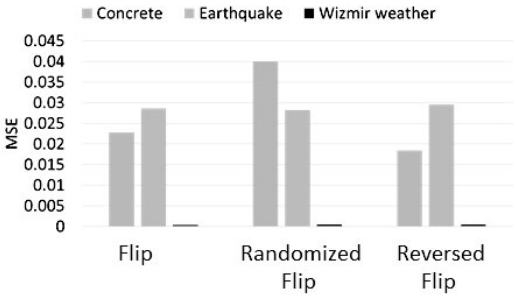

Fig. 6: Comparison of iTrim defense for existing(flip) and new two(reversed flip and randomized flip) attacks over all dataset

We generated the graph for every dataset over all regressor. These graphs are presented in Appendix. Moreover, from intuition and our results we can conclude that MSE becomes higher for higher poisoning rate. At last, we show the the result of MSE of attack for individual dataset and regressor in Appendix section.

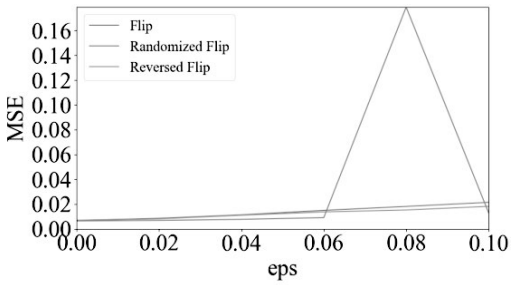

Fig. 7: MSE during attacks on ElasticNet regressor

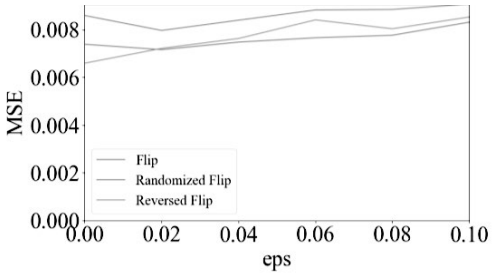

Fig. 8: MSE during attacks on Huber regressor

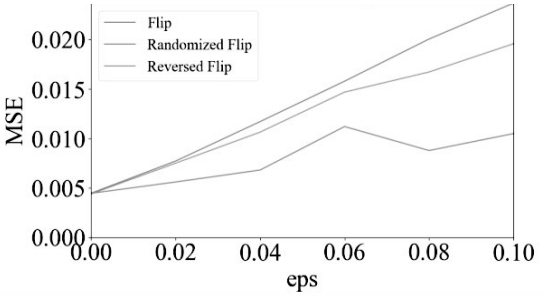

Fig. 9: MSE during attacks on KernelRidge regressor

Fig. 10: MSE during attacks on Lasso regressor

From figure 14 to figure 20 show average MSE during defense for Flip attack and Reversed and Randomized Flip attack on individual regressors over all dataset. We find out the Lasso Regressor is the most sensitive for both attacks and defenses. Randomized Flip generate more mean squared error(MSE) for 8% poisoning rate. Moreover, the error is much higher comparative to other regressors. For other regressors, we notice randomization in results. For some regressors, Randomized Flip attack perform better in defense and for some other regressors, Reversed Flip attack perform better than Flip attack. Again from the results of defenses, we find the weakness of iTrim defense. The reason behind it is that the iTrim defense is a generic defense mechanism blindly trying to find the optimal poisioned data points. Therefore, our experiments and results clearly identify the lackings and find the necessity of better defense mechanism for data poisoning attacks on non linear regressors.

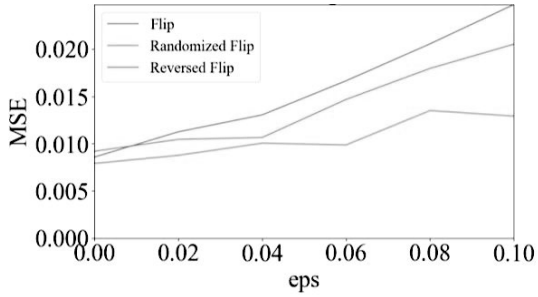

Fig. 11: MSE during attacks on MLP regressor

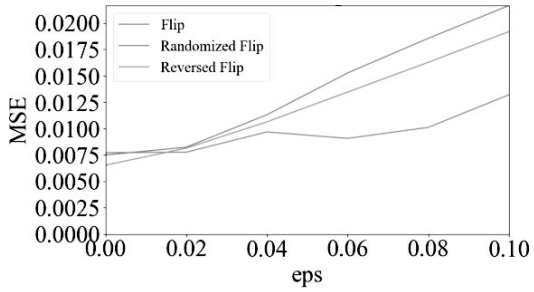

Fig. 12: MSE during attacks on ridge regressor

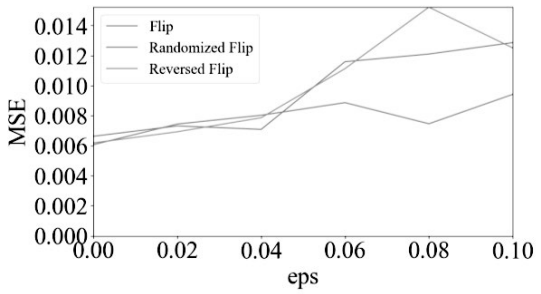

Fig. 13: MSE during attacks on SVR regressor

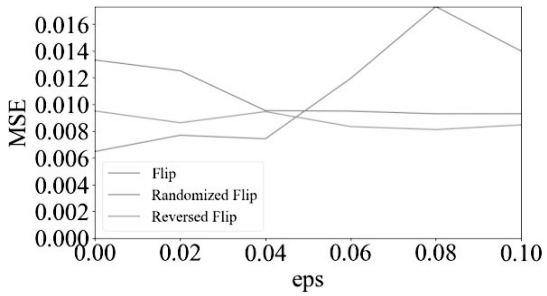

Fig. 14: MSE during iTrim defense for attacks on ElasticNet regressor

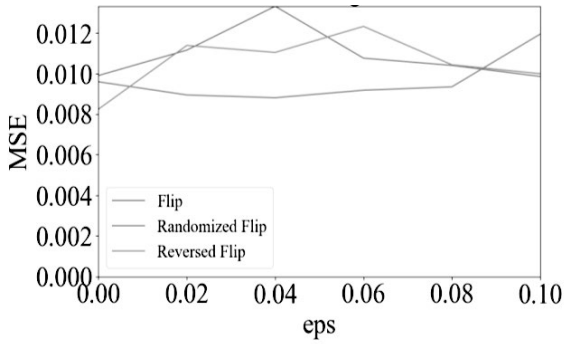

Fig. 15: MSE during iTrim defense for attacks on HuberRegressor regressor

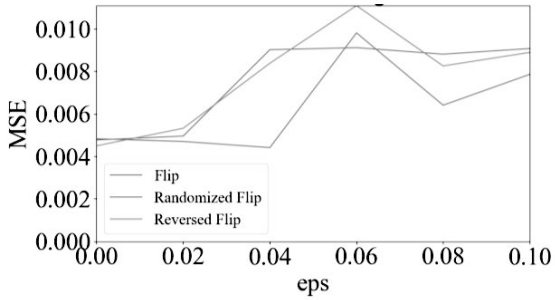

Fig. 16: MSE during iTrim defense for attacks on KernelRidge regressor

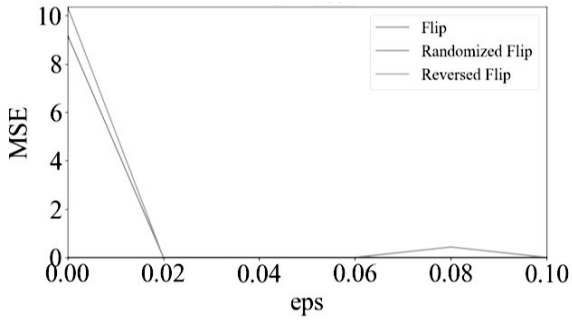

Fig. 17: MSE during iTrim defense for attacks on lasso regressor

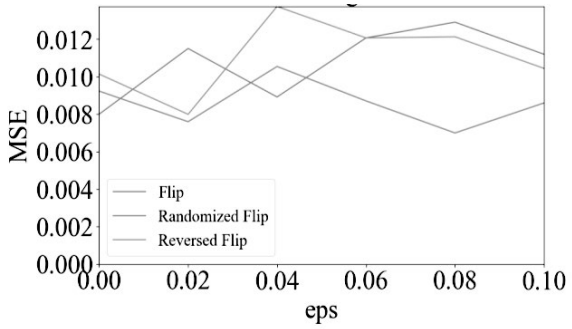

Fig. 18: MSE during iTrim defense for attacks on MLP regressor

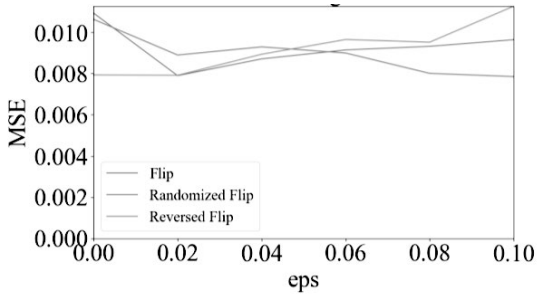

Fig. 19: MSE during iTrim defense for attacks on ridge regressor

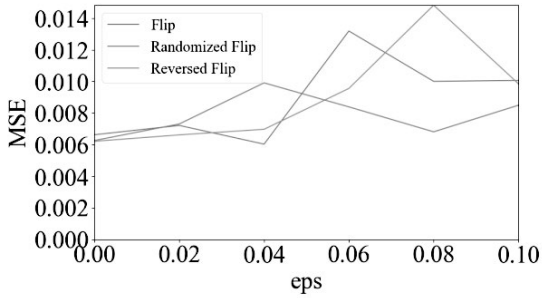

Fig. 20: MSE during iTrim defense for attacks on SVR regressor

5. CONCLUSION

An innovative randomization-based strategy for nonlinear regression has been developed in this research. The suggested attack is then evaluated, and we find out that the existing defense mechanism is ineffective in mitigating the attack. In the future, we aim to introduce a defense mechanism to mitigate the attacks. Furthermore, the randomization attack has been tested only on numerical data sets. Therefore, it can be implemented on image datasets and then evaluated to determine whether the attack has a norm for generalized input or not.

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Challenges and Opportunities of Big Data and Predictive Analytics for Effective Supply Chain Management

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ABSTRACT

With the emergence of big data and predictive analytics, the fourth industrial revolution (4IR) has transformed the field of supply chain management, providing new opportunities and challenges for organizations.The purpose of this systematic literature review is to investigate the challenges and opportunities of big data and predictive analytics for effective supply chain management in 4IR. Big data and predictive analytics, in particular, can help businesses improve forecasting accuracy, reduce lead times, and improve inventory management. Furthermore, the use of these technologies can provide insights into customer demand patterns and supply chain risks, allowing organizations to make better decisions and save money. The study does, however, highlight a number of challenges associated with the use of big data and predictive analytics for effective supply chain management in the 4IR. These challenges include concerns about data quality and privacy, as well as the requirement for specialized skills and resources to effectively implement and use these technologies. Moreover, including big data and predictive analytics in the entire supply chain management strategy necessitates a multidisciplinary approach that involves collaboration between many departments inside the business as well as external partners and stakeholders. The literature reviewed in these papers reveals key challenges and findings related to big data analytics (BDA) in supply chain management (SCM), such as factors influencing BDA proficiency, the importance of BDA in SCM, enablers and challenges in leveraging big data in the food supply chain, and potential benefits of BDA in sustainable supply chain management. Additionally, the papers offer a comprehensive analysis of the research scope, opportunities, and perspectives on BDA in SCM, covering various aspects including enablers, challenges, benefits, implementation issues, and future research directions. Big data and predictive analytics may play an important role in successful supply chain management in the 4IR, allowing firms to improve their operations and decrease costs. So far, implementing these technologies successfully necessitates careful planning, investment, and coordination throughout the entire supply chain ecosystem. To fully capitalize on the benefits given by big data and predictive analytics in the context of the 4IR, organizations must solve the problems associated with these technologies.

Keywords: Supply chain management; Big data; Predictive analytics; Fourth industrial revolution; Resource utilization.

1. INTRODUCTION

In recent years, the importance of sustainability in supply chain management has gained significant attention due to the growing concern about the environmental and social impact of business operations. The emergence of big data and predictive analytics has the potential to transform the way organizations manage their supply chain sustainability by providing valuable insights to optimize their operations, reduce their environmental footprint, and increase their social impact [1]. Recent research papers show that implementing sustainable practices in supply chain management can lead to significant benefits for organizations, such as cost reduction, improved reputation, and increased customer loyalty as in Fig. 1. Another study aims to provide a comprehensive review of existing literature on big data analytics in supply chain management and identify research gaps to suggest future directions for alternative theoretical perspectives and analytical methods [2]. Similar to other research papers, this study highlights the growing interest in leveraging big data in the food supply chain and emphasizes the need for further research to optimize food processes and support food procurement, processing, and marketing [3]. Other research papers show that big data analytics has the potential to significantly enhance sustainability and supply chain performance in various industries and contexts, but its successful implementation requires addressing challenges such as data privacy and compatibility while fostering a comprehensive understanding of the research profile and potential research questions [4]. The aim of the systematic literature review (SLR) was to uncover the existing research trends, distill key themes, and identify areas for future research in the application of Big Data in operations and supply chain management (OSCM) [5].

The motivation behind this research is to provide insights into the current trends and future perspectives of Big Data Analytics in Supply Chain Management, Logistics Management, and Inventory Management and identify research gaps and future directions for its effective implementation [6]. The authors show the importance of considering ethical, security, and privacy considerations when implementing big data analytics in supply chain management [7]. Another study highlights the potential of big data analytics capabilities in improving environmental

performance in e-procurement and emphasizes the need for a focus on both the technological and human aspects of BDAC for successful implementation [8]. This study aids policy-makers in conceptualizing the mutual interaction of the barriers for developing policies and strategies to improve the penetration of BDA in manufacturing SC [9]. Another research contributes to the advancement of the body of knowledge on big data and blockchain by identifying key implementation guidelines and issues for blockchain in supply chain management [10].

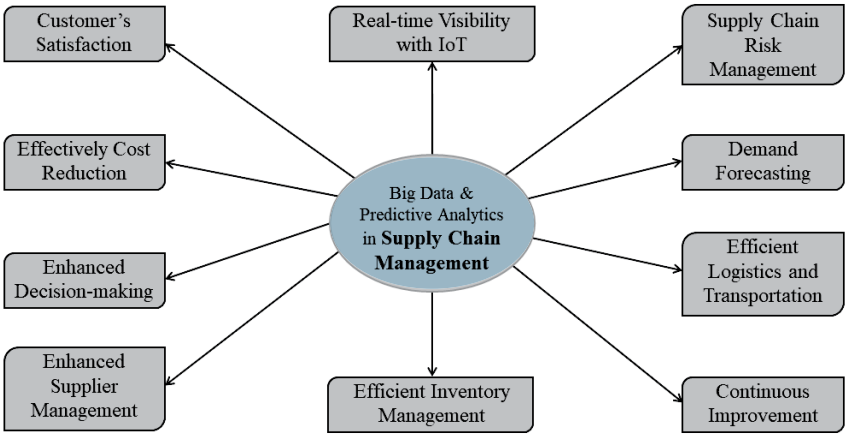

Fig. 1: Benefits of big data and predictive analytics in supply chain management

1.1 Significance of predictive analytics in SCM

Customer Satisfaction: Predictive analytics allow businesses to obtain better knowledge of their customers' preferences, behaviors, and sentiments. Organizations may customize their services, increase product availability, and improve the entire customer experience by evaluating consumer data. It ends up in enhanced client happiness and loyalty, as well as, eventually, corporate development.

Cost reduction: Organizations may find potential for cost reduction and operational efficiency gains by embracing big data and predictive analytics. Analyzing transportation data, for example, may enhance route planning and reduce fuel consumption, while predictive maintenance can reduce equipment downtime and maintenance costs. These cost-cutting techniques have a beneficial influence on the bottom line and increase overall supply chain profitability.

Enhanced Decision-making: Organizations may make educated decisions based on accurate and up-to-date information by evaluating enormous amounts of data from numerous sources. This contributes to better overall supply chain performance by optimizing inventory levels, improving demand forecasts, identifying bottlenecks, and mitigating hazards.

Real-time Visibility with IoT: Big data and predictive analytics provides real-time monitoring and visibility throughout the supply chain. Organizations receive real-time insights into the state and performance of their supply chain by gathering and analyzing data from numerous sources, such as IoT sensors, RFID tags, and social media. This enables proactive issue detection, faster problem resolution, and better customer service.

Efficient Inventory Management: By investigating historical data, consumer demand patterns, and supply chain dynamics, big data analytics may assist in optimizing inventory levels. This allows firms to cut carrying costs, stockouts, and total inventory turnover. Predictive analytics may also detect fluctuations in demand and seasonality, allowing firms to modify inventory levels to avoid excess or inadequate stock.

Supply Chain Risk Management: Big Data and predictive analytics contribute to the identification and mitigation of possible supply chain issues. Organizations may predict and proactively manage supply chain interruptions by accessing data from external sources such as weather forecasts, economic indicators, and geopolitical events. This enables disaster preparedness, alternate sourcing methods, and resilient supply chain operations.

Improved Demand Forecasting: Predictive analytics forecasts demand with improved accuracy by using historical data, industry trends, and external variables. Organizations may optimize their production, inventory, and distribution operations by knowing client preferences, market dynamics, and demand trends. This decreases stockouts and unnecessary inventory while also ensuring a more responsive supply chain.

Therefore, the value of big data and predictive analytics in supply chain management is based on its capacity to give actionable insights, optimize operations, decrease costs, mitigate risks, and improve customer satisfaction. In today's complex and dynamic supply chain world, leveraging these technologies enables firms to remain competitive, react to changing market conditions, and achieve operational excellence.

However, despite the potential benefits of these technologies, there is still a lack of research exploring their applications and limitations in supply chain sustainability. Despite the potential benefits, the adoption of big data and

predictive analytics in supply chain sustainability is still in its early stages, and there is a need for further research to explore the challenges and opportunities associated with their use. This paper aims to contribute to the existing literature by conducting a systematic review of recent research on big data and predictive analytics in supply chain sustainability, with a focus on identifying the key challenges and opportunities associated with their use. By doing so, this paper aims to provide valuable insights for organizations seeking to implement these technologies to improve their sustainability performance.

1.2 Key contributions

- The key challenges and findings identified in the literature include factors influencing BDA proficiency in supply chain professionals, the importance of BDA in SCM, enablers and challenges of leveraging big data in the food supply chain, and potential benefits of big data analytics in sustainable supply chain management.
- Analyzing research scope and opportunities for big data application in operations and supply chain management.
- This paper provides a diverse range of perspectives on big data analytics in supply chain management, addressing various aspects, including enablers, challenges, benefits, implementation issues, and future research directions.

2. LITERATURE REVIEW

Recent research papers highlight the significant benefits that organizations can achieve by implementing sustainable practices in supply chain management. Tobias Schoenherr [1] aims to identify factors that influence supply chain professionals' proficiency in using big data analytics (BDA) and investigate the impact of BDA proficiency on quality and cost performance in supply chain management, taking into account environmental competitiveness as a moderating factor. In Lee and George Mangalaraj [2], their study conducts a systematic literature review to present a framework from interdisciplinary perspectives on big data analytics in supply chains. The study examines theoretical foundations and research models from an organizational perspective, analyzes technical aspects, and identifies research gaps and future directions.

Abderahman Rejeb et al. [3], the authors aim to perform a systematic literature review to identify the enablers of leveraging big data in the food supply chain and to capture the latest developments in this field. They also aim to identify the significant benefits of applying big data in the food industry and outline challenges and future research directions. Joash Mageto [4], aims to explore the potential of big data analytics (BDA) in enhancing sustainable supply chain management (SSCM) within manufacturing supply chains, as well as identifying challenges to BDA implementation in this context.

Shalini Talwara et al. [5], aimed to conduct a systematic literature review to identify the different facets of Big Data application in operations and supply chain management (OSCM) and develop a conceptual framework titled the Dimensions-Avenues-Benefits (DAB) model for BDA adoption, along with potential research questions to support future investigations in the area. Sumit Maheshwari et al. [6], they aim to provide insights into the progress and challenges in the field of Big Data Analytics in Supply Chain Management, Logistics Management, and Inventory Management, based on a review of 58 papers from 2015-2019. Nnamdi Johnson Ogbuke et al. [7], aim to conduct a comprehensive review of big data supply chain analytics, exploring its application in supply chain management and its benefits, as well as examining ethical, security, privacy, and operational challenges, and how organizations employ this tool to predict and direct their operations. In [8], the authors aim to investigate the potential of big data analytics capabilities (BDAC) to improve environmental performance in e-procurement, and to explore the mediating effect of BDAC between e-procurement and environmental performance. Rakesh D. Raut et al. [9], aimed to identify and assess barriers to the implementation of Big Data Analytics in Indian manufacturing supply chains using an integrated approach consisting of ISM and DEMATEL, and to provide insights for policy-makers to develop strategies and policies to improve BDA penetration. Balan Sundarakani et al. [10], The aim of this research is to investigate the implementation of blockchain in an Industry 4.0 environment from a Big Data perspective in supply chain management through an action research method and case study approach. The study identifies key implementation guidelines and issues for blockchain in supply chain management.

These studies emphasize the importance of integrating sustainability considerations into supply chain processes and operations, as it can result in improved environmental performance, cost savings, enhanced reputation, and increased customer loyalty. By addressing social, environmental, and economic aspects, organizations can create a more resilient and responsible supply chain that aligns with evolving consumer expectations and global sustainability goals.

3. CHALLENGES AND OPPORTUNITIES

These papers address various challenges related to the implementation, proficiency, capabilities, ethical considerations, and specific contexts of big data analytics in supply chain management and these identified lacking areas and scopes for new research can guide researchers in further exploring and expanding the knowledge.

3.1 Key challenges in predictive analytics in SCM

There are various difficulties in implementing predictive analytics for effective supply chain management as shown in Fig. 2. To begin, establishing the quality and availability of data is critical since inconsistencies and gaps may affect the precision and reliability of predictive models. Another problem is integrating and harmonizing data from many sources, which necessitates data mapping and transformation. Scalability and computing needs must also be addressed, as large amounts of data might be

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privacy, system compatibility, and the legal framework governing data privacy. Additionally, exploring the economic and environmental impacts of implementing big data analytics in sustainable supply chain management could be valuable. The article [6] analyzes the significance of big data analytics in supply chain management and suggests future research directions. Further research could concentrate on exploring a wider range of applications of big data analytics in the product lifecycle and emphasizing sustainable and enterprise production. The paper [10] explores the implementation of blockchain and big data analytics in supply chain management. Future research could further investigate the scalability and applicability of the proposed architecture and explore additional case studies to validate the findings and expand the understanding of big data analytics in supply chain design.

4. CONCLUSION

This research has made significant contributions to the field of big data analytics in supply chain management. It has identified key challenges and findings related to factors influencing BDA proficiency, highlighted the importance of BDA in SCM, explored enablers and challenges in leveraging big data in the food supply chain, examined the potential benefits of big data analytics in sustainable supply chain management, and provided valuable insights for future research in the area. The papers collectively offer a diverse range of perspectives, covering various aspects of big data analytics in supply chain management, including enablers, challenges, benefits, implementation issues, and future research directions. These contributions enhance our understanding of the role and impact of big data analytics in optimizing operations and supply chain management processes.

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Design and Implementation of a Face Detection-Based Door Controlling System for Improved Home Security

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ABSTRACT

The advent of Internet of Things (IoT) technology has led to significant advancements in the field of home security systems. One can build a highly automated and safe smart home by utilizing advanced IoT devices and the internet. In this paper, we present a face detection-based door control system for improving home security utilizing IoT technology. The suggested system detects and recognizes the appearance of the individual standing in front of the door using a facial recognition technique. The device uses a camera to record a person's face, which is then processed using a facial recognition system. If the face matches the data in the system, the door unlocks immediately, enabling the individual to enter the home. If the faces do not match, the system sends a notification to the owner, notifying them of a potential security incident. A low-cost Arduino based microcontroller system, sensors, and a camera module are used to build the system. The photo of the individual is captured by the camera, and the image is processed by the Arduino based microcontroller system. The system also has a Wi-Fi module, which allows it to connect to the internet and communicate with other smart home appliances. The proposed system offers several advantages over traditional door control systems. For instance, the proposed system eliminates the need for keys, which are often misplaced or stolen. Moreover, it increases security by employing face recognition technology that cannot be quickly hacked. Finally, it enables remote access control, allowing the homeowner to operate the door from anywhere in the universe using a smartphone or tablet. Therefore, the presented face detection-based door control system provides an efficient and safe way to regulate house entry. With the growing demand for home security systems, this system has the potential to play an important role in maintaining the protection of homes and families.

Keywords: Internet of things (IoT); Home security systems; Facial recognition; Camera module; Proteus; Remote access.

1. INTRODUCTION

In recent years, technological improvements have transformed the way we approach several parts of our life, including home security. Concerns about safety and the necessity for strong security systems have encouraged the development of novel solutions. A face detection-based door control system [1,2], which employs cutting-edge computer vision techniques to improve home security, is one such solution.

Traditional home security systems sometimes rely on physical locks, keys, or access codes, which can be compromised or impersonated. However, with the arrival of advanced face identification algorithms and the widespread availability of low-cost image cameras, a new era of home security has begun. The goal of this system is to use the unique properties of human faces to authenticate and provide access to authorized persons, ensuring increased security against illegal entrance. The fundamental goal of this research is to design and build a robust and dependable face detection-based door control system that can interact easily with current security infrastructures, as illustrated in Figure 1. This system can properly identify and authenticate persons based on their facial traits by utilizing cutting-edge computer vision methods such as convolutional neural networks (CNNs) [3], LPBH algorithms [2, 4] and face recognition techniques. This sophisticated degree of security offers an extra layer of safety, discouraging possible attackers and giving homeowners peace of mind. This approach has various advantages over standard access control systems, in addition to the obvious security benefits. For starters, it does away with the need for actual keys or access credentials, which may be easily forgotten, stolen, or traded. Individuals may instead acquire access by merely displaying their faces to the system, making the procedure more convenient and efficient. Furthermore, this technology may be readily incorporated into current security systems, including smart home installations, to

create a unified and complete security solution. A number of stages and components are involved in the design and implementation of a facial detection-based door control system. First, an accurate and dependable face detection algorithm [4] must be chosen or built. This algorithm will be in charge of detecting and locating human faces in collected photos or video streams. Once the faces have been spotted, facial recognition algorithms will be used to compare them to a pre-registered database of permitted individuals. For increased scalability and accessibility, this database may be handled locally or connected to a cloud-based service.

The system will use hardware components such as cameras, microcontrollers, and suitable communication modules, as shown in Figure 1, to enable real-time and flawless operation. These components will enable picture or video stream collection and processing, as well as the execution of face detection and identification algorithms. A user interface will also be created to help with system configuration, enrollment of authorized users, and monitoring of access records on an Android phone. This face detection-based door control system's effective deployment will considerably improve home security by offering an accurate, efficient, and user-friendly access control mechanism. It has the ability to change how we view and manage home security by providing greater protection against invasions and unwanted access. This technology offers a significant advancement in increasing the security and safety of modern houses by using the capabilities of computer vision and face recognition technologies. To identify the person from the local database of household members created by the system, local binary pattern histograms are used. The core elements of this system are security, monitoring, and real-time control of automation.Recently, researchers proposed some solutions for home security based on face-detection [1,2,3,4,5]. Some of the solutions have used Passive Infrared and Ultrasonic sensor [1] and others system utilized ANN [3], LBPH algorithm [2, 4].

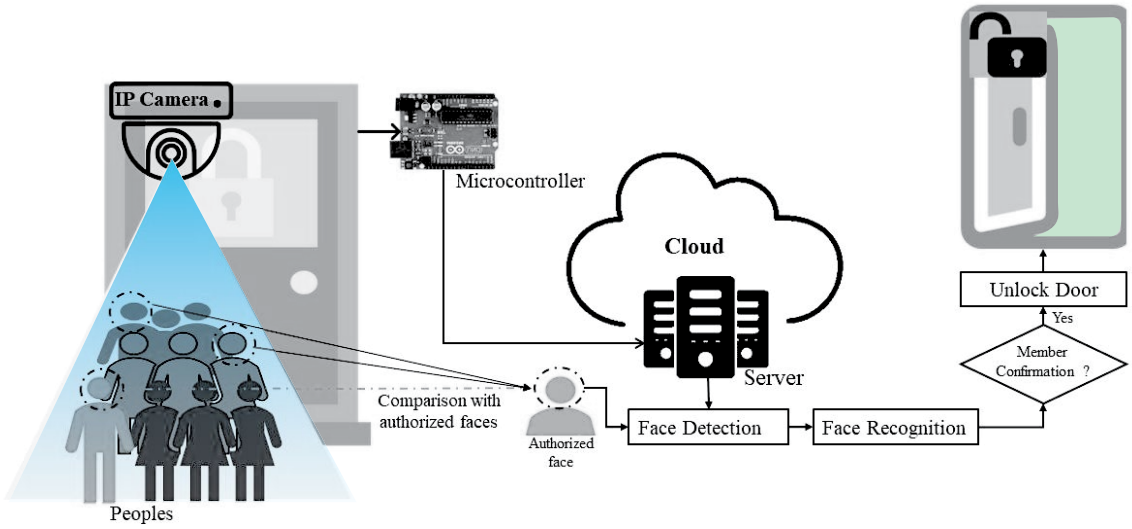


Fig. 1: Overview of the face-detection based door controlling system

1.1 Contributions

The main objective of this research is to design and develop a smart home security and safety system for ensuring a smart secure home to avail the following benefits:

- Only allow the authorized person to enter into the
- room
- Automatic LPG Gas and Fire detection
- The data group we receive will be monitored from anywhere and can be viewed at the smartphone

We will look at the literature study, comprehensive design, implementation, and assessment of this system in the following sections, highlighting the important components, internal architecture, and technologies involved. We will demonstrate the usefulness and feasibility of our face detection-based door controlling system for increased home security by investigating its capabilities, performance, and possible limits.

2. LITURATURE REVIEW

Security and automation systems for the house are intelligent technologies that improve and modernize daily life. Currently, the home automation system is solely concerned with automating the house or a variety of power-hungry tasks. The emphasis of the system prototype that is being presented is on it being quick, secure, and simple for regular people to utilize. Compared to the old system, it is less expensive and offers more advantages, such as security. Using supervised classification and Gabor filtering, the author of [5] suggested a unique face recognition method. A high rate of facial identification is

achieved by utilizing this methodology, which starts with the usage of a 2D filter bank and ends with the production of a 3D robust face for vector average distance in supervised classifiers and threshold-based face verification methods. A powerful face detection technique was put forth by the author in [6]. The concepts of integral images, an effective AdaBoost classifier, and cascade classifiers are introduced in this study, which reduce computations and produce a quick and effective detection system. A mechanism to guarantee vehicle security was suggested by the author in [7]. The technology, which is based on Arduino, takes a picture of the individual trying to start the car. PCA is the algorithm utilized for face recognition. The writers of [8] employed an embedded platform that was extremely innovative and simple to use.On the basis of the Raspberry Pi board, they suggested an image capture method for embedded systems. Using the Raspberry Pi and Pi camera with Open CV's computer vision algorithms, the author of the project "Raspberry Pi Face Recognition in Treasure Box" provided a fantastic example. It is able to access the most recent and intriguing computer vision techniques, such as facial recognition, by generating the most recent version of Open CV. In [10], the writer He constructed a system with a sophisticated surveillance camera capable of face detection and recognition at the same time, utilizing the OPENCV library and Eigen face approach. All processing was completed on a Raspberry Pi running the Raspbian OS. The authors of [11] proposed their work using a Raspberry Pi 2 B+ model with a camera interface to take pictures and then turn those pictures into grayscale ones using an image processing technique. According to the author in [12], the notion of face recognition might be applied in real time by creating MATLAB code utilizing the image capture toolbox and PCA using Eigen faces as the primary technique.

3. PROPOSED SYSTEM

The ESP32 CAM and the Blynk App were used to create the smart Wi-Fi door lock that was discussed in this article. In this straightforward working setup, when someone rings the doorbell, the owner gets a notification on his or her phone that includes a picture of that individual. After verifying the image, the owner can also unlock the door via a mobile device.

A Wi-Fi Door Lock with ESP32 CAM and Internet of Things (IoT) technology are used by the proposed Door Security System application to manage the door, track its status, and boost home security. With the use of the Blynk communication protocol, a home's security can be improved by linking a smartphone to a door lock system. ESP32 camera, Blynk, TCP/IP, Wi-Fi lock system, IoT-based door lock, and home security are some examples of related terms.

3.1 Proposed logical design

Figure 2 and 3 illustrate the proposed logical diagram of face detection-based door controlling system which includes NodeMCU, BuckModule, ESP32-CAM, FlameSensor, MQ-6Sensor, Adapter, ServoMotor, LCD Display, Buzzer.

ESP32-CAM:

The small-size camera module of the ESP32 CAM WiFi Module Bluetooth with OV2640 Camera Module 2MP is used for Face Recognition in this project.

NodeMCU:

The IoT platform NodeMCU is open source Hardware based on the ESP-12 module and firmware that runs on Espressif Systems. ESP8266 Wi-Fi are also included.

BuckModule:

A buck converter is a common DC-DC converter that effectively transforms a high voltage to a low voltage. Power conversion efficiency increases and so, battery life is extended, heat is reduced, and smaller gadgets may be made.

MQ-6Sensor and flame sensor:

A flame detector is a sensor that detects and responds to the presence of a flame or fire, allowing for flame detection and suppression. MQ-6 has been liquefied. The Petroleum Isobutane Propane Gas Sensor Module is an inexpensive method to add basic gas detection to this project.

Servo and adapter:

A 12V, 5A Micro Power Adpater motor. For use with the Arduibo/Raspberry Pi 3 Models A+/B/B+/Zero and other high-current devices: A servomotor is a rotary or linear actuator that can regulate angular or linear position, velocity, and acceleration precisely.

Liquid crystal display (LCD) with a buzzer:

An LCD is a flat display that employs light modulation. When supplied by a DC source, the liquid display characteristics and these 5 volt active buzzers provide a continuous beep or tone. This sort of buzzer just needs an ON/OFF input.

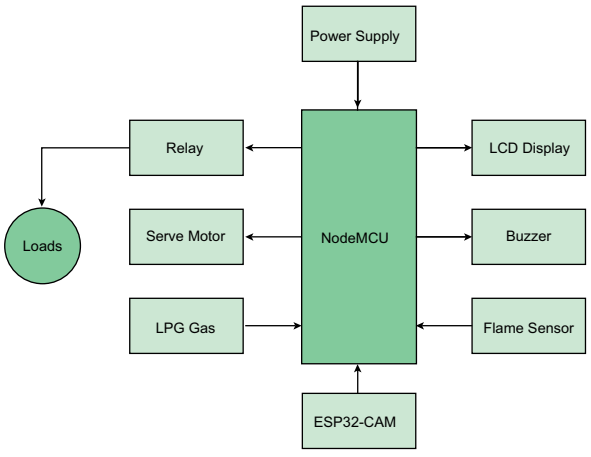


Fig.2: Proposed logical diagram of face detection-based door controlling system

3.2 Tools and softwares

Proteus simulation software: The best simulation tool for different microcontroller designs is Proteus, which is what we utilized. It is primarily well-liked due to its availability. of almost all microcontrollers in it.

Arduino software: Open-source software that can be obtained for free at www.arduino.cc is used to program the microcontroller. We may create mini-programs for the microcontroller using this Arduino software. 'Sketch' is the name of these applications. The sketches are ultimately sent via USB connection to the microcontroller. Later on in the programming section, more on that.

Android apps: The majority of the time, Blynk is used online. This app uses a certain server to transfer data. The software must be registered on the designated server before being accessed using a user name and password. Data is transmitted from the controller's Internet head to the server, which then sends software data that we may access from anywhere.

3.3 Circuit diagram for hardware implementation

Applications and face detection Even though there hasn't been any fabrication at this point, the project is still regarded as a success. The aforementioned issues will be resolved, and because the project will be successful due to the low cost of the components employed, the implementation phase will follow once the job is finished economically.

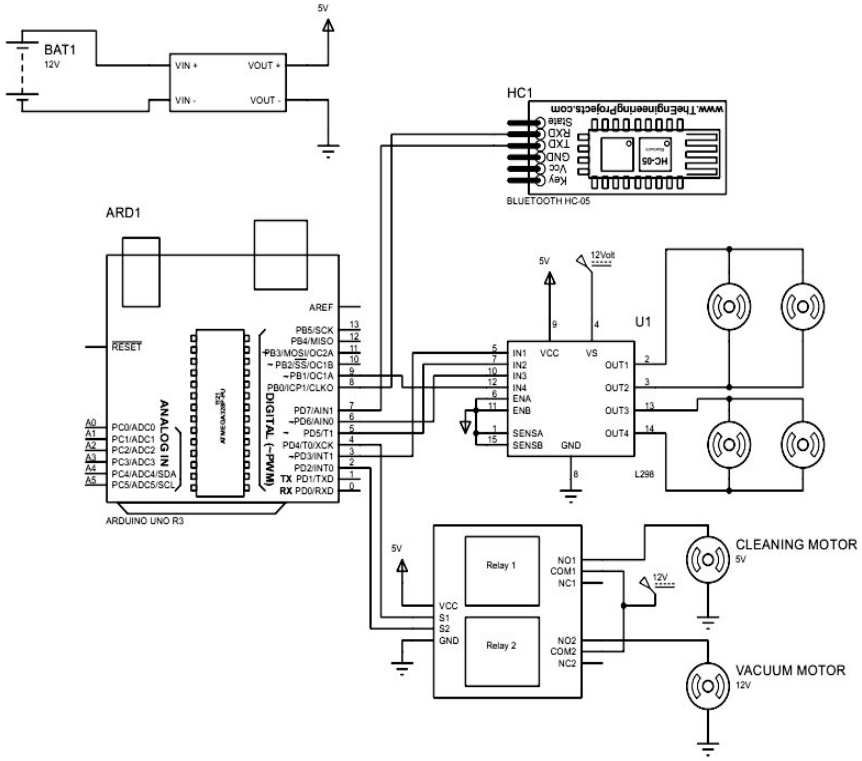


Fig. 3. Details circuit diagram for hardware implementation

4. RESULTS AND DISCUSSION

First, we must enroll the faces in order to recognize them using the ESP32-CAM. To do that, switch on the settings for face detection and identification, then click the Enroll Face button. Saving many faces requires multiple tries. If a face is recognized in the video feed after the faces have been registered, the ESP32 will cause the relay module to unlock the door. It recognizes faces whenever someone approaches the door first, and if it has already registered the face, it unlocks the door. The prototype created acts as a catalyst for further study aimed at creating a more reliable and embedded real-time smart door lock system with apps and face detection. its capacity to alert key players to a fire and an LPG gas leak. On-line monitoring of notifications is also possible, along with video monitoring from the project's display. The internet also allows us to turn on and off a light in addition to the door.

4.1 Hardware implementation

This paper describes the development of a door lock system that combines facial recognition with the ESP32 CAM for more precise face identification. Because it serves as the system's brain and regulates the door locks and unlock systems, the ESP32 CAM is powered by a battery. Figure 6 illustrates the hardware implementation the proposed module. This door lock system uses facial recognition technology. Here, a person's face is recognized in order to operate the door lock mechanism. One of the defenses for maintaining the home's physical security is a door. A robber can enter the house with ease and take the contents if the door is frequently left unlocked. Initially, a door could only be locked or unlocked with a real key, but as technology advanced, a more modern door was invented, called a digital door, which could lock or unlock doors without the need for a physical key. We put forth an application called Face Recognition Door Lock, which is built on Arduino and uses Internet of Things (IoT) technology to monitor the door's condition, manage the door, and boost security. The door will lock or unlock automatically with the help of an ESP32 camera. Future studies will be motivated by the established prototype in order to create a more reliable and embedded real-time smart door lock system with apps and face detection. its capacity to alert key players to a fire and an LPG gas leak.

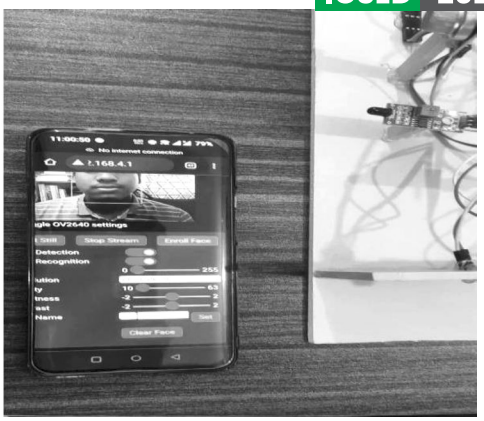


Fig. 4: Face detection & monitoring using android phone

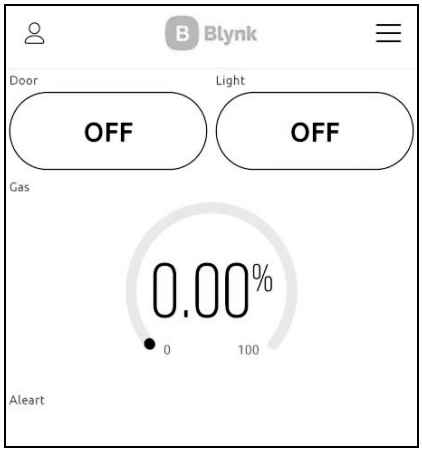
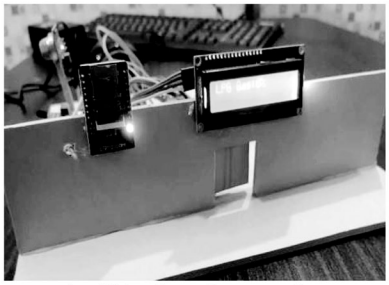
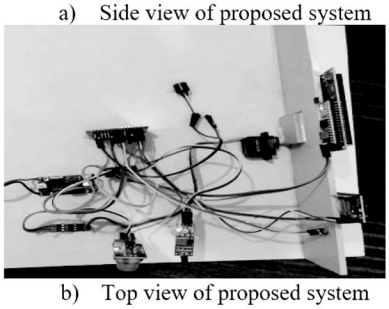


Fig. 5. Realtime status monitoring of door using apps



a) Side view of proposed system



b) Top view of proposed system

Fig. 6: Hardware implementation of proposed system

Figures 4 and 5 show the implementation details of project with Blynk app platform. This apps helps to detect face with IP CAM and to monitoring the realtime video stream.

4.2 Estimated costs

The gross cost of proposed module is listed below Table 1 which show the unit price of each components.

Table 1: The cost details of components used in proposed module

SL No	Components	Quantity	Unit Price	Total Price (BDT)
1	Node MCU	1	950	950
2	Buck Module	1	120	120
3	ESP32Cam	1	940	940
4	Flame Sensor	1	200	200
5	MQ-6 Sensor	1	250	250
6	Adapter	1	380	380
7	Servo Motor	1	250	250
8	LCD Display	1	500	500
9	Buzzer	1	30	30
10	Board	1	300	300
11	Male to Male Jumper Wires	1	100	100
12	Male to Female Jumper Wires	1	100	100
13	Male to Female Jumper Wires	1	100	100
14	Female to Female Jumper Wires	1	100	100
15	Others	--	1,000	1,000
			Gross cost of the module	**5,320**

4.3 Testing the proposed module

We have tested several times in real-time trials. The proposed module shows excellent performance in controlling the door by quickly detecting faces. A few samples of testing performance are given below in Table 2.

Table 2: Face detection and door controlling performance

Trials	Face Detection time (miliseconds)	Performance
Authorized Person 1	100	Face Matched Succeed
Authorized Person 1	105	Face Matched Succeed
Unauthorized Person 1	120	Face Unmatched Succeed
Authorized Person 1	103	Face Matched Succeed

5. CONCLUSION

Face recognition increases home security and restricts access to a place to a small number of chosen individuals. Thus, a residence can be given far higher protection and exclusivity than it would have with a traditional lock and key by using this reasonably affordable and accessible technology. its capacity to alert key players to a fire and an LPG gas leak. The prototype created acts as a catalyst for further study aimed at creating a more reliable and embedded real-time smart door lock system with apps and face.

Despite the fact that there has yet to be any manufacture, the project is nevertheless regarded as a success. The aforementioned issues will be resolved, work is currently in the implementation phase to wrap things up cheaply, and this project will be a success because the components employed are not expensive.

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Runoff Estimation in the Dakatia River Basin, Bangladesh using SCS-CN Method in the GIS-RS Platform

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ABSTRACT

Rainfall and runoff are the two most vital hydrological drivers to take into account when evaluating water resources. The Soil Conservation Service Curve Number (SCS-CN) method is widely used for estimating runoff following rainfall. The SCS-CN model relies on inputs such as the Weighted Curve Number (WCN), Precipitation (P), and Hydrological Soil Characteristics (HSG). In this study, we computed the daily runoff of the Dakatia River basin for the years 2010 to 2020 using the SCS-CN method. Our findings show that the average annual volumetric runoff for the basin was 21.75107 m3, which is nearly 22% of the average annual rainfall volume. Proper application of SCS-CN can assist in the sustainable management of water resources, stormwater runoff, and environmental protection.

Keywords: Rainfall; Runoff; GIS; RS; SCS-CN; Dakatia basin.

1. INTRODUCTION

When evaluating water supply, runoff is an important hydrologic aspect to take into account [45]. Runoff is a key hydrologic variable in the majority of cases requiring the management of water resources. Runoff occurs when precipitation flows down a basin stream after surface and subsurface losses have been satisfied. The length-width-area-form, area, channel pattern, soil type, vegetative cover, landscape uses, and hydrological conditions of a river basin are all important factors that affect the rainfall-runoff cycle [46]. The surplus water, boulders, and silt that exceed the river system after evaporating are referred to as "runoff." Runoff occurs and is measured as a result of several essential rainfall characteristics, including intensity, duration, and scatter. When a lot of water permeates the soil and more water from raindrops, snowpacks, or other resources flows over the top, stormwater runoff occurs. The hydrologic cycle's most important phase is this one [47]. The sustainable water capacity of water depositing, soil design, and moisture infrastructure, as well as the requirement to avoid sediments and upstream flooding, are all determined by surface runoff studies [48]. Soil penetration often establishes the link between significant runoff and the amount of rainfall. Rainfall and runoff are linked in a very complex way that takes into account various precipitation patterns and stream feature [49, 50]. Rainfall causes runoff, which is affected by the volume, timing, and dispersion of the precipitation. In addition to these precipitation components, a variety of watershed factors can have an impact on the prevalence and volume of runoff [51]. When creating hydrological systems and coastal protection techniques, inputs like precipitation in a catchment or river basin are crucial [52]. Making the right allocations of water supplies is also another significant difficulty in the management of water resources [53].

There are many ways to calculate runoff, including the sensible response, the Green Ampt method, and the SCS-CN method [54]. Evaluation of rainfall's seasonal and geographical variation The Tropical Rainfall Measurement Mission's (TRMM) Multi-Satellite Precipitation Analysis (TMPA) is available for download and research. One of the approaches that is most commonly used to predict how much surface runoff will occur in watersheds during specific precipitation events is the SCS-CN approach. This method requires straightforward equations as well as readily available tables and curves. A high density of curves in metropolitan areas suggests strong runoff and poor permeability, whereas a light weight of curves suggests low runoff and high incursion (in dry soil) [55]. The Soil Conservation Service-Curve Number (SCS-CN) approach was created in 1969 by the National Resources Conservation Service (NRSC), a division of the United States Department of Agriculture (USDA). Estimating direct runoff level based on storm rainfall intensity is a straightforward, reliable, and steady compositional technique. This method uses numerical basin properties to compute runoff. The design is especially designed for the runoff potential by employing a particular runoff curve number (CN), which establishes it. When computing the runoff curve number, the antecedent soil moisture status, soil type, and type of land use are all taken into account (AMC). Land use, meteorological situation, agronomic factors, moisture content, and the diversity of soil types are the main factors in analyses of rainfall and runoff. Four soil type groups (HSG) are created by classifying Group A, Group B, Group C, and Group D.

In Bangladesh, research was done to calculate runoff using the SCS-CN model in the Khulna city, Surma basin, and Jamuneswari river basin [56], [57],[58]. Despite being one of the most important river basins in Bangladesh, there is a dearth of thorough studies on how to estimate runoff

using the CSS-CN model in the Dakatia river basin. Decision-makers, planners, and stakeholders can gain from the study's conclusions by getting useful information for planning and getting ready for the future.

2. MATERIALS AND METHOD

2.1 Study area

The Dakatia river basin is situated between 90° 15′ 29.96″ and 90° 27′ 13.78″ E and longitudes 22° 67′ 40.47″ to 23° 41′ 51.24" N latitude, with a total area of 3,756 km2 (Fig. 1). As a result, thorough research is necessary to establish guidelines and select objectives for the streams in this area. Despite the fact that soil erosion negatively affects agricultural yield and, in turn, negatively affects the sustainability of the nation's food security, only a tiny number of drainage basin soil erosion evaluation studies have been conducted in it. Therefore, the potential for soil erosion and inundation at the same diameter will be assessed in this study.

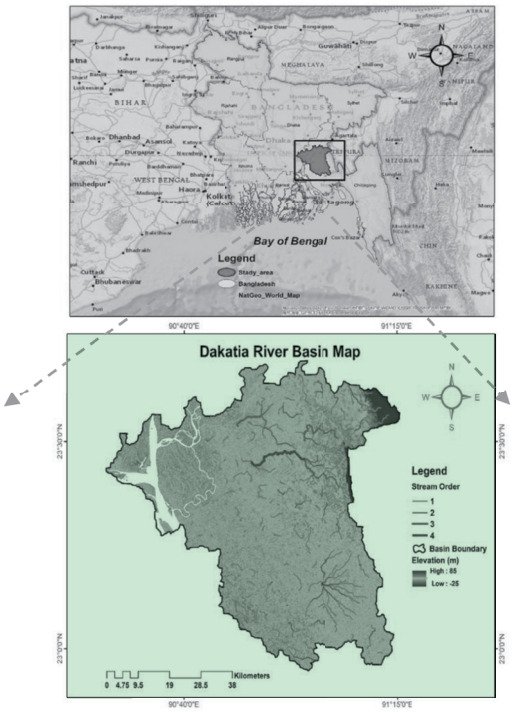

Fig 1: Location map of the study area

A southbound canal from the Dakatia river is known as the 'Noakhali Khal'. The channel meanders westward until it approaches Shekherhat, where the old stream splits off to join the Meghna near Raipur. The new, larger canal passes through Chandpur Khal to the west of Chandpur Town before entering the Meghna [59].

The Meghna river Delta has a monsoon climate as well as warm, tropical weather, and like other parts of the nation, the area has been greatly impacted by the heavy monsoon winds. Its average annual rainfall is 2686 mm, according to Fig. 5. The ancient weather of Bangladesh has had yearly temperature changes that vary from 15 °C to 34 °C, with an estimate of approximately 26 °C. The south-west monsoon, which arises over the Indian Ocean and delivers hot, moist, and unstable air, is what drives rainwater to drop. (https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-historical). According to LULC and DEM, the Dakatia Basin has the most croplands and the least bare ground, with an average elevation of 9.42 m.

2.2. Methodology

2.2.1. SCS-CN model

The amount of peak discharge that can arise from precipitation in a river system is typically determined using a number of hydrological modeling techniques. According to the sort of raw data and conditions, these simulations could vary from complicated to simple. To predict runoff in the watershed, straightforward empirical formulas are integrated with intricate features, including obvious river system characteristics [60]. The SCS-CN is used by many people, especially agricultural designers, environmentalists, and hydrologists, to calculate storm water from rainfall [17–19]. The phase of run-off measurement that is significantly more crucial is identifying the stream or drainage region of the river system. The SCS-CN technique is the most popular empirical method used to estimate direct runoff from a catchment (United States Department of Agriculture, 1972). In this study, the SCS-CN method has been used to determine the volumetric relationship between runoff and rainfall. However, the SCS-CN approach is used to elucidate the water balance equation, as shown below (Eq. 1).

$$Q = \frac{(P-I_a)^2}{(P-I_a+S)} \quad \text{..... (1)}$$

where the abbreviations Q, P, Ia, and S stand for early absorption, runoff depths, precipitation intensity, and reservoir retention, respectively.

Initial absorption, or the amount of rainfall that falls on the ground before runoff begins, is frequently calculated to be 0.2S [61]:

$$Q = \frac{(p-0.2s)^2}{(p+0.8s)} \quad \text{.....(2)}$$

Here, S is the function of CN

$$S = \frac{(25400-254)}{CN} \quad \text{.....(3)}$$

A, B, C, and D are the four groups that make up the hydrologic soil group (HSG), according to how quickly soil infiltrates into the basin area. The antecedent moisture condition (AMC) is divided into three groups based on the restrictions on precipitation throughout the dormant and growing seasons (AMC I, AMC II, and AMC III). The technical release served as the source for the CN value in this instance. Natural Resources Conservation Service, United States Department of Agriculture (USDA, 1986) By weighting curve numbers related to watershed or basin area, the SCS approach has been improved to operate with larger watersheds or basins. This method was initially intended to

be used with 15 km^2 basins [62]. Eq. (4) of Weighted Curve Number (CNw/CN_{II}) is given below;

……..(4)

where
CN_{II} is weighted curve number
CN_i is curve number
A_i is area with curve number CN_i

3. RESULTS AND DISCUSSION

In order to determine surface runoff and average annual erosion in the Dakatia river basin, this study used the SCS-CN approach and the RUSLE model. Numerous interrelated components have an influence on the river discharge activity, which is extremely complicated, nonlinear, and variable. A detailed runoff evaluation is carried out in order to effectively support and maintain water resources. Croplands are the main land use class in the study region, according to the most recent available data. Two more patterns of land use, bare land and open grassland, are essential for stormwater runoff. The hydrologic soil group, which includes the soil type, class, and permeability, is very useful for determining the potential runoff. For HSG types A, B, C, and D, this study yielded the soil map, spatial information, and other secondary sources. The findings show that the hydrological soil group C/D type covers the majority of the Dakatia river system.

3.1 Landuse property utilization

On the land use and land cover map, the Dkatia river basin's area has been used for crops to the extent of 1943.86 km^2 (51.74%), trees cover 769.26 km^2 (25.6%) of the area, grasslands cover almost 9.98 km^2 (0.27%), flooded vegetation covers 6.34 km^2 (0.17%), and bare ground covers 1.77 km^2 (0.05%). The built-up area in the study region is 619.18 km^2 (16.48%), while the river and water bodies are 206.25 km^2 (5.49%). Crops, trees, built-up areas, grasslands, and water bodies are the main LULC groups that make up the study area (Fig. 2). Table 2 displays specific statistics on the land use and land cover of the research area.

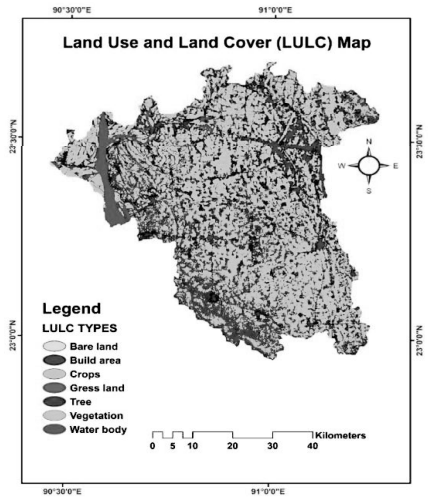

Fig 2: Different types of land use the study area

Table 2: Land use and land cover (LULC) pattern

SN	Land use patttern	Area (km^2)	Area (%)
1	Water body	206.25	5.49
2	Trees	969.26	25.80
3	Flooded Vegetation	6.34	0.17
4	Crops	1943.86	51.74
5	Build-up area	619.18	16.48
6	Bare land	1.77	0.05
7	Grass land	9.98	0.27

3.2 Hydrologic soil group

Four distinct hydrologic soil classes—A, B, C, and D—have been formed based on soils' ability to transfer water and their potential for infiltration. Table 3. lists both the classification of soil requirements and the outputs of the HSG categorization. The largest portion of the Dakatia River Basin, or around 1117.93 km^2, is covered by hydrological soil group C. The study area's hydrological soil group C/D encompasses 2237.13 km^2 (64.10%), group D hydrological soil includes 39.06 km^2 (1.12%), and group D/D hydrological soil covers 96.21 km^2 (2.76%). Specific curve numbers are displayed by distinct land uses within unique hydrologic soil groups, and these curve numbers are used to reflect a watershed's propensity for runoff [63, 64]. However, the soil map was changed into a hydrological soil group map and combined with a land use map made using satellite data in order to derive the curve number value [65].

Table 3: Composition of the research area's hydrologic soil groups (HSG)

SN	HSG*	Soil texture*	Possible discharge	Typicalcompositions (Ross et al. 2018)	Area (km^2)	Area (%)
1	C	Sandy clay loam, clay loam with silt in it, loam with silt in it, etc.	Reasonably high	< fifty percent sand and twenty to forty percent clay	1117.93	32.03
2	D	Clay, sands silt, and clay loam	High	More than 40% clay and 50% sand	39.06	1.12
3	C/D	Loamy sand loam, silt loam with silt in it, silt and clay with silt in it, etc.	High	<fifty percent sand and twenty to forty percent clay	2237.13	64.10
4	D/D	Silt, sands clay, and clay loam	High	More than 40% clay and 50% sand	96.21	2.76

* Soil texture classes that typically comprise hydrologic soil groups (HSGs) (USDA, 2009)

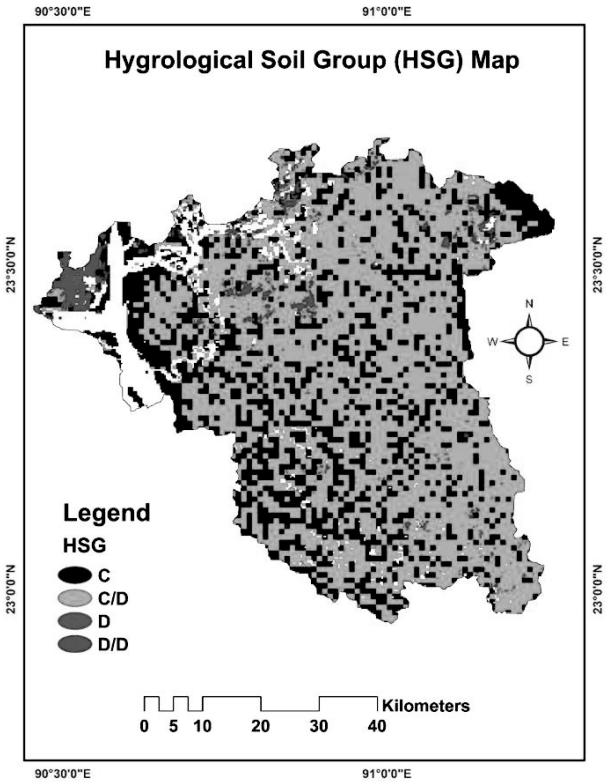

Fig 3: Different hydrological soil group in the study area

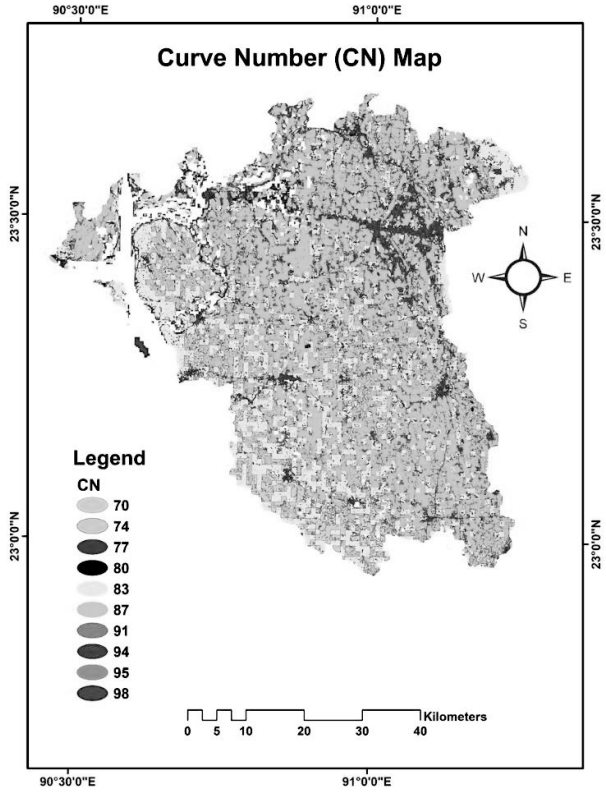

Fig 4: Different curve number in the study area

The HSG is classified into four parts, most likely A, B, C, and D, based on the penetration resistance of the topsoil. For the GIS framework to be eligible for the dimensions of the curve number, the required adaptation, overlay operation, LULC class, and HSG deception were completed (CN). Fig. 4 displays the CN map of the research area. Table 4 outlines the specific connections between the land use/ land cover, hydrological soiol group and the CN map of the research area. Table 4 outlines the specific connections between the LULC, HSG, and CN.

The SCS-CN approach can be used to elucidate the water balance equation, as shown below.

Table 4: Curve number for Dakatia river basin

SN	LULC	HSG	Curve Number (CN)	Area (km^2)
1	Bare land	C	91	1
2	Bare land	C/D	91	0
3	Bare land	D	91	0
4	Bare land	D/D	91	0
5	Build area	C	94	230
6	Build area	C/D	94	346
7	Build area	D	95	11
8	Build area	D/D	95	13
9	Crops	C	83	391
10	Crops	C/D	87	1350
11	Crops	D	87	21
12	Crops	D/D	87	75
13	Flooded vegetation	C	98	1
14	Flooded vegetation	C/D	98	3
15	Flooded vegetation	D	98	0
16	Flooded vegetation	D/D	98	0
17	Grass land	C	74	3
18	Grass land	C/D	74	1
19	Grass land	D	74	0
20	Grass land	D/D	80	0
21	Tree	C	83	458
22	Tree	C/D	70	493
23	Tree	D	70	4
24	Tree	D/D	77	5
25	Water body	C	98	30
26	Water body	C/D	98	41
27	Water body	D	98	2
28	Water body	D/D	98	3

3.2 Region-weighted curve number

The curve number is calculated using the AMC, a non-dimensional number, run-off index, soil hydrological group, land-use class, and hydrological condition (CN). Depending on how well it can absorb water, each soil type is divided into one of four hydrologic soil groups: Group A, B, C, or D. The CN readings can be between 1 and 100. The run-off increases in tandem with rising CN values. An overlay assessment was conducted on the soil, land use, and hydrological soil group mappings from Arc GIS 10.8 to create a new attribute table. The findings from this HSG and the attributes table are used to produce the average area-weighted curve number for the research area. Waterways have a peak parameter of 98 and a lowest curve number of 70.

3.4 Rainfall analysis

Here, there is a range in the average annual rainfall. The current study therefore makes use of rainfall data from 2010 to 2020. The annual rainfall averaged 2686 mm from 2010 to 2020. 5294 mm of rain fell on average annually in 2017, while 1763 mm fell on average annually in 2012. It is clear that the annual average rainfall in the study area has been continuously increasing throughout the years. However, in contrast to any other region in Bangladesh, the annual rainfall is also substantially higher on average. It is possible to see this variation in precipitation as a result of land use patterns, geographic location and topography, atmospheric circulation patterns, etc.

3.5 Runoff assessment

In this study, the precipitation data from 2010 to 2020 were examined. The yearly rainfall and runoff for the Dakatia river basin are displayed in Fig. 5. In this study, runoff was calculated using the SCS-CN method. The Soil Conservation Service Curve Number (SCS-CN) model is commonly used to determine the amount of water discharge for a specific rainfall event [66]. From 2010 to 2020, the river basin's average yearly runoff was 579 mm, with the largest runoff ever measured in 2017 at 1910 mm and the lowest at 177 mm in 2012. The average yearly runoff depth volume, or 21.75×10^7 m^3, accounts for 22% of the region's average yearly runoff.

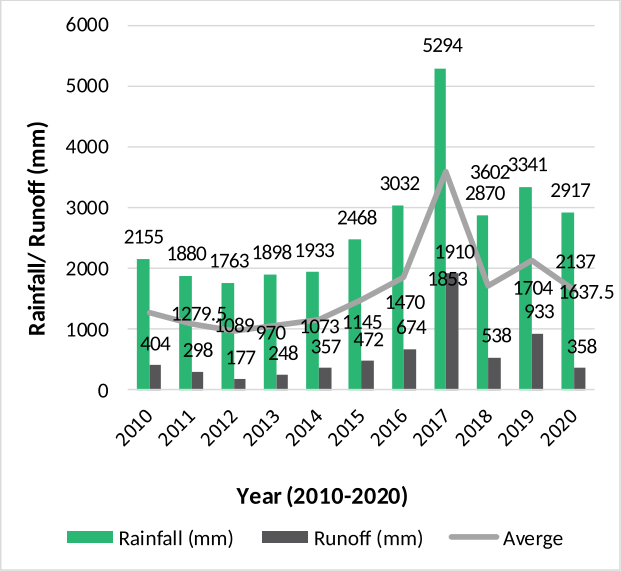

Fig 5: Variation in annual rainfall-runoff over an 11-year period (2010-2020)

4. CONCLUSION

According to the research, the SCS-CN approach and GIS software can be used to calculate runoff. This approach can be used successfully for watershed management. The possibility of runoff varies in the research region because of the variety of land use, land cover, and soil types. Strong discharge is indicated by the Dakatia river basin's high curve number, which has never been less than 70. Between

2010 and 2020, the river basin's yearly runoff was 579 mm, with a total yearly discharge volume of 21.74× 10^7 m^3 yr^{-1}. However, the river basin's highest runoff was recorded at 1910 mm in 2017 and its smallest runoff at 177 mm in 2012. According to the land use map, crops are the most prevalent form of land use in the Dakatia River basin. Four hydrological soil groups—C, D, C/D, and D/D—each with a varying permeability—were used to categorize the soil in the research area. According to the soil map, most of the study areas are covered by the hydrological soil category C/D.

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Challenges with Solid Waste Management in the SAARC Countries: A Structured Review

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ABSTRACT

Urban solid waste management (USWM) is a widespread issue. The issues are exacerbated by the disproportionally higher volume of urban solid waste (USW) generation in South Asian Association for Regional Cooperation (SAARC) countries such as Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka, and Afghanistan, particularly in the context of increased urbanization, population growth, and economic globalization. Examining the current level of solid waste management in SAARC countries, encouraging information exchange, and outlining potential improvements to USWM systems that must be tailored to local conditions are the objectives of this effort. For this, a thorough review of the literature was done. The findings indicated that these SAARC countries' management systems lack well-developed structures. The solid trash is improperly kept and disposed of in erroneous locations during the collecting stage, which is highly inefficient. The engagement of the informal sector in USWM is unique to SAARC nations, highlighting the need to integrate and formalize these activities for USW collecting. It is generally known that composting provides advantages in terms of encouraging better applications for organic waste and reducing the quantity of trash sent to sanitary landfills because of the high organic content. Last but not least, decision-makers will be better informed about solid waste creation and the decentralization of services supplied.

Keywords: SAARC; Solid waste; Urban solid waste management (USWM).

1. INTRODUCTION

Urban solid waste (USW) is the leftovers from cleaning operations such as street sweeping, home and public cleaning, and other domestic tasks [1, 2]. Cities all over the world are growing more and more worried about the expansion of USW, partly as a result of the increased need for specific municipal management strategies. The creation, separation, storage, collection, transportation, processing, recovery, and disposal of diverse waste products are all part of urban solid waste management (USWM). To complete the necessary tasks, the many stakeholders in the municipality, the populace, and the local administration must all work together. USWM's principal purpose is to conserve natural resources in order to protect the environment and the general public's health. As a result, USWM has become a global concern, particularly in developing-country cities. In particular, urbanization has surged in the SAARC countries of Bangladesh, India, Pakistan, Bhutan, Nepal, the Maldives, Sri Lanka, and Afghanistan over the last three decades. Over the past three decades, urbanization has accelerated rapidly in all of these countries, but notably in the SAARC (Bangladesh, India, Pakistan, Bhutan, Nepal, Maldives, Sri Lanka, and Afghanistan). Urbanization has led to a huge increase in trash production. Gross Domestic Product (GDP), industrialization, population growth, urbanization, and an increase in living standards are the main factors driving this pace of growth in USW. Economic advancement, industrialization levels, social standards, and local environmental conditions all have an impact on the rates of USW formation. In light of this, Bangladesh, India, Pakistan, Bhutan, Nepal, Maldives, Sri Lanka, and Afghanistan are classified as having high human development scores in the Human Development Report, with corresponding HDIs of 0.804, 0.754, and 0.738. (UNDP, 2015). Furthermore, South Africa and India were classed as having medium levels of human development in the assessment (0.666 and 0.624, respectively). Even though USWM is governed by the SAARC countries, the open standards do not fit the circumstances there. [67] assert that incorrect implementation of the law is mostly to blame for the USWM's ineffectiveness. The aforementioned facts demonstrate the importance of USWM studies in SAARC in helping countries adjust to the quick changes occurring in their home area. As a result, it is crucial to encourage the sharing of experiences and management ideas while deciding on the best strategies to use in each country. This article's objective is to comprehend USW management in SAARC countries.

2. METHODOLOGY

The method of data analysis have been decorated following bellow subsections. The method that was used in the collection of data for the study was achieved by means of review, survey and observation from existing literatures and company reports on MSW management technologies. SAARC Countries and 2 high income countries like-Germany and Switzerland were selected for comparing the waste management practice in the two countries as shown in Figure 11. Where Germany is an advanced country

compared to SAARC Countries which is still undergoing development. Also, MSW treatment technologies were compared to determine which is used by any of these countries and to recommend the appropriate option that can be adopted for MSW treatment, considering environmental impacts and the cost of adopting the preferable option.[32]. Strenth and weekness are shown in table 12.

2.1 Generation and composition of USW

Table 1 provides a summary of USW output and composition in SAARC countries and Table 2 provides a summary of USW output and composition in high income countries. It has been noted that expanding urbanization and increased garbage output have occurred during the previous three decades, particularly in India. According to [4,] MSW output per capita in India varies from 0.2 to 0.5 kg/inhabitant/day, with an annual increase of 1 to 1.33 percent. Furthermore, because of the high levels of urbanization in some places, the generation may be higher. Emphasizes that the amount and composition of waste produced in the country have changed significantly over the last 20 years as a result of both population growth and economic expansion, making waste management a challenge that must be overcome by developing and implementing effective techniques for each type of waste produced.

Table 1: Generation and compostion of USW in SAARC countries

Countries	Authors	Generation and Composition	
Bangladesh	[68]	Generation-	23,688 tons/day
		Per capita generation-	0.74 kg/day
		Composition-	Food waste-68.69%, Fabrics-3.06%, Papers-13.8%, Wood-3.78%, Metal-0.17%, Plastic-4.75%, Others-10.28%
		Projection-	In 2025, garbage generation is anticipated to be 47,000 tons per day
India	[69]	Generation-	1,69,864 tons/day
		Per capita generation-	0.45 kg/day
		Composition-	Food waste-68.69%, Glass-0.93%, Papers-9.27%, Rags-1%, Metal-1.49%, Plastic-7.59%, Others-0%, Inert-22.57%
		Projection-	161 Mt of MSW, or about five times higher in four decades, in 2041.
Pakistan	[67]	Generation-	71,000 tons/day
		Generation per capita-	65 kg/day
	[67]	Composition-	Food waste-67.69%, Glass-0.70%, Papers-2.80%, Rags-1.0%, Metal-0.10%, Plastic-9.8.0%, Others-12.70%, Fabrics-6.90%
		Projection-	-
Nepal	[70]	Generation-	523.8 tons/day
		Generation per capita-	0.66 kg per capita
	[71]	Composition-	Organic waste makes up 46% of the waste stream, followed by 11% of soil and building debris, 10% of plastics, 7% of glass, 6% of paper and paper products, 5% of metals, and 5% of rubber and leather. Textiles (1%), hazardous wastes (1%), and miscellaneous wastes made up the remainder (8 percent).
		Projection-	-
Bhutan	[72]	Generation-	3,272 tons/year
	[73]	Generation per capita-	0.53 kg/C/D
	[72]	Composition-	The percentage of putrescible trash was 31.0%, followed by paper 20.4%, plastics 10.8%, and leather, wood, textile sand, and rubber (LWTR) 8.7%. Total inorganic materials included 24.0 percent glass, 10.8 percent ferrous metal, 2.5 percent non-ferrous metal, and 8.4 percent inert materials (stones, ash, soil, construction and demolition waste). Other miscellaneous e-materials made up 5.1 percent of the total inorganic materials (167 tons/year).
		Projection-	-
Sri Lanka	[74]	Generation-	1.04 tons/year
		Per-capita generation	0.62 kg/day
	[75]	Composition-	66% organic wastes, 8% plastics, 2% glass, 13% paper and paper products, 3% metals, other wastes (8%).
		Projection-	-
Maldives	[76]	Generation-	5,643.89 tons per year.
	[77]	Per-capita generation -	0.66 kg/PC/Day
	[76]	Composition-	Biodegradable garbage made up 68 percent of the total municipal solid waste, while non-biodegradable waste made up 32% of the waste.
		Projection-	-
Afghanistan	[78]	Generation-	23,586 kg per year.
	[79]	Per-capita generation -	0.43 kg/capita/day
		Composition-	Organic 74%, paper 5%; Glass 2%; Plastic 7%; Metal-4%; Others 8%;
		Projection-	-

Table 2: Generation and composition of USW in high income countries

Country	Authors	Generation and Composition	
Germany	[32]	Generation	47 million tons / year
		Per-capita generation	0.57 kg per- capita
		composition	organic waste 19%; metals and glass 45%, combustible waste 36%
		Projection	-
Switzerland	[33]	Generation	64970 tons / year
		Per-capita generation	0.84 kg per-capita
		composition	Putrescible- 58.6%, Paper and cardboard- 13.3%, plastic- 12.3 % Clothing and Leather- 4.3%, glass-1.7%, metal- 1.5%, others- 6%,
		Projection	-

2.2. Storage

Storage is a crucial step in creating an effective USWM. The way solid waste is stored has an impact on how it will be transported before collection. Garbage should be kept in trash containers that were chosen based on their characteristics at the time of formation; for instance, each waste should have a container that is mechanically and chemically compatible with it. In India, waste storage is limited, with most rubbish being disposed of in public parks and streets with no source separation; nevertheless, communal garbage containers are employed in some locations [17]. The authors remark that they saw challenges with maintaining the quality of public garbage cans and the prevalence of covert dumping spots in storage areas during their various studies across India. However, Table 3, depicts the USW storage scenario in SAARC countries and Table 4, depicts the USW storage scenario in high income countries.

Table 3: Storage System of USW in SAARC countries

Countries	Authors	Storage System
Bangladesh	[80]	Recipient: large vehicles, closed trucks, haul container trucks, huge concrete bins, demountable large steel transport containers, roadside spaces, and underutilized open low-lying locations are also possibilities.
		Residential waste, hospital/clinical wastes; institutional wastes such as schools, colleges, universities, and government offices; building demolition wastes street sweeping; and drain cleaning
India	[81]	Recipient: Decomposable and non-decomposable garbage are frequently placed in bins (no segregation of waste is performed), large vehicles, closed trucks, haul container trucks, huge concrete bins, demountable large steel transport containers, roadside spaces, and underutilized open low-lying locations are also possibilities.
		Residential waste, hospital/clinical wastes; institutional wastes such as schools, colleges, universities, and government offices; building demolition wastes street sweeping; and drain cleaning
Pakistan	[82]	Recipient: decomposable and non-decomposable garbage are frequently placed in bins (no segregation of waste is performed), large vehicles, closed trucks, haul container trucks, huge concrete bins, demountable large steel transport containers, roadside spaces, and underutilized open low-lying locations are also possibilities.
		Location: Residential wastes, hospital/clinical wastes, institutional wastes (including schools, colleges, universities, and government offices), building demolition wastes street sweeping, drain cleaning
Nepal	[83]	In Kathmandu Metropolitan City, 89 percent of families separated and stored their organic waste from the rest of their garbage.
		Residential waste, marketplaces, inns, and eateries; hospital and clinic wastes; institutional wastes from schools, colleges, and government buildings; and garbage from construction and demolition projects; street sweeping; and drain cleaning
Bhutan	[72]	Recipient: Trolley, bins, metallic sheet, swing bins, and masonry concrete are some of the materials used. Trolley bins were of the open variety, with wheels and lids. Concrete containers with no cover of any kind. Compactors, massive concrete bins, and large steel carry containers that are demountable.
		Location: Residential wastes, markets, hotels, and restaurants, hospital/clinical wastes, institutional wastes from government offices, colleges, and schools, demolition trash from buildings under construction, and street sweeping and drain cleaning
Srilanka	[74]	Recipient: Metal sheet, swing bins, bins, trolleys, and masonry concrete. Open-type trolley bins with wheels and lids were available. bins made of concrete that are permanent and have no covers. big concrete bins, demountable massive steel hauls, and compactors containers
		Residential waste, markets, hotels, and restaurants; hospital/clinical wastes; institutional wastes from schools, colleges, and government offices; and garbage from building demolition street sweeping; and drain cleaning
Maldips	[76]	Recipient: Non-biodegradable garbage might be compacted, stored, and transported to an incinerator plant. Non-biodegradable garbage might be compacted, stored, and transported to an incinerator plant.
		Residential waste, Markets, hotels, and restaurants; hospital/clinical wastes; institutional wastes such as schools, colleges, universities, and government offices; building demolition wastes; street sweeping; and drain cleaning
Afganistan	[84]	Recipient: Metal sheet, swing bins, bins, trolleys, and masonry concrete. Open-type trolley bins with wheels and lids were available. bins made of concrete that are permanent and have no covers. Huge concrete bins, compactors, and removable large steel carry containers
		Residential waste, Hospital/clinical wastes; institutional wastes such as schools, colleges, universities, and government offices; building demolition wastes; street sweeping; and drain cleaning

Table 4: Storage system of USW in high income countries

Countries	Authors	Storage System
Germany	[32]	All households are obliged to take part in this system, Trade waste is collected together with household waste. Commercial waste It is mostly collected in large or small containers and taken by the producer or the contracted collection company to the waste disposal plant, where it is treated together with the household waste.
Switzerland	[34]	Recyclable collection, non-recyclable collections, city area's collections.

2.3. Collection, transfer and transportation

To prevent excessive material accumulation and reduce dangers to protect the environment and public health, the collection and transmission of USW must be prohibited. done on a regular basis. Transportation must be undertaken in suitable vehicles selected depending on the quantity and kind of solid waste being transported, as well as topographical conditions, according to recommendations issued by the regional transportation network [22]. Bangladesh, India, Pakistan, Sri Lanka, Nepal, Bhutan, the Maldives, and Afghanistan all employ the door-to-door collecting technique, according to Table 5, which outlines how USW is collected, transferred, and transported in SAARC nations. Because households must go to the locations where dumpsters or containers are placed for garbage disposal, collection at particular distribution sites is dependent on public involvement and awareness. This frequently doesn't occur, which leads to the creation of covert deposits. And Table 6, Transportation, transfer, and collection of USW in high income countries.

Table 5: Transportation, transfer, and collection of USW in the SAARC countries

Countries	Authors	Collection, transfer and transportation
Bangladesh	[80]	Dump trucks, standard trucks, open trucks, tractors with trolleys, tipping trucks (container carriers), desludging vacuum tankers with tractors, and power tillers with trolleys are examples of collection vehicles.
India	[85]	Dump trucks, regular trucks, open trucks, tractors with trolleys, tipping trucks (container carriers), desludging vacuum tankers with tractors, and power tillers with trolleys are all examples of collection vehicles. Only 22 to 28 percent of the entire municipal garbage is processed and handled, and only 75 to 80 percent of it is collected.
Pakistan	[82]	Mazda truck, compactor, arm roll, Mazda arm roll, mechanical sweeper, loader, Bedford dumper, Nissan dumper, Volvo dumper, loader GW & tractor trolley, Gali sucker, and chain bulldozer are just a few examples of the equipment they can provide.
Nepal	[83]	In Kathmandu Metropolitan City, garbage collection methods such as primary, secondary, and direct collection are available. By hand, handcart, tricycle, open truck, direct collection, and tractor Tractor, open truck, container carrier; secondary collection .
Bhutan	[86]	Dump truck, regular truck, open truck, tractor with trolley, tipping truck (container carrier), desludging vacuum tanker with tractor, and power tiller with trolley are examples of collection vehicles.
Srilanka	[75]	In Kathmandu Metropolitan City, there are methods for collecting rubbish from homes that are primary, secondary, and direct. Tricycle, Tractor, Open Truck, by hand, handcart, tricycle, direct collection Secondary collecting methods include a tractor, an open truck, and a container carrier.
Maldips	[76]	In Kathmandu Metropolitan City, garbage collection methods such as primary, secondary, and direct collection are available. Tricycle, Tractor, Open Truck, by hand, handcart, tricycle, direct collection Secondary collecting methods include a tractor, an open truck, and a container carrier.
Afganistan	[84]	Mazda truck, compactor, arm roll, Mazda arm roll, mechanical sweeper, loader, Bedford dumper, Nissan dumper, Volvo dumper, loader GW & tractor trolley, Gali sucker, and chain bulldozer are some of the equipment available. .

Table 6: Transportation, transfer, and collection of USW in high income countries

Countries	Authors	Transportation, Transfer and Collection Methods
Germany	[32]	transported away for further treatment. All households are obliged to take part in this system and to pay the waste collection fees charged by the local public collection service supervised by the local or municipal authority.
Switzerland	[33]	Currently there are six compactor trucks (four with 8 tonne capacity and two with 12 tonne), used in the collection of type B and five dump trucks (with 3 tonne capacity) for the selective collection, type A. The compacter trucks ride, on average, 21,000 km/month and the dumpers 9000 km/month.

2.4. Selective collection

The reuse, recycling, and composting cycle is fed by the activity of selective collecting. Recycling materials are distinguished from non-recyclable and biological waste using this procedure. Composting will be the intended use for organic material. The SAARC selective collection synopsis is shown in Table 7, in India, the selective collection operation is mostly carried out by governmental entities, sometimes in collaboration with the informal sector, Voluntary Delivery Points and door-to-door (VDP). India, according to [81], the informal sector is mostly responsible for carrying out the task; little government involvement is involved in reclaiming these items. The existence of the informal sector in these nations is not a deliberate development; rather, it results from the population's perception of the country's economic situation. Table 8, Treatment Process in high income countries

Table 7: Treatment Process in SAARC countries

Countries	Authors	Treatment Process
Bangladesh	[80]	Source reduction, reuse, recycling, composting, land filling, and energy recovery are all important.
India	[87]	Composting (including aerobic and vermicomposting) and waste-to-energy are now India's two most creative methods of waste disposal (incineration, pelletisation, biomethanation). Shriram Energy Systems, Ltd., a Hyderabad-based company, has developed a waste-to-energy facility in Vijaywada. SELCO International Ltd. opened a new facility in Gandhamguda. Shriram Energy Systems Ltd. of Hyderabad will put a third waste-to-energy facility online.
Pakistan	[82]	The most common technique in Pakistan is crude open dumping, and dump sites are frequently set on fire to lessen the volume of collecting rubbish, contributing to the air pollution created by the exposed discarded material itself.
Nepal	[88]	Other treatment options are frequently more expensive than landfilling. For instance, incineration is used to dispose of 73% of the waste produced in Singapore. About 90% of the trash volume was reduced by incineration. However, the cost of incineration was around 6-7 times that of landfill. 2002 (Bai and Sutanto).
Bhutan	[72]	There are no waste treatment or recovery facilities in the city, neither by the City Corporation nor by private enterprises. However, there are several unofficial recycling centers in the city that take common recyclables such paper, rubber, glass, plastic, and metal.
Sri Lanka	[89]	Hospital wastes and some industrial wastes are treated in incinerators, but MSW is not treated in incinerators. a number of waste-to-energy solutions were launched. The Western Province will receive a few extra plants. Additionally, MSW anaerobic digestion has been used for a very long time. There are continuing studies into producing biogas. .
Maldives	[77]	Maldives has a lower organic waste composition due to its rapidly developing construction industry, which contributes significantly to the composition of their waste.
Afghanistan	[84]	Through education and practice, strategic implementation of solid waste reduction, reuse, and recycling becomes a must. This might be accomplished by reengineering present solid-waste management practices from traditional to integrated techniques, resulting in a cleaner, more ecologically efficient, and cost-effective system. The 3R method's direction is also developed as an approach.

Table 8: Treatment Process in high income countries

Countries	Authors	Treatment Process
Germany		Plasma Arc Gasification, Conventional Gasification, Pyrolysis, Incineration Composting
Switzerland		Recycle, Composting, Incineration

2.5. Treatment and final disposal

Inadequate treatment of USW causes financial losses, jeopardizes the health of the populace, and depletes natural resources [90]. [91] say that each USW treatment procedure lowers disposal costs as well as the overall volume of waste produced. Despite these obviously positive effects of treatment, all the publications we read emphasized the difficulties that SAARC countries had in implementing therapeutic activities. Table 9, displays the various disposal types currently in use and Table 10, Final Disposal Procedure of USW in high income countries.

Table 9: Final disposal procedure of USW in SAARC countries

Countries	Authors	Final disposal procedure
Bangladesh	[92]	In Bangladesh, there isn't a sanitary landfill that is well-designed. Two sites, Matuail and Amin Bazaar, in Dhaka were converted to sanitary landfills.
India	[93]	Waste that cannot be recycled, repurposed, or processed typically ends up in a land fill or open dump. More than 80% of the garbage that is collected in India is carelessly dumped in dump yards, endangering both human health and the environment.
Pakistan	[82]	Open disposal with no processing other than the separation of recyclables by scavengers in low-lying areas.
Nepal	[83]	Due to a lack of financing, the implementation of a contemporary disposal technique such as land burning or incineration is not viable.
Bhutan	[72]	Waste collected from three areas was disposed of at the Toribari sanitary landfill.
Sri Lanka	[89]	22 open dumps disposal sites
Maldives	[76]	Open waste burning; and 93.8% of people disposing of their waste at the dumpsite, while 6.2% chose other areas of town to dispose of their waste.
Afghanistan	[84]	There are two landfill sites, Gazak 1 and 2, but appropriate techniques are rarely used, so they appear to be open dumping sites.

Table 10: Final Disposal Procedure of USW in high income countries

Countries	Authors	Final Disposal Procedure
Germany	[32]	Recycled wastage are sold to 3rd party, incinerated wastage are used in land filling, Biodegradable are used for making compost.
Switzerland	[34]	All sorted material is sold to about 20 companies or middlemen, which sell to industries that recycle the materials. The revenue gained from recycling is approximately US$119,811.32, but this revenue could be greater if the sale was made directly to the purchasing industries, at least those close to São Leopoldo. The biodegradable waste could also be recycled if there was a composting plant in the town. Putrescible waste and those that cannot be recycled because they have not been sorted on the cooperatives, are forwarded to a private sanitary landfill; the municipal administration paid in May (2011) US$102,645.34 to dispose the waste at the landfill, namely, US$26.86 per tonne.

3. COMPARISON BETWEEN SAARC AND HIGH-INCOME COUNTRIES

Table 11: Comparision between SAARC countries and high income countries

Parameter	SAARC Countries	High income countries
Generation	(23.586 + 5,643.89 + 1.04 + 3,272 + 1,91,187 + 2,59,15,000 + 6,20,00,360 + 86,46,120) = 96,761,607.516 tons/year.	(4,70,00,000 + 64,970) = 4,70,64,970 tons / year.
Per capita	0.74 kg/day 0.45 kg/day 65 kg/day 0.66 kg per capita 0.53 kg/C/D 0.62 kg/day 0.66 kg/PC/Day 0.43 kg/capita/day	0.57 kg per capita 0.84 kg per capita
Treatement	1. Source reduction, reuse, recycling, composting, land filling, and energy recovery are all important. 2. Composting and waste-to-energy are now India's two most creative methods of waste disposal. 3. The most common technique in Pakistan is crude open dumping, and dump sites are frequently set on fire to lessen the volume of collecting rubbish, contributing to the air pollution created by the exposed discarded material itself. 4. Other treatment options are frequently more expensive than landfilling. For instance, incineration is used to dispose of 73% of the waste produced in Singapore. About 90% of the trash volume was reduced by incineration. However, the cost of incineration was around 6-7 times that of landfill. 2002 (Bai and Sutanto). 5. There are no waste treatment or recovery facilities in the city, neither by the City Corporation nor by private enterprises. However, there are several unofficial recycling centers in the city that take common recyclables such paper, rubber, glass, plastic, and metal. 6. Hospital wastes and some industrial wastes are treated in incinerators, but MSW is not treated in incinerators. a number of waste-to-energy solutions were launched. The Western Province will receive a few extra plants. Additionally, MSW anaerobic digestion has been used for a very long time. There are continuing studies into producing biogas. 7. Maldives has a lower organic waste composition due to its rapidly developing construction industry, which contributes significantly to the composition of their waste. 8. Through education and practice, strategic implementation of solid waste reduction, reuse, and recycling becomes a must. This might be accomplished by reengineering present solid-waste management practices from traditional to integrated techniques, resulting in a cleaner, more ecologically efficient, and cost-effective system. The 3R method's direction is also developed as an approach.	1. Plasma Arc Gasification, Conventional Gasification, Pyrolysis, Incineration Composting. 2. Recycle, Composting, Incineration
Final disposal	1. In Bangladesh, there isn't a sanitary landfill that is well-designed. Two sites, Matuail and Amin Bazaar, in Dhaka were converted to sanitary landfills. 2. Waste that cannot be recycled, repurposed, or processed typically ends up in a land fill or open dump. More than 80% of the garbage that is collected in	1. Recycled wastage are sold to 3rd party, incinerated wastage are used in land filling, Biodegradable are used for making compost. 2. All sorted material is sold to about 20 companies or middlemen, which sell to industries that recycle the materials. The revenue gained from recycling is approximately US$119,811.32, but this revenue could be greater if the sale was made directly to the purchasing industries, at

	India is carelessly dumped in dump yards, endangering both human health and the environment. 3. Open disposal with no processing other than the separation of recyclables by scavengers in low-lying areas. 4. Due to a lack of financing, the implementation of a contemporary disposal technique such as land burning or incineration is not viable. 5. Waste collected from three areas was disposed of at the Toribari sanitary landfill. 6. 22 open dumps disposal sites. 7. Open waste burning; and 93.8% of people disposing of their waste at the dumpsite, while 6.2% chose other areas of town to dispose of their waste. 8. There are two landfill sites, Gazak 1 and 2, but appropriate techniques are rarely used, so they appear to be open dumping sites.	least those close to São Leopoldo. The biodegradable waste could also be recycled if there was a composting plant in the town. Putrescible waste and those that cannot be recycled because they have not been sorted on the cooperatives, are forwarded to a private sanitary landfill; the municipal administration paid in May (2011) US$102,645.34 to dispose the waste at the landfill, namely, US$26.86 per tonne.

Table 12: Strenth and weekness of the procedure

SN	Streanth	Weekness
fi	A huge amount of waste could become an opportunity to get more GDP.	Huge amount of waste gathering, which consumes land areas.
2	By segregating the USW, it can be used in different ways. Some materials could be recycled, reused, converted into assets, or converted into energy sources.	Open dumping causes health and environmental issues.
3	By developing this system, many jobs could be created.	It could contaminate the soil and underground water.
4		Lack of knowledge of USW management to manage.

4. CONCLUSION

This study used a systematic evaluation to assess the state of urban solid waste management in SAARC nations. The production rate, content, storage form, collection, and primary MSW treatment and disposal methods are all significant elements of the USWM. Several characteristics of the SAARC countries include poor management systems, involvement of the informal sector, high levels of organic waste and the use of landfills and covert areas for final disposal. Lack of funding, adequate local infrastructure, planning, quantity data, types of waste produced and a clear definition of duties for the agents involved in the process are the key barriers to USWM that these countries face. By putting long-term planning measures that support generation reduction, separation at source, recycling, composting, and landfill volume reduction into action, these countries may enhance the USWM system. The significant contribution of the unorganized sector to MSW collection and separation in SAARC nations must be emphasized. It is clear that the informal sector is not incorporated into the formal management system, despite the fact that this integration would boost USWM's effectiveness. Regarding the integration process, this might happen through expert instruction as well as the legalization of the employment of these waste pickers, which would result in an increase in the quantity created. Decentralization of USWM services is acknowledged as a vital step for the development of effective USWM in SAARC nations, along with clear definitions of duties and responsibilities for the public and commercial sectors, in collaboration with the populace. The management system may benefit from this decentralization as it starts to take local characteristics into account while planning the management system. Inadequate MSW management, in terms of treatment methods, recycling, final disposal, and management strategy, results in financial loss and endangers the public's health and the environment. It is important to note that there isn't a single USWM model that would satisfy every country's requirements. Each solution must take into account social, economic and environmental considerations, including political preferences and the availability of financial resources. Political preferences, the availability of financial resources and environmental consciousness are examples of social, economic and environmental influences.

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Landuse Landcover Changes and Their Impact on Land Surface Temperature using Remote Sensing Technique in Gazipur Sadar, Bangladesh

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ABSTRACT

The objective of this study was to use remote sensing (RS) technology to determine how changes in land use and land cover (LULC) in the Gazipur Sadar, Gazipur, Bangladesh, influence the local mean land surface temperature (LST). Using ERDAS Imagine 14 and Arc GIS 10.5, layer stacking, mosaicking, and subsetting of a satellite image were performed beforehand. Using a supervised classification approach and the maximum likelihood method, LULC changes between 1992 and 2022 were determined. The percentage of land classified as "Urban Area" increased from 19% in 1992 to 28% in 2022. Between 1992 and 2022, agricultural and forest land in Gazipur Sadar decreased by 5.02 percent and 2.15 percent, respectively. It was discovered that a rapid change from forested to urban areas had occurred. The Land Surface Temperature (LST) values increased by 2.52°C between 1992 and 2022 as Gazipur Sadar's urban sprawl increased. Comparing the years 1992 and 2022, the highest and lowest values for the normalized difference vegetation index (NDVI) were 0.72 and 0.2, respectively. The response was demonstrated by the regression line, which demonstrated a strong inverse correlation between NDVI and LST. The findings of this research will help urban planners and environmental technicians comprehend the effects of LULC change (e.g., loss of vegetation cover, land used for agriculture, and water bodies to accommodate comprehensive urban growth) on LST and recommend the most effective policy measures to control it.

Keywords: LST; NDVI; LULC; RS; GIS.

1. INTRODUCTION

In general, urban areas are where the majority of unexpected changes occur. The pattern of development promotes urbanization [1]. More people remaining in cities increase traffic, pollution, and other concerns, as well as changes to ecosystems, ecology, topography, and the environment[2]. Agriculture around the world suffers from both the short- and long-term impacts of climate change[3]. Changes in precipitation[4] extreme heat stress, changes in land surface temperature (LST), and human migration from rural to urban areas all harm crop health over time. Changes in land use and land cover (LULC) have a long-term impact on urban land surface temperature (LST) [5]. The conversion of wetland, vegetated, and agricultural areas into built-up areas is the primary cause of increasing LST in urban areas, which is exacerbated by urbanization[6]. LULC alteration is one of the main factors behind this conversion. Research has shown that the LST in urban areas is typically 2 to 4 degrees Celsius higher than in rural areas[7]. Several variables, such as horizontal and vertical urban growth, construction materials, the distance between buildings, placement of public areas, roads, transit stops, large and small industrial centers, etc., have a direct effect on the temperature concentration[8]. Changes in land use and land cover (LULC) have extensive effects on ecosystem services by influencing ecosystem functioning at local to global dimensions [9] and in response to human-controlled factors such as environment and government planning [10]. The study of LULC development [11] can yield enlightening information about past practices, current LULC patterns, and the probable future pattern of LULC. Changes in LULC raise LST, thereby generating urban heat islands (UHI) that are associated with above-average energy consumption, air pollution, and potential health issues for residents [11]. Using Remote Sensing (RS) and Geospatial Information System (GIS) technology to evaluate LULC and LST variations in urban applications is an increasing area of application[12]. Increased interest in utilizing GIS and RS to study ecological changes, biodiversity, and global warming[13] has resulted in their widespread application. Direct field visits to identify changes in LULC parameters and to monitor LST are challenging, costly, and error-prone[14]. In addition, the combination of RS and GIS technologies makes it easier to evaluate, monitor, and model LULC and LST changes[15]. In addition, due to the development of statistical methods employing remotely sensed data, the spatiotemporal modeling of LULC and LST dynamics has taken on substantial prominence in the resolution of issues associated with land cover change and increase in temperatures. Utilizing thermal infrared sensors with differing spatial resolutions[8] researchers analyzed LST properties (according to LULC categories) in a variety of urban settings. Due to the geographic nature of the LULC and LST change simulation, a spatial strategic approach is necessary. Modeling LULC and LST scenarios has played a significant role in ensuring sustainable development by

representing the state of current and future development demands[16].

The Normalized Difference Vegetation Index (NDVI) has the potential to provide information on plant cover activities and the vegetation's response to climate change during annual and seasonal variations [17]. There was a correlation between NDVI values and plants, and NDVI variation reflects the broad range of biodiversity in plants [18]. Using the NDVI value, which reflects the condition of the vegetation, it is possible to ascertain with relative simplicity the daily variations in LST[11]. The NDVI is also valuable for analyzing global and regional variations in plant growth cycles[19]. Monitoring is possible for plant health, plant responses to climate change, and seasonal plant processes NDVI[20]. For calculating NDVI values, near-infrared (or red) reflectance is the most important factor[21]. Because of the relationship between evapotranspiration and precipitation and the productivity of vegetation covers[22], NDVI is a valuable technique for analyzing plant cover performance at the landscape scale. Utilizing geospatial information systems (GIS) and radiosondes (RS) has aided significantly in studying and quantifying LULC and LST fluctuations [23]. Information regarding the LULC at a particular time and location. Due to the enhanced capabilities of the RS and GIS, LULC and LST shifts can be mapped and identified with remarkable precision[24].

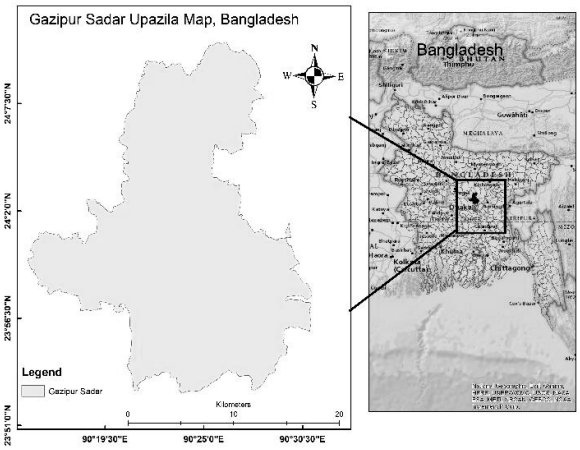


Fig. 1: Gazipur Sadar study map

Table 1: Specification of Landsat satellite data

No.	Satellite	Pixel	Spectral resolution	Band	Path/Row	Date
1	LANDSAT 5	30 m	Multispectral (8 bands)	1,2,3,4,5,7	137/043	April, 1992
2	LANDSAT 8	30 m	Multispectral (11 bands)	1,2,3,4,5,6,7,9	137/043	April, 2022

numerous types of vegetation[25]. Assessing recent changes in LULC and LST patterns in Gazipur Sadar, Bangladesh, is the primary objective of this study. To evaluate urban evolution, calculating LULC for 1992 and 2022 in the study area is one of the study's primary objectives.

(1) Evaluate urban change in the study area by calculating LULC for 1992 and 2022.
(2) calculating Land Surface Temperature (LST) from 1992 to 2022 in the study location.
(3) Examine vegetation change using NDVI measurements between 1992 and 2022.

Assess the relationship between LST and NDVI in the Gazipur Sadar from 1992 to 2022.

2. MATERIALS AND METHOD

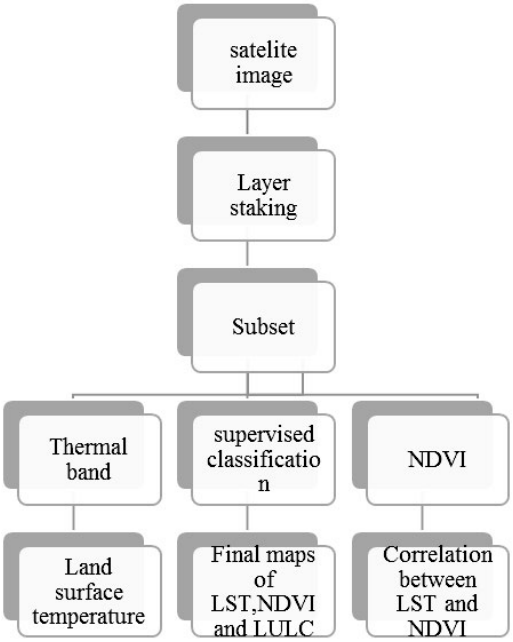


Fig. 2: Flow chart of the research method

2.1 Study area

The study concentrated on the regions of Gazipur Sadar Upazila. Gazipur Sadar Upazila is located north of Dhaka at coordinates 23 degrees 53 minutes and 20 seconds north latitude and 90 degrees 09 minutes and 42 seconds east longitude. Throughout history, this region has been covered in dense Vowal Pargana (Sub-Division) forests (Sub-Division). Gazipur was historically a component of the Dhaka district. However, in 1984, it was elevated to a district and is now a part of the Dhaka Division. According to other estimates, 60% of the world's population will be urban by 2025[26]. In 2013, municipal administrations were constituted in Gazipur. Although urbanization is increasing in some regions, the location of Gazipur is determined by numerous factors. Population- and location-wise, Dhaka is the most prominent city in Bangladesh. The proximity of Gazipur Sadar Upazila to Dhaka has had a significant impact on the area's industrial-ization and development.

2.2 Landsat data

NASA's Earth Explorer (https://earthexplorer.usgs.gov/) provided access to Landsat-based imagery of the area surrounding the research area with a mapped LULC class [27]. For LULC, LST, and vegetation change detection, Landsat images from the Operational Land Imager (OLI), Landsat 8, Enhanced Thematic Mapper Plus (ETM+), and Landsat 5 Thematic Mapper (TM) were used (Table 1). The LULC structure comprises four distinct categories, including the vegetation, developed areas, and water-based features of the study area.

2.3 Image processing and classification

The satellite observatory utilized multispectral Landsat images to examine LULC and LST. Band 6 is a thermal band used for LST, whereas band 8 has not been utilized due to the need for additional research to validate the bands prior to writing further about them. Eight distinct spectral regions build up the Landsat data. ERDAS was used to process Landsat images, enabling layer stacking (the method used to generate a multiband image from discrete bands) and subsetting (the selection of a study region after layer stacking) Imagine 14[28]. After the merging of the data, satellite datasets between 1992 and 2022 were spatially analyzed using the maximum likelihood method to identify LULC patterns in the study location. Using Arc GIS 10.5 [28] to create polygons around several demonstration locations, training samples for each LULC type were obtained. As a consequence of the Landsat images, pixels within these polygons were used to investigate section covers of various LULC classes. Figure 2 details the methodology implemented.

2.4 Accuracy assessment

Evaluation of several image processing techniques in classification included an accuracy evaluation step. The error matrix was the most popular and all-encompassing approach to evaluating accuracy[29]. Equation was used to determine producer accuracy, user accuracy, and total accuracy (1).

$$\text{Overallaccuracy} = \frac{\text{number of sampling classes classified corectly}}{\text{number of reference sampling classes}} \quad (1)$$

How well RS categorization agrees or is correct relative to the reference data is quantified by the kappa (K) values. In statistical terms, kappa (K) looks like this: A This is how kappa (K) looks like in the statistical world: [29]

$$\kappa = \frac{Ovserved\ accuracy - Chance\ assesment}{1 - Chance\ Agreement} \quad (2)$$

spatial resolution of 30 m 30 m for the years of 1992 and 2022, identifying a range of plant varieties, an agricultural region, and

2.5 Estimation of NDVI

For instance, in the interest of monitoring the extent of vegetation, the normalised difference vegetation index (NDVI) was computed. When NIR is the near-infrared band, these are the projected NDVI values: (TM and ETM band 4, OLI band 5)

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (3)$$

in addition to R, the red spectrum (TM and ETM band 3, OLI band 4).

The NDVI is a measure with estimated values between 1 and -1 that was derived from Landsat imagery.

2.6 Estimation of LST

LST is an overall word for referring to the average temperature of all terrestrial objects. Several scholars calculated the LST by applying standard measurements to Landsat data[30]. It was the TM, TM+, and OLI thermal bands that were used to calculate the predicted LST values (band 6 and band 10). The whole procedure for determining LST is detailed down below. For starters, we used Equation (1) to convert the L values to spectral radiance (4).

$$L\lambda = gain \times \text{QCAL} + \text{offset} \quad (4)$$

where L is the spectral radiance and QCAL is the DN value of the quantized calibration of a pixel. Second, using Equation (5)[31],

$$T = \frac{K2}{\ln(\frac{K1}{L\lambda} + 1)} \quad (5)$$

we transformed the spectral radiance value into a temperature: K1 = 607.76, K2 = 1260.56 for Landsat 4 and 5 (TM), and K1 = 772.88, K2 = 1321.07 for Landsat 8 (OLI).

Ultimately, the temperature, originally measured in Kelvin, was converted to Celsius (C°) using Equation (6)[32]

$$T(C°) = T(K) - 273.15 \quad (6)$$

Table 2: The areal distribution of land use land cover (LULC) in 1992 and 2022

LULC Classes	1992		2022	
	Area(K m^2)	Area(%)	Area(Km^2)	Area(%)
Agriculture/ Vegetation	286	62.44541	263	57.42358
Water	28	6.113537	19	4.148472
Forest/Tree	53	11.57205	43	9.388646
Urban Area	91	19.869	133	29.0393
Total	458	100%	458	100%

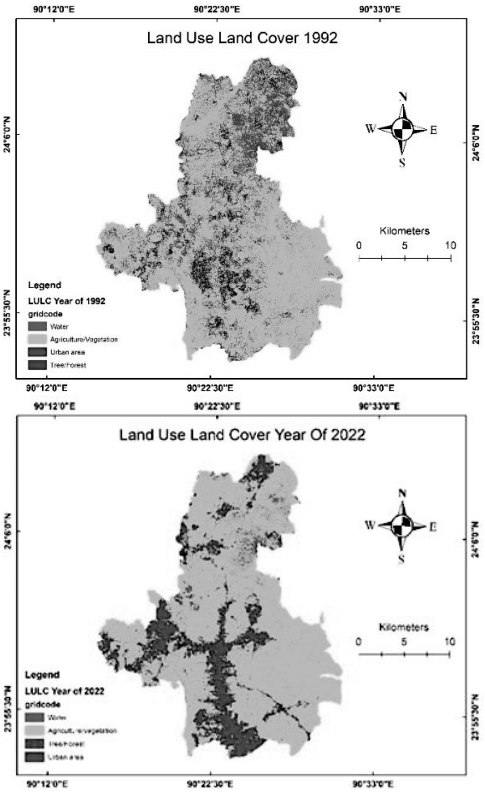


Fig. 3: Land use maps for the years 1992 and 2022 of Gazipur sadar

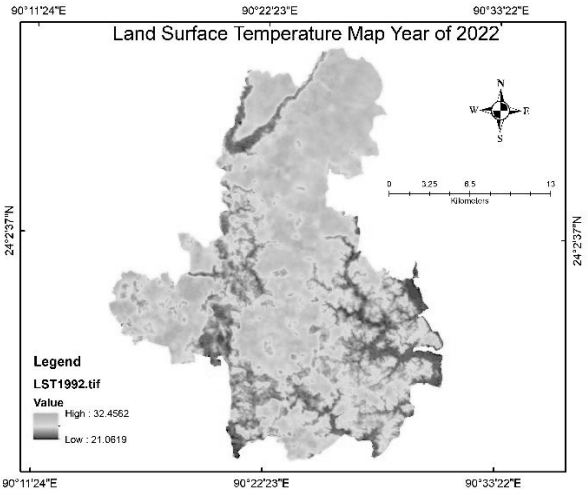
3. RESULTS AND DISCUSSION

3.1 Land use land cover (LULC) changes

Figure 3 shows that, using a supervised classification method, the land cover types (agriculture/vegetation area, trees/forest, waterbodies, and urban area) in Gazipur Sadar change significantly from 1992 to 2022. In 1992, 62.44 percent of the land was used for cultivation and other agricultural purposes, 6.11 percent was covered by water, and 19.869 percent was developed. Table 2 shows that in 2022, 57.42% of the Earth's surface was covered by agricultural and vegetated areas, 4.14 % by aquatic bodies, and 29.03% by urban space. (Table 2). The urban area of the study area grew from 1992 to 2022, as indicated by the increasing red line.

The percentage of Gazipur Sadar classified as "urban area" in 1992 was 19.8869%. In contrast, urban populations increased by 29.033 percent between 1992 and 2022. From 1992 to 2022, the "urban area" area in Table 3 increased significantly despite the overall increasing pattern. 94.15 % of the "urban area" was covered in 1992. The expansion of regions beyond the main metropolitan area of the study area explains these changes. However, increases was noticed in the far east and west. Other communities were established to the west and east, expanding the urban separation of the study area.

However, according to our findings, after agricultural and forest land, as well as the surface of water, were converted into road networks, commercial and residential areas were developed. The population of Gazipur sadar of 8,66,540 in the year of 2001 census and 18,20,374 in the year of 2011 census, [33]. As the population of Gazipur Sadar increased, construction expanded into new areas. In only 30 years, approximately 5% of the land that had been covered by vegetation and vacant land was converted into urban areas, according to our results. Several residential areas have been constructed on formerly forested land in the region, according to study. As the community becomes more dense, it encourages more residents, which in turn strengthens the economy. LULC change detection aims to determine which LULCs have encountered annual decreases or increases. Using the data provided by change detection, the rate of change in the LULC can be accurately determined. In recent years, the built-up area has increased by [34], while the population has grown at a somewhat slower rate. It is expected that increasing urbanization [17] will have grievous consequences for Gazipur's green spaces in the coming years. The upper and lower baselines of LULC classes exhibiting the least and greatest change under a LULC were chosen to identify vegetation changes over the last several years [35].



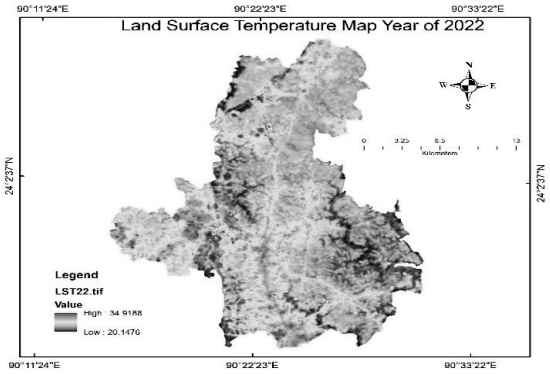


Fig. 4: Land surface temoerature maps for the years 1992 and 2022 of Gazipur sadar

3.2 Accuracy assessmet

The kappa (K) values and user and producer accuracy for various LULC classes between 1992 and 2022 are displayed in Table 5. The average accuracy of producers in 2022 was 89.4%, while the average accuracy of consumers was 88.6%; in 1992, it was 88.6%. In 1992, total categorization accuracy was 81%, and in 2022, it was 86%, both of which are commendable. In the region under study, the reported Kappa (K) values in 1992 were 0.79 percent, and in 2022 they were 0.82 percent. The mapmaker determines the accuracy of the map, but the accuracy of the map from the user's perspective is what matters. Comparing our data revealed that the two classification accuracy rates were quite similar, indicating fewer incorrect classifications.

Table 3: Accuracy and kappa (K) coefficient summaries for producers and consumers in Gazipur sadar

LULC Classes	1	2	3	4	Avg.	1	2	3	4	Avg.	Overall accuracy	K
1992	88	86.9	85.6	80.2	88.1	92.3	90.8	86	95.7	91	0.81	0.79
2020	85.7	89.5	88.2	87.4	89.4	83.5	95.7	84.7	85.5	88.6	0.85	0.82

where 1 : Agriculture/Vegetation 2 : Water 3 : Tree/Forest 4 = Urban Area

3.3 Land surface temperature (LST) changes

Figure 4 represents the area distribution and spatial pattern of LST over two years (for example, between 1992 and 2022) in Gazipur sadar. Geographical, temporal, and concentration characteristics of the LST reflect the rapid changes between LULC classes. In 1992, the LST was predicted to range between 21.06°C and 32.56°C, and between 20.14°C and 34.42°C in 2022. This increase is completely mathematical; however, using the geographical average resulted in a more accurate measurement of the temperature rise, indicating that the LST has increased by approximately 2°C between 1992 and 2022. With the built-up area of the study, the region is expected to increase between 1992 and 2022, and the LST must be increased. In contrast, the central region (Gazipur Sadar) exhibits a rise in LST as a consequence of accelerated urbanization and diminishing waterbodies and vegetative land. In 2022, the difference between the greatest and lowest temperatures was 34.91°C and 20.14°C, respectively. Maximum temperature anomalies in 1992 were (32.45°C) and minimum temperature anomalies were (21.06°C) (Table 6). Given the limitations of the RS-derived LST calculation, the difference between the estimated and observed LST can be utilized for future analyses, such as Temperature and LST condition index simulations in the research region. In addition, the maximum LST values in Gazipur sadar were recorded in the densely urbanized and rapidly increasing urban area.

3.4 Normalized difference vegetation index (NDVI) changes

NDVI assessment using Landsat images is based on the visible light absorbed by plants, the energy used for photosynthesis, and the near-infrared (NIR) radiation reflected by vegetation. Figure 5 depicts the NDVI model developed from 1992 to 2022 using Landsat images. In 1992, NDVI values in the study area ranged from 0.32 to +0.72, but by 2022, these values had migrated to 0.14 and 0.50, respectively (Table 6). Higher NDVI values, as well as an abundance of vegetation and trees, higher NDVI indicate more fertile and productive regions. However, areas with the lowest NDVI values, such as subsoil waterbodies and urbanized land, indicated the lowest levels of productivity. According to the NDVI map, this indicated that the most productive portion of the study region had experienced a significant decline in productivity. Considering that the NDVI value is greater in forested areas than in barren soil, the increased vegetation area may have an effect on the overall greenness of vegetation as seen by a satellite in the study region. There were significant differences between the NDVI measurements from 1992 and 2022.

Table 4: The highest and lowest possible LST and NDVI values

Years	LST		NDVI	
	Min	Max	Min	Max
1992	21.06	32.45	−0.32	0.72
2022	20.14	34.91	−0.2	0.55

Table 5: Change analysis from 1992 to 2022 in Gazipur

LULC Changes	1992-2022 (30 Years)		
	Changes	Area	%
Agriculture/Vegetation	263-286	23	-5.02%
Water	19-28	9	-1.96%
Forest/Tree	43-53	10	-2.1%
Urban Area	133-91	42	9.17%

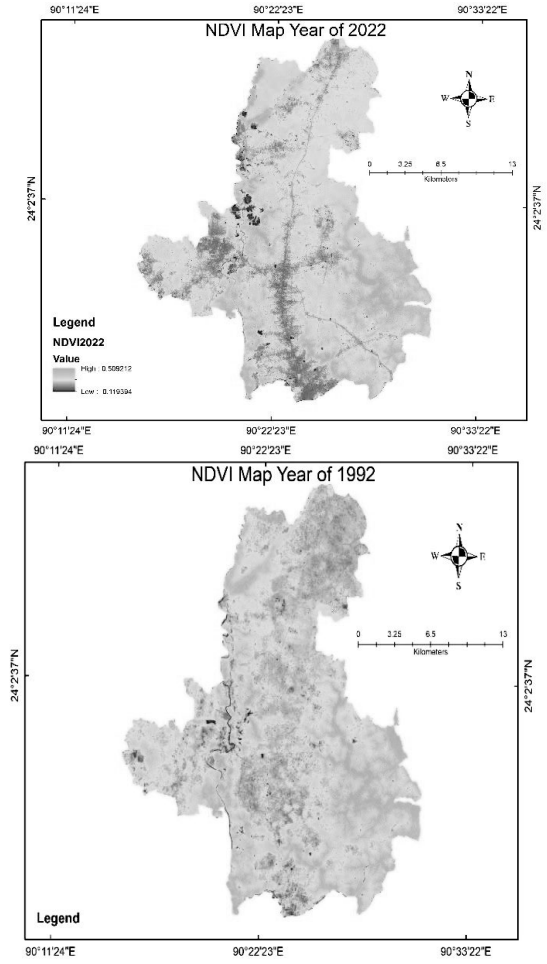


Fig. 5: Analyzing Gazipur sadar NDVI maps from 1992 and 2022

3.5 Relationship between LST and NDVI

Figure 6 shows the correlation between NDVI and LST. The regression line revealed a significant negative correlation between NDVI and LST with remarkable clarity. Two years of linear regression analysis (R2) revealed that LST and NDVI are negatively correlated, with R2 values of 0.46 for 1992 and 0.39 for 2022, indicating a negative relationship. (Figure 6). These findings suggest that Land Surface Temperatures (LST) may result in a decrease in plant coverage. As a consequence of the inverse relationship between NDVI and LST, we understand that dense vegetation results in moderate temperatures. Variations in LULC are directly affected by the LST and NDVI. This also suggests that places with lower NDVI values have less vegetative spread as a result of urban expansion, whereas places with higher NDVI values have dense vegetative spread, and that LST increases with the decrease in vegetative density. After discovering a strong correlation between LST and NDVI, it becomes possible to use direct regression in LST forecasting if NDVI estimates for the research region are already available. Using NDVI data, LST can now be predicted with pinpoint accuracy. From 1992 to 2022, the NDVI values decreased due to urbanization and forest cover loss. The lowest NDVI values correspond to the highest LST values, and vice versa; this relationship also indicates that high-LST areas are predominantly devoid of vegetation, whereas low-LST areas have a larger proportion of their soil covered by vegetation.

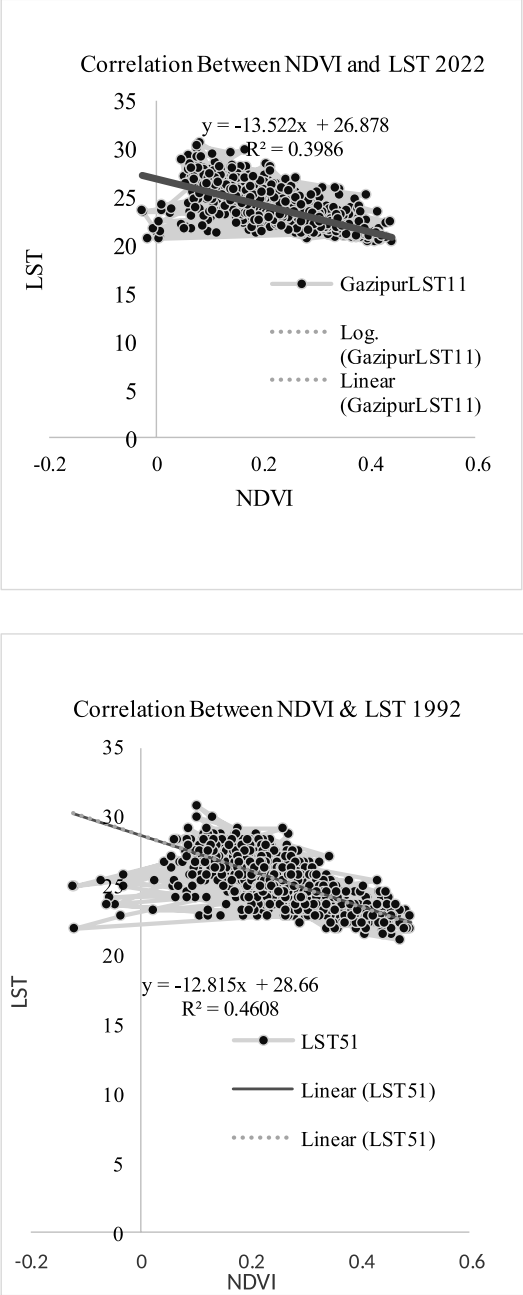


Fig. 6: Relationship between LST and NDVI for the years 1992 and 2022 of Gazipur sadar

4. CONCLUSION

The primary objective of this study was to analyze the impact of LULC changes on LST in the Gazipur sadar using RS and GIS software. In 1992, a total of 19.87% of the area was categorized as an "Urban Area"; by 2022, this percentage had increased to 29.02%. Between 1992 and 2022, the tree cover in Gazipur Sadar decreased by 5%. In formerly agricultural regions, rapid urbanization was observed. As the population of Gazipur Sadar increased from 1992 to 2022, the average annual LST raised by two degrees. In addition, the regression analysis demonstrates an effective inverse relationship between NDVI and LST. According to the available data, the concomitant decline in the availability of water and vegetation is a significant factor in the reduction of vegetated areas. As a result of these shifts, natural ecology, and biodiversity have been lost, which could lead to a variety of environmental issues if developed regions continue to expand. The findings of this study will enhance the capacity of geographic region policymakers to develop comprehensive regional and national land management plans. If we were able to increase our agricultural output, not only would the economy of the people and the country benefit, but we would also be able to make significant progress ahead.

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GIS and AHP Based Flood Susceptibility Mapping of Halda Basin, Bangladesh

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ABSTRACT

Floods are hydrological disasters that can change a region's physical, economical, and environmental conditions. For identifying flood risk areas and preparing mitigation strategies, flood susceptibility mapping is essential. The aim of the present work is to develop a flood risk map for the Halda Basin, the North-eastern region (NER) of Bangladesh's Chittagong division, using the multi-criteria decision analysis (MCDA) - analytical hierarchy process (AHP) approach in a GIS environment. The specified hazard and vulnerability indicators characterize the topographical, geological, meteorological, drainage, land use, land cover, and demographic attributes of the Halda Basin. According to the final susceptibility map, 9% and 69% of the basin area, respectively, are in high and moderate risk categories for flooding. The Fatikchari, Raozan, and Hathazari upazilas of Chittagong district and the Manikchari upazila of Khagrachari district are found to have moderate to high flood susceptibility. Among them, Fatikchari upazila is found to be the most flood-affected upazila than any other due to the lowest elevation and slope, an urbanized region, heavy rainfall, an impervious to semi-permeable soil type, and close proximity to the drainage network. The findings of this research can be used by the local governments and policymakers to minimize the loss of life and property and to make better decisions before and after the event.

Keywords: Flood susceptibility; Geographic information system (GIS); Analytical hierarchy process (AHP); Multi-criteria decision-analysis (MCDA).

1. INTRODUCTION

Geological, hydrological, and climatic events that cause catastrophic events result in enormous loss of life and property as well as damage to the ecosystem. Flooding is the most frequent and costly hydro-meteorological catastrophe because of the significant damage it results in[1]. The frequency and severity of floods have significantly increased over the past few decades due to irregular rainfall distribution, quick snowmelt, overflowing rivers, deforestation, unchecked development, and unplanned human settlement near riverbanks and coastal regions [2]. Between 2000 and 2019, floods impacted almost 1.5 billion people, accounting for % of all catastrophes worldwide. Asia alone accounted for 41% of all flood events[3]. Flood intensity fluctuates across time and space, and its occurrence and harmful repercussions cannot be avoided in the future[4]. The Halda River basin has a significant impact on the economy and ecological health of southeast Bangladesh. The projected annual value of all tangible resources is $US 20.5 million [5]. However, due to a number of floods, the life and property of the basin area impacted significantly.

The first step in regional or local flood management is to identify susceptible locations and to have a thorough knowledge of the interactions and linkages between social, economic, and environmental aspects so that emergency rescue and mitigation measures may be taken. An essential instrument for implementing a successful flood control system is an extensive flood risk map [6]. At the local, governmental, and international levels, several research on flood assessment have been carried out using MCDA and various methods [7]–[11]. Several researchers have carried out GIS-based flood vulnerability evaluations utilizing different methods [12]–[14]. The analytical hierarchy process (AHP) has been used to develop a specialized decision-making framework for flood susceptibility mapping[15]. Using PCM, several flood vulnerability characteristics in AHP are rated according to their significance[16].

There is no any singe reseach by using GIS-AHP methods to determine flood susceptibility zone of halda river basin. Therefore, the main objective of the current study is to assess flood-prone areas using MCDA and GIS to create high-resolution maps of flood risk of Halda river basin.

2. STUDY AREA

The Halda river, which flows into the Bay of Bengal after passing through the Chittagong area, is a significant river in Bangladesh (Fig. 1). It is well-known for its spectacular natural beauty and for being a source of freshwater fish, particularly the famous Hilsa fish. The river plays an important role in the economy and culture of the region, supporting agriculture, fishing, and tourism[17]. The Halda river is 110 km long when including its headwaters, and 100 km long when excluding them. The watershed for the Halda River is located in latitudes 22°24 and 22°54 N and longitudes 91°48 to 91°53 E.It has a total area of 1,682.92 km2, with water making up 12.33 km2 and land occupying 1670.59 km2. The basin is home to a diverse range of flora and fauna, including many endangered species [18]. Despite its importance, the Halda

River basin faces a number of challenges, including flood and ensure the long-term sustainability of the river and its surrounding ecosystem.

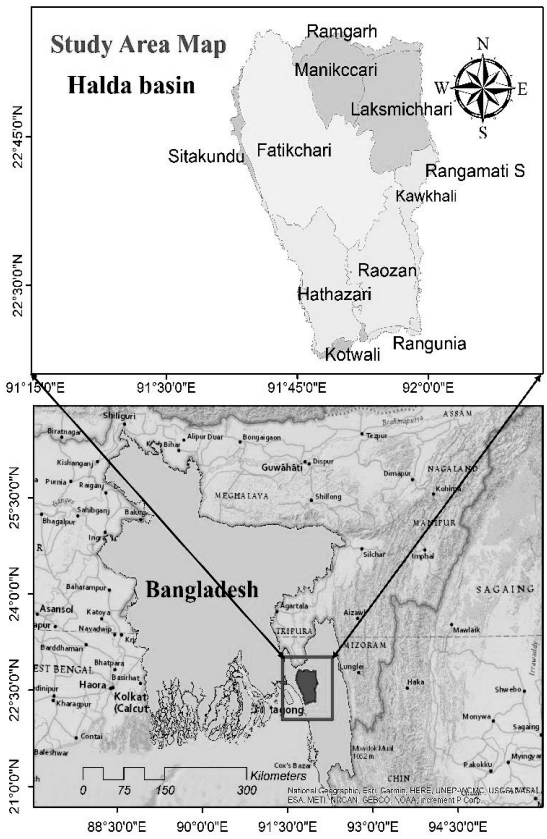

Fig. 1: Study area map of Halda basin

2. DATA AND METHODS

The two main forms of data used in this research were remotely sensed data and observed data. Table 1 provides a detailed breakdown of these facts.

Table 1: Sources of data for this research

SN	Data type	Data source
1	Rainfall data	Bangladesh meteorological department (BMD)
2	DEM	https://earthexplorer.usgs.gov
3	LULC	http://www.globallandcover.com

and erosion. Efforts are underway to address these issues

The critical factors for flood assessment were chosen after reviewing a number of research [19], [20].In the current study, suitable theme maps were produced using nine conditioning elements. Some of these variables are elevation, slope, precipitation, land use and land cover (LULC), normalized difference vegetation index (NDVI), distance from rivers and roads, and drainage density. Each criterion was well-stated and preprocessed into raster datasets. They were ranked according to the opinions of specialists in the fields of local administration, local professionals, meteorology, disaster management, and soil management, and then their weights were evaluated using AHP. The weightage linear combination method of AHP was used to create a final flood susceptibility map after conducting a multi-criteria analysis. Depending on how likely it was that each parameter's range would be in the flooding zone, five susceptibility levels were assigned to each criterion (5: very high, 4: high, 3: moderate, 2: low, and 1: very low).

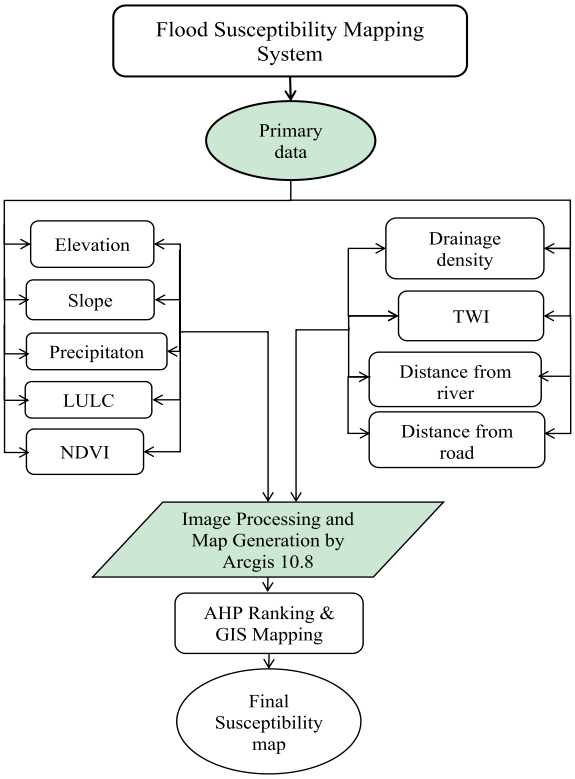

Fig. 2: Flow chart of methodology

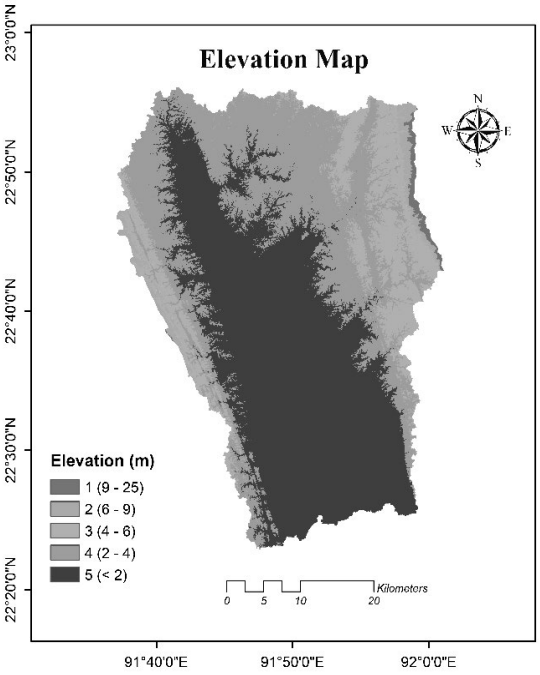

Fig. 3: Elevation map of the Halda basin

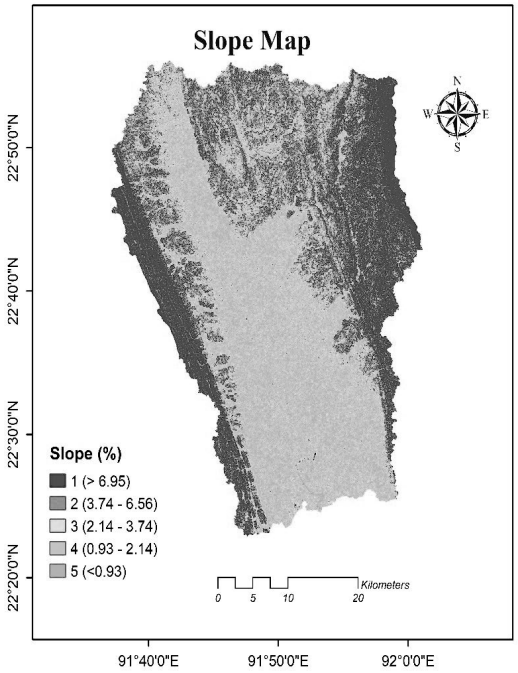

Fig. 4: Slope map of Halda basin

2.1 Elevation

Elevations often play a significant role in identifying the places that are at danger of flooding. This element primarily affects the flow direction control and flood depth, as well as the flooding spread[21]. Flooding is more likely to occur downstream in places with flat slopes and lower elevations than it is in locations with higher elevations. Fig. 3 shows that elevation of the middle part of the Halda basin is very lower than the surrounding area. So these lowest areas are highly susceptible to flood. SRTM 1 arc-second (30 m resolution) DEM is used to construct the elevation layers. With the use of a zonal statistics tool, the characteristics were computed and the empty data was filled, mosaicked, and extracted by mask [22].

2.2 Slope

Since it controls the speed of water flow and the infiltration of surface runoff, the slope is crucial for analyzing flood hazards[23]. The contours of the elevation were used to estimate slopes. The Slope map consists of five classes. As a result, the area with the lowest slope is severely affected by floods, as per the classification process. The study area's western and eastern portions were formed with a steeper slope than other areas. The land's slope in the middle section is much lower than that of the surrounding (Fig. 4).

2.3 Precipitation

One important factor that contributes to the frequency of floods is precipitation. The economy, human communities, and aquatic and terrestrial ecosystems may all suffer as a result of extreme precipitation enhancement increasing the severity and frequency of floods [24].

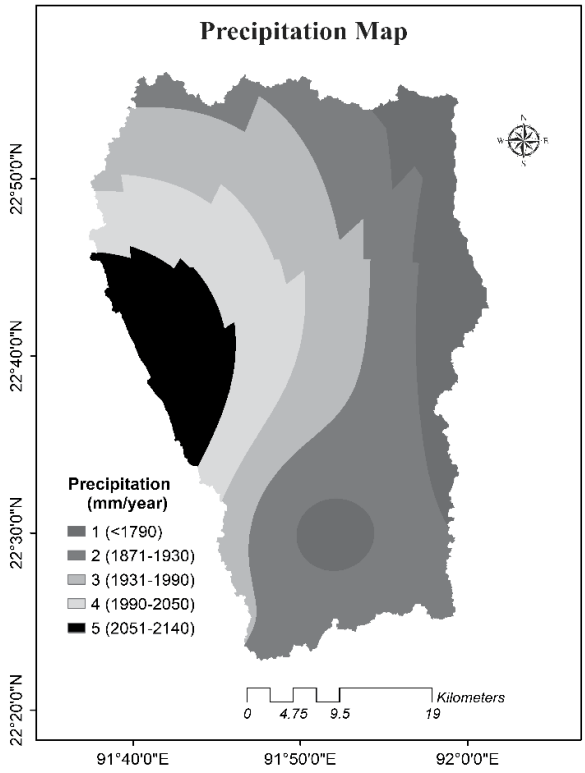

Fig. 5: Precipitation map of Halda basin

Four weather stations altogether were divided into separate grids for mapping precipitation. Krigging, a kind of geostatistical interpolation, was used to gather and distribute throughout the research region the average precipitation data for the years 2011 – 2018. Fig. 5 shows that the western part of the basin experiences the most precipitation.

2.4 Land use land cover (LULC)

Runoff, infiltration, and rainfall absorption are only a few examples of the several hydrological parameters that are governed by LULC [7]. Water overflow is increased in urban and pasture areas, but water infiltration and abstraction are boosted by forests and thick natural vegetation. The following five categories make up the land use and land cover map: (a) water body; (b) built-up area/settlement; (c) agricultural land; (d) natural vegetation; and € barren ground. The classifications are then checked by computing the kappa coefficient [25]. Fig. 6 demonstrates how such a central portion of the basin is urbanized and has an agricultural landscape. These areas are far more vulnerable to flooding since they are lower than other areas.

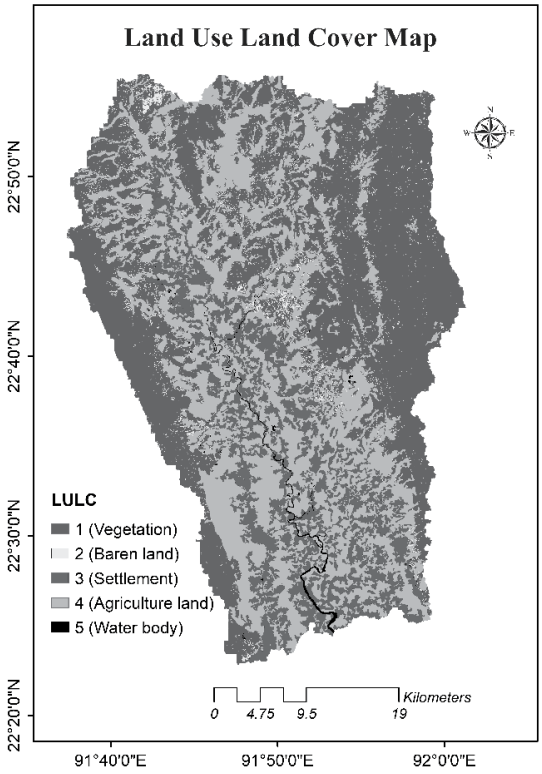

Fig. 6: Land use land cover map of Halda basin

2.5 Normalized difference vegetation index (NDVI)

For the NDVI calculations in our work, the ArcGIS 10.8 software used resampling cubic convolution of calibrated reflectance values from Landsat 8 images [26]
Equation 1:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

where *NIR* is near-infrared red band reflectance (band 5) and *RED* is red band reflectance (band 4)

Fig. 7 illustrates that a lower NDVI value indicates a less vegetated region and a higher value indicates an urban area.

2.6 Drainage density

Drainage density, which denotes paths for flow accumulation, is the length of river channels divided by the basin's surface area[27]. The drainage network map of the study area is created using hydrological tools, and drainage density is examined using the GIS line density tool[25]. The middle region of the basin was formed by several rivers, which increased the drainage density there (Fig. 8). Due to insufficient rive, the mountainous region has a lower valuethan other areas.

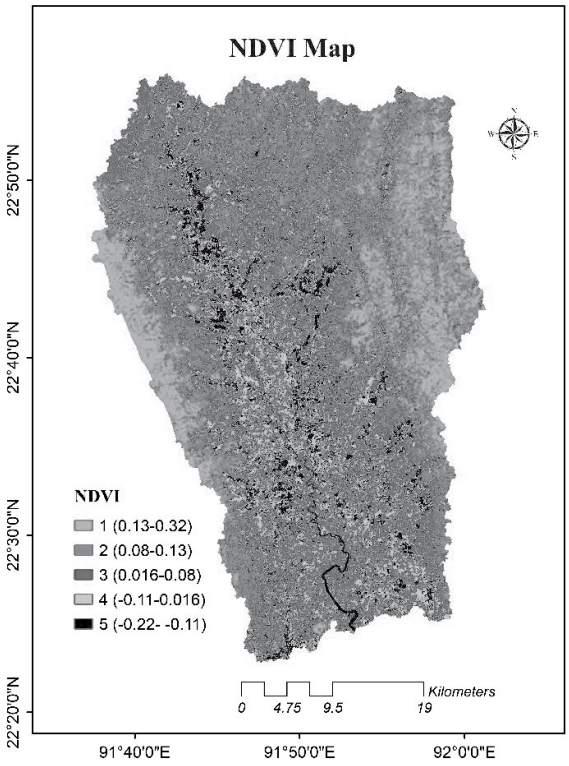

Fig. 7: NDVI map of Halda basin

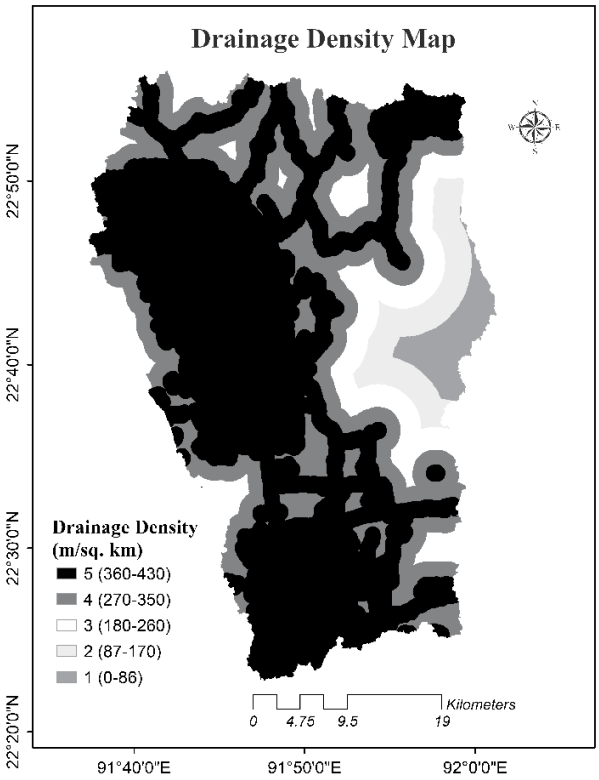

Fig. 8: Drainage density map of Halda basin

2.7 Topographic wetness index (TWI)

Topographic wetness index (TWI) is used to map flood-inundated areas and analyze how topography impacts a watershed's hydrological process[28]. Using DEM data, slope and flow accumulation layers are generated for TWI (Fig. 9). TWI is calculated using the formula (2) provided by [29]

$$\mathrm{TWI} = ln\left(\frac{\mathrm{A}}{\tan\beta}\right) \quad (2)$$

where tan β is the ground surface slope and A is the source contributing area.

Relatively high TWI values indicate flood-prone areas, whereas lower values indicate areas with the steepest slopes and the least likelihood of flooding [27].

2.8 Distance from the river

Predicting flood risks requires information of the distance to river channels.. When a river overflows, its volume will be greater than its ability to drain, and the water depth in regions close to the riverbank will rise dramatically. The waterlogging and flood risk will spread beyond the immediate vicinity of the nearest river as a result of the flooding [6]. A raster layer is created by using the Euclidean distance tool of GIS [7].

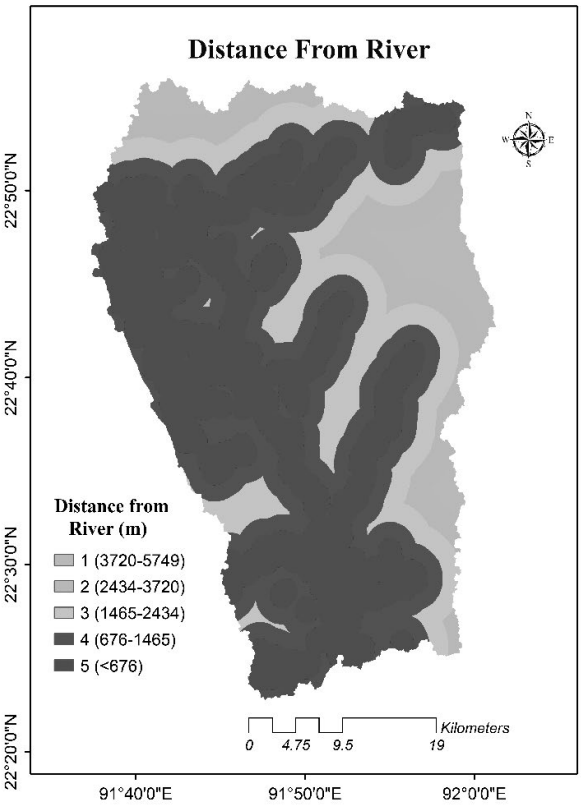

Fig. 9: Distance from river map of Halda basin

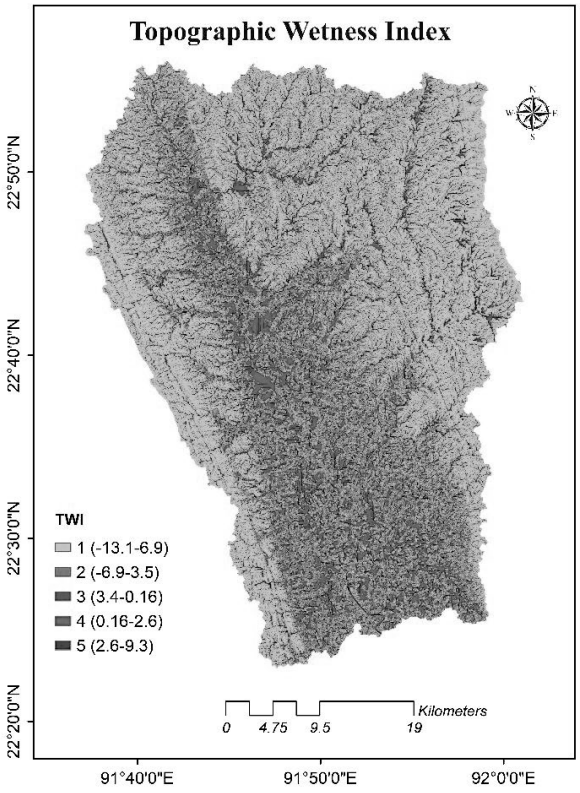

Fig. 10: Topographic wetness index (TWI) map

2.9 Distance to roads

One of a region's most important infrastructure elements is a well-connected, well-maintained transportation system. During an emergency, road connectivity is essential for relief and rescue efforts.

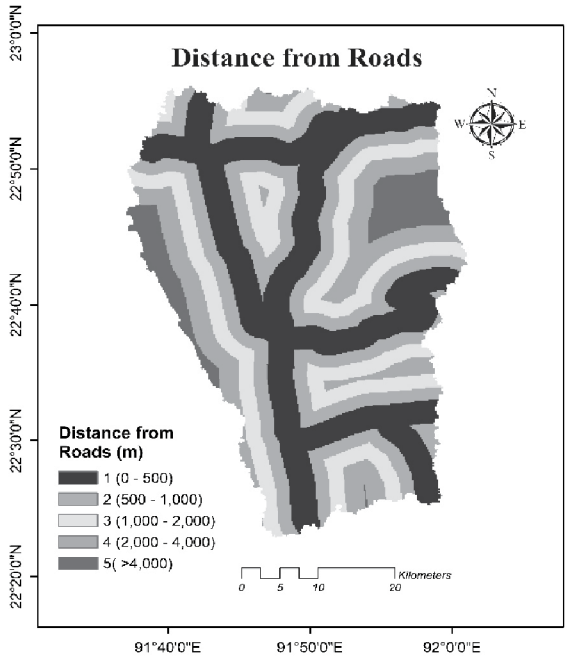

Fig. 11: Distance to roads map of Halda basin

Settlements closer to highways are less at risk since they can be rescued or evacuated more quickly than people living in remote places [12]. Major and small roads are retrieved from OpenStreetMap and digitized in GIS. Finally, the GIS tool for Euclidean distance produces a raster dataset.

2.10 AHP modeling approaches

AHP is a multi-perspective, multi-objective decision-making paradigm that allows planners and users to statistically calculate a scale of preference from a menu of alternatives[30]. By using a ranking scale, Saaty et al. (1980) proposed a PCM approach to create weighting factors for each specific criterion [31], in which a random consistency index was computed and evaluated[32]. Depending on the number of components or various matrix arrangements, the average RI changed. The consistency ratio (CR), which was established as the ratio of the consistency index (CI), was used for validation[33]. Permeability and land cover dynamics had a substantial influence on flood occurrence in the135esearchh region, but anthropogenic interference had a minor impact, and CR value should be the criteria to justify the weightage:

$$CR = \frac{CI}{RI} \quad \text{.....(3)}$$

$$CI = \frac{\lambda max}{n-1} \quad \text{.....(4)}$$

where
CR is consistency ratio
CI is consistency index
λ_{max} is average value of consistency vector
N is number of criteria

To validate the criteria weights, the final CR value should be low (<0.10).

3. RESULTS AND DISCUSSION

Flood risk susceptible zones mapping is a very helpful approach that enables minimizing flood hazard hazards in order to support decision-makers and planners in having adequate control over the prone regions, and subsequently provide correct and sustainable socio-economic development. The approach used in this work is based on a combination of spatial (MCDM-GIS) and statistical (AHP) modeling. The Flood Hazard map study findings reveal that 9% (or around 155 km^2) of the overall area is flooded with a high flood risk possibility. The Fatikchari, Raozan, and Hathazari upazilas of Chittagong district and the Manikchari upazila of Khagrachari district are found to have moderate to high flood susceptibility (Fig. 12). Among them, Fatikchari upazila is found to be the most flood-affected upazila than any other due to the lowest elevation and slope, an urbanized region, heavy rainfall, an impervious to semi-permeable soil type, and close proximity to the drainage network. In the past, several flash floods have occurred in the Fatikchari upazila [34], [35] that are consistent with our research. Structures with raised platforms should be allowed in medium-floodplain regions, but no infrastructure should be allowed in high-floodplain regions likewise low-flood plain regions. Residents of low-floodplain regions ought to have access to public infrastructure in the event of a flood. Retrofitting river banks will be essential for lowering food loss and boosting flood storage [36]. Finally, addressing food and assets insecurity in the Halda basin area may be aided by using the current research map findings as a guide. Governments and policymakers can be aware of high-risk areas in order to properly manage flood consumption and plan the development of essential flood preventive measures.

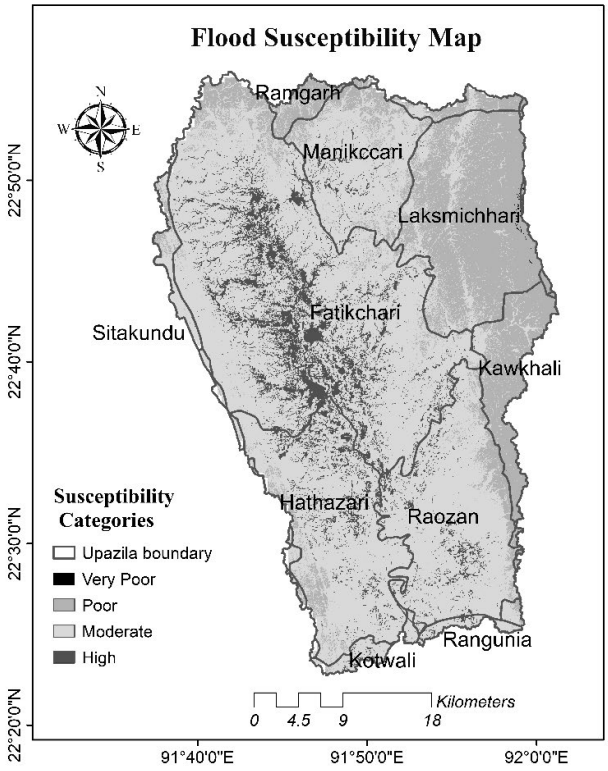

Fig. 12: Flood susceptibility map of Halda basin

4. CONCLUSION

This study demonstrated the potential of GIS and MCDA-AHP techniques for flood risk mapping in the Halda Basin of Bangladesh. The analysis showed that flood risk in the basin is primarily influenced by topography, land use, and drainage density. For effective flood management and disaster preparation in the research region, the created flood risk map may be utilized. This study also offers useful infor- mation for policymakers, stakeholders, and academics to pinpoint flood-prone locations and prioritize mitigating measures. Additionally, this study offers insightful information that can help policymakers, stakeholders, and academics to identify flood-prone locations and prioritize mitigation activities. Overall, this study offers a reliable tool for mapping flood risk in other areas with similar characteristics.

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Flood Impacts, Management and Community Contributions Regarding Floods in Northwest of Bangladesh: A Case Study on Bhurungamari Upazila, Kurigram

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ABSTRACT

Bangladesh, a nation with a significant risk of flooding, is located in Southeast Asia at the confluence of said powerful Ganges, Brahmaputra, and Meghna waterways. Here, Kurigram district, on the other hand, is more prone to floods and riverbank erosion, as well as one of Bangladesh's poorest districts. The study areas were Char Bhurungmari and Paiker Chhara unions of Bhurungamari Upazila in Kurigram. Bhurungamari Upazila is one of the flood porn areas in the Kurigram district. The aim of the study was to identify flood impacts and community contributions to flood management in the study area. For conducting the study, a field survey was conducted to collect data from diverse people in these two unions in Bhurungamari Upazila. Secondary data were also collected and analyzed to obtain possible flooding scenarios. Respondents were generally experiencing a severe food and economic crisis known as manga. About 65% of households were Tin-house residents and they were affected mostly by flooding in the agricultural sector (29.5%) as the community faced mainly riverine floods (almost 76%). Moreover, about 69% of floods in the study area stayed longer time creating long-term effects, though indigenous knowledge provided vital benefits for flood early warning systems (about 40%) whereas electrical devices contributed 32% vitality. About 95% of males contributed to flood management by making boats while 95% of females contributed by making potable stoves. Females played a vital role in preserving fresh water, 85% of females in the study area preserved fresh water during flooding. Both male and female inhabitants contribute differently but equally throughout the flood management process. Further study could be conducted to identify the health and mental situations of flood-affected areas in Kurigram District.

Keywords: Floods; Management; River; Monsoon.

1. INTRODUCTION

Bangladesh would be regarded even as a nation with the highest risk of natural disasters, namely flooding [1] . Due to its strategic position, topographical settings, rainfall, and atmospheric conditions, and being prone to a variety of hazards every year that has a consequence on its inhabitants, health, and possessions [2]. Researchers believe to be the biggest dangerous geothermal threat within the globe is floods [3]. Hurricanes, heat, habitat, typhoons, water logging, tidal waves, rainstorm, sou'wester, and salt infiltration are typical threats [4]. Inundation is regarded as the worst disaster due to the way it affects assets, employment, and health (transportation, agriculture, and animals) [5]. It is indeed clear that of all the harm, the property received the most destruction (52.66%). According to some authors, the 2018 Global Hazard rankings place Bangladesh in 9th place globally and is the second-most rainfall nation across all of the East [6]. In Bangladesh, there aren't systematic data on yearly disasters. These disasters in 1954, 1955, 1974, 1987, 1988 1998, 2004 & 2007 each created huge destruction to structures and a considerable death toll. Storms in 1987, 1988, 1998, 2004, and 2007 all left behind major harm [7]. Sudden floods can take an area anywhere downwards again from the source of the rainfall, often kilometers away. Since Bangladesh is now a floodplain nation, disasters frequently impact its border area. As a result, it is known here that the area is susceptible to floods [8]

Paiker Chhara and Char Bhurungamari Union in Bhurungamari Upazila are mostly flood-prone areas in the Kurigram district. Most principal waterways in such Upazilas seem to be the Teesta, Dharla, and Brahmaputra streams that while monsoonal discharge enormous amounts of rain, flooding the nearby regions [9] . Additionally, groundwater recharge flows and continued, intense rains in northern and inland Bangladesh have definitely led to floods near the bottom regions. Residents of this region ultimately experience a lack of access to clean water and sanitary facilities, which makes various societal issues worse as they are so closely related [10]. Such security weaknesses and concerns, as well

as the significance of organizations in managing flood catastrophe responses, hinder female attempts at risk palliative and adjustment [11]. Regarding effective disaster prevention and management, a solid organizational structure as well as a planned, all-encompassing strategy are essential[12].

So, this study has been conducted at Char Bhurungamari and Paiker Chhara union in Kurigram district of Bangladesh to understand the current existing adaptation strategies, flood impacts, and role of the community at various levels of flood management. The study's main objective is to identify the impacts of floods and assess the community's contribution to flood management in the study area. This study is important to understand the actual scenario of flood management and community involvement situations of flood disasters.

2. MATERIALS AND METHOD

2.1 Study area

The study was conducted in 11 villages situated in the Northwestern part of the country, Paiker Chhara and Char Bhurungamari union of Bhurungamari Upazila under Kurigram district of Bangladesh are selected as the study area.

This areas are mainly agricultural dominant area and they produce paddy, jute, potato, maize etc. They also practice cows, goat, duck and hen for earning and overall literacy rate in this area is still poor due to poverty.

2.1.1 Bhurugamari upazila

Bhurungamari Upazila (kurigram district) area 236 sq. km, located between 26°02' and 26°14' north latitudes and in between 89°36' and 89°48 east longitudes. Density 835 (per sq. km). In contrast to the overall mean of 58.77% illiteracy, Bhurungamari does have an educational attainment of 39.57% on the mean (7+ years) [13]

2.1.2 Paiker Chhara union

The area of Paiker chhara union is 22.911 km² and located at 26°06'31.9"N to 89°42'16.6"E, the total population of this union is 24802. The male of this area is 12230 and the females are 12572 and the number of eating people is 6310 [13].

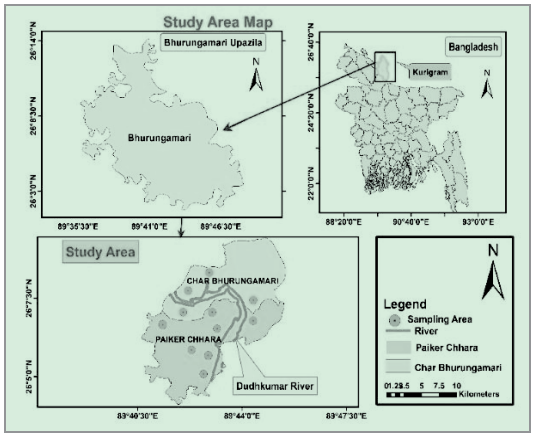

Fig. 1: Study area map

2.1.3 Char Bhurungamari union

The area of Char Bhurungamari union is 19.261 km² and located at 26°07'59.4"N to 89°43'59.3"E, the total population of this union is 14720. The male of this area is 7188 and female is 7532 and eating persons 3708 [13]

2.2 Dudhkumar river

The Dudhkumar River originates in Bhutan's Himalayan Mountain range that flows southeast across India before emptying into the Brahmaputra streams in Bangladesh. It is situated in the northwestern part of Bangladesh's Northern part area. The watercourse joins Bangladesh close to Shilkhuri inside the Kurigram municipality's Bhurungamari Upazila. The riverbed is 220 kilometers long and has an area of approximately roughly 5,800 sq. km, from which over 240 total areas would be in Bangladesh. The coverage region is located outside of Bangladesh in around 96% of cases [14].

2.3 Location and sources of survey sites

Table 1: Location and spots of the survey

Name of villages	Latitude	Longitude	Union
Gochidanga char	26°06'00.2"N	89°42'30.2"E	Paiker Chhara
Pateswari para	26°6'15.36"N	89°42'20.41"E	
Paikdanga char	26°7'3.24"N	89°42'51.0"E	
Beldah	26°5'6.48"N	89°42'53.36"E	
Ariarkuti	26°6'48.47"N	89°41'22.63"E	
Jolapara	26°5'18.14"N	89°43'0.52"E	
Chhit Paiker Chhara uttarpara	26°5'54.88"N	89°43'28.31"E	
Arazi paikdanga	26°7'7.62"N	89°44'14.04"E	Char Bhurugamari
Bahalkuri	26°8'16.10"N	89°42'11.69"E	
Islampur purbapara	26°8'14.10"N	89°42'9.61"E	
Samader ghat	26°7'9.65"N	89°41'33.10"E	

2.4 Socio-demographic status in the study srea

In assessing the flood sanitary picture of the study area, notably in words that information linking ability, accurate evaluation of interviewees' social and demographic traits is essential. To make it easy to obtain the findings, the survey replies had split into different categories. Many inquiries were made of the responder, which provided important phenotype information. This questionnaire contained personal data like age, gender, education, spouse, occupation, salary, earnings close relatives, and others due to the significant correlation between healthcare and vulnerability along with environmental sanitation.

2.5 Data collection

A field survey was conducted to collect primary data from the local community through questionaries. For the secondary data collection, the literature review was conducted, and extracted data from some authentic data sources. The study questionnaire is provided in Table 2.

2.6 Impact assessment

Assessment of impact was conducted by analyzing the data collected from the local community by statistical methods. Various impacts percentage were obtained by the analysis of data and evaluated their vitality by graphical representation namely Bar Chart, Pie Chart, etc.

3. RESULTS AND DISCUSSION

3.1 Respondent's age group & sex ratio in the study area

Table 2 shows that the age group status of the respondents varies. In Table 1, below 20 age respondents 6%, 14.5% of respondents aged between 21-30, 26% of respondents aged between 31-40, 23.5% age respondents aged between 41-50, 18% of respondents aged between 51-60, and 60 above respondents are 12% in the study area. The study had a total of 200 participants, with a male-to-female ratio of 47% to 53%. According to estimates, the typical dimensions of the family in tragedy zones is 4.54, which is a bit larger than just the global rate [15]. The percentage of people for both Upazilas used to have a household of four to five people [16]. However, Poor levels of literacy, a high parental number, and income increase the study homes' susceptibility to flooding [17] .

3.2 Household pattern in the study area

Bhurungamari Upazila is a poor upazila in the Kurigram district. We know that the Kurigram neighborhood is impoverished. Another study finds that, In the char-land area, most of the people (more than 80%) live below the poverty line [18]. The majority of inhabitants in the Paiker Chhara Union and Char Bhurungamari Union are poor. As a result, the housing pattern in this area is poor, and the average household size is small. The survey, states that the household pattern status of the respondents varies. In the figure, 65% of respondents' households are tin, 20.5% jute, and straw 8.5%, building 4%, and 2% in the study area. Most of the homes have kutcha or mid architecture and Jhupri, in contrast, side, contributed 0.93 [15]. However, the home building does, in effect, help to lessen the effects of flooding [19]

Table 2: Questionnaire used to conduct the study

SN	Question	Remarks
1	What's your name?	
2	What is the name of your union?	
3	How many members of your family and their sex and age?	
4	What types of houses do you live?	(Tin/Straw/Jut/Building/Others)
5	What is the main disaster in your region?	(Flood/ Drought/ Salinity/ Sidr/Aila/ Others)
6	Types of floods in your region?	(Flash floods/River floods/Monsoon floods/ Others)
7	Duration of floods in your region?	[Shorter (<1 month) / Medium (15 days)/ Longer (> 1 month)]
8	Which sector is more damaged during floods in your region?	(Agriculture/Cooking/Residents/Health/Sanitation/Transport/Livelihood/ Education/ Food security)
9	Sanitary condition of your houses during floods?	(Protected/ unprotected)
10	Which way do you get flood information in your region?	(Indigenous knowledge/ Electric device/ Warning by mouth/ Warning by organization/ Warning by govt/ Others)
11	Role of community in pre-flood activities?	(House repairing/ Making matcha/ Preserve dry food/ Preserving vegetable seeds/ Collecting dry wood/ Plantation/ Making portable stoves/ Collecting medicine/ Preserving pure water/ Emergency cooking materials/ Making boats or rafts)
12	What kind of action is taken during floods?	(Role of family homage/ Role of health/ Looking livestock/ Searching pure water/ Collecting relief/ Boiling unsafe water/ Regular flood water monitoring/ Poisonous wormier thinking)
13	What kind of roles are played by women after the flood?	(Collect to new soil/ Homestead gardening/ Elevation and repair houses/ Livestock rearing / Making fence)

Table 3: Age group and sex ratio (Field survey, 2021)

	Group	**Respondents Number**	**Percentage**
Ages (year)	>20	12	6%
	21-30	29	14.5%
	31-40	52	26%
	41-50	47	23.5%
	51-60	36	18%
	60 +	24	12%
		Total=200	Total=100%
Sex			
	Male	**Female**	**Percentage**
	47%	53%	Total=100%

3.3 Seasonal disaster schedule in the study area

According to the responders, regular floods occur from April through September, peaking in July and August. Normal river erosion occurs from June to September, peaking in July and August. In char regions, bank degradation is a frequent occurrence, then both studied locations experience this often and a million-acre of the area gets lost due to riverbed degradation each year[20].

Then there's manga, which is a natural phenomenon among Kurigram residents. As a result, the residents of Paiker Chhara and Char Bhurungamri are also dealing with comics. It's usual manga in this area from April to September, and it's at it peak in July and August.

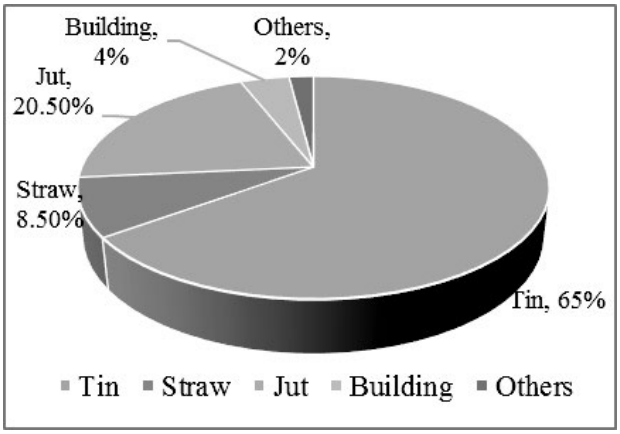

Fig. 2: Household types (Field survey, 2021)

3.4 Major flood-impacted sectors in the study area

The study revealed that the affected area status of the respondents varies. In the figure, 29.5% of respondents are affected by the agricultural sector during floods, 7% by transport, residence 11%, health 4.5%, livelihood 22%, cooking sector 15%, food security 5%, livestock 4% and education 2% in the study area. According to a survey, the most flood impacts area is agriculture.

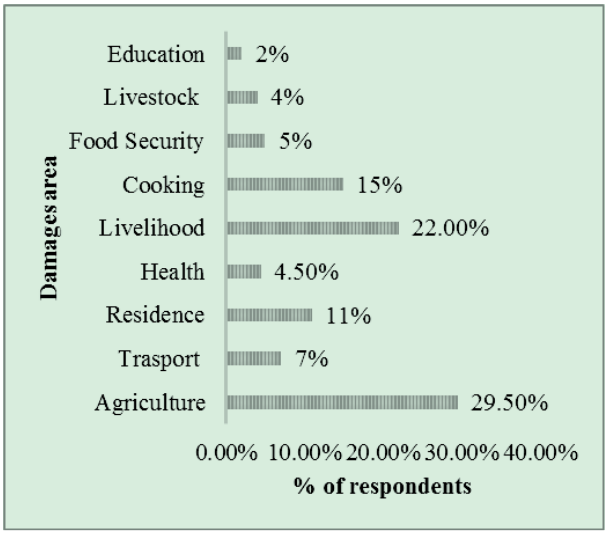

Fig. 3: Most flood-affected areas

BBS authority investigated that, Inundation had an impact on homes (54.69%) [15] and the life, prosperity, but also affordable growth of Bangladesh is now seriously threatened by steam environmental concerns including temperature and climate challenges [21]. It is clear that compared to homes, the estimated daily harm to households in non-shelters was larger. However, the authorities as well as non-governmental groups made an effort to offer financial assistance and many kinds of essential items [22].

3.5 Types and duration of floods

The study area is situated on the bank of the Dudhkumar River. So, river flooding is a common phenomenon in the study area. Every year study area is facing flooding and riverbank erosion. A flash flood is also responsible for heavy losses in the northwest of Bangladesh. Highways, houses, and even food were all destroyed by catastrophic severe flooding in Pakistan, creating a trail of devastation with death [23] . In (Fig 4), it was stated that the types of floods vary. In the figure, 68.5% of respondents' perceptions are river floods, monsoon floods 16 %, 12.5% flash floods, and others 3% in the study area. (Fig 5), represented that, 19% of respondents' perception duration of floods is shorter, 69% longer, and 12% mid-range in the study area. Here, longer means < 1-month, shorter means >1 month, and mid-range means about 15 days. This catastrophic event is a quick surge of rainwater through land that is often brought along by rainstorms [24]. Another author reported that, throughout Bangladesh, the rainy season alongside the different intensities of related floods was expected every year [25].

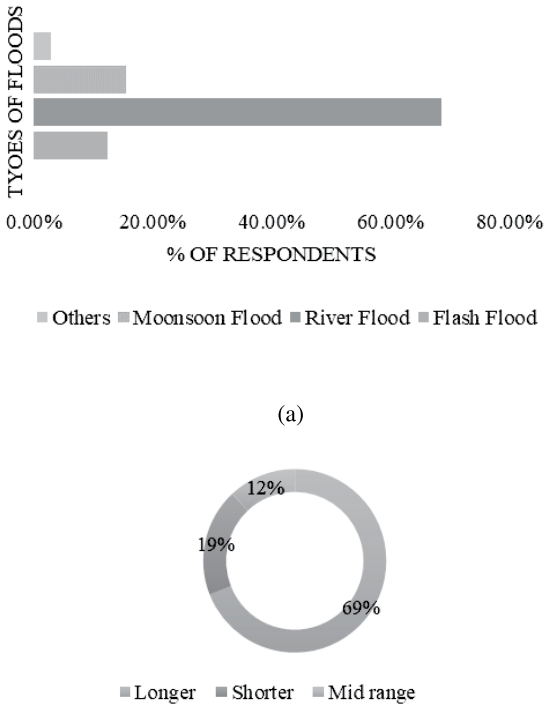

Fig. 4: (a) Types of floods and (b) Duration

3.6 Sanitation conditions during floods

At the time of floods, in study areas, women face severe sanitation crises. Because women feel shame to go outside of the home. But a male member can toilet in an open place during floods in rural areas of Bangladesh. In (Fig. 5) stated that the sanitation condition status of the respondents varies. In the figure 85% of unsafe sanitation and 15% of safe sanitation during the flood in the study area. Mahmood, 2004 claims that now in Bangladesh, the majority of illnesses get brought due to a scarcity of sanitary facilities but mostly impact the poor people and especially those in remote regions [26]. However, Rangpur had the highest proportion of families who practiced public incontinence 4.98%percent [15]

3.7 Sources of floods information in the study area

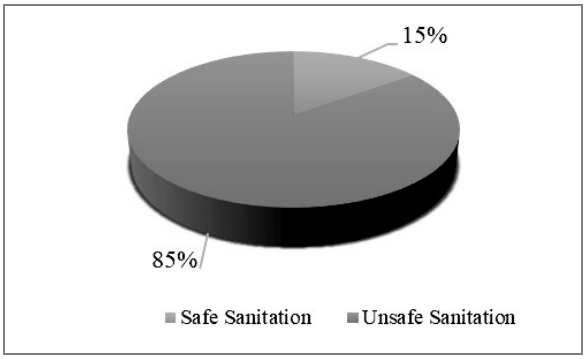

Fig. 5: Sanitation status

Flood information is obtained from a variety of sources, according to respondents in the research area. They do, however, find the most information from indigenous knowledge, followed by electric devices, which include television, the internet, and other electronic devices. They also obtain knowledge through conversing with others; for example, a female goes from one house to another, discussing impending floods. In the Republic of Korea, teaching about disasters often takes the shape of talks, and practical exercises, including scenarios [27]. The study revealed that the sources of information in the study area vary. In (Fig. 6), 7% of respondents find warnings by an organization, 32.5% warnings by electric device, indigenous knowledge 37.5%, the word with mouth11.5%, warnings by government 3.5%, and 8% in the study area. Another paper reported numerous lives, as well as homes, could be saved because of catastrophe forecasts, detection systems, and neighborhood flood mitigation. To disseminate catastrophe alerts, the EAS design allows the use of networks of TV and radio stations [28] . However, Training in catastrophe planning may typically be required [29].

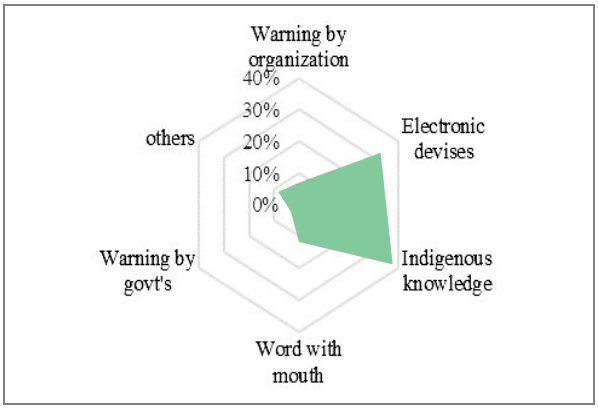

Fig. 6: Various flood Information Sources

3.8 Role of community in pre-flood activities

The study revealed that the pre-flood status of the respondents varies. In the figure preparedness and repair houses as 30% male, 60% female, and 10% are children. Making matcha males 65%, 25% female, and 10% are children, preserving dry food respectively male 65.5%, female 28.5% and 15% of children are preserved food. Collecting dry wood males 75%, females 20%, and children 5%, Preserving vegetable seeds males 5%, females 95%, and no children are preserving seeds, Plantation males 44.5%, females 35%, and children 20.5%, 95% stoves are made by the female, 5% children help their mother to build the stoves, Collecting of medicine as male 84.5%, 10% female and 5.5% are children, Preserving pure water as male 15%, female 85%, making boat/ rafts male as 95%, female 2% and children 3%, collecting emergency cooking material as a male 5.5%, female 90.5% and children 4% in the study area (Fig. 7). Another paper revealed that women performed the majority of such chores to defend against storm danger. Its current work aids in reducing losses from disasters [30].

3.9 Respondent's contribution to flood

The survey states that the roles of respondents during floods vary. In the figure 55% were female, 20% male, both 20% and 5% had no response as a role of family dignity, 75% female, 14.50% male and 10.5% both as a role of health, 59.50% female and 15% male, 21.5% both and 5% no response as looking livestock,85% female, 10% male and both 5% are searching pure water during floods, 19.50% female, 65.50% male, both 10% and 5% no response as a role of collecting relief, regular flood water monitoring as male 45%, female 10%, both 45%, concern/ thinking poisonous wormier as male 40%, female 45%, both 5% and no response 10%, boiling unsafe water as male 3%, female 92% and both 5% during floods in the study area (Fig. 8). However, women will not receive enough aid, therefore, aren't seen as the main provider for the home and [31] reported that females also usage make foldable burners, gather charcoal, manufacture needed medications, create raw food like Chira, Muri, and Khoi (each produced of rice), sugar and bread, but applied money for the children's expenses.

3.10 Role of women in post-flood activities in study area

In Fig. 9, 5% of female respondents are carrying to new soil, homestead gardening 19.50%, elevation, and repair of houses 31.50%, livestock rearing 32%, making fences 3% and 9% traditional handicraft and embroidery as the role of post-flood activities in the study area. House gardening is both a successful business and a reliable source of minerals for family restaurants [32]. Post-flood rehabilitation is one of the most important stages of neighborhood reconstruction since work related to it is frequently handled by women [30].

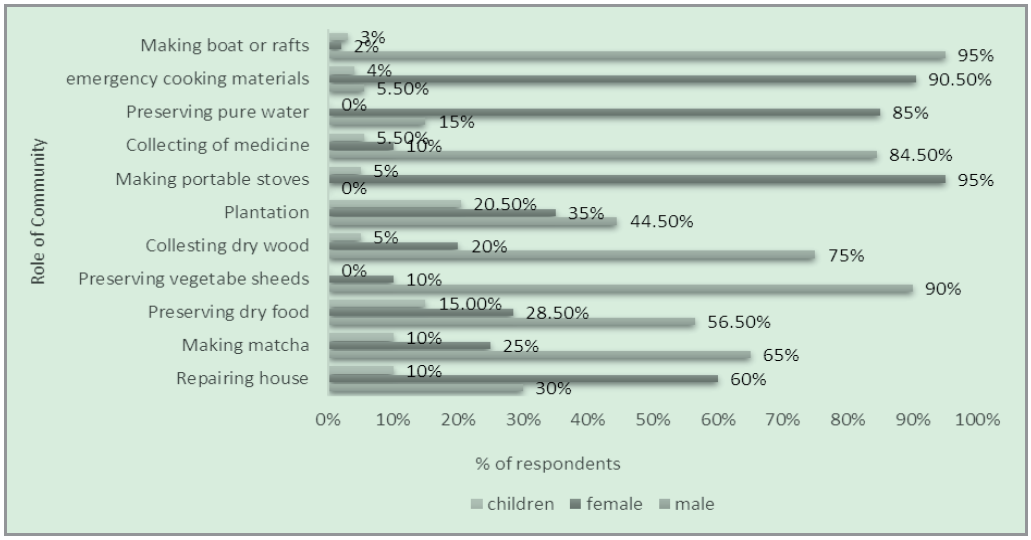

Fig. 7: Pre-flood status of respondents

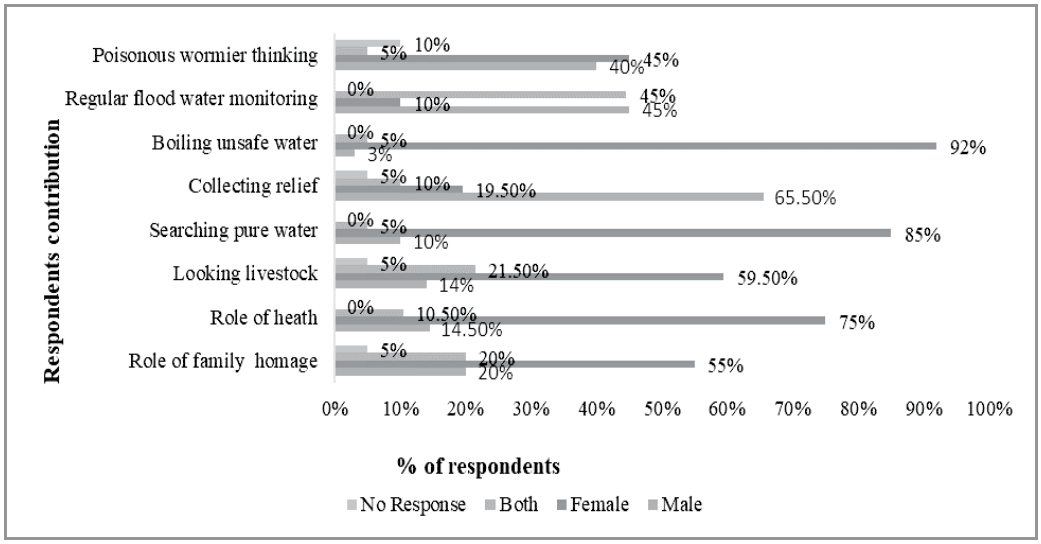

Fig. 8: Community response during floods

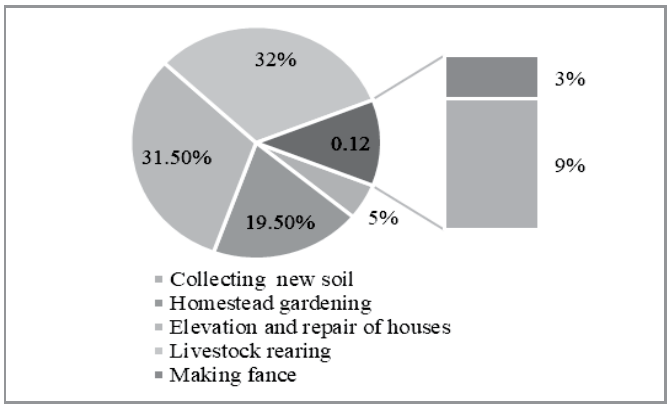

Fig. 9: Post-flood activities of women

4. CONCLUSION

Because of its geographical location, the Paiker Chhara and Char Bhurungamari union in Kurigram's Bhurungamari Upazila is prone to flooding. Dhudhkumar River, where the research area is located severely faces monsoon floods. Moreover, a flash flood is also sometimes seen here. Most of the local people live in Tin made houses here and so more prone to the adverse effects of floods and are mostly affected by the agricultural sector. Their livelihood is also hampered by the long-lasting flood disaster within the area. Both men and women try to prevent and manage the flood disaster in different ways within different phases of the flood. Men mainly work outdoors to manage flood disasters like making boats and preserving vegetables shed, etc. whereas women contribute by indoor job mainly as making potable stoves, preserving fresh water, boiling water to purify, etc. Children are also seen to help their parents with little effort such as preserving dry food, making Macha, etc. After evaluating all of these it was found that Char people's economic situation is dire and leads to hardship in life. Although various non-governmental organizations (NGOs) work in the area, further monitoring and work progress should be evaluated by the authority to efficiently help the flood affected. Furthermore, the government should assist flood victims with food and medicine, also ensuring transparency in the provision of these materials. More studies could be conducted in the area to identify opportunities to resist and manage flood damages and improve the health and livelihood of the local community.

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Assessment of Future Drought Condition Over Bangladesh By Using SPI and SPEI Indices

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ABSTRACT

Climate change is expected to cause an increase in the frequency and severity of droughts in many regions of the world, including Bangladesh. This study aims to assess the future drought conditions of Bangladesh using the latest climate model simulations from the Coupled Model Intercomparing Project Phase 6 (CMIP6). We analyzed the results of ACCESS-CM2 model derived from CMIP6 that was run with SSP5- 8.5 scenario. We used the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) to identify and characterize drought events. We compared the drought conditions of the historical period (1981-2018) with the projected conditions for the future periods of 2021-2050. Our results indicate that, in general, the frequency and severity of droughts are likely to increase in Bangladesh in the future, with the greatest changes projected for the next decades. We found that the northern and northwesterly regions of the country were likely to experience the most severe droughts in the past. Additionally, the spatial distribution of change in drought characteristics indicates that the drought-vulnerable areas will be shifted from northwestern to central and southern coastal in the future due to climate change, which could have significant implications for agriculture, water resources, and food security in the country. Overall, our findings suggest that urgent actions are needed to improve the resilience of Bangladesh to future droughts, including the development of drought preparedness and response plans, the promotion of water-efficient agriculture practices, and the implementation of effective water management strategies.

Keywords: Drought; CMIP6; Climate change; SPI and SPEI; Bangladesh

1. INTRODUCTION

Drought is a period of unusually dry weather that is severe enough to generate a hydrological imbalance and has implications for a moisture shortfall with regard to human water use [1]. Drought is one of the most frequent climate extremes in Bangladesh [2]. Early drought warnings and assessment of the present drought condition are crucial in an overpopulated country like Bangladesh where food security is always a serious problem. Early warning assists farmers and agricultural administrators to take the required precautions to prepare for future droughts. On the other hand, the relevant policymakers will use the information on drought to take early and appropriate decisions to maintain food security in the country whenever drought occurs. Therefore, the necessity for a drought early warning system is essential. Many well-known drought indices have been developed globally to evaluate the severity of droughts: The Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI), and the Standardized Precipitation Evapotranspiration Index (SPEI). Temperature and precipitation are needed as information sources for PDSI, but unlike SPI, it is unable to evaluate multi-scale drought features[3]. In Bangladesh, some studies were conducted to identify historical drought by using SPI and SPEI [4], [5], [6]. Several studies have been carried out to evaluate future changes in drought characteristics over Bangladesh using

CMIP5 climatological projections [7], [8]. In spite of the fact that a few studies have been carried out on future drought predictions, not a single study has been carried out in the past on the process of future drought assessment by using the newly-released CMIP6 dataset under future warming scenario SSP5-8.5 in Bangladesh.

With the aforementioned information in mind, the aim of the research is to forecast future drought characteristics by examining the future changes in drought duration, frequency, and intensity as represented by the ACCESS-CM2 model from the CMIP6 dataset using the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) under several future scenario SSP5-8.5. This study's findings can assist decision-makers, planners, and all other stakeholders in getting a great potential for development and better preparation for the decades to come.

2. STUDY AREA

The country of Bangladesh is usually located between latitudes 20.34° - 26.38° N and 88.01° - 92.41° E. It shares borders with Myanmar in the southeast, the Bay of Bengal in the south, and India on three of its four sides (west, north, and northeast) (Fig. 1). The Ganges, Brahmaputra, and Meghna (together known to as the GBM river system) are the three main river systems that flow through the nation, which is a low-lying flood plain. The country's height varies from just above mean sea level (MSL) in the south to 105.

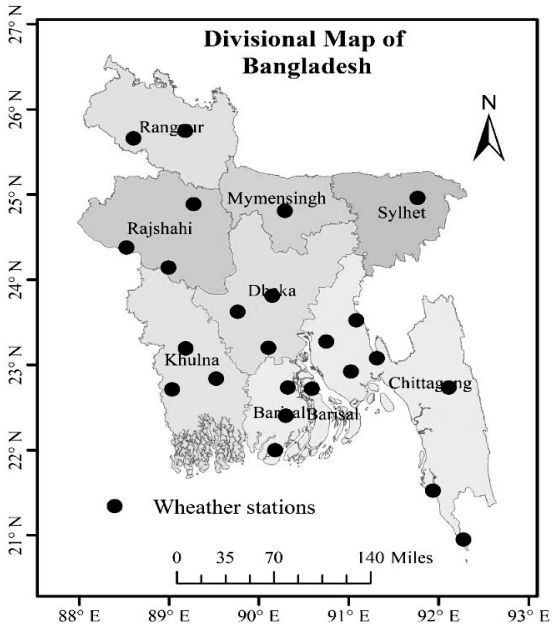


Fig. 1: Geographic location of Bangladesh showing 8 administrative divisions

meters above MSL in the north [9]. The country was divided into eight administrative divisions and the northwestern divisions were highly prone to severe droughts. The northeast and southeast of the country, however, have little raised areas and hills. In contrast to many other nations with tropical climates, Bangladesh experiences hot, humid summers with significant monsoon rains. In recent years, Bangladesh has experienced rising sea levels, more intense weather events, and more variable rainfall [10]. Bangladesh is extremely vulnerable to the effects of climate change, and the country is especially susceptible to drought due to its geographic location, physiography, seasonal low rainfall pattern, high rainfall variability, more extreme weather events (especially an increase in temperature), and high population density [10]–[14].

3. DATA AND METHODS

3.1 Observation and CMIP6 data

Mainly two types of data i.e., precipitation and temperature were used for the period 1981-2018 and 2021-2050. The Bangladesh Meteorological Department provided the 24 weather stations included in this historical climate data set (BMD). This study analyzed simulation results from available climate models that participated in CMIP6 [15]. In replicating Bangladesh's annual and seasonal rainfall and temperature, Kamruzzaman et al., (2021) revealed that MIROC5 was the most proficient among CMIP5 GCMs while ACCESS-CM2 was the most proficient among CMIP6 GCMs. Hence, in this study the climate model ACCESS-CM2 among CMIP6 GCMs has been selected.

3.2 Methods

SPI and SPEI, two indices from a variety of meteorological drought indices, will be utilized in this research. While the SPEI calculation needs both rainfall and mean temperature data, the SPEI calculation simply needs rainfall data. The "ClimPACT2" program will be used to calculate the SPI and SPEI indices [16]. SPI and SPEI values over three months represent short-term drought features, SPI and SPEI values over six months show medium-term drought conditions, and SPI and SPEI values over a year reflect long-term drought conditions for an area. For the purpose of identifying long-term droughts, the SPI and SPEI indices were examined for periods of twelve month. The twelve-month indices for December in this case comprise data from January to December. The SPI and SPEI values are standardized so that the mean is zero and that positive and negative values, respectively, indicate wetter and drier than normal conditions. Due to the similarities of their philosophies, the SPI and SPEI employ the same drought category categorization criteria. Table 1 displays the categorization of the SPI and SPEI indices.

Table 1: Drought category using the SPI and SPEI

SPI Values	SPEI Values	Category
2 and above	2 and above	Extremely wet
1.50 to 1.99	1.50 to 1.99	Very wet
1.00 to 1.49	1.00 to 1.49	Moderately wet
–0.99 to 0.99	–099 to 0.99	Mild drought
– 1.00 to – 1.49	– 1.00 to – 1.49	Moderate drought
– 1.50 to – 1.99	– 1.50 to – 1.99	Severe drought
≤ – 2.00	≤ – 2.00	Extreme drought

Following the computation of both indices, correlation and regression techniques will be used to determine whether there is a correlation between SPI and SPEI in various Bangladeshi regions. In order to evaluate the trends, frequency, and severity of droughts between the study periods of 1981-2018 (historical) and 2021-2050 (future period) several statistical studies will be carried out. The following flowchart outlines the study's approach (Fig. 2).

Drought indices will be mapped using the Geographic Information System (GIS). The SPI and SPEI station-based findings across Bangladesh will be interpolated using the well-known and most often applied deterministic method for SPI and SPEI mapping, Inverse Distance Weighted (IDW) [17]. The IDW is a straightforward deterministic interpolation technique based on the hypothesis that sample values closer to the forecast location have a bigger impact on the prediction value than sample values farther away.

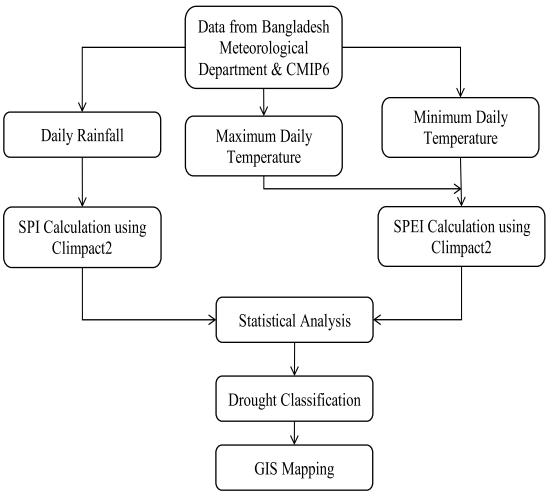


Fig. 2: Flowchart of the methodology of the study

Time series drought analysis has identified the most extreme and severe drought years, and then geographical variations for the worst drought years have been detected.

4. RESULTS AND DISCUSSION

4.1 Time series and spatial distribution

This study looked at time series and spatial distributions from 1981 to 2018 and 2021 to 2050. We illustrate the performance of the drought index computation for drought identification. Based on the frequency of the incidents for each drought category at 12-month timescale, drought risks in Bangladesh have been evaluated. Using ArcGIS 10.8 software, the SPI and SPEI were computed from the observed stations data and interpolated at each time step to establish the spatial extent of the drought in Bangladesh.

4.1.1 Time series for historical period (1981-2018)

Using monthly rainfall and temperature time series data from 1981 to 2018, the SPI and SPEI techniques were used to assess the historical droughts over Bangladesh. The results indicate that multiple drought episodes occurred at various time periods, taking into account extreme, severe, and moderate droughts. The two worst of them, for SPI-12 and SPEI-12, respectively, were measured in the years 1992-1993 and 1994-1995 (Fig. 3). According to Banglapedia these droughts caused significant damage to crops, particularly to rice and jute, the primary crops of northwest Bangladesh[18].

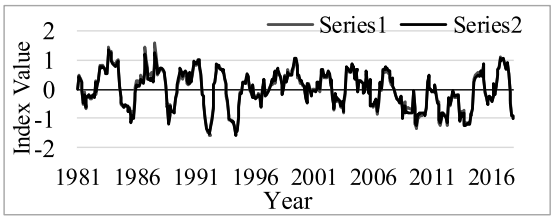
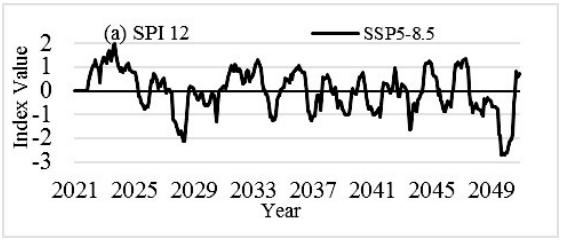
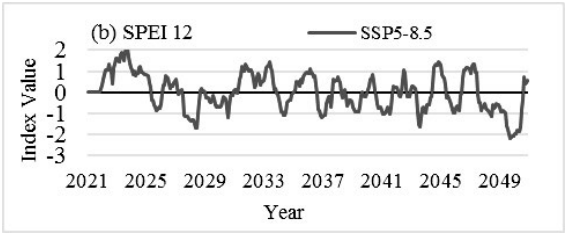


Fig. 3: SPI and SPEI values for the entire Bangladesh 12-month timescales

4.1.2 Time series for future period (2021-2050)

Figures 4a-b show the value of SPI and SPEI at 12-month timescales over Bangladesh under the scenario SSP5-8.5 from 2021 to 2050. More extreme droughts have been seen by SPI-12 than SPEI 12 under scenario SSP5-8.5 (Fig. 4a). According to Fig. 4a, 2028 and 2049 would be the extreme drought years. On the other hand, SPEI-12 has predicted a less future extreme drought years than SPI-12. Only 2049 are observed as the extreme future drought year by SPEI-12 (Fig. 4b). SPEI-12 has evaluated the severe droughts in the years 2028, and 2043 (Fig. 4b).





4.1.3 Spatial distribution for historical period (1981-2018)

The enormous drought years in 1988–89, 1992–93, 1994–95, 2009–10, 2012–13, and 2014–15 were detected by SPI 12 (Fig. 5). Droughts occurred in these years as a result of the lower amount of rainfall . Except for winter, observed rainfall in Bangladesh is highest in the east and progressively declines to the west [9]. Rangpur, Sylhet, and Chittagong divisions suffered extreme droughts in 1994–1995, when Dhaka and Mymensingh divisions suffered severe droughts (Fig. 5c). Some parts of the Dhaka and Rajshahi divisions faced extreme drought from 2009–2010 (Fig. 5d). Fig. 5b shows that the middle to southern parts of the country experienced severe droughts. In 2012–2013, Mymensingh, Dhaka, and Barisal divisions faced severe droughts (Fig. 5e). Fig. 5a and Fig. 5f show that the northern part of the country experienced mild droughts.

Again, SPEI 12 has detected the significant drought years in 1985–86, 1988–89, 1992–93, 1994–95, 2009–10, and 2013–2014 (Fig. 6) . Except for the winter season, the annual and seasonal temperature is also highest in the western portion of Bangladesh and progressively declines to the east [9]. Therefore, western part faced more worst drought than other regions. Rangpur and Sylhet divisions suffered extreme droughts from 1994–1995, while other divisions suffered severe and mo derate droughts (Fig. 6d).

Dhaka, Khulna, Barisal and Rajshahi divisions faced severe drought in 2009–2010 (Fig. 6e). Fig. 6c depicts the severe droughts that occurred in 1992–1993 in Dhaka, Khulna, Chittagong, and certain areas of Rajshahi and Barisal divisions (Fig. 6c).

Mainly droughts are more frequent in Bangladesh due to high temperature and low rainfall. Our findings can be compared with Mia et al.(2017) and Uddin et al. (2020) [19], [20].

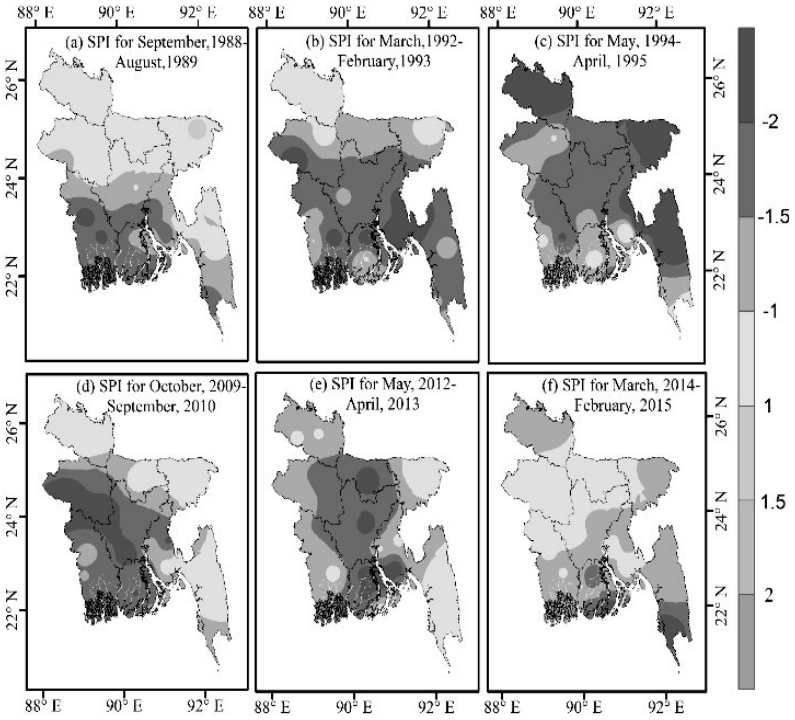


Fig. 5 (a-f)**:** Spatial distribution of SPI at 12-months scale in different years.

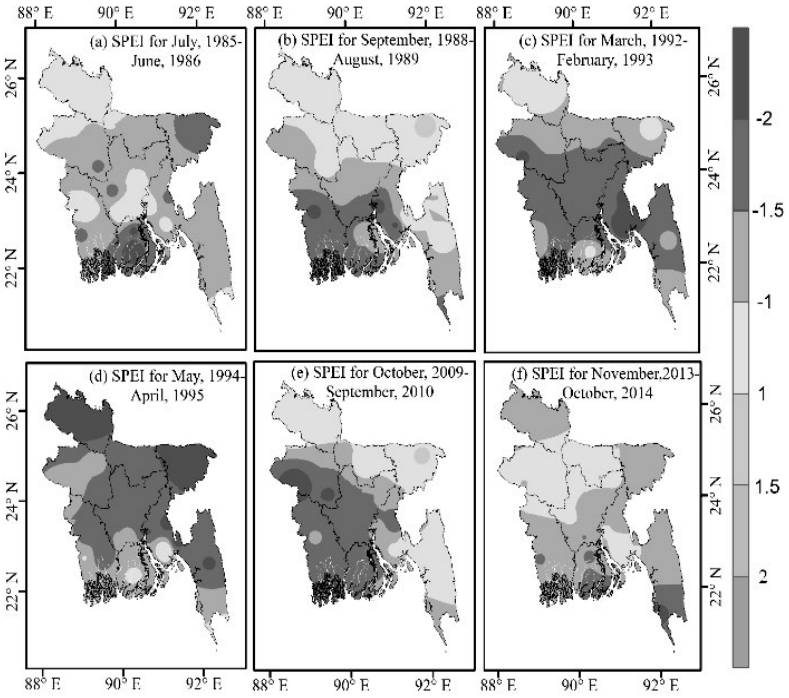


Fig. 6 (a-f)**:** Spatial distribution of SPEI at 12-months scale in different years

4.1.4 Spatial distribution for future period (2021-2050)

Figure 7 shows that the worst years for the extreme and severe drought, as forecasted by SPI-12's scenario SSP5-8.5, will be 2026-2029, 2032-2035, and 2041-2042. For Bangladesh's western and south-western areas will be faced more worst drought. Annual precipitation in most regions of Bangladesh is expected to rise in the twenty-first century, according to some reports. Drought-prone northern region will see the greatest increase in rainfall; however, rainfall in the southwest will decrease.
Therefore, that the drought-vulnerable areas will be shifted from northwestern to central and southern coastal in the future [8], [9].

Again, in accordance with scenario SSP5-8.5, the SPEI-12 will be the worst years for index predicts that 2027-2030, 2036, 2042-2043, and 2048-2050long term drought (Fig.- 8). SPEI-12 under scenario SSP5-8.5 was unable to identify more long-term extreme drought than SPI-12. The worst drought year among them will be in 2049 and 2050, when the entire country of Bangladesh would experience extreme and severe drought (Fig. 8e-f).

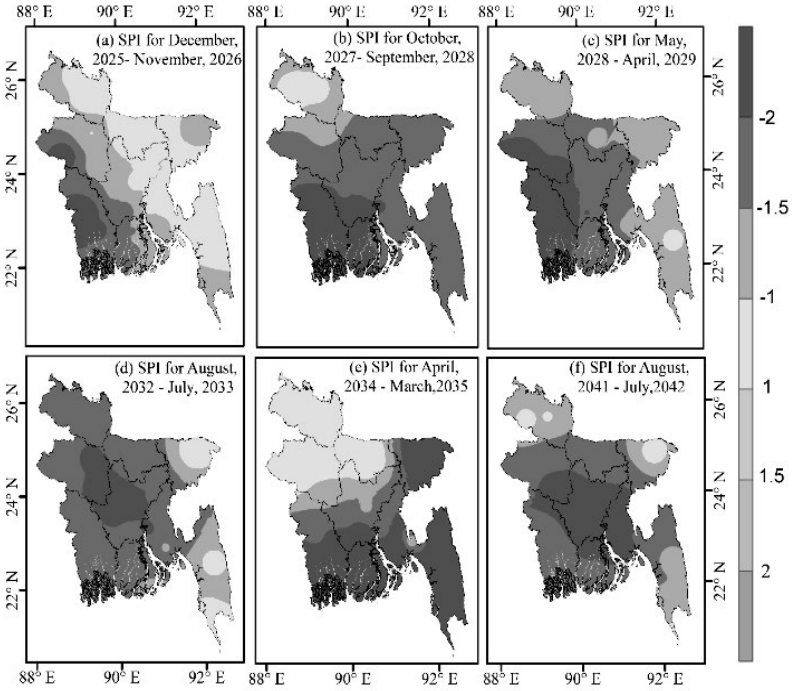


Fig. 7 (a-f)**:** Spatial distribution of SPI at 12-months scale in different years under SSP5-8.5

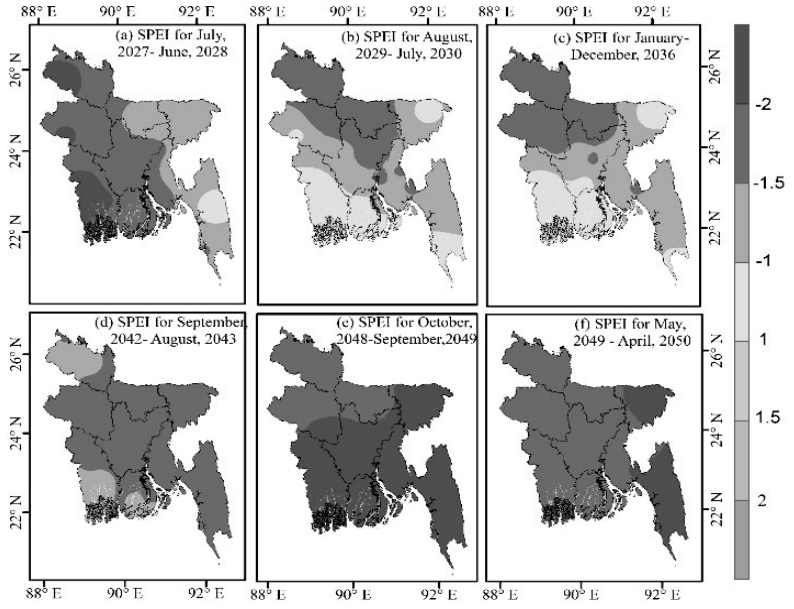


Fig. 8 (a-f)**:** Spatial distribution of SPEI at 12-months scale in different years under SSP5-8.5

4. CONCLUSION

This study provides valuable insights into the projected future drought conditions across Bangladesh using the latest generation of climate models, CMIP6. The results indicate that the country would probably endure more frequent and severe droughts in the future decades. The spatial distribution of change in drought characteristics indicates that the drought-vulnerable areas will be shifted from northwestern to central and southern coastal in the future due to climate change. The projected changes in precipitation and temperature patterns, along with the increasing population and growing demand for water, will pose significant challenges to the country's water management systems and food security. The findings of this study underscore the urgent need for policymakers and stakeholders to develop effective drought risk management strategies, such as improving water-use efficiency, implementing water conservation measures, promoting crop diversification, and investing in drought-tolerant crops. Additionally, it is essential to strengthen the country's climate monitoring and early warning systems to help farmers and vulnerable communities prepare for and respond to drought-related disasters.

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Typical Employee Health Impact of a Ceramic Industry in Bangladesh: A Case Study

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ABSTRACT

The heavy ceramic industry involves generating pollutants at a large scale and extracting them into the environment. Ceramics manufacturing requires high energy, several chemicals, and some solid raw materials, which result in a remarkable amount of pollutants. This study aimed to find the possible pollutants and their effects on human health and the environment at a ceramics factory in Maheshpur, Jhenaidh. A consistent survey indicates that the ceramics factory produces many pollutants at the time of ceramic production raw materials processing, batching, grinding, drying, press forming, firing, glazing, drying, printing, and packaging are the main steps of production. All steps are involved in generating pollutants. Besides pollutants, the ceramics factory produces lots of noise and a bad odor. The workers and people living around the factory are affected by all this, which is already visible in that area. Major health effects that are visible in that area are skin diseases, breathing problems, hearing problems, headaches, eyesight problems, and many other problems as this paper identified. Some visible environmental effects like solid waste generation, water contamination, soil damage, increasing temperature, and other problems. Some pollutants, which are not visible, like some gaseous pollutants, heavy metals, etc., that emit into soil, water, and air have some adverse effects on both the environment and human health. The factory is going to be a big threat to the environment of the area. The factory should take some initiative to overcome this problem. You have to create awareness among the worker to be careful at the time of working. To ensure a safe environment, the stakeholders have to ensure the lowest possible emission of pollutants into the atmosphere, water, and soil, as well as the least amount of noise and odor generation in the environment.

Keywords: Creramic industry; Heavy metals; Raw materials; Diseases.

1. INTRODUCTION

Pollution becomes the most important issue in this modern era. Industrial pollution is one of it. There are various kinds of factories in our country and around the world. This factory can emit many pollutants into the environment. One of the sectors is ceramic manufacturing. With the exception of some utilized in glazes and colors, the raw ingredients used to make ceramic products are all-natural. Raw materials that aren't made of clay are the other category. Kaolinite, illite, chlorite, and montmorillonite are the main minerals found in clays. Quartz, feldspar, calcite, and dolomite make up the majority of the mineral components in non-clay materials [1]. Around one million tons of chemicals are manufactured annually in high volumes, with the production of those chemicals increasing daily [2]. According to the World Health Organization, only outdoor air pollution is thought to be responsible for 2% of all heart and lung conditions, 5% of all lung malignancies, and 1% of all chest infections. The high energy and chemical requirements for ceramics manufacture produce a significant quantity of waste and pollution. The primary contributors to eco-toxicity include heavy metals like arsenic, copper, cadmium, chromium, zinc, and others found in these substances (barium carbonate, bentonite, boric acid, cadmium oxide, cadmium sulfide, calcite, ceric oxide, cupric oxide, and potassium dichromate) [3]. Heavy metals are pervasive, long-lasting, and not biodegradable. Metals with these qualities can be harmful over time. Metals build up significantly in sediment, where they eventually find the way into the food chain. chain via water, plants, or leaking into groundwater. Heavy metals are to blame for brain damage or diminished mental and central nervous system performance [4]. Gypsum waste is regarded as the second-most harmful material after clay debris. H_2S is characterized as a poisonous, flammable gas with a strong, offensive smell of rotten eggs. H_2S has various adverse effects on human health depending on its concentration, frequency, and exposure duration. Kansas Department of Health and Environment reported that H_2S gas at low concentrations produces irritation to human eyes and breathing problems for asthmatic patients. Above a concentration of 500 ppm, H_2S can cause serious damage to human health, such as spasms, respiratory arrest, and even death [5]. Heavy metals could enter the human body in three ways: ingestion, dermal contact, and inhalation. Therefore, children living in industrial areas may easily suffer from high health risks due to the contaminated urban soils. Many studies have demonstrated the negative effects of heavy metals on human health [4].

As a result of the manufacturing of ceramics, gaseous effluents containing various quantities of pollutants, primarily dust particles, lead, and fluorine, as well as other substances (oxides of sulfur, nitrogen, and carbon; boron, zinc, calcium compounds, etc.) in minor or negligible quantities, are released into the atmosphere. Now, I am talking about a rural area of the Jhenaidah district near the

Tushar Ceramics Factory. This factory started its journey in this factory. It joins the party responsible for creating an uncertain situation in the environment. People in this defined area already face some problems. The main kinds of diseases are being spread after the 2017–18 season. This paper is going to tell you about the chemical pollution from this factory. Find out the way those pollutants interact with humans and its effects on human health. This study aims at identifying the pollutants and their potential sources, along with proper pathways, and understand the effects of the pollutants on human health.

2. MATERIALS AND METHOD

2.1 Research approach

A survey method is adopted to determine the typical employee health impact of a ceramic industry in Bangladesh based on the proposed objectives.

2.2 Study area

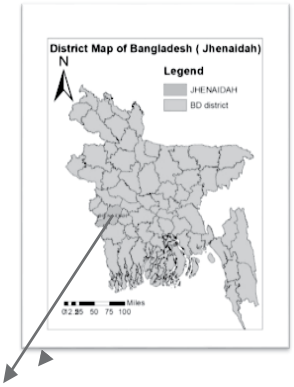
The name of the selected ceramics factory is Tushar Ceramics Factory which is located in village of Saratala under the union of Fatepur, 35 km away from the main town of Jhenaidah district and 4km away from the Masheshpur Upazila.

2.3. Sampling technique and sample size

The technique of stratified random sampling was used to obtain cross-sectional data for these studies. The labors and local people were selected randomly from within the selected areas. As a result, a total of 25 people were selected randomly (15 labors of the factory based on shift hour and 10 living people near the factory based on distance).

2.4. Data collection technique

Face-to-face key informant interviews with labors and people near the factory were conducted for data collection. Date of data collection was 15th June 2022 to 25th June 2022.



2017. We face many problems after starting the journey of

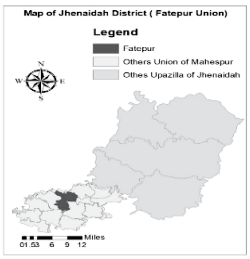


Fig. 1: Location of Tushar Ceramics Factory

2.5. Study tool

Survey questionnaires containing both structured and nanostructured questions about duration of shift and people's distance from the factory,health symptoms of the interviewers due to temperature, odor noise exposure etc.

2.6 Data analysis

All data were coded, entered and then analyzed using the Statistical Package for Social Sciences (SPSS) program, version 16 and MS excel 2019. Descriptive results were expressed as numbers, and percentages for categorical variables.

3. RESULTS AND DISCUSSION

3.1 Result and discussion of industrial production

Ceramics production brings about environmental pollution, which mainly includes air pollution, water pollution, and solid waste pollution. This kind of pollution can cause various negative effects on the environment and, above all, on humans. This paper is about those pollutants from the Tushar Ceramics Factory and their effects on human life. The production process for the general manufacture of heavy ceramics can be divided into four main stages: raw material preparation, shaping, thermal treatment, and post-processing.

3.1.1 Raw materials preparation

The receiving and storing of raw materials take place in the first stage. Moreover, they undergo batching, grinding, screening, and classification processes. Clays are particularly beneficiated and calcined for the production of refractory materials. During calcination, a ceramic material is heated to a temperature below its melting point to release unwanted gases or other components and cause structural change to generate the desired composition and phase product. Typically, calcination takes place in rotating kilns [6].

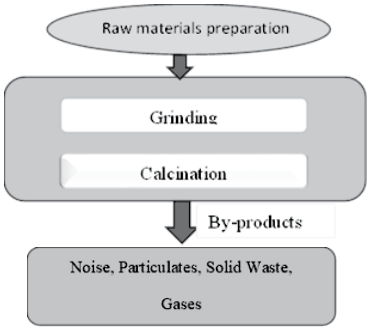


Fig. 2: Emission of pollutants at the stage of raw materials preparation

3.1.2 Shaping

After choosing the raw materials for the shaping step, they are blended with water to create a clay body with the desired qualities. Auxiliary materials (additives) may then be added The survey was carried out on 25 people. 15 of them were factory workers, and 10 of them were outsiders. Those 15 workers are divided into three groups according to their working time, and they are divided into four groups. Three working shifts are running here in the Tushar Ceramics Factory. Day shift, evening shift, and night shift (Table: 2.2) to the clay body to give the end product certain features (shrinkage, porosity, strength, color, and refractoriness) [7]. Afterward, the clay body is kept in silos and utilized for various shaping techniques, including soft or stiff mud molding, extrusion, and pressing, depending on the type of material, the amount of water present, and the final product that is to be created. Several processes, such as pressing, extrusion, or molding, can be used to carry out shaping operations [8].

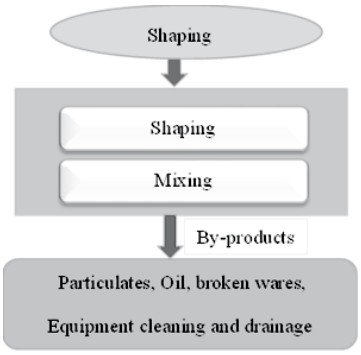


Fig. 4: Emission of pollutants at the stage of shaping

3.1.3 Thermal treatment

The ceramics must be preheated after being shaped. Drying is the initial process, which can be done outside or frequently inside tunnel kilns. Driers are heated primarily by waste heat recovered from the kiln's cooling zone and occasionally by burners powered by natural gas or fuel oil, raising the temperature to 120 °C over the course of a 24-hour period [8]. Secondly, firing occurs mostly in oxidizing atmospheres in gas-heated tunnel kilns, unless roller, Hoffman, or shuttle kilns are used. According to a particular product, the baked goods are programmed for various factors, like firing temperature or duration. In this method, clay pipes made of vitrified clay are heated to a maturation temperature between 1150 and 1250°C, while a wide range of refractory products is heated to a temperature between 1250 and 1800°C [9]. The manufacture of impregnated refractory shapes using pitch involves special procedures that require a low temperature (250–300oC) tempering in a kiln [8].

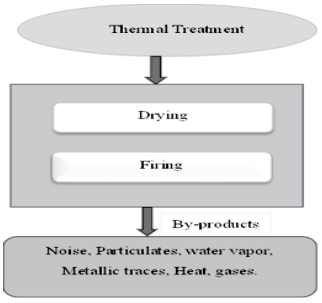


Fig. 3: Emission of pollutants at the stage of thermal treatment

3.1.4 Packaging and delivery

The finished goods are selected and inspected for quality, then packaged, shipped, and distributed in the final stage [10]. To seal the package containing the ceramic products, they utilize several types of plastic. Such plastic trash is produced during the packing process. Tushar Ceramics Factory transported the goods for marketing purposes using a variety of vehicles. To transport the raw materials, they also used trucks. Vehicle emissions can often be divided into three categories: hydrocarbons (HC), nitrogen oxides (NOx), and carbon monoxide (CO) [11].

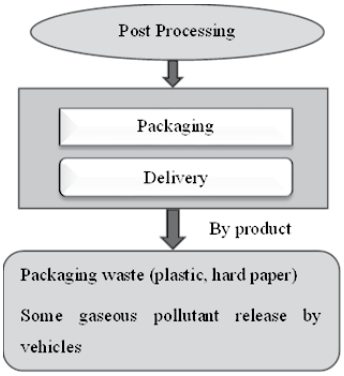


Fig . 5: Emission of pollutants at the stage of post-processing

3.2 Visual human effects of Tushar Ceramics Factory

The by-product of the Tushar Ceramics Factory causes some problems that are already visible. The four stages of production cause many solid by-products, liquid wastes, and gaseous pollutants. Besides this, the factory produces

lots of noise, odor, and heat-related to production. All these elements can be harmful to human health at some point, and these effects are already visible around the Tushar Ceramics Factory. The major problems in the area are breathing problems, skin problems, oculonasal problems, hearing loss, nausea, and headaches.

3.2.1 Breathing problem

Above the effects, the most visible effect is the breathing problem of the people in this area. Bad odors, SP, and various gases in the atmosphere may be the main reasons behind this scenario. The workers and people living around the factory get in contact with the dust and bad odor of the factory, which may be the main reason behind the breathing problem.

3.2.2 Water-borne diseases

This factory is near a channel, and the releasing liquid waste dumps into that side. Nevertheless, people are connected with this channel for their agricultural purposes. Therefore, it may cause various diseases like dengue, diarrhea, etc.

3.2.3 Hearing problem and headache

People who live near the factory have to face some severe problems as headaches and hearing loss may result from the high sound levels generated by the factory. Standard threshold shift (STS) is defined as a 10 dB or more change in the average hearing threshold at 2000, 3000, and 4000 Hz. So, even if the audiogram is not abnormal, a positive STS is important to find those workers susceptible to the hazardous effects of noise on hearing [12]. At the time of manufacturing, various machinery and Vachel's produce lots of noise around the industry. Occupational Safety and Health Administration (OSHA) requires that all workers exposed to noise greater than 85 dBA be screened for NIHL annually (US Department of Labor (USDL)). Fibers with diameters >3 m are essentially non-respirable in humans and therefore present no significant chronic health hazard [13].

3.2.4 Oculonasal Problem

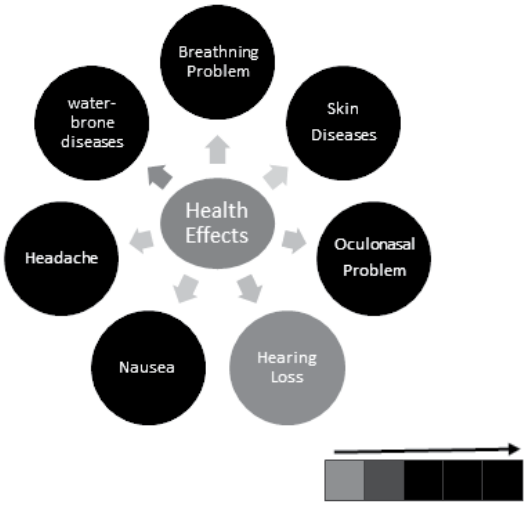
Some dust particles present in the atmosphere are very harmful to human eyes and noses. Industrial odors can cause oculonasal problems. Mainly during working hours, the worker and the shopkeeper close to the factory are affected by these dust particles and odors.

3.2.5 Skin diseases

Although mechanical irritation of the upper airways and skin can occur from fibers with larger diameters [14]. Nutrients, especially nitrogen, and phosphorus, stimulate the growth of toxic species of phytoplankton in both fresh and marine waters. consumption of toxic algae or irritation Organisms that feed on them can cause serious harm to humans and other terrestrial animals. The resulting toxins can cause skin damage [15].

3.2.6 Nausea

The bad odor that is speared by the Tushar Ceramics Factory in the atmosphere. Sometimes this bad odor is going to be in an intolerable situation. This bad odor can cause some problems, like nausea.



3.3 Result and discussion of survey among people

We made another survey among the workers and the living people near the factory of Tushar Ceramics Factory. We try to find out the major changes in that area in recent years and the major problems in the area. The worker and people living near Tushar Ceramics provide us with different opinions [Table 3.1]. The most visible problems at this moment in the factory are the increasing temperature, the noise problem, the odor problem, and the presence of dust in the atmosphere. The worker can have some problems that can be considered a limitation of the study. The problem of hearing, feeling, and seeing the dust particle is considered a limitation of the study. Another problem is the time of the survey. This paper is based on interviews with 15 workers at three different times when they worked in the factory. Therefore, this difference in time can be another cause of the difference in results. This is considered a limitation of this paper. Here in this survey, we got a very common opinion from the workers: increasing temperature [Figure 3.5]. The temperature has been rising steadily since the Tusher Ceramics Factory began its journey, as is typical for the factory's gaseous emissions. Figure 3.5 shows that there is an odor and dust present in the atmosphere of the area, and the noise becomes high at different times of the day.

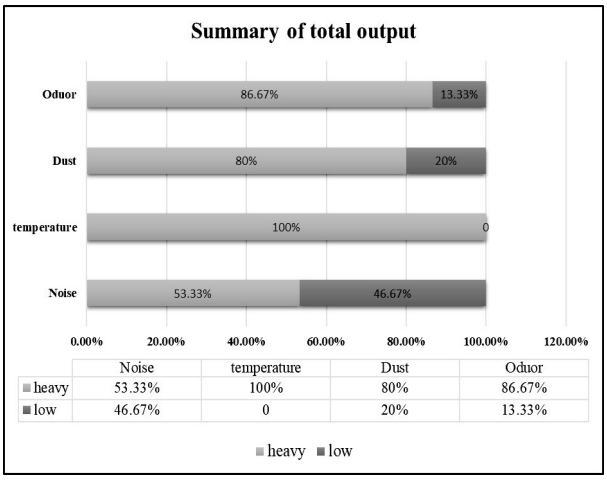


Fig. 7: Result of the survey among the worker of the factory

Another survey was carried out among the people living near the ceramics factory. We surveyed 10 people based on their distance from the ceramics factory [Table 3.2]. Here in this survey, some big trees, the flow of the air, and the problem of hearing and seeing the dust particles are considered limitations of the study. The survey also consists of four main problems in that area. According to the responses of all of the participants, the main problem that faces the people living in the area is the increasing temperature. There is also the presence of noise, odor, and dust in the area. Nevertheless, it is noticed that the presence of this is decreasing with increasing distance, according to the opinions of the participants.

In Fig. 3.6, the diagram shows that the intensity of the noise is high at a low distance, but with increasing the distance, the intensity of the noise is decreasing. After 800 m, the noise of the factory becomes low. Therefore, there is no chance of sound pollution from industrial activities, according to the survey.

Table 1: Survey results of the worker on the environmental issue

No. of Participant	Working Hours	Increasing temperature		Noise		Odor		Dust in atmosphere	
		Yes (%)	No (%)	Heavy (%)	Low (%)	Acrid (%)	Light (%)	Heavy (%)	Low (%)
05	Day shift	100	0	60	40	80	20	100%	0%
05	Evening shift	100	0	20	80	80	20	100%	0%
05	Night shift	100	0	80	20	80	20	40%	60%

We try to find out the major changes in that area in recent years and the major problems in the area. The worker and people living near Tushar Ceramics provide us with different opinions (Table 1). The most visible problems at this moment in the factory are the increasing temperature, the noise problem, the odor problem, and the presence of dust in the atmosphere. The worker can have some problems that can be considered a limitation of the study. The problem of hearing, feeling, and seeing the dust particle is considered a limitation of the study. Another problem is the time of the survey. This paper is based on interviews with 15 workers at three different times when they worked in the factory.

Table 3.1 shows that the increasing temperature is 100% to the respondents and noise level was varies among the working hours that heavy was in day, evening and night shift which was 60%, 20% and 80% respectively. On the other hand noise level is low at Evening shift which was 80%. Acrid was high for Odor and that is 80% all the shifts and Dust in the atmosphere was heavy at Day and Evening shifts.

3.3.1 Circulation of odor

Odors can circulate into the atmosphere through the air. In Fig. 3.7 is shown that the odor circulation near Tushar Ceramics Factory with distance. The first 400 meters from the factory are heavily polluted with industrial odor, as the participant's opinion which was 100%. After that, with increasing the distance, the intensity of the industrial odor is decreasing. 600–800 m, there is no presence of industrial

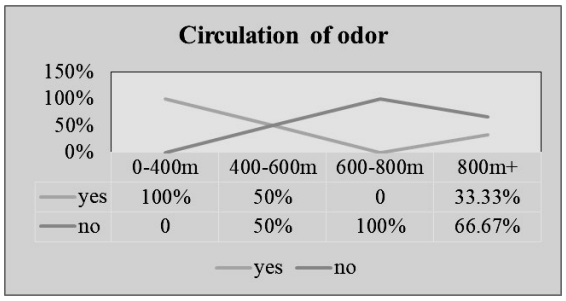


Fig. 8: Presence of odor in the atmosphere of the area with distance

Another survey was carried out among the people living near the ceramics factory. We surveyed 10 people based on their distance from the ceramics factory (Table 2). Here in this survey, some big trees, the flow of the air, and the problem of hearing and seeing the dust particles are considered limitations of the study. The survey also consists of four main problems in that area. According to the responses of all of the participants, the main problem that faces the people living in the area is the increasing temperature which was 100%. There is also the presence of noise, odor, and dust in the area. Heavy noise was 66.67% near 0-400 m and the presence of dust was in 0-400 m and no dust was more than 800 m according to Table 3.2. Nevertheless, it is noticed that the presence of this is decreasing with increasing distance, according to the opinions of the participants odor, but after 800 m, there is the presence of industrial odor, according to some of our participants. The reason for this is probably scattered airflow or something else, as we mention in our limitations.

Table 2: Result of the survey among the living people near thr factory based on distance

No. of Peo -ple	Distance (m)	Noise			Dust		Temperature		Odor	
		Heavy (%)	Moderate (%)	Low (%)	Yes (%)	No (%)	Increase (%)	Decrease (%)	Yes (%)	No %
03	0-400	66.67	33.33	0	100	0	100	0	100	0
02	400-600	50	50		50	50	100	0	50	50
02	600-800	-	50	50	0	100	100	0	0	100
03	800 +	-	-	66.67	0	100	100	0	33.33	66.67

So above all discussions, we can say that the people who live near the factory have to face some environmental and health problems because of industrial pollution. Especially, people who live around 400 m from the factory have high health risks, and people who live between 400 and 800 m from the factory are also moderately in danger. They have some effect on those who live near the factory and work there because of the emissions of pollutants into the air, water, and soil. Every uncontrolled factory is dangerous for the environment in that area of the factory. As the Tushar Ceramics Factory has an uncontrolled process of production, it will be more dangerous for the environment of the area day by day. The factory should take some initiative to reduce pollution of the environment. The method they followed to release the solid and liquid waste without any kind of planning is too harmful to the environment, and there is no treatment process for releasing wastewater from the factory. There is no proper management or planning for gaseous pollutants either. The use of methane gas and the release of some greenhouse gases increase the temperature day by day. This should be stopped or controlled as soon as possible. They should find an alternative method for the burning and drying stages of production. Otherwise, it is going to be difficult to maintain the natural environment as well as live near the Tushar Ceramics Factory.

4. CONCLUSION

Industrial growth is a very common scenario in this modern era. The era of economic growth is dependent on the industrial sector. The ceramics factory is one of those. A ceramics factory has a heavy production system, and this emits many by-products at the time of their production. The by-product can cause various environmental problems and many human health effects. At the time producing the ceramics product, it produces various physical, chemical, and gaseous pollutants. The factory emits the by-product and its extensions into the atmosphere, water, and soil. The byproduct works as a pollutant and causes pollution of soil, water, and the atmosphere, which has some negative effects on the environment and human health as well. Noise and odor are also produced by the ceramics factory, which causes noise pollution and atmospheric uncertainty. All this pollution and atmospheric uncertainty cause various health effects on humans. At the time of production, the ceramics factory produces some greenhouse gases. Greenhouse gases are responsible for global warming. So this factory is going to be a threat to the environment of the area. The factory should take some initiative to overcome this problem. You have to create awareness among the worker to be careful at the time of working. If we have to live a safe life, we just need a safe environment. To ensure a safe environment, we have to ensure as little pollution as possible in the atmosphere, water, soil, and noise emissions in the environment. If it is possible to ensure a safe environment, the safe environment will help you lead a safe life.

ACKNOWLEDGMENT

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Assessment of Future Groundwater Potential Zones using Multi-criteria decision-making Technique: A Case Study at Karnaphuli River Basin, Bangladesh

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ABSTRACT

The extraction of groundwater has been increasing globally for many reasons. This has accelerated the need to identify potential grondwater zones and it is important for any area in sustainable development as well. Remote sensing techniques with multicriteria decision analysis (MCDA) have a broad application including groundwater study. The current study aims to assess future (2041-2060) potential groundwater zones in Karnaphuli River Basin using MCDA in geographic information system (GIS) environment with compatibility of Analytical Hierarchy Process (AHP). Seven thematic layers have been preapared namely for geology, lineament density, topsoil permeability, precipitation, slope, land use land cover, drainage density. Weights and ranks assignment has been done based on Saaty's AHP model, extensive literature reviews and expert opinions. The final layer which is the integrated visualization of all seven layers depicts that in future around 1.11% of Karnaphuli River Basin area would have excellent potentiality as groundwater source, 18.49% would have 'Good' potentiality, 42.95% as 'Fair' and 37.45% as 'Poor'.

Keywords: MCDA, AHP, GIS, Groundwater, Remote sensing.

1. INTRODUCTION

Groundwater is an excellent natural resource of fresh water for drinking, irrigation, domestic and industrial purposes. Though 70% of the earth surface is covered with water, only 3% of this water volume is freshwater and groundwater contains 35% of total freshwater sources [94]. Nearly half of the global drinking water supply comes from groundwater [95]. The increasing population, the rapid pace of development and intensive agriculture to fulfill the growing global demand for food and energy have resulted in the overuse of groundwater and exposure to pollution. worldwide. As a consequence, groundwater levels are declining in many regions of the world and vulnerability to pollution is increasing [96],[97]. These phenomena will be severe in the future with changing climate if integrated sustainable management plans with proper scientific technology have not been adopted by authorities.

Prediction of future potential groundwater zone for any area is a part of sustainable management and resource plans. This particular prediction is generally done based on the natural recharge potentiality of groundwater. Various methods and techniques have been developed by researchers to assess natural recharge of groundwater such as a) hydrogeological technique b) geological technique c) geophysical technique, and d) remote sensing (RS) technique [97]. Among all these four, remote sensing technique get priority to many researchers considering the facts it saves times and costs, does not need rigorous physical experiments and allows to allocation of data for far future also. RS technique can be combined with numerous ways for example, logistic regression[98], frequency ratio model [99], random forest model[100], artificial neural network [101], support vector machine [102], decision tree [103], multi criteria decision analysis (MCDA) etc. MCDA model aligning with the analytical hierarchy process proposed by Dr. T L Saaty and Dr. Ernest Forman [104] is one of the most popular approaches in groundwater potentiality study for its simplicity, accuracy, flexibility and ubiquity [105]. MCDA-AHP can handle complex problems in a structured systematic way ensuring all relevant factors are considered [106]. Therefore, in this study geographic information system (GIS) based MCDA-AHP model has been adopted for future potential groundwater zone study.

In Bangladesh, 97% of rural people depend on groundwater for drinking needs [107]. Around 86% of the total extraction of groundwater in Bangladesh is used for irrigation purposes [108]. Many studies have already been done on different areas in Bangladesh including hilly areas for groundwater potentiality. However, no study has been found for the karnaphuli river basin assessment of future groundwater potential zone though this particular area in Bangladesh holds significant importance for natural resources, diversity of the ecosystem and future tourism potentiality. Hence, this study aims to assess future (2041-2060) groundwater potential zones in Karnaphuli river basin.

2. MATERIALS AND METHOD

2.1 Study area

The Karnaphuli basin lies between 21°54′30″ (N)–22°43′14″ (N) and 91°53′31″ (E)–92°36′44″ (E) located in the southeastern hilly region of Bangladesh, was selected for the study (Figure 1). This basin has total area of 2231.9 km2. This region extended to 15 upazillas within the Bandarban, Rangamati, Chittagong districts. The basin

consists of mainly three types of soils – alluvial, hilly and tidal swamp soil. Alluvial soil generally found in riverbanks which is rich in nutrients and has good to moderate drainage. Hilly soils are often rocky in nature and tidal swamp soils are generally observed in near coastal zones [109]. Apart from these, red soils and soil with acid sulfate also lie in this basin. (link) The whole area experiences heavy rainfall during monsoon and tends to increase in future (CMIP6**).**

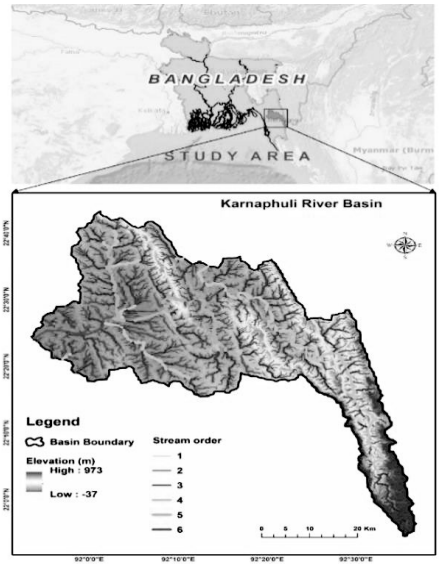

Fig. 1: Karnaphuli river basin

2.2 Data & generation classification of thematic layers

Both primary and secondary data set have been used in this study. Data source and associated tools, application procedure etc. have been presented at below table,

Table 1: Data sources and applications

Layer Name	Data Source	Tools/ Applications/Procedure	Software
Geology	USGS Earth Explorer	Scanned, Rectified, Projected	All applications done in ArcGIS 10.8 environment.
Slope	Digital Elevation Model (Landsat 8)	Spatial Analysis Tool	
Lineaments	USGS Earth Explorer	Principal Component Analysis, Automatic Line Extraction	
Drainage Density LULC	Digital Elevation Model (Landsat 8) ESRI 2021 Open Database	Length of drainage Classification	

2.3 Assigning rank and weight

The groundwater potential zones were analyzed and evaluated by combining all the spatial layers using overlay weighted method. Individual spatial layers were reclassified to uniform rank 1–5 before the overlay operation was done. Here, 1 represents Very Low groundwater potentiality and 5 represents Very High groundwater potentiality (Table 1). At Table 1, geology, lineament density, topsoil permeability, precipitation, slope, landuse landcover (LULC), dranage density are presented F1 to F7 respectively. Based on AHP model, all weights have been assigned through pairwise comparisons matrix. The ranks were given to the parameters considering extensive literature reviews expert opinions and associated studies related to study area and groundwater [110],[111],[112],[113]. Geology was assigned to highest rank; whereas land use land cover (LULC) and drainage density were assigned lowest ranks. Finally, sub-variable under parameters were specified with individual ranks. (Table 2)

Table 2: Normalized pairwise comparison matrix (seven layers) developed for AHP based groundwater potential zoning

Factors	F1	F2	F3	F4	F5	F6	F7	Weight
F1	7	6	5	4	3	2	1	0.38
F2								
F3								
F4								
F5								
F6								
F7								
Total								1.0

Table 3: Weights assigned for different groundwater control parameter

Factor	Weight	Rank	Over All
Geology			
Valley alluvium and colluvium	38	5	190
Dihing and Dupi Tila Formation Undivided		4	152
Dihing Formation (Pleistocene and Pliocene		4	152
Dupi Tila Formation (Pleistocene and Pliocene)		3	114
Girujan Clay (Pleistocene and Neogene)		1	38
Bhuban Formation (Miocene)		2	76

Boka Bil Formation (Neogene)		2	76
Tipam Sandstone (Neogene)		4	152
Lineament Density			
Very High	19	5	95
High		4	76
Moderate		3	57
Low		2	38
Very Low		1	19
Topsoil Permeability			
Mixed Moderate & Rapid	12	3	36
Mixed Moderate & Slow		1	12
Moderate		2	24
Mostly Moderate		2	24
Mostly Moderate WS Rapid		3	36
Mostly Moderate WS Slow		1	12
Mostly Rapid WS Moderate		4	48
Mostly Slow WS Moderate		1	12
Rapid		5	60
Slow		1	12
Precipitation			
Very High	10	5	50
High		4	40
Medium		3	30
Low		2	20
Very Low		1	10
Slope			
0-5	8	5	40
5-10		4	32
10-20		3	24
20-30		2	16
>30		1	8
LULC			
Cultivated Land	6.6	5	33
Forest		3	19.8
Grass Land		3	19.8
Shrub Land		4	26.4
Wetland		5	33
Waterbody		5	33
Urban/ Built up area		1	6.6
Drainage Density			
Very High	6.4	1	6.4
High		2	12.8
Moderate		3	19.2
Low		4	25.6
Very Low		5	32

3. RESULTS AND DISCUSSION

3.1 Geology

Geology and geological formation, which is regulated by lithology, landform, and underlying rock structure plays a critical role in determining the quality, quantity and availability of groundwater [114],[115].The geology of Karnaphuli River Basin can be divided broadly into hilly and alluvial parts. The details of subdivisions are presented in tabular form below [116]

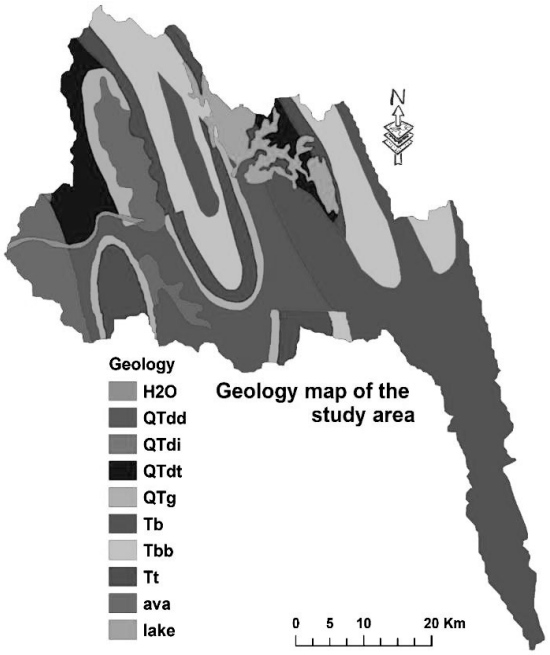

Fig. 2: Geology map of the study area

Table 4: Details of the geological group formation and corresponding bed rock

SN	Geology Symbol	Description	Bed Rock (link)
1	ava	Valley alluvium and colluvium	Loose, unconsolidated sediments consist of heterogeneous range of rock types and sediments ranging from silt to rock fragments of various sizes
2	H_2O	Water body	Did not considered in analysis
3	Lake		
4	QTdd	Dihing and Dupi Tila Formation Undivided	Most parts of rocks are poorly consolidated, grain size medium, occasionally pebbly sandstone and clayey sandstone with inter beds of mottled clay
5	QTdi	Dihing Formation (Pleistocene and Pliocene	The rocks are in most part poorly consolidated: medium-grained, occasionally pebbly sandstone and clayey sandstone with inter beds of mottled clay
6	QTdt	Dupi Tila Formation (Pleistocene and Pliocene)	Fine to medium grained pebbly and cross-bedded sandstone with subordinate clay stone and siltstone
7	QTg	Girujan Clay (Pleistocene and Neogene)	Mottled clay along with subordinate mottled sandy clay, sandstone along with subordinate ferruginous sandstone
8	Tb	Bhuban Formation (Miocene)	Well-bedded siltstone and shale
9	Tbb	Boka Bil Formation (Neogene)	Well-bedded siltstone and shale
10	Tt	Tipam Sandstone (Neogene)	Coarse-grained, massive sandstone, cross bedded

3.2 Lineaments

Lineaments are liner, curvilinear, rectilinear features of the earth's tectonic origins that reflect the subsurface lithological structures, including joints, fractures, cleavages, and faults visible through satellite images. Lineaments are considered secondary porosity and hence fractures, joints, dykes, bedding planes, etc. structures play a significant role in the permeability of groundwater [117, 118]. Lineaments and groundwater are interconnected in a complex way.They can be expressed in different forms and the feathers can control the flow of groundwater by providing preferential pathways for water to move through the subsurface.

In our study area, higher rank has been assigned areas with high lineament density (4.83% of total area) due to good infiltration and porosity; whereas, the areas with low lineament density (29.97% of total area) are assessed to have poor groundwater potentiality and hence has been assigned lower rank. The entire area is classified into four categories according to lineament density as shown in Figure 5.

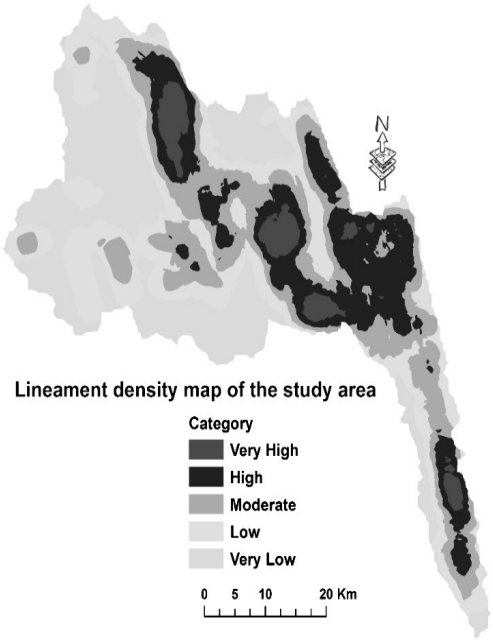

Fig. 3: Lineament density map of the study area

3.3 Topsoil permeability

The uppermost layer of soil (topsoil) has a signification influence on amount of water to be percolated and infiltrated and as consequence recharge of groundwater. To estimate the rate of infiltration, the main factors can be cited as soil texture, soil structure and hydraulic characteristics [119]. These factors verify the overall permeability of topsoil. In this study, karnafuli River Basin area has been segregated into rapid, slow, moderate and the intermediate of these classes based on topsoil permeability (Figure 4). After assigning weight, 44.66% of our study area is observed as having moderate permeable soil and 25% having rapid permeable soil property.

Since hydrologic cycle is a closed cycle, the recharging process of groundwater of a catchment highly depends on amount of the precipitation receives that particular catchment receives. Rainfall is the only form of precipitation in Bangladesh and during monsoon (June to October) it receives approximate 90 percent of total rainfall [120]. For this study, we divided karnafuli basin area into five categories according to precipitation volume. This is illustrated in figure 5. Historical collected data has been modified at CMIP environment.

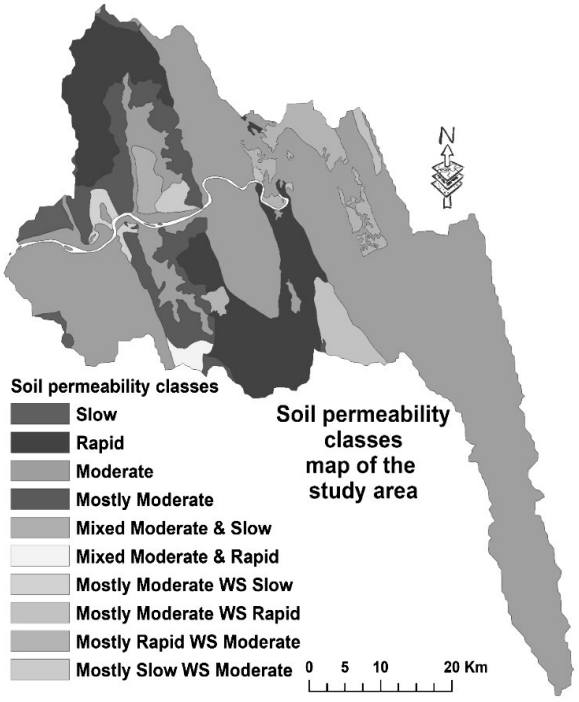

Fig. 4: Soil permeability classes map of the study area

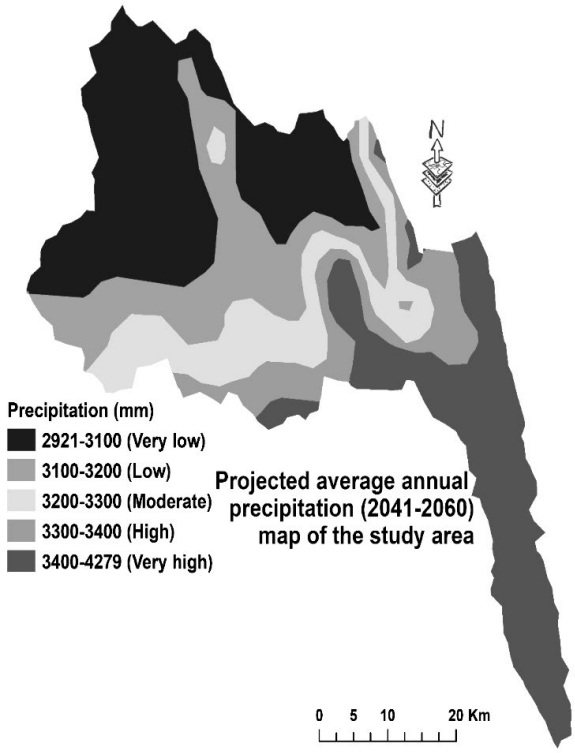

Fig. 5: Precipitation classes of the study area (projected)

3.4 Precipitation

Mathematically hydrologic budget or balance can be written as [121]:

$$P = Q + G + ET + \Delta$$

where

Δ is the Precipitation
Q is the Runoff/ Discharge/ Outflow
G is the Evapotranspiration
Δ is the change in the Storage [Change in storage: Ss (surface water) + Ssm (soil moisture) + Sg (ground water)]

3.5 Slope

Steep grounds help to high volume of surface run-off and as consequence little or no infiltration. On the other hand, flat and little sloping lands promote high infiltration and enable to contribute more than steeper land to recharge groundwater [122], [123]. Considering this, areas of Karnafuli river basin having less slope has been assigned higher rank and steeper areas are given lower rank as well. The slope range of this river basin is 0°–30°.

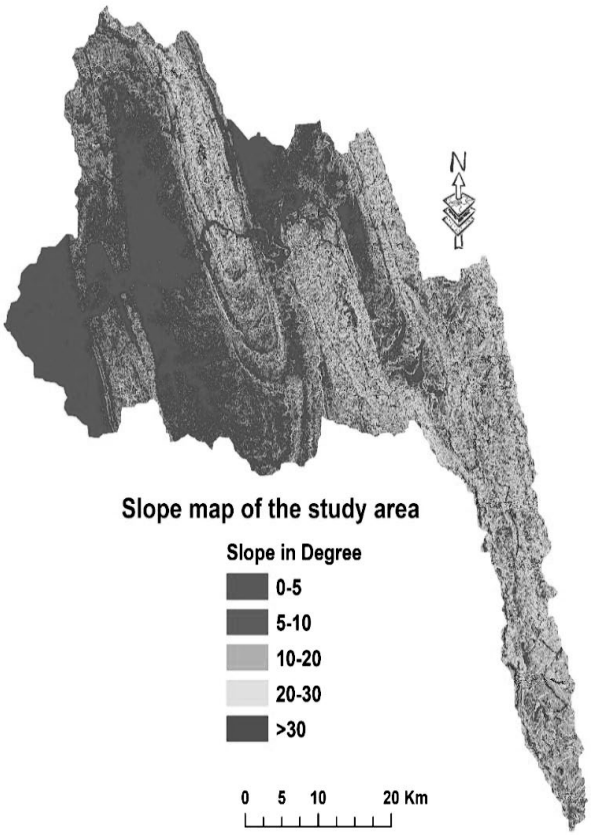

Fig. 6: Slope map of the study area

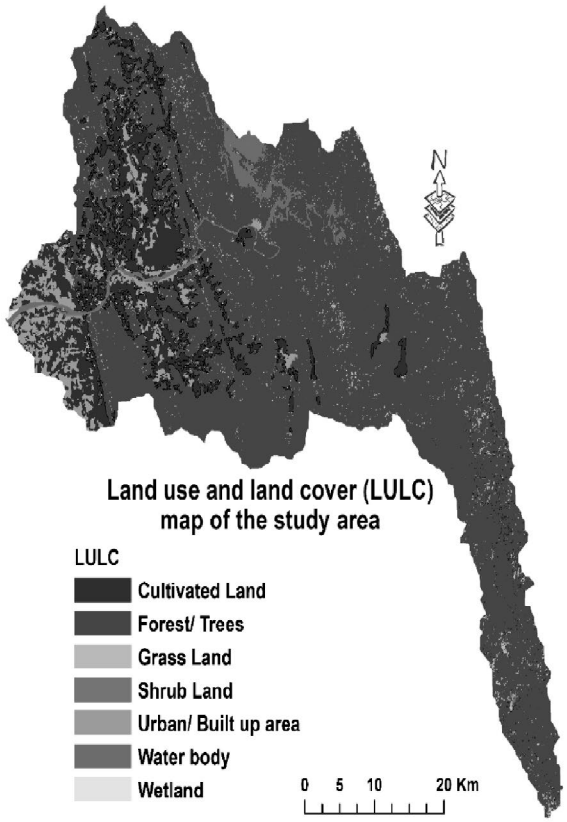

Fig. 7: Future land use and land cover map of the study area (2050)

3.6 Land use land cover (LULC)

Land use and land cover have a direct control on recharge capacity of a region. (8843) Hydrologic phenomena like infiltration, surface runoff, condensation, evapotranspiration is influenced by vegetation types, soil moisture etc. Lands with manmade structures like buildings, parking lots, pavements, roads etc. have impermeable surface cover which have no natural infiltration capacity and hence majority of precipitation ends up at surface runoff or loss. On the other hand, lands with moderate or dense forest, evergreen vegetations and agricultural lands have moderate surface runoff and great infiltration capacity which later contribute to recharge groundwater. Additionally, baren land or lands with grass or shrub may have infiltrate capacity in between evergreen land and human settlement. Base on this concept, low to ranks have been appointed for our study area. By satellite Landsat 8 image interpretation it is obtained that 4.52% area of karnaphuli river basin human have human settlement and more than 70% of the land have forest or tree cover.

3.7 Drainage density

Mathematically, drainage density is a measurement of the amount of channel length per unit area of a watershed or drainage basin. It can be expresses as,

$D_d =$

where D_d is the drainage density, D_i is the total length of water channels or streams in the area A [124].

Drainage density is the reflection of many information of a catchment or watershed such as infiltration, runoff, permeability, surface material, subsurface formation, lithology, climate, slope characteristics, history of the area and overall channel spacing etc. Though streams are excellent and continuous source of groundwater recharge, densely distributed streams and high stream flow indicate high volume of runoff and low infiltration rate of the catchment. Low infiltration leads to low groundwater recharge. So, areas with mountainous relief, impermeable subsurface, sparse vegetation have high drainage density and low groundwater potentiality. In contrast, areas with highly permeable soil, flat and comparatively less slopy have low drainage density and high potentiality for groundwater. After supervision, 24% of our study area shows high drainage density and 19% of study area shows very low drainage density.

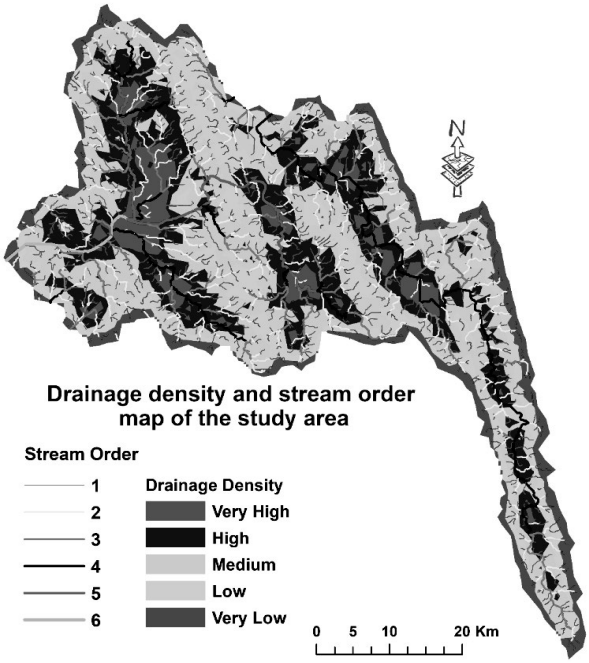

Fig. 8: Stream order map of the study area

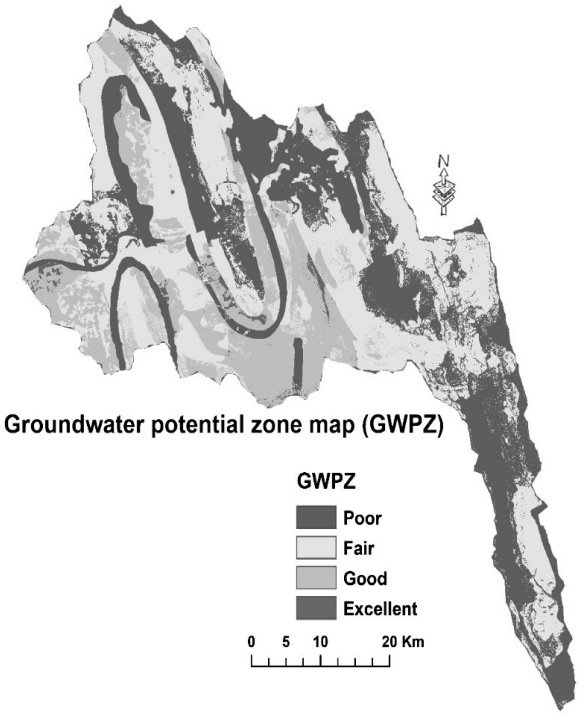

Fig. 9: Groundwater potential zone of the study area

3.8 Ground water potential zones

All the seven thematic layers (Geology, lineament density, topsoil permeability, precipitation, slope, drainage density, land use and land cover) were integrated in a GIS platform and as final output a single groundwater potential map was produced depicting the overall scenario for potentiality of the groundwater (Figure 9). Four different classes cited as 'Excellent', 'Good', 'Fair' and 'Poor' GWPZs were categorized at the final single map layer.In our study area, the 'fair' category of potentiality is expected to be dominant in the year 2041 to 2060 because it would extend around 43% of the total area (958.58 km^2) [Table 3]. Additionally, only 24.68 km^2 area is expected to show 'excellent' potentiality as future groundwater source. No fixed pattern has been found for the 'excellent' type combining all seven criteria. However, both fair and excellent groups would have mostly forest cover lands and moderate slopes in future.

As mentioned in section 2, the karnaphuli river basin spread to fifteen different upazillas and three districts to various extends. Table 3 has been presented to visualize the future GWPZ scenario for these upazilla and districts (calculation has been done for only the areas that fall under Karnaphuli river basin). In future, physical tests (i.e. borelogs) can be done for cross validation.

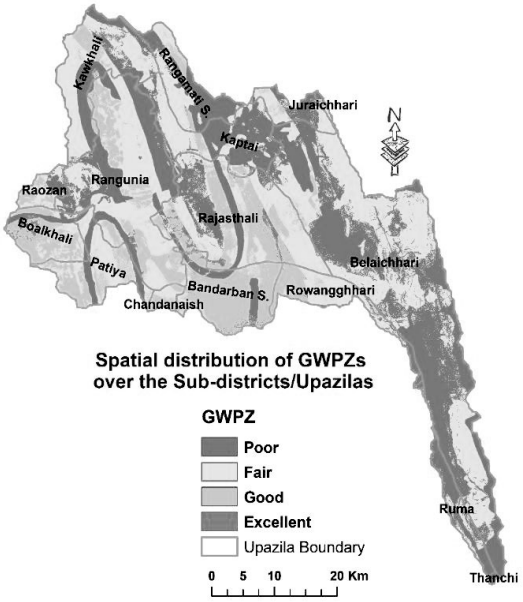

Fig. 10: Spatial distribution of groundwater potential zones (GWPZs) over the districts and Upazila

Table 5: Groundwater potential zones of the study area

SN	District	Sub- District/ Upazila	Potential zones				Grand Total
			Excellent	Good	Fair	Poor	
1	Bandarban	Bandarban Sadar	3.45	96.24	14.17	16.69	130.55
2		Ruma			10.36	37.02	47.38
3		Rowangghhari	0.37	23.34	41.50	9.67	74.89
4		Thanchi			0.20	1.56	1.76
5	Chittagong	Boalkhali	5.05	45.12	20.88	9.94	80.99
6		Chandanaish		7.87	6.70	0.07	14.65
7		Patiya		32.29	53.87	17.95	104.12
8		Rangunia	2.02	69.89	162.94	106.94	341.78
9		Raozan		8.73	14.76	7.96	31.45
10	Rangamati	Rangamati Sadar	0.27	9.83	60.95	65.21	136.27
11		Belaichhari	0.001	4.94	305.02	363.13	673.10
12		Juraichhari			1.71	1.75	3.46
13		Kaptai	0.36	7.21	52.47	78.67	138.71
14		Kawkhali	0.62	16.79	87.91	55.13	160.45
15		Rajasthali	12.54	90.36	125.11	64.16	292.16
		Grand Total	24.68	412.61	958.58	835.84	2231.71

4. CONCLUSION

This paper describes a case study conducted at the Karnaphuli River Basin to evaluate potential groundwater zones in the future using a multi-criteria decision-making technique.Sustainable use of natural resources like groundwater is crucial for sustainable better future. In Bagladesh, most development activities and constractions at southern part have been done without proper planning which may toll on delicate ecosystem. This study successfully suggests the potentially that karnapphuli river basin area will hold in future (upto year 2060) as groundwater source into four catagories (namely excellent, good, fair, poor). The study area possess an excellent potentiality in tourism sector and keeping pace with changing perspective of global citizens may become a choice for living place for remote workers. So, the outcome of this study will help stakeholders, authorities , developers and planners in long term socioeconomic development.

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Effects of Oblique Flow on the Groin Area and its Remedial Measures

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ABSTRACT

The downstream alluvial rivers are very complex and irregular in nature. The deflected flow from the sandbars makes the problem even more complicated. This study examines the effect of oblique flow on the groin-protected area and its mitigation measures. Numerical simulation was conducted by using a two-dimensional numerical model, iRIC (Nays 2DH). An upwind difference scheme for advection terms and a zero-equation turbulence model were employed. A schematized straight channel of laboratory scale with one-fifth of the channel width as the groin length was considered in the study. First, the effect of oblique flow on the area of conventional groins was examined, and then two different options were considered to minimize the effects – (i) replacing the conventional groins with combined groins, and (ii) placing long permeable dyke along the normal line of groins. Because of the oblique flow generated from the sandbar-like structure, the flow was accelerated near the conventional groins highly, and the scour near the groins increased accordingly which could make them unstable. The provision of combined groins which allow flow through them modified the flow condition significantly – the flow velocity was reduced in the groin field causing decrease in erosion in the channel bank. But near the groin head, flow vortices were found high. However, the permeability in the combined groin could modify this effect. The long permeable dyke placed along the groin tip minimized the intensity of flow velocity and vortices there, and developed very slow flow region in the groin field. This also diverted the oblique flow in a good manner. Thus the erosion in the groin area was minimized. This approach can be considered in the alluvial rivers for stabilizing the riverbanks, groins, and river channels as well.

Keywords: Oblique flow; Bank erosion; Combined groin; Long permeable dyke; iRIC (Nays 2DH).

1. INTRODUCTION

Rivers consider a water source, then for finding food, for conveyance, by way of self-justifying measures, and for hydropower to drive equipment. Maximum rivers of the lowland pass over the alluvium plain which is highly prone to erosion and deposition because of its dynamic nature. Erosion of the riverbank is one of the key phenomena which is triggering the instability of the bank. Numerous river training works are being practiced in the rivers to stabilize the river channels, among which groins are broadly used in the world [1] - [3]. The groin largely diverts the flow direction so that the flow velocity is suggestively reduced in the area of the groin, and in that way, erosion of the bank is diminished [4]. However, numerous groins remain unsuccessful to role properly and they cannot withstand in their places when oblique flow attacks the area. Due to this type of flow, flow characteristics adjacent to the groin change and intensify highly, and flow currents follow very close to the bank. The rate of erosion becomes higher near the bank line; henceforth this amplifies shear velocity near the bank line and forms a robust secondary current [5]. Flow velocity privileged the arrangement is inferior to the river environment. However, such structures could increase the biodiversity of aquatic species by forming habitats and providing shelter for them. The river's mainstream, where the velocity is high, is inappropriate for weak and small fishes. That is why the dead zone is a suitable shelter for them. Many investigational and numerical categories of research have been executed to examine the flow pattern and scouring around groins [6-9]. Oblique flow attacks the earthen shank of a spur; at the same time, flow circulation occurs and bed materials are removed from the side of the launching apron, and slip circle failure occurred

Although many studies have been led to explore the upshot of oblique flow causing instability of groins, the studies on its minimization are not sufficient yet. The present study examines the effect of oblique flow on the groin area made by a series of conventional groins and its minimization with two different approaches to choose the best option - (i) a long permeable dyke along the groin tip; (ii) providing downstream aligned combined groins.

2. BASIC EQUATIONS CASTOFF IN THE MODEL

iRIC (International River Interface Cooperative), a pre- and postprocessing software claim and outline for computational models of flow and sediment transport in rivers is used in this study. The application is a Graphical User Interface (GUI) that allows the model user to shape, track, and envision the results of the system's computational models. The GUI affords tools for edifice both structured and unstructured grids, defining topography and other boundary conditions on the grid, and significant grid-dependent values such as grain size, vegetation, and hindrances by mapping restrained values to the grid or by creating user-defined polygons with attributes of grid-dependent value. It associations the functionality of MD SWMS, developed by the USGS (U.S. Geological Survey), and RIC-Nays, settled by the Foundation of Hokkaido River Disaster Prevention Research Center

2.1 Equations

2.1.1 Basic flow equations

The equation of continuity in orthogonal coordinates [11] is considered as (Eqn. 1),

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0. \quad (1)$$

Equations of motion,

$$\frac{\partial (uh)}{\partial t} + \frac{\partial (hu^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -hg\frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} + D^x \quad (2)$$
$$\frac{\partial (vh)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2)}{\partial y} = -hg\frac{\partial H}{\partial y} - \frac{\tau_y}{\rho} + D^y$$

2.1.2 k-ε model

The eddy viscosity coefficient ν_t in the standard k-ε model [11] is expressed by the following equation (Eqn. 3):

$$\nu_t = C_\mu \frac{k^2}{\varepsilon} \quad (3)$$

where C_μ is a model constant

The constants used in the model are summarized in Table 1.

Table 1 : Model constants

C_u	$C_{1\varepsilon}$	$C_{2\varepsilon}$	σ_k	σ_ε
0.09	1.44	1.92	1.0	1.3

2.1.3 Model of river bed friction

In Nays2DH, the friction of the river bed [11] is set using Manning's roughness parameter. For Manning's roughness parameter, the user can define this parameter locally in each computational cell. Manning's roughness parameter n can be known from the coefficient of riverbed shearing force C as follows (Eqn. 4):

$$C_f = \frac{g n_m^2}{h^{\frac{1}{3}}} \quad (4)$$

This Manning's roughness parameter can also be estimated from the relative roughness height, k_s, by using the Manning-Strickler equation [11] as follows (Eqn. 5),

$$n_m = \frac{k_s^{\frac{1}{6}}}{7.66\sqrt{g}} \quad (5)$$

where k_s is the relative roughness height.

2.1.4 Bed load transport

The equation for the transport of bed load used in the model as per Ashida and Michiue [11] is as follows (Eqn. 6),

$$q_b = 17\,\tau_{*e}^{1.5}\left(1 - K_c\frac{\tau_{*c}}{\tau_*}\right)\left(1 - \sqrt{K_c\frac{\tau_{*c}}{\tau_*}}\right)\sqrt{S_g g d^3 r_b} \quad (6)$$

where, τ_* is Shields number, τ_{*e} is effective Shields number, τ_{*c} is critical Shields number, K_c is the modification function of the effect of the local bed slope on the sediment transport, r_b is the function of the exchange layer thickness.

2.2 Model setup

In this study, three cases are considered for studying the effect of oblique flow and its mitigation; these are Oblique flow with conventional groins (Case 1), long permeable dyke along normal line of groins (Case 2) and combined groins (Case 3) which are shown in Figs. 1(a-c), respectively. The hydraulic and geometric parameters are presented in Table 2.

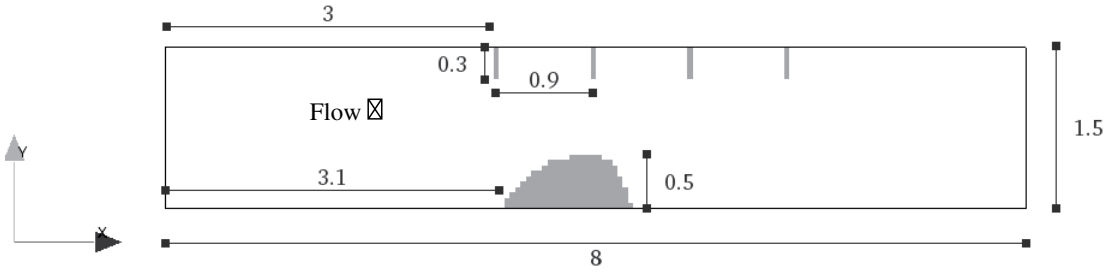


Fig. 1 (a): Conventional groins with sandbar-like obstruction (Case 1)

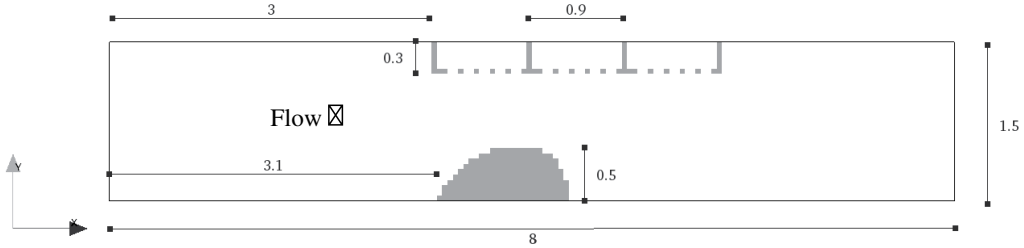


Fig. 1 (b): Long permeable dyke with sandbar-like obstruction (Case 2)

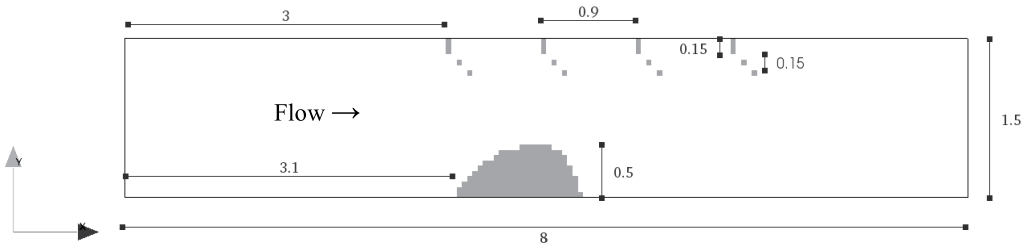


Fig. 1 (c): Combined groins with sandbar-like obstruction (Case 3)

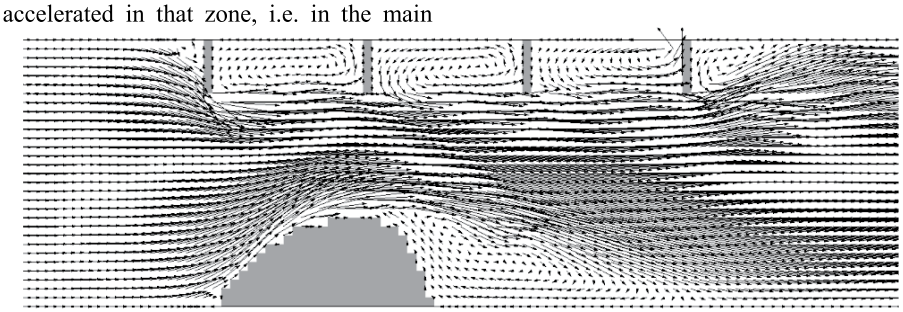
Table 1: Hydraulic and geometric parameters for the simulation cases

Cases	Groin Type	L (m)	W (m)	Q_0 (m^3/s)	h_0 (m)	S_0	n
Case 1	Conventional groins	9	1.5	0.03	0.1	0.001	0.02
Case 2	long permeable dyke along normal line of groins	9	1.5	0.03	0.1	0.001	0.02
Case3	Combined groins	9	1.5	0.03	0.1	0.001	0.02

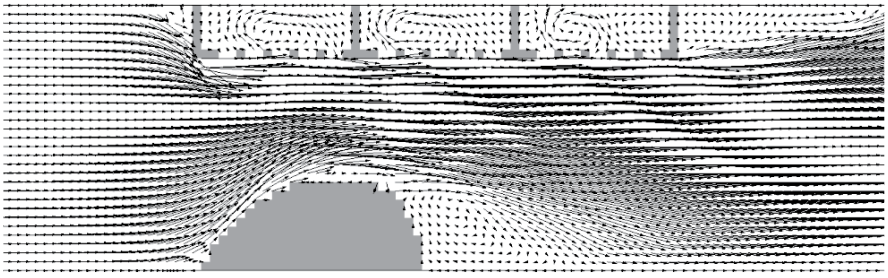
Here L = Length of straight channel, W = channel width, Q_0 = upstream discharge, h_0 = water depth at downstream, $S_{\text{亚}}$= channel slope, and n = Manning's roughness coefficient. In the simulation process, uniform discharge of 0.03 m^3/s at upstream side and 0.10 m water surface at downstream is considered as boundary condition. The same hydraulic condition is maintained for all the cases for comparing their performance.

2.3 Simulated results

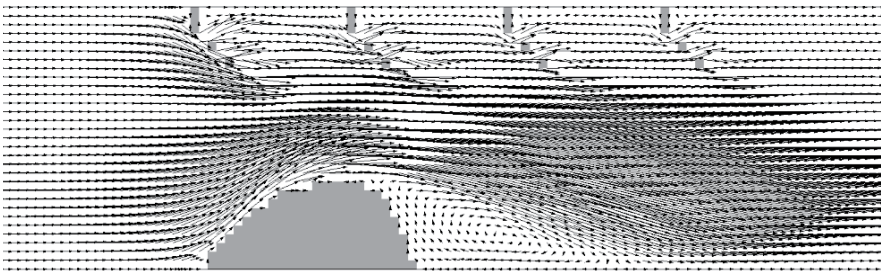
The results found from the simulation for three different cases are presented in this section. This can be observed that the velocity vectors induced by the obstruction due to the groin and sandbar-like structure both is diverted and accelerated in that zone, i.e. in the main channel. The flow currents can be marked very low in the downstream areas of these structures. Fig. 2 presents the simulated velocity vectors and recirculation zones around groins for (a) Case 1, (b) Case 2, and (c) Case 3.



(a)



(b)



(c)

Fig. 2: Computed velocity vectors and recirculation zone around groins for (a) Case 1, (b) Case 2, and (c) Case 3

For all the cases, the model successfully reproduces the overall flow features of the flow field around the groin. The simulated results demonstrate that the flow is uniform at the upstream boundary; hence, the flow vectors are straight and parallel to the bank. Nevertheless, when the flow passes the groin, the flow deviated towards the middle area of the channel due to obstruction of flow in the channel sides by the groin and obstacle. The flow recirculation zones are evident at the downstream region of the groins for the first two cases, i.e. Case 1 and case 2.

3. COMPARISON OF SIMULATED RESULTS IN DIFFERENT CASES

3.3.1 Velocity profiles

For conventional groins, the resultant velocity profiles are equated with Combined groins and long permeable dyke along the normal line of groins results measured at $y\ l$ = 2.0 and 4.0, where l = 30 cm is the length of the groin. Fig. 3 shows the comparison of velocity profiles for different lateral distances ($y\ l$
velocity and water depth were V_{avg} = 0.19 m/s and h = 0.1 m, respectively. In the figure, all the velocities were normalized by V_{avg}. In the figure, $x\ l$ = 10.1 indicated the groin position along flume direction.

Figs. 3(a-b) expression the contrast among velocity profiles (V) for case 1, case 2, and case 3. For each case, the longitudinal velocity profiles are compared at a lateral position of $y\ l$ = 2.0 and 4.0. In the figure, all the velocities are normalized by V_{avg} = 0.1929 m/s and here $x\ l$ = 10.1 indicates the groin position in the longitudinal direction. The assessments among the three cases illustration reasonable differences. Along line $y\ l$ = 2, the peak of velocities is initiate at longitudinal distances of $x\ l$ =13.1, 14.95, and 16.5 for case 1, case 2, and case 3, respectively. For the line $y\ l$ = 4, the peak of velocities is initiate at longitudinal distances of $x\ l$ = 2.0, 14.2 and 17.34 for case 1, case 2, and case 3, respectively. From the figures, it is detected that the peak of velocity is found maximum at the position of head of groin when $y\ l$ = 4.

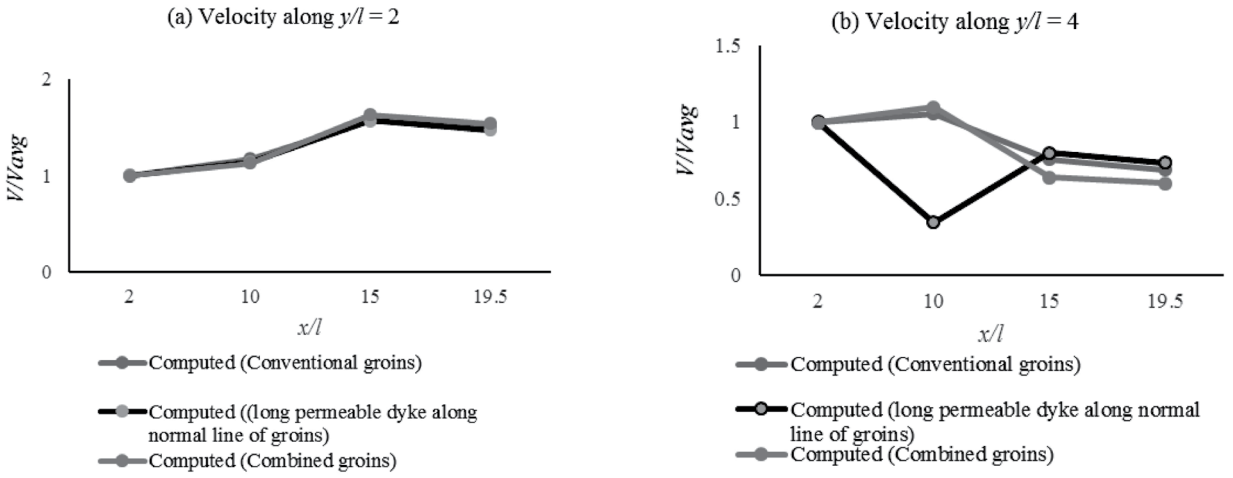


Fig. 3: Comparison of velocity profiles developed in the different cases at (a) y/l = 2, and (b) y/l = 4

From the figures, it is pragmatic that the peak of velocity is originate minimum at the position of head of groin when $y\ l$ = 4. These peak velocities are found to be decayed with the longitudinal distance $x\ l$ However, for $y\ l$ = 4, the decay of velocity along the downstream is found to be slower compared to the region $y\ l$ = 2. The minimum velocity for case 3 is found lower than the other two cases for all the sections of x/l Figs. 4(a-c) illustrate the simulated velocity contours with shaded color for Case 1, Case 2 and Case 3, respectively.

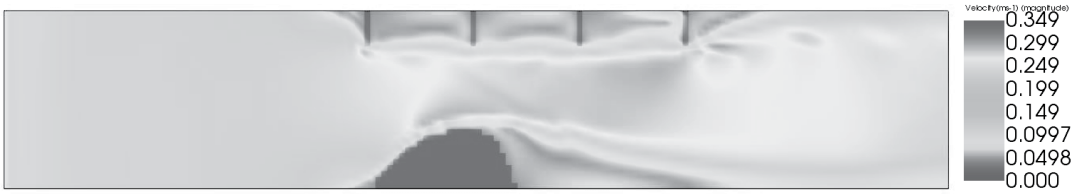


Fig. 4 (a): Computed Velocity for Case 1 developed by iRIC Nays2DH

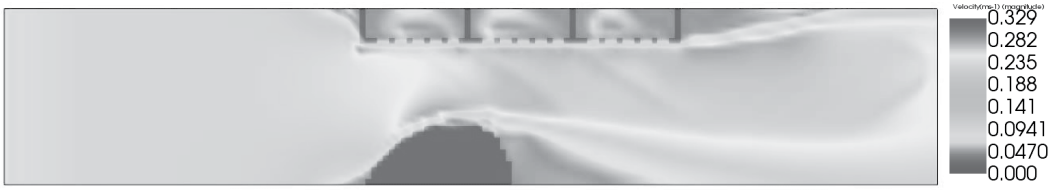


Fig. 4(b): Computed Velocity for Case 2 developed by iRIC Nays2DH

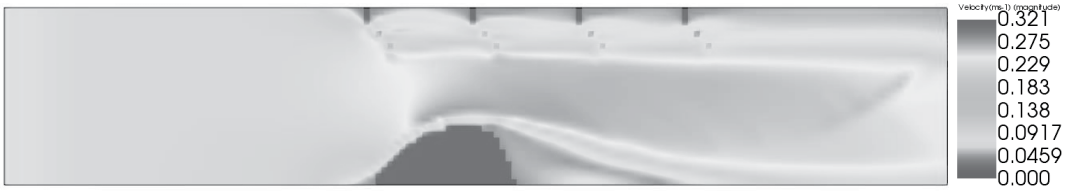


Fig. 4(c): Computed velocity for Case 3 developed by iRIC Nays2DH

The results are initiated to be comparable in nature. For all the cases, the velocity contour along the middle bank is higher than the left and right bank at the middle stream region of it the channel; indicating the deflection of flow towards groins and deflectors. The downstream circulation zone is found to be a larger long permeable dyke along a normal line of groins compared to combined groins. Similarly, the circulation zone for combined groins is found to be larger compared to Conventional groins. In the figure, the flow field is found to be divided into four distinct regions: (i) the uniform flow at upstream end, (ii) big circulation of low velocity zone at the downstream of the channel, (iii) a small low velocity zone near the foot at the upstream of groins, and (iv) high velocity zone at the middle zone created due to the deflector and groins. The high velocity zone is found to be decayed towards downstream and the low velocity in circulating zone is found to be regained. The computed velocity and elevation change profiles of present study are compared among case 1, case 2, and case 3. From the simulation, it is observed that the peak of velocity and elevation change is found maximum at the position of head of groin when lateral distance $y\ l$ = 4, where l is the groin length. The position of maximum velocity and elevation change is found to be shifted towards downstream with increasing x/l Figs. 5(a-c) show the simulated the changes in bed elevation for Case 1, Case 2, and Case 3, respectively.

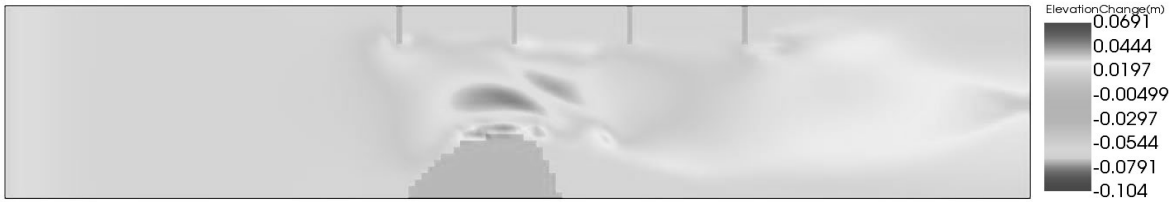


Fig. 5(a): Computed change in bed elevation for Case 1 with conventional groin models



Fig. 5(b): Computed change in bed elevation for Case 2 with a long permeable dyke

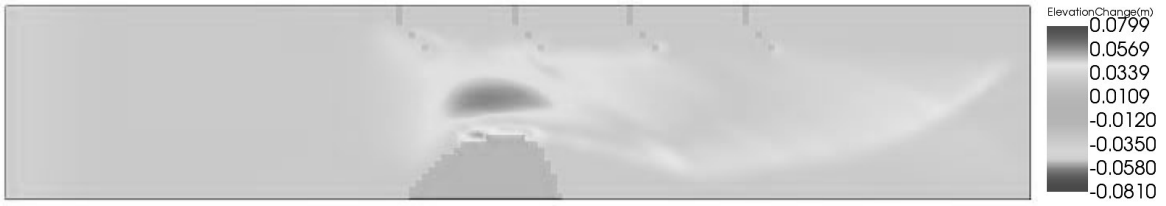


Fig. 5(c): Computed change in bed elevation for Case 3 with combined groins

The results are found to be resembled with the change in hydraulic characteristics due to the different groin arrangements. Like the velocity contour, for all the cases, the elevation change can be recognized higher at the middle stream region of the channel compared to the left and right banks. Four distinct flow regions as described in the velocity contours are also clearly visible in the contour of elevation changes. Here in the Case 1, where the conventional groins were used, the scour near the first and last groins is observed; however, this is negligibly small in the other two cases. Moreover, in Case 2, large scour hole is not formed as found in the other cases, except in the immediate downstream of bar-like obstacle.

4. CONCLUSION

This study has examined the effects of deflected flow in the areas with groins and has explored conceivable solution against these effects. The study results have been evaluated through flow fields, velocity profiles, and elevation changes due to groins of different arrangements and configurations in a straight open channel. In the numerical simulation, the general flow features around groins are reproduced successfully. The flow fields are found to be divided into four distinct regions: (i) the uniform flow at the upstream end, (ii) a big circulation of low-velocity zone downstream of the groin, (iii) a small low-velocity zone near the foot at the upstream of the groin, and (iv) high-velocity zone at the middle zone created due to the deflector and groins. The computed velocity and elevation change profiles observed in the present study are compared for the three different cases - Case 1, Case 2, and Case 3. The high-velocity zone which is established near the head of conventional groins is created (Case 1) to be decayed with the long permeable dykes (Case 2) and the combined groins (Case 3), and the low velocity of flow is obtained in the recirculating zone. From the simulation, it is concluded that the long permeable dyke along the normal line of groins exhibits better results compared to conventional and combined groins, where both the near bank and near groin head velocities are reduced, and scour is also minimum accordingly. The velocity and bed level profile also designates that groins with long permeable dyke facilitate the navigation channel with regular flow environment. This study provides us with a way of stabilizing groins, riverbanks, and main channels.

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Investigation of the Effective Coagulation Dose on Textile Wastewater Quality

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ABSTRACT

Textile industries govern the country's economy, but their rapid and unplanned expansion is particularly concerning for the environment and human health. Because the textile industry produces a lot of wastewater, it needs to be treated before discharge. There are many ways to treat the wastewater, like physical treatment, chemical treatment, and biological treatment. Combinedly, physio-chemical treatment is the greatest solution when biological treatment is expensive, complex, and time-consuming and produces a lot of wastewater. Bangladesh has poor wastewater management in the textile sector. The rules are not followed by the industries, and even many textile industries do not have effluent treatment plants (ETP). This study is aimed at giving emphasis on the present scenario of wastewater quality parameters of the textile industry and further treatment for selecting the optimum coagulant dose. The investigation was carried out in Gazipur's textile industries. For treatment, Coagulants include Ferric Chloride, Ferric Sulfate, Alum, and PAC are applied at a specific dose by using a jar tester. Among the coagulants, the best coagulant is selected through their removal efficiency and different dosages are applied to find the effective coagulant dose. The pH, TSS, turbidity, color, and COD removal efficiency were measured. The reduction efficiency of pH was 58%, the removal efficiency of turbidity was 98.98%, the removal efficiency of TSS was 97%, the removal efficiency of color was 90.44%, and the removal efficiency of COD was 90.87%. These results were achieved by using ferric chloride as a coagulant in wastewater treatment.

Keywords: Textile; Wastewater; Coagulation; Flocculation.

1. INTRODUCTION

Bangladesh is a developing country that has rapidly industrialized in a variety of sectors over the last two decades. Textile industries are vital to the Bangladesh economy than all other industries. This sector accounts for 79% of Bangladesh's total exports, making it the world's second largest garment exporter [1]. It contributes to the GDP and GNP of Bangladesh, and it employs 45 percent of the country's industrial workforce [2].

Textile production is a complicated and time-consuming process. It is based on a three-step process that involves turning fiber into yarn, then fabric, and finally textiles. Fabrication of these into cloths or other artifacts follows [3]. Slashing, bleaching, mercerizing, and dyeing are the major water-consuming steps and produce a large amount of wastewater [2]. Strong acids, strong alkalis, inorganic chlorinated compounds, sodium hypochlorite, organic compounds such as dye stuff, bleaching agent, finishing chemicals, starch, thickening agent, surface active chemicals, wetting and dispensing agents, and metal salts are used at various stages. Various dyes are used for coloring purposes during the dyeing stage; multi-color is used to improve the best of products.

These chemicals used in wet process and produces waste water may cause changes to the physical, chemical, and biological properties of the surrounding aquatic ecosystem. That waste-water effects the water quality parameters, i.e., total dissolved solids (TDS), total suspended solids (TSS), pH, chemical oxygen demand (COD), and biological oxygen demand (BOD) [4]. The vast majority of the compounds are non-biodegradable as well. The Department of the Environment developed several wastewater guidelines that industries must meet. However, they are not always followed effectively [4]. Almost every industry is in violation of the DoE rules. One of the most fundamental reason is that most of these industries do not have any ETP (effluent treatment plant).

Table 1: Quality of water discharged from seven industries with the DoE prescribed standard [5]

Water Quality Parameters	Season	Name of the Industry							Bangladesh Standards (ECR, 1997)
		Colombia Washing Plant Limited	Genesis Washing Limited	Fareast Knitting and Dyeing Industry Limited	Interstoff Apparels Limited	How Are You Textile Limited	Knit Asia Textile Limited	Southeast Textile Limited	
Temperature (°C)	Rainy	43	43.5	45.1	39	42.1	38	41	40
	Winter	45	47	46	43	45.7	34.8	44.2	
pH	Rainy	9.5	10	10.5	9.1	8.9	9.5	9.2	6.5-9.0
	Winter	9.9	10.2	9.9	10.5	10.4	9.2	10.5	
TSS (mg/L)	Rainy	120	115	330	120	310	195	210	100
	Winter	100	110	390	130	377	215	190	
TDS (mg/L)	Rainy	4247	5015	6412	5540	5240	5800	5410	2100
	Winter	4418	5425	6700	5730	5575	6123	5614	
DO (mg/L)	Rainy	1.2	0.6	1.4	0.8	0.00	1.9	1.3	4.5-8.0
	Winter	0.11	0.00	0.08	0.00	0.00	0.02	0.00	
BOD (mg/L)	Rainy	498	480	390	420	471	392	485	150
	Winter	515	507	403	445	495	478	503	
COD (mg/L)	Rainy	1310	1590	1184	1200	1500	1462	1194	200
	Winter	1360	1650	1216	1120	1634	1531	1184	

Severe water pollution contributed by textile is an alarming situation in Bangladesh. To solve this issue, wastewater must be properly treated before being discharged. In many circumstances traditional biological approaches are useless. On the other hand, physio-chemical procedures are not destructive. It is based on coagulation-flocculation to destabilize colloids and separate phases through sedimentation [6]. The efficiency of this method is determined by raw wastewater characteristics, solution pH

and temperature, coagulant type and dosage, and mixing intensity and duration [7].

We have done this investigation because textile effluent is a severe danger to the aquatic system and socioeconomic pattern. The purpose of this study was to determine the extent of pollution and concentrations of various physicochemical parameters in order to characterize wastewater from textile dyeing industries. Additionally, we determined the optimum effective dosage of coagulants and flocculants agents to treat the wastewater.

2. WASTEWATER TREATMENT

Coagulation-flocculation is a chemical water treatment procedure used before sedimentation and filtration (e.g. quick sand filtration) to improve a treatment process' capacity to remove particles.

2.1 Coagulation

To neutralize the negative charges on non-settleable particles, coagulant chemicals having charges opposite those of the suspended solids are introduced to the water [8].

The little dispersed particles might cling together once the charge has been neutralized. Micro-flocs are somewhat bigger particles that are not visible to the human eye. The water should be clean around the freshly produced micro-flocs. If this is not the case, coagulation and the charge of certain particles have not been neutralized. It's possible that more coagulant chemicals will be required [9].

To accomplish good coagulation, need a high-energy, rapid-mix to disseminate the coagulant correctly and stimulate particle collisions. Coagulation is unaffected by excessive mixing, whereas inadequate mixing leaves this process unfinished. In a rapid-mix chamber, contact time is usually between one and three minutes. Coagulants are selected based on their availability and performance [10].

2.2 Flocculation

Flocculation is a gentle mixing stage that transforms submicroscopic micro-floc into visible suspended particles. When micro-floc particles encounter, they join together to form pin-flocs, which are bigger, visible flocs. Additional collisions and interactions with added inorganic polymers (coagulant) or organic polymers increase the size of the floc. Macro-flocs are created, and coagulant aids, or high molecular weight polymers, may be introduced to assist bridge, bind, and strengthen the floc, add weight, and accelerate the settling rate. Water is ready for sedimentation once the floc has acquired its optimal size and strength [8].
Design contact durations for flocculation range from 15 to 20 minutes to an hour or more, and flocculation necessitates careful monitoring of mixing velocity and mix energy. The mixing velocity and energy are normally tapered off as the size of the floc grows to prevent it from ripping apart or shearing. It's tough to bring flocs back to their original size and strength once they've been broken apart. The degree of control accessible to the operator in flocculation is significantly dependent on the equipment type and design [11].

3. MATERIALS AND METHOD

The various physicochemical parameters were studied and the effective coagulants and its dose is selected in this study for determining and comparing water quality, which included temperature, pH, dissolved oxygen (DO), chemical oxygen demand (COD), total dissolved solids (TDS), and total suspended solids (TSS). The samples were collected and brought to DUET's Chemical and Food Engineering's environmental lab for examination. The physicochemical parameters were analyzed using the Standard Methods for the Examination of wastewater.

3.1 Sample collection

The samples were collected in textile industries from five garment industries in Gazipur. All of the industries have effluent treatment plants (ETPs) and the samples were collected from ETP inlet water (before treatment). The samples were marked as wastewater-01, wastewater-02, wastewater-03, wastewater-04 and wastewater-05 respectively according to their sources. The collected samples were stored in different plastic bottles, which were pre-treated by washing with distilled water. To avoid contamination and the effects of light, these sample bottles were kept at room temperature.

3.2 Analysis

The wastewater characteristics were determined by following the standard methods. pH was measured using digital pH meter (HACH- HQ11d meter). Two buffer solutions containing pH 4.0 and 7.0 were used to calibrate the digital pH meter. TDS was estimated quickly using an electrical conductivity (EC) or TDS meter. Water transmits electricity, but the true conductors are the dissolved minerals (ions) in the water. Because pure (distilled) water is a poor conductor of electricity, the more dissolved minerals in the water make it more conductive. TDS and Conductivity were measured using HACH-HQ14d, TSS and color were measured using HACH spectrophotometer DR6000.

An electronic turbidimeter is the most precise technique to determine the turbidity of water. A light source and a photoelectric cell are included in the turbidimeter, which correctly detects the light scattered by suspended particles in a water sample. So, Turbidity was measured using a turbidity meter of HACH-2100Q.
DO was measured using Optical Dissolved between oxygen and certain luminescent dyes. COD of the samples was measured after digestion of the samples by using potassium dichromate oxidant in an acidic environment at 150˚C in the LABTRON COD digester and by using a HACH spectrophotometer DR 6000.

3.3 Treatment

Ferric chloride, ferrous sulfate, alum, and PAC have been selected due to their high efficiency, effectiveness in

clarification, cheapness, and availability. Ferric chloride, ferrous sulfate, alum, and PAC were produced in a quick-forming, dense, rapid-settling manner. During coagulation process, we made only 550 mg/L solutions of $FeCl_3$, $Fe_2(SO_4)_3$, Alum, PAC by adding 165 mg of solute respectively in 300 ml of raw wastewater. Then, an effective coagulant is selected for the selection of its effective doses. To find the effective dose of coagulant, we made 350, 450, 550, 650, and 750 mg/L of $FeCl_3$ by adding 105, 135, 165, 195, and 225 mg of solute respectively in 300 ml of water. To identify the optimal dosage of coagulants, all tests were conducted at room temperature using the jar test method. For coagulation, four beakers were put on jar tester and swirled vigorously at 150 rpm for 150 seconds. Then, in a 300 ml solution, 18 mg of anionic polymer (60 mg/L) was added as a coagulant aid, and the mixture was agitated gently for 15 minutes at 15 rpm for flocculation. The flocs were allowed to settle for 30 minutes before samples were collected for examination.

4. RESULTS AND DISCUSSION

Generally, the water quality discharged from different textile industries need to be properly monitored for better environmental protection. The average water quality discharged from five different textile industries and standard limits in The Environment Conservation Rules (ECR, 1997) prescribed by Department of Environment (DoE), Bangladesh (Table 2).

Table 2: Quality of water discharged from the five industries with DoE prescribed standard

Water Quality Parameter	Sample Water					DoE Prescribed Standard
	wastewater 01	wastewater 02	wastewater 03	wastewater 04	wastewater 05	
Temperature (°C)	42	40.5	47	44	43.5	40
pH	8.45	8.82	9.47	7.67	10.12	6.5-9.0
TDS (mg/L)	866	2430	8770	9580	6270	2100
Conductivity (µS/cm)	1691	4630	1558	1861	3702	1200
DO (mg/L)	7.54	7.63	7.67	7.69	7.45	4.5-8
Turbidity (NTU)	321	53.5	252	196	659	10
TSS (mg/L)	411	75	359	259	348	100
COD (mg/L)	1394	461	1194	534	761	400
Color (Pt-Co)	1732	1828	2939	1766	2176	-

4.1 Investigation of wastewater quality from textile industry pH

The pH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range. Water emitted from these enterprises has a pH range of 7.67 to 10.12. (Table 2). The discharged water, in other words, was alkaline. Figure 1 depicts the pH differences between these five sectors. The sample wastewater 05 had the highest pH of 10.12, whereas sample wastewater 04 had the lowest pH of 7.67. (Fig. 1).

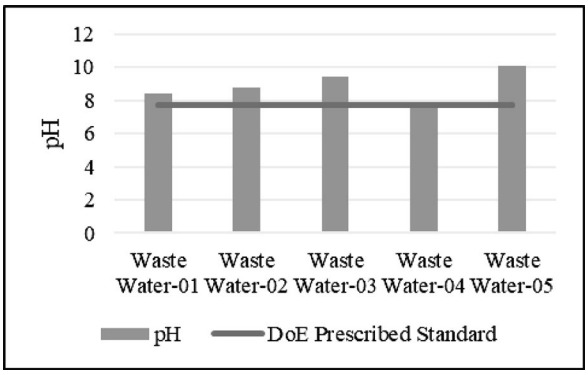


Fig. 1: Comparison of pH

4.2 Total suspended solid (TSS)

The total suspended solids (TSS) value of studied industries water ranges from 75-411 mg/L (Table 2). The variation in TSS of these five industries is shown in figure 2. The highest TSS of 411 mg/L was observed in sample wastewater 01 and the lowest was observed in sample wastewater 02 (Fig. 2).

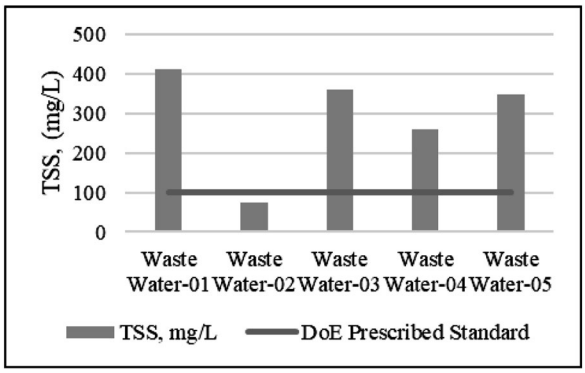
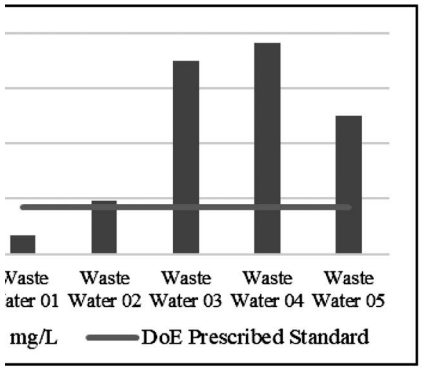


Fig. 2: Comparison of TSS

4.3 Total dissolved solid (TDS)

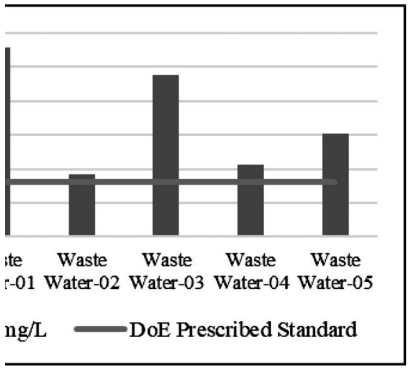
The total dissolved solids (TDS) concentrations varied from 866-9580 mg/L, while the Bangladesh standard value is 2100 mg/L (Table 2). The comparison of TDS concentrations is shown in figure 3. The highest TDS of 9580 mg/L was observed in wastewater sample 04 and lowest TDS of 866 mg/L was observed in wastewater sample 01 (Fig. 3)



ig. 3: Comparison of TDS

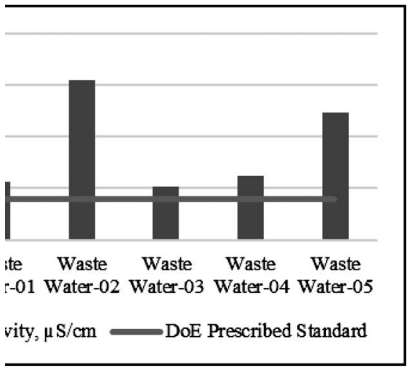
ygen demand (COD)

of COD values is shown in Fig. 4. It is graph that only two samples (sample 02 with the DoE prescribed standard.



ig. 4: Comparison of COD

vity values ranged from 1558-4630 µS/cm, desh standard value is 1200 µS/cm (Table of conductivity is shown in figure 5. The vity of 4630 µS/cm is observed in sample d the lowest conductivity of 1558 µS/cm mple wastewater 03 (Fig. 5).



5. Comparison of conductivity

4.6 Turbidity

The turbidity values ranged from 53.5-659 NTU, while the Bangladesh standard value is 10 NTU (Table 2). The variation of turbidity concentrations is shown in figure 6. The highest turbidity of 659 NTU is observed in sample wastewater 05 and the lowest turbidity of 53.5 NTU is observed in sample wastewater 02 (Fig. 6).

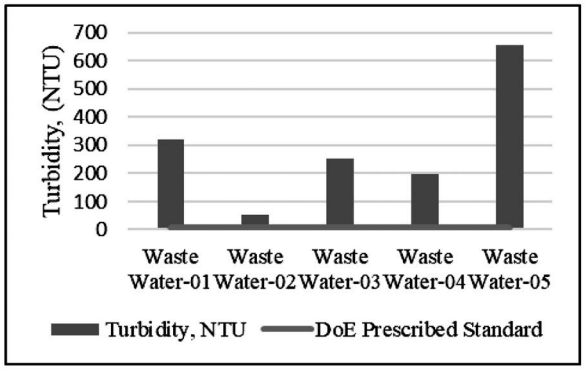


Fig. 6. Comparison of turbidity

4.7 Color

The color values ranged from 1732-2939 Pt-Co during the (Table 2). The variation of color concentrations is shown in Fig. 7. The highest color value of 2939 Pt-Co is observed in sample wastewater 03 and the lowest color of 1732 Pt-Co is observed in sample wastewater 01 (Fig. 7).

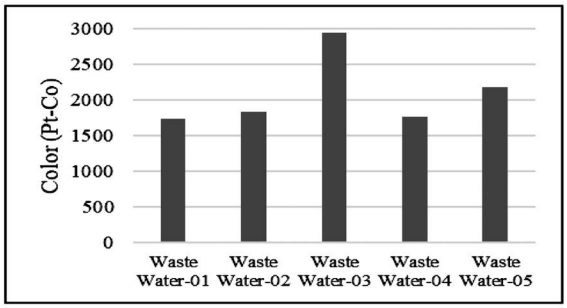


Fig. 7. Comparison of color

4.8 Optimization of coagulant dose

One of the most significant criteria to consider in the coagulation and flocculation processes is the coagulant dose. The coagulant performs poorly in flocculation due to insufficient dosage or overloading. To reduce dosing costs and achieve optimal clearance rates, the appropriate coagulant dosage must be calculated. As dosages increased, all coagulants' removal rates increased until they achieved their optimum levels. Their removal rates fell at dosages above the optimum due to overdose, which caused the coagulation to destabilize, resulting in lower removal rates. Wastewater sample 3 has taken for treatment process.

4.9 pH value

Figure 8 show that, pH has been reduced by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. The efficiency of pH removal for Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer is intermediate. The pH reduction shows better results when using Ferric Chloride + Polymer. pH values are reduced 48%, 36.11%, 31.2%, and 25% respectively by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. In this case, Ferric Chloride is better for the removal of pH.

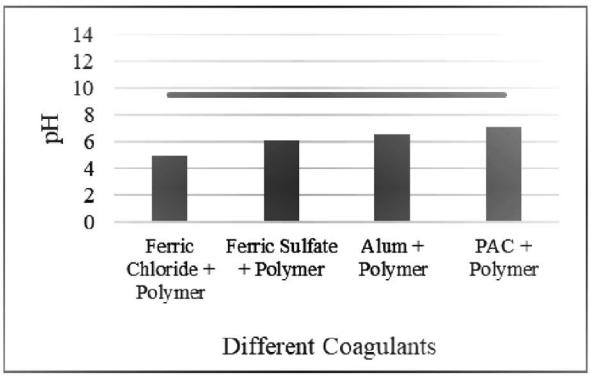


Fig. 8. pH values for different coagulants of 550 mg/L

Figure 9 shows that, coagulant induced the decrease of pH. Among all the doses, 350 mg/L has the minimum effect on the final pH. On the contrary, 750 mg/L causes the most significant pH decrease.

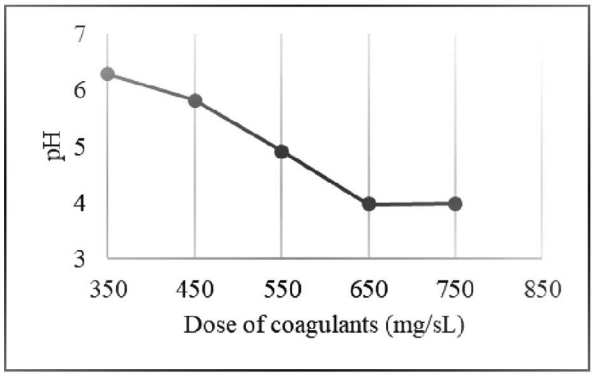


Fig. 9. pH values for different dose of $FeCl_3$

As a result, pH plays a crucial part in the coagulant's operation. Different findings from the trials are studied in the following figures to better understand the behavior and to find the best circumstances using the classic jar test.

4.10 Conductivity

Figure 10 shows that the conductivity has been increased by using Ferric Chloride + Polymer, Alum + Polymer, and PAC + Polymer and decreased by using Ferric Sulfate + Polymer. The efficiency of conductivity removal for Ferric Sulfate + Polymer is very law. Conductivity value is removed 5.6% by using Ferric sulfate + polymer. In this case, Ferric sulfate + polymer better for the removal of conductivity.

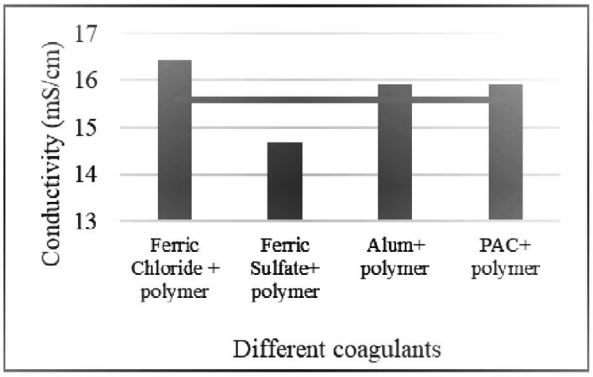


Fig. 10. Conductivity values for different coagulants of 550 mg/L

4.11 Total dissolved solids

Figure 11 shows that TDS has been increased by using Ferric Chloride + Polymer, Alum + Polymer, and PAC + Polymer and decreased by using Ferric sulfate + polymer. The efficiency of TDS removal for Ferric Sulfate + Polymer is very law. TDS value is removed 6% by using Ferric sulfate + polymer. In this case, Ferric sulfate + polymer better for the removal of TDS.

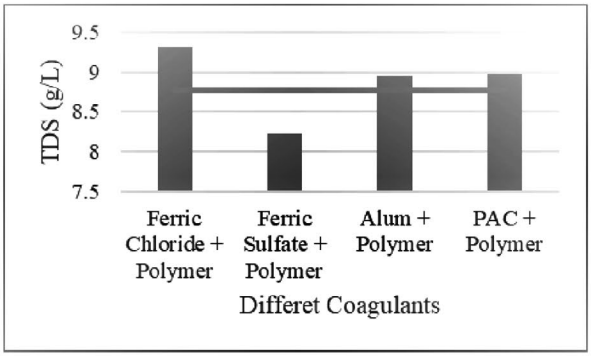


Fig. 11. TDS values for different coagulants of 550 mg/L

4.12 Total suspended solids

Figure 12 show that, TSS has been removed by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. The efficiency of TSS removal for Ferric Chloride + Polymer, Ferric Sulfate + Polymer, and PAC + Polymer is law and for Alum + Polymer is very high. The TSS reduction shows better results when using Alum + Polymer. TSS values are removed 44%, 10%, 77%, and 16% respectively by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. In this case, Alum + Polymer is better for the removal of TSS.

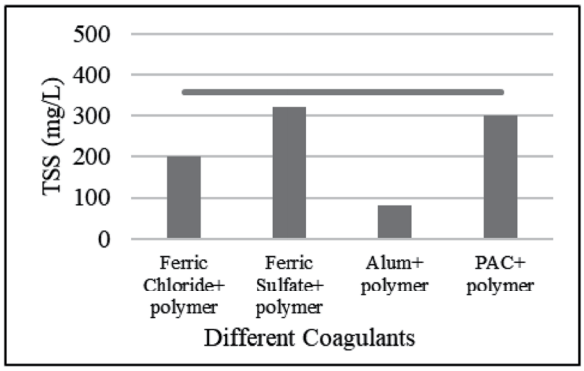


Fig. 12. TSS values for different coagulants of 550 mg/L

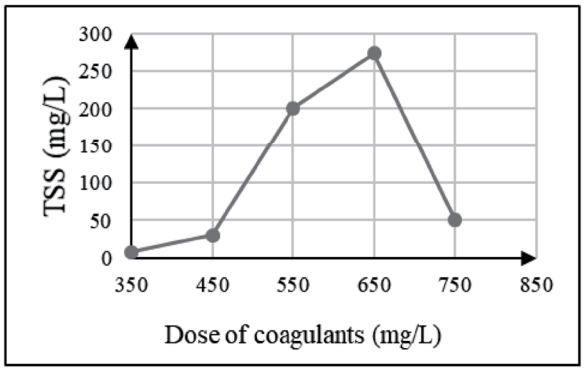


Fig. 13. TSS values for different dose of FeCl3

Fig. 13. TSS values for different dose of $FeCl_3$ Figure 13 show that, removal efficiency is 23.68% at 650 mg/L is not good. But decrease in coagulant dose Ferric Chloride shows even better result than others and become saturated at 350 mg/L with 97.77%. Among all the doses, 650 mg/L has the minimum effect on the final TSS. On the contrary, 350 mg/L causes the most significant TSS decrease.

4.13 Turbidity

Figure 14 show that, Turbidity has been removed by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. The efficiency of turbidity removal for Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer is very high. The turbidity reduction shows better results when using Ferric Chloride + polymer and Ferric sulfate + polymer. Turbidity values are removed 97%, 89%, 70%, and 55% respectively by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. In this case, Ferric Chloride + Polymer is better for the removal of turbidity.

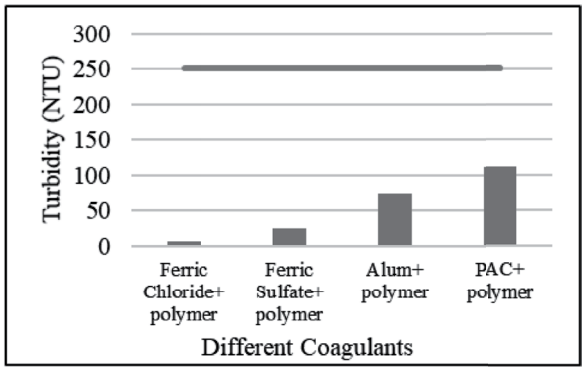


Fig. 14. Turbidity values for different coagulants of 550 mg/L

Figure 15 shows that; removal efficiency is 92.42% at 650 mg/L. But decrease in coagulant dose Ferric Chloride shows even better result than others and become saturated at 350 mg/L with 98.98%. among all the doses, 650 mg/L has the minimum effect on the final turbidity. On the contrary, 350 mg/L causes the most significant turbidity decrease.

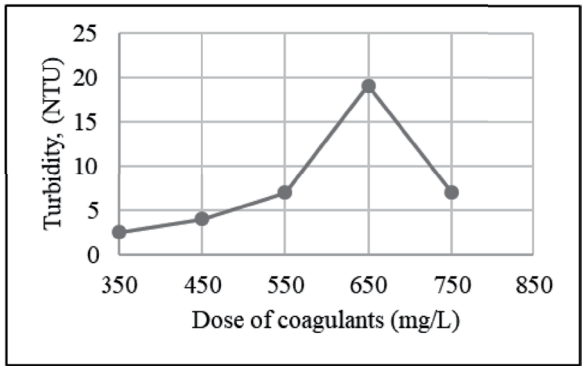


Fig. 15. Turbidity values for different dose of FeCl3

4.14 Color

From the Fig. 16, Color has been removed by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. The efficiency of color removal for Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymeric is very high. The color reduction shows better results when using Ferric Chloride + polymer. Color values are removed 78%, 70%, 77%, and 76% respectively by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. In this case, Ferric Chloride + Polymer is better for the removal of color.

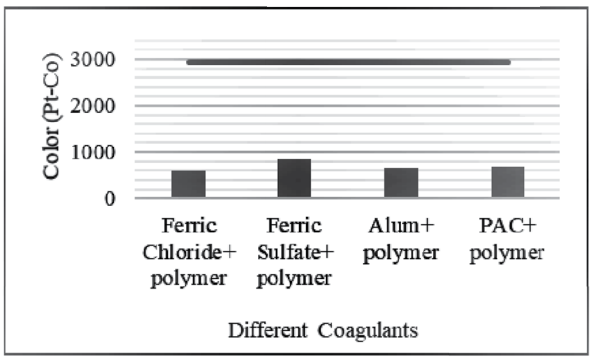


Fig. 16 Color values for different coagulants of 550 mg/L

From Fig. 17, it is obvious that adding coagulants to wastewater with coagulant aid improves color removal. In case of 750 mg/L, Ferric Chloride was better with removal of 93%, whereas the other four were not very efficient in removing color. Ferric Chloride shows even better result than others and become saturated at 750 mg/L with 93%. among all the doses, 350 mg/L has the minimum effect on the final color. On the contrary, 750 mg/L causes the most significant color decrease.

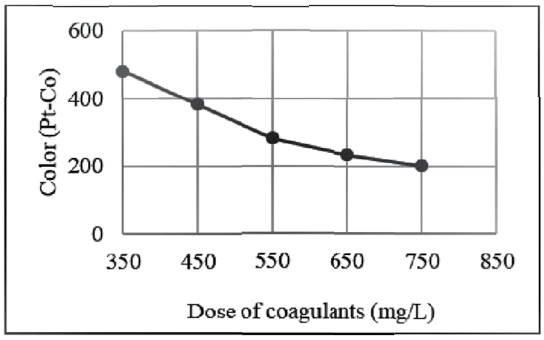


Fig. 17. Color values for different dose of $FeCl_3$

In case of 750 mg/L, Ferric Chloride was better with removal of 93%, whereas the other four were not very efficient in removing color. Ferric Chloride shows even better result than others and become saturated at 750 mg/L with 93%. Among all the doses, 350 mg/L has the minimum effect on the final color. On the contrary, 750 mg/L causes the most significant color decrease.

4.15 Chemical oxygen demand

From the figure 18, COD has been removed by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. The efficiency of color removal for Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymeric is very high. The COD reduction shows better results when using Ferric Chloride + polymer. Color values are removed 79%, 75%, 74%, and 72% respectively by using Ferric Chloride + Polymer, Ferric Sulfate + Polymer, Alum + Polymer, and PAC + Polymer. In this case, Ferric Chloride + Polymer is better for the removal of COD.

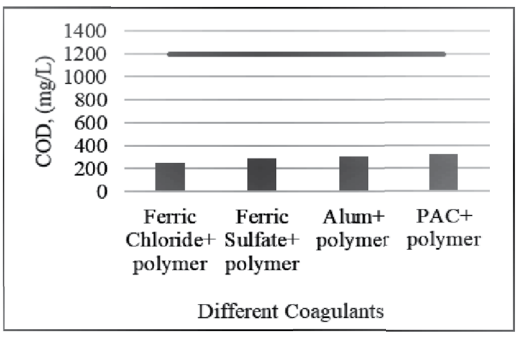


Fig. 18. COD values for different coagulants of 550 mg/L

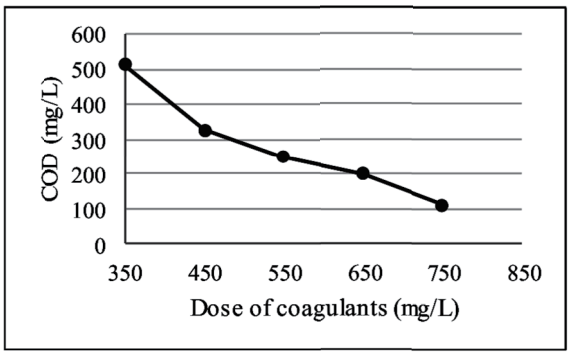


Fig. 19. COD values for different dose of $FeCl_3$

The addition of 750 mg/L of coagulant with coagulants aid produced excellent results, as shown in the figure 19. At 350 mg/L Ferric Chloride showed the minimum removal of 57.12%. So, in this case 750 mg/L can be said optimum dose.

5. CONCLUSION

The study found that the volume of wastewater produced by the companies under investigation frequently exceeds allowable limits. Textile dyeing factories in the Gazipur region produced substantial amounts of wastewater including a variety of physicochemical pollutants at levels much above the DoE regulation. With the growing number of textiles dyeing businesses, the concentration of these pollutants is rising at an alarming pace. It is extremely harmful to both aquatic and human life [12]. As a result, if discharge without treatment has a significant negative impact on the environment, wastewater should be treated to ensure better industrial water quality for current and future generations.

Textile wastewater treatment study has been successfully operated by $FeCl_3$, $Fe_2(SO_4)_3$, Alum, PAC (Poly-aluminum-chloride) at 550 mg/L of dosage with 60 mg/L of coagulant aid. Among them, $FeCl_3$ has a high removal percentage of Turbidity, Color, TSS, and COD of the wastewater were 97%, 78%, 44%, 75% and pH reduction percentage of the wastewater was 48% which is acidic. This could be one of the study's flaws. Applying different dosages of $FeCl_3$ resulted in good efficiency at 750 mg/L.

The treated wastewater quality slightly satisfied the Bangladesh Environment Conventional Rules 1997. The

study suggested that the use of $FeCl_3$ of 750 mg/L with coagulant aid provides best result for treatment of textile wastewater.

Textile effluent contains dyes, microorganisms and heavy metals such as Lead (Pb), Arsenic (As), Chromium (Cr), Nickel (Ni), Copper (Cu), Cadmium (Cd), Mercury (Hg), Zinc (Zn) etc. Further work can be done on the dyes, microorganisms, and heavy metal characterization [13]. The study work can be done on a wide range of coagulants and dosages to find the most effective coagulant.

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A CFD Modeling of the Effect of Trees on Urban Air Pollution Dispersion from Road Traffic Emission in Dhaka City Canyon

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ABSTRACT

Traffic emission is the predominant source of air pollution in urban areas. Trees utilization is one of the optimal urban planning strategies for the healthy living of urban inhabitants. The role of trees on the roadside and the rooftop or in the middle of street canyons is immense reducsing pollution. A Numerical simulation has been performed using ANSYS Fluent solver to investigate the flow behavior as well as the impact of the vegetation on the reduction of the traffic-exhausted pollutants in the urban street canyons. The numerical simulation has been carried out based on Reynolds Averaged Navier-Stokes (RANS) using the finite volume method (FVM) for the k-ϵ turbulent model in commercial CFD (Computational Fluid Dynamics). To calculate the physical phenomena of wind flow; it has been imported velocity profile, turbulent kinetic energy, and pollutants dissipation rate using UDF (User Define Function) of the programming language C/C+. The influence of the trees on pollutants concentration of CO (carbon monoxide), CO_2 (carbon dioxide), and PM10 (Particulate matter) have been investigated considering: (1) without trees, (2) with tress as 5m, 10m, 15m, and 20m tall trees. Tree-free streets work better to disperse the traffic-exhausted pollutants inside the urban street canyon. The street width varies due to different trees configuration. As a result, the speed of the wind varies, and the dispersion of vehicles emission hampers considerably. There is a matter of concern; the tree plantation on the rooftop fund is more conscious because of the trees and the height of the building. In the end, it has been found that the tree plantation has an influence in reducing the harmful pollution in urban street canyon pavements.

Keywords: RANS; ANSYS FLUENT; Vegetation; Pollutants dispersion; Traffic emission; Finite volume method.

1. INTRODUCTION

Pollutant dispersion in urban areas has been a concern in densely populated cities because pollutants harm the environment and human health.

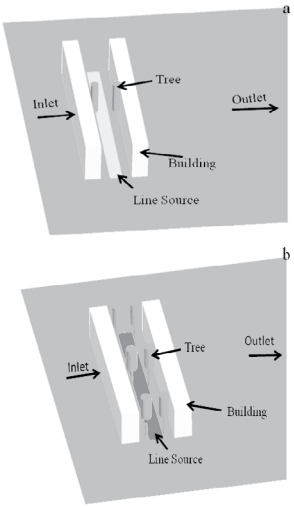


Fig. 1: The geometrical model (a) double trees inside canyon and (b) multi trees inside canyon

The environmental conditions in large cities have gradually deteriorated during the last two decades owing to pollutant emissions from motor vehicles. The number of air quality monitoring stations is insufficient to describe the distribution of pollutants over the street accurately.

Pollutants generally reduce air quality in city areas exhausted from motor vehicles including automobiles, trucks, three-wheeler, and trains. Nowadays, many city planners have shown interest in urban forestry through tree plantations to make green space and vegetation into them in the urban environment. The researchers have been working for decades on the benefits of green spaces and vegetationby considering the use of lower energy to reduce air pollution [1-3] and protect from harmful rays. They have also looked for ways to decrease storm water runoff, heat island mitigation, protect the reduction of pavement vegetation, and reduce traffic noise for the well-being of the urban population [4-10]. The trees work to reduce traffic pollutants by removing pollutants from the atmosphere which have been deposited on the plant surfaces. On the other hand, trees themselves work as obstacles concerning the airflow that leads to the concentration of pollutants inside the canyon. In the literature of the work, there have been several studies performed about the effect of trees on urban air quality [11, 12]. A pioneering experiment has been performed on wind tunnel flow behavior at the University of Karlsruhe to measure the concentration of the pollutants at the windward side, and at the leeward side in isolated symmetric street canyons with several aspect ratios considering different wind directions [12]. It has shown that

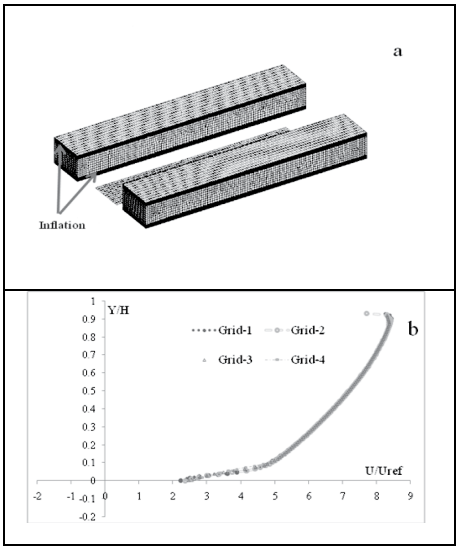


Fig. 2: The meshing of the model (a) represents the mesh of a model with inflation (b) the graph about grid independency

the concentration of the pollutants inside the canyon depends on the wind direction and the aspect ratios of the street canyons rather than trees avenue porosity that has typically found the city life. To simulate CODASC case model, there had been applied several Computational Fluid Dynamics (CFD) models, and parameterized the aerodynamics as well as the deposition of the effect of trees to study the wind flow behavior and the dispersion of the pollutants inside the complex geometries [13-21]. From later studies, Gromke and Blocken [17] have found that at the pedestrian level, the concentration of the pollutants has increased for various trees in the generic urban neighborhood. Several researchers have investigated the effect of the trees considering aerodynamics with particular a particular area of Lisbon and Aveiro (Portugal) [15]. Several authors have worked with the purely dynamic point of view to investigate the concentration of pollutants in Leicester (UK) [18, 19]. Gromke et al. [2] have also found the concentration of several pollutants is reduced by up to 60% with the presence of continuous hedgerows. These results show that the effects of trees and urban vegetation generally are strictly dependent on their interaction with geometry and meteorological conditions. Studies tend to agree that the aerodynamic effect of trees is more signification than deposition [22, 19]. The main objective of this study is to address the aerodynamic effect of trees using the CFD dispersion model in combination with carbon monoxide (CO) in Dhaka city street canyon and suburbs. It allows a comprehensive evaluation of the effects of trees on pollutant dispersion. In the present investigation, pollutant dispersion simulation in urban areas is carried out numerically by applying a RAN based k-ε turbulence model. A species transport equation has been solved for the gas dispersion simulation. Finite volume methods (FVM) based on ANSYS FLUENT 17.0 have been used for simulation purposes.

2. MODEL DESCRIPTION AND VALIDATION

The computational Fluid Dynamic model is used to describe and then validated against the CODASC wind-tunnel experiments in this part.

2.1. Model description

In the CFD model ANSYS FLUENT solver software package version 17.0 has been used. In this research, the simple fluent over one standard solver of ANSYS FLUENT has been applied to solve the Reynolds-averaged Navier-Stocke equations with the k-ε turbulence model using SIMPLE Scheme [23]. The SIMPLE Scheme is an iterative method to solve the algebraic system of equations. A termination criterion of 10-6 is used for all field variables here. The k-ε turbulence models with the standard k-ε model, the renormalization group (RNG) k-ε model [24], and the realizable k-ε model [25] are employed as well. To verify the performance of the model the simulation has been validated by comparing the data with the research work of Gromke and Ruck [26, 27] that was obtained from the wind tunnel experiment with the wind tunnel experiment using CODASC. At first, simulating a subscale model is considered to reduce cost and time consumption.

A three-dimensional CFD model is used to understand the pollutant transport process and distribution patterns in street canyons with three different configurations. CFD results are compared with concentration data from wind-tunnel experimental data (CODASC). According to the World Meteorological Organization classification the soil surface has considered smooth with a rough surface of 0.03m [28]. The surface between the buildings has been considered rough surface of 0.01m works as an occasional obstacle. An idealized tree population has been considered that corresponds to the average tree profile encounters in Tejgoan of Dhaka. In regards to tree species management, studying the impact of the vertical distribution of leaves for different tree species and different canopy shapes leaves room for future research. The trees have been modeled as a porous media resulting in a perturbation of the airflow and the removal of particles via deposition. The model has simulated turbulent wind velocity as of 4.6 m/s to investigate the flow behavior.

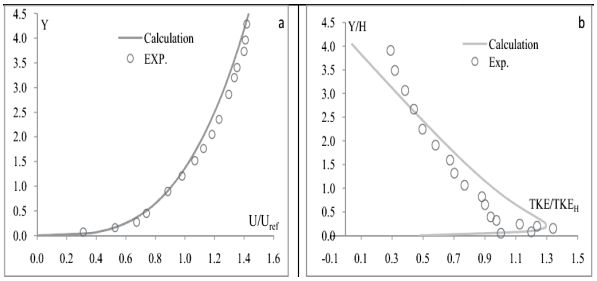


Fig. 3: Comparison between simulated data and experimental data (a) represents the velocity profile and (b) represent the turbulent kinetic energy

However, the simulation has been done considering the laminar wind flow with a velocity of 1m/s which is the wind velocity in the winter season in Bangladesh. The

mean velocity flow and the turbulent dissipation have been set up to follow a logarithmic law to reflect an atmospheric boundary layer profile on the bounding edges of the computational domain.

2.2. Three dimensional street canyon numerical experiment

The model is designed similarly to the wind tunnel experimental model with an aspect ratio one has scaled of 1:150, similar to the actual isolated street canyon model perpendicular to approaching flows. The wind-tunnel model consists of two parallel buildings of 0.12 m×0.12 m×1.2 m (H×W×L), and the distance between the two paralleled buildings is 0.12 m. Second, some models have been chosen to reflect Bangladesh's urban areas with building height H = 18 m and road width W = 7.5 m. This measurement represents a deep street canyon of H/W = 2.4. We have also examined non-uniform, irregular street canyons in one model as step-down-up-down. The height of the first, second, and third buildings are 5m, 10m, and 20m. In Fig. 1 all models are shown.

2.3. Grid independence test

For the wide acceptance of a model, it is necessary to test the grid of the mesh. The grid independence study in a numerical model is a necessary factor. The simulation will have no validity if it depends on the grid of the mesh. We have used several grids to check our present study simulation. For some numerical experiments, we have also used different grids: grid-1 (max face size: 0.02 and node: 1757647), grid-2 (max face size: 0.03 and node: 688431), grid-3 (max face size: 0.04 and node: 359835), and then grid-4 (max face size: 0.05 and node: 259165). For making an appropriate grid ANSYS FLUENT 17.0 is used, near the street floor, the cell has been made finer than the cell at the top of the buildings to capture the boundary layer phenomenon properly. The velocity distribution at the inlet for all cases remains the same and matches the experiment; a similar distribution has been observed for all grids in the middle of the street canyon. We have taken grid 0.03 for our simulation purposes shown in Figure 2(b).

2.4. Model validation

Model validation is performed prior to case studies. The current model is validated against the wind tunnel experiment's data from the study of Gromke and Ruck [26, 27]. The validation plot against the CODASC experimental results have been presented in Fig. 3 showing the

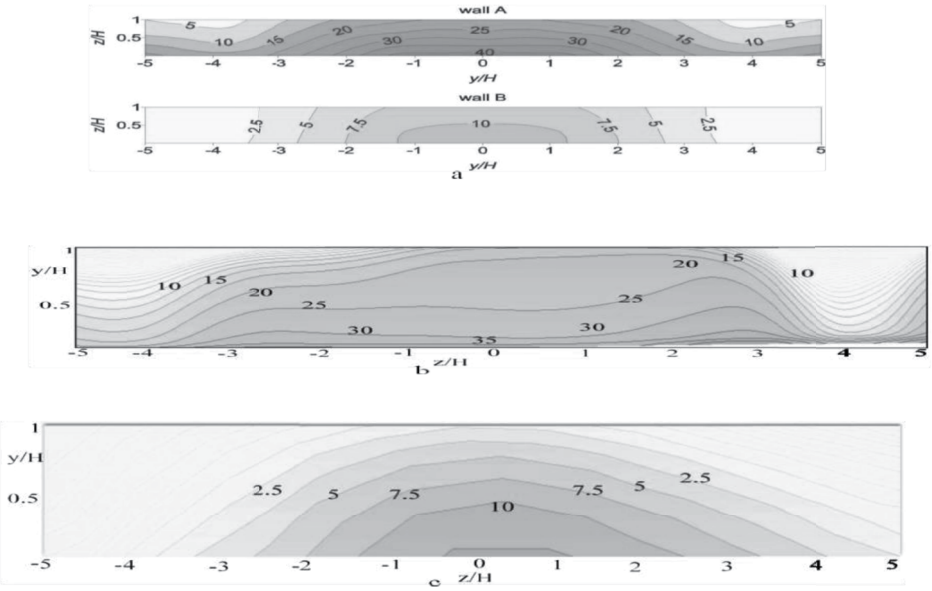


Fig. 4: Comparison between simulated results and the CODSC experimental data considering contour (a) represents CODSC data of CO mass fraction at leeward and windward, and (b) and (c) simulated CO mass fraction at leeward and windward respectively

agreements in terms of inlet velocity profile Fig. 3(a) and 3(b) inlet turbulent kinetic energy (TKE). In addition, the normalized pollutant concentrating contours inside the canyon on both sides at leeward (wall addition, this model also has had validated against CODASC experimental results. The time-averaged CO mass fraction has shown (wall A) and windward (wall B) in Fig. 4(a-c) respectively. It could be seen that the normalized concentration in leeward (wall A) in Fig. 4(a) is approximately 75% higher than that of windward (wall B) in Fig. 4(b). Similar visualization is obtained in terms of RANS model as well as shown in Fig. 4 (b, c). Meanwhile, Fig. 5 and 6 depict

the comparison between the present RANS experimental and the wind tunnel experimental results. A quantitative presentation of the pollutant concentration has also been executed at five various span wise position on both leeward (wall A) and windward (wall B) as Z/H= 0; Z/H= 1.66; Z/H= 3.334; Z/H= -1.66; and Z/H= -3.334. Based on the demonstrations from Figures 5, 6 have shown that the current numerical simulation results have good agreement with the CODASC experimental results.

3. NUMERICAL EXPERIMENT SETUP OF DIFFERENTIAL CONFIGURATIONS

3.1. Numerical approach

For three-dimensional simulations, the mesh structure used in this domain is shown in Figure 2 using structured, uniform hexahedral mesh, and the physical model has discredited. The computational time required for three-dimensional simulations is approximately three times two-dimensional simulations. This study two different kinds of street canyon configurations under the perpendicular approaching flows have considered. Cars that use fossil fuels are the sources of air pollution which oxidized products. The air pollutants that could identify that pass through the street canyons are carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), unburned hydrocarbons, volatile organic

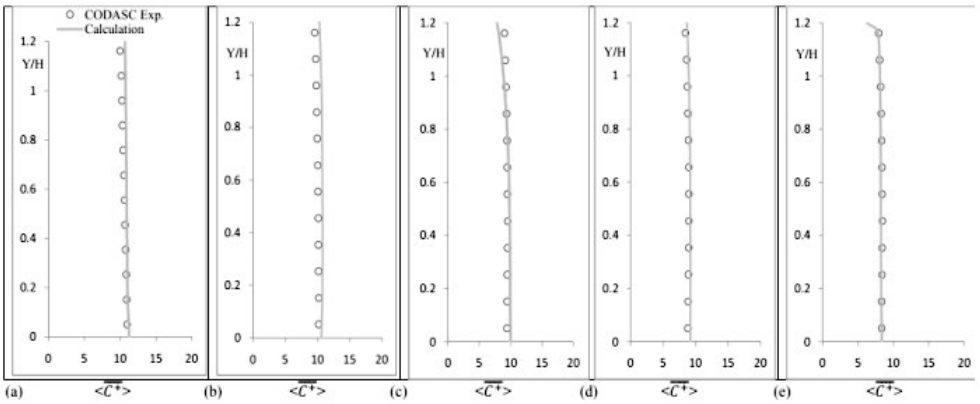


Fig. 5: Time-averaged normalized pollutant concentration profiles at five separates span wise positions on Windward (wall A) (a) Z/H = 0; (b) Z/H = 1.66; (c) Z/H = 3.334; (d) Z/H = -1.66; and (**e**) Z/H = -3.334 to compare current RANS vs. WT experiment

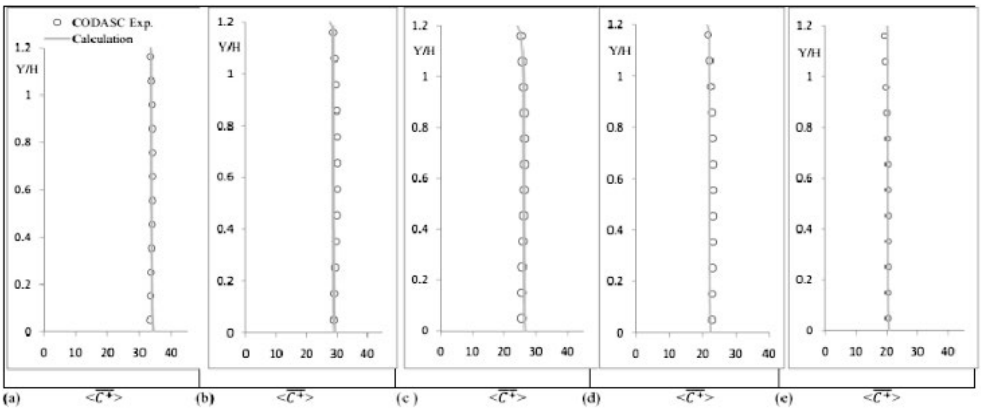


Fig. 6: Time-averaged normalized pollutant concentration profiles at five separates span wise positions on Leeward (wall A) (a) Z/H = 0; (b) Z/H = 1.66; (c) Z/H = 3.334; (d) Z/H = -1.66; and (e) Z/H = -3.334 to compare current RANS vs. WT experiment

compounds (VOCs) (propane, ethylene, toluene, xylene, benzene, butane, ethane, and pentane), suspended particulate matter (SPM), and SPM is the main substances of the complete combustion. And for incomplete fuel combustion of fuels, CO is produced. Nitrogen oxides are also produced from the relation between nitrogen and

oxygen in the air with high temperatures and complete combustion inside the engines [29-31]. CO has chosen as the source gas in this study that has very negative impact on life particularly on those who live near the main road. People suffer from cerebral shrinkage. In urban areas several vehicles move have considered inserting species where several pollutants-related traffic run because rapid chemical reactions only affect pollutant concentrations due to the short distances observed between the sources and receptors within the avenue [32]. Since, the flow of the wind and the pollutant dispersion into street canyons are highly turbulent. This simulation, the RANS-based well-accepted k-ε turbulence model in the RANS has used due to turbulence near tall buildings through the street canyon. The wind is considered normal to the street canyons, and the source of the pollutants is assumed to be linear. To calculate the pollutant concentration using ANSYS FLUENT solver atmospheric boundary layer (ABL) is incorporated through a defined function (UDF).

The RANS equations include mass equation, momentum equation, and mass transport equation, which are expressed by the flowing:

$$\frac{\partial \rho}{\partial t} + \frac{\partial u_i}{\partial x_i} = 0 \quad (1)$$

$$\rho \frac{\partial u_i}{\partial t} + \rho \frac{\partial}{\partial x_i}\left(u_j u_i + \overline{u_i' u_j'}\right) = -\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_i}(\tau_{ij}) \quad (2)$$

$$\frac{\partial C^{\alpha}}{\partial t} + u_j \frac{\partial C^{\alpha}}{\partial x_i} = \frac{\partial}{\partial x_i}\left((D^{\alpha} + \frac{\vartheta_t}{S_{ct}})\frac{\partial C^{\alpha}}{\partial x_i}\right) \quad (3)$$

where u_i and P are the Reynolds average velocity and pressure respectively, u_i' is the fluctuating velocity, $\rho$is the fluid density, ϑ is the kinematic viscosity, C^{α} is the concentration of pollutant species α, D^{α} is the diffusivity, ϑ_t is the turbulence eddy viscosity, and S_{ct} is the turbulence Schmidt number. The term $\overline{\rho u_i' u_j'}$ is the time averaged rate of momentum transfer due to turbulence. The k-ε RANS based dispersion model is used to determine the turbulent velocity where the pollutants dispersion equation is coupled with the k-ε model. The transport equation for the turbulent kinetic energy and dissipation rate ε is given below.

The k-equation is:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho k u_i) = \tau_{ij}\frac{\partial \bar{u}_i}{\partial x_j} - \rho\varepsilon + \frac{\partial}{\partial x_j}\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right) \quad (4)$$

The ε-equation is

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = C_{\varepsilon 1}\frac{\varepsilon}{k}\tau_{ij}\frac{\partial \bar{u}_i}{\partial x_j} - C_{\varepsilon 2}\frac{\rho\varepsilon^2}{k} + \frac{\partial}{\partial x_j}\left(\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right) \quad (5)$$

where $\vartheta_t = C_\mu \rho \frac{k^2}{\varepsilon}$, $C_\mu = 0.09$, $\sigma_k = 1\sigma_\varepsilon = 1.3$, $C_{\varepsilon 1} = 1.44$, and $C_{\varepsilon 2} = 1.92$

3.2. Boundary condition

The computational domain with finer resolutions by making irregular tetrahedral and hexahedral grids has been used to simulate the neutral atmospheric boundary layer.

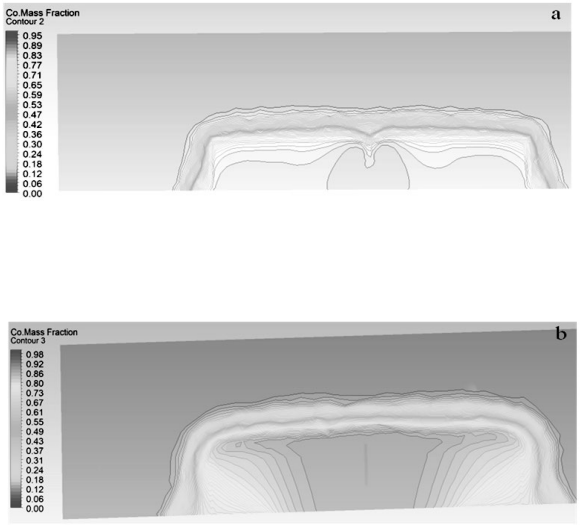


Fig. 7: The figures represent the CO mass fraction for the double trees (a) the contour at the windward, and (b) the contour at the leeward.

For most of the cases, 1.75 million computational cells have been used. The ground surface has specified as a rigid plane with specified surface roughness. A simple velocity inlet condition (specifying velocity, turbulent kinetic energy (TKE), and turbulent dispersion rate ε profiles) is used for all FLUENT simulations with a specific pressure at the middle of the flow domain and used outflow conditions at the outlet. All simulations are carried out as transient state solutions of the Navier-Stokes equations and for the conservation of mass species. To increase the accuracy and reduce numerical diffusion second ordered discretization schemes have been used. The specific methods are second-order upwind for pressure, momentum, k, and ε, and the SIMPLE has been used for the pressure velocity coupling. The flow variables have recalculated each iteration that starts from an initial guess to solve each equation up to a user-specified error. The termination criterion has usually based on the residuals of the corresponding equations. After the first iteration, the residuals have done with the residuals for the scaling. A termination criterion of 10-6 has been used.
In this article, it is considered for each case that residuals reached the chosen level and are stopped after about five thousand iterations to get steady-state solutions. It is observed that the flow values remained the same concerning the number of iterations whereas certain quantities reached convergence at a different rate than other quantities. A grid convergence study is made on the solution to quantify the influence of grid resolution. To perform this, we have used different systematical and

substantial refined grids. The minimum grid refinement ratio is about 1.1 to allow discretization error to be differentiated from other error sources (iterative convergence errors, computer round off, etc.).

We have used a velocity profile that's equal to the wind speed profile used in CODASC at the inlet as

$$u(y) = 4.7\left(\frac{y}{H}\right)^{0.3} \quad (1)$$

While turbulent kinetic energy and dissipation rate profiles are specified as follows:

$$k = \frac{u^{*2}}{\sqrt{C_\mu}}\left(1 - \frac{y}{\delta}\right) \quad (2)$$

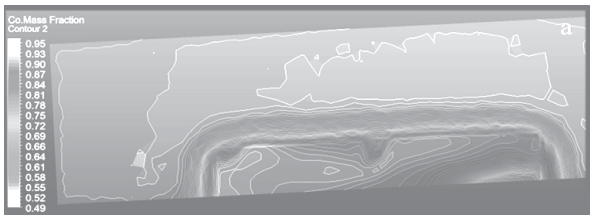
$$\varepsilon = \frac{u^{*3}}{ky}\left(1 - \frac{y}{\delta}\right) \quad (3)$$

here u, y, δ, , y, δ, u^*, and k are vertical velocity profile, vertical distance, boundary layer depth, frictional velocity, and Von Karman constant respectively with C_μ

The building walls have considered no-slip boundary conditions, and the upper boundary has been considered a symmetry boundary. In Bangladesh, the dispersion source has mainly related to traffic which emits CO pollutants which have considered widespread traffic emissions. It has chosen to release CO with an emission rate of 10 g/s. The pollutants source of CO is located at the ground level, as shown in Figure 1. The comparison between the simulated inlet velocity profile and CODASC data has shown in Figure 3. It has been shown that the present calculation and experiment data are well-matched.

3.3. Fluent simple traffic source dispersion step up

For the validation of dispersion results, we have considered a traffic source placed in the neutral atmospheric boundary layer for the case of CO dispersion. For the gas dispersion simulations, we have made a reduced computational domain with dimensions of 2.88 m by 2.88m in the horizontal and 4.56m in the vertical direction. At the inlet, the flow of CO rate has considered as 10 g/s which is similar to the CODASC urban model used in FLUENT



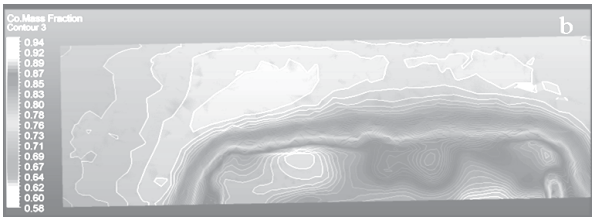


Fig. 8: CO mass fraction for the multi trees (a) the contour at the windward, and (b) the contour at the leeward

The reduced domain size allowed us to further refine the grid near the release and downstream of it, especially in those regions where the plume is evolving. Near the traffic sources, the grid elements are about 0.01m in size and grow with a ratio of 1.2. The traffic source is positioned perpendicular to the wind direction at 0.0001m downwind at the inlet. Overall, 1.75 million computational cells have used. Setting the CO source term at the required discharge position in the geometry, the traffic source has simulated with a separated volume. The dimensions have used for the traffic source in CODASC; we have also used the same area to form the base of volume. The height has set to 0.0001m. Several tests have performed before choosing this value by verifying the independence of FLUENT results from the specific choice of the height of the volume source. It has observed that there is no influence on the final concentration results between the height of 1.5 m and 2m.

4. RESULTS AND DISCUSSION

In this section, we have compared our CFD simulations and validated them against the CODASC database [12]. After validating the data obtained from simulations, we evaluated the effects of trees on the concentration level of CO inside the street canyon. We have also paid attention which is related to the concentration of pollutants as aerodynamics and wind speeds as well as wind directions. Finally, we have used CFD simulations to provide comprehensive evaluation of concentration levels and the effects of trees.

4.1. Model seasonal uncertainty

The simulated concentrations of CO have been analyzed in Figures 7, 8. The results obtained from the simulation showed a concentration of CO has underestimated by at least 20% compared with the experimental results. This underestimation is a common feature of the air quality dispersion model in Dhaka [33]. The main reason behind this underestimation is diesel vehicle emissions that exhaust CO due to incomplete combustion of the diesel [34]. Therefore, the reduction of CO concentrations has been found due to deposition velocity that further enhances a sink in the leaf seasons. In the winter season, trees usually have lees leaves, so the concentrations have been overestimated which refers to another mechanism of overestimation. In the rainy season, the weather is wet deposition that has not been considered

in this study with rain which works as a sink of CO pollutants. However, sometimes the wet weather would lead to concentrations due to the resuspension.

4.2. Influence of trees under different wind directions

In this section, we have focused on the impact of the trees under different wind directions on the traffic emission of CO. The influence of wind direction on CO concentrations has been emitted by traffic for a wind speed of 5 m/s, without 4.2 m/s. On the other hand, in different seasons, the pollutants are trapped due to trees in Dhaka city. The effect of the aerodynamics is similar during the leaf seasons that increase the concentrations of the CO that are equivalence to 1.2g/m^3. Similarly, it has been found that the influence of the deposition is more than that of the aerodynamic impact as reduction of 1.4% in spring and autumn and 2.1% in summer. It has also been found that in the summer season, the deposition has higher than in spring and autumn because of great leaf region density shown in Figure 9.

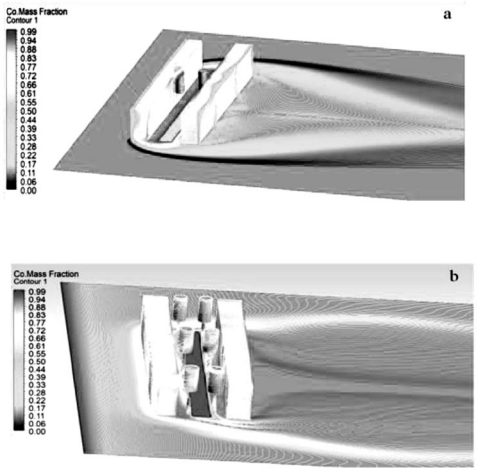


Fig. 9: CO mss fraction both double trees and multi trees (a) denotes double trees (b) demonstrates multi trees

4.3. Influence of trees under different wind speeds

The results showed that the different wind speeds have a greater effect on the CO mass concentration dispersion due to lower wind speed concentrations being high shown in Figures 7, 8. In the summer season, the traffic exhaust pollutants have increased by 16.7% at a wind speed of 3 m/s where due to deposit concentration decreased by 3.4%. Dispersion and deposition do not decrease at the same rate across the different wind speeds, suggesting that the effects of trees are not linear with wind speed changes. However, little turbulent dispersion occurs at lower wind speeds because trees act as obstacles to wind flow, explaining the wind-trapping ability of trees at lower wind speeds. The pollutant's particles suspended to deposit on leaves takes much time to dispersion at lower wind speeds. Furthermore, the concentration of pollutants has increased lead deposition, and fewer pollutants dispersion occurs at lower wind speeds.

4.4. Effects of trees at Dhaka measurement area

The streets parallel to the prevailing winds can mitigate the concentrations of the pollutants from the analysis of CFD data in Dhaka city. However, trees also exacerbate trapping for wind directions perpendicular to the street canyon orientation, and tree planting would not improve air pollution in this situation. In this study, we have used the CFD model for the simulation by considering no effects on the branches and the trunks of the trees. Here results suggest that the remains of trunks and branches or possibly the presence of evergreen pine trees seem to play a role in winter.

4.5. Effects of trees on pedestrians in Dhaka road

In the whole of Dhaka city at a pedestrian height of 1.5 m, the effects of the concentration of CO have been analyzed with the CFD model shown in Fig. 9. The pollutants are subsequently spread from the sources of the pollutant with the introduction of the slightly changes the distribution of concentrations. Sometimes at a pedestrian level to study the effect of the trees becomes difficulties when the concentration decreases or increases is important to find the trapping ability of trees, particularly around the required region. A reason for this increase might be the high number of trees towards the East of the monitoring site that act as a barrier to the prevailing winds coming from the South West. Therefore, increasing the pollution concentration is moderated due to reducing the wind velocities. On the other hand, we consider that the trees are along the street, and it has been found that the effects of the aerodynamics of trees on pollutants concentration are influential. In the particular case of Dhaka city road, where prevailing winds are parallel to the street canyon, more weight has been given to favorable wind directions.

5. CONCLUSION

The simulation has been carried out considering CO gas as the only vehicular exhaust. Based on the traffic rate and composition of traffic at the ground level, the rate of the emission of CO has been calculated in kg/m^{3}s. The present study is a novel validation of the model with CODASC wind tunnel experiments. In this study, we have achieved several conclusions in Dhaka city region that the aerodynamic effects of trees over the depositions have an impact.

- The low wind speed there have the worst effects on trees on air quality since the turbulent mixing inhibited. It indicates from the previous findings inside street air quality has altered by tree.
- When wind blows along with street less pollutant concentrates inside the canyon. Though, trees act as a barrier to disperse pollutants that don't harm the residential. However, when wind blows in other directions, trees act as a sink of the pollution.

- In the winter and rainy seasons trees work well to reduce pollution than in the other seasons. Pollutants usually concentrate on the leaf's surfaces and gain weight by mixing with water molecules dropped down to the soil surface. So, the more the trees, the less the pollution inside the residential buildings.

The above findings the leaving room for further studies and suggest; it is a crucial need for research to provide effective tree-planting policy advice for urban planners of Bangladesh. It could lead to substantial air quality improvements depending on the interaction of trees with local meteorological conditions and building arrangements in Dhaka city.

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Locally-crafted Prefabricated Dwellings of "Ghorer Hat" in Munshiganj: An Investigation into Local Housing Provision and User Preference

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ABSTRACT

Riverbank erosion is a recurring natural disaster in Bangladesh that is quietly altering the landscape of this country. Bounded by two erosion-prone rivers, Munshiganj district suffers from the unavoidable scourge of riverbank erosion periodically. To coexist with this preconditioned crisis, local masons of Munshiganj devised an indigenous solution: prefabricated and portable wooden houses which can be dismantled and relocated during disasters. These handcrafted dwellings are bought and sold as products in local marketplaces known as *"Ghorer Hat"*. Due to demand, the local industry of prefabricated houses has bloomed in different parts of Munshiganj in the last three decades. Despite these portable dwellings being an excellent example of an indigenous response to recurring natural disasters in an area, published literature on this topic are almost nonexistent. This research aims to address the research gap. The goal of this research is to identify the most preferred features of the prefab dwelling models of *"Ghorer Hat"* and recommend strategies for improving the existing dwelling models. The researcher followed qualitative methodology and adopted participatory strategies to meet the research objectives. The study started with secondary data collection through a review of existing literature. After that, primary data collection took place through a field survey. Analysis of the collected data led to the documentation of the production process, classification of house models and identification of user-preferred characteristics of different dwelling models. Assessing all the findings, the researcher explored scopes of improvement in the existing local housing provision and investigated ways of incorporating users' feedback during the development of the prefab dwellings. As a concluding remark, the researcher recommends collaboration among the architect, the producers (local businessmen), the builders (local masons) and the users (local people) to carefully examine the existing situation and to propose a flexible, adaptable, contextual solution that can be periodically modified through users' review.

Keywords: River erosion; Prefabricated house; Portable; Participatory approach; User preference.

1. INTRODUCTION

In some places of Munshiganj, rows of new empty houses are displayed. These houses are made of timber structures, timber frames with white tin panels, and multiple chala tin roofs. All the different parts of these houses are prefabricated. The local masons assemble the prefab parts, and the completed homes are showcased as ready-to-move-in dwellings in a local marketplace. A buyer can come to this place, choose from displayed samples or order a custom size. After that, the chosen house is flat-packed and delivered to the buyer's homestead. The builders reassemble the house within a few days. These places where the traditional wooden houses of Munshiganj are bought and sold are locally known as "Ghorer Hat" [3]. These dwellings are adaptable to the ever-changing landscape of erosion-affected areas. Local people of Munshiganj prefer buying these houses rather than investing in building more permanent structures because of the portability of these houses. In times of climatic hazards, these houses can be dismantled within a day and reassembled in a safer area. In comparison, buildings made of brick and concrete are not portable and are lost forever. These prefab dwellings promise progress and a way to preserve identity. Because of the demand, the local industry of prefabricated houses has bloomed in different parts of Munshiganj. Prefabricated houses of "Ghorer Hat" in Munshiganj enable people to achieve a sense of security in a context where being displaced is the only truth of life. These portable knocked-down dwellings are an excellent example of an indigenous response to recurring natural disasters in a context. But apart from some news articles, published literature on this topic is scarce.

As Bangladesh is moving towards achieving Sustainable Development Goals by 2030, the country needs to catch up with housing provision shortages [4]. Experts have agreed that attempts at alternative approaches are necessary to meet the housing needs faced in urban and rural areas [5]. Using local materials and construction techniques should be promoted instead of prioritizing concrete-built forms over indigenous houses in rural housing. There is a need to strengthen local housing provision innovation to meet housing shortages locally. The local industry named "Ghorer Hat" in Munshiganj results from years of dialogue between manufacturers, customers, and the site. The distinctive characteristics, such as portability, knock-down, etc., are not introduced by outsiders but are invented and improved by local people in the face of environmental threats. This local industry is practicing an indigenous technique, using local materials, creating employment for local people, and contributing hugely to local housing provision. Prefabricated houses produced and sold in Ghorer hats in Munshiganj are selected as the setting for this research to contribute to the

investigation of alternative housing approaches and to boost the local housing sector. The focus is to learn about a context, its climate challenges, and local hazard-resistant techniques. Slight modifications and application of new approaches can make a huge impact and sustain local practices.

This research aims to identify the most preferred features of the prefab dwelling models of "Ghorer Hat" and recommend strategies for improving the existing dwelling models. The objective of this research is to document the construction process, classify the dwelling models, collect user feedback about the valuable features of these models, and identify scopes of improvement. As mentioned above, there is an absence of research in this specific context, mainly focusing on construction techniques, available products, and user preferences. This paper intends to address this research gap and serve as a resource for future investigations.

The research paper will progress by introducing the methodology of the research. This section will discuss the methods used here and the approaches taken to achieve the aim of this research. After that, the paper will summarize the literature review findings and the field survey outcomes. Then the author will dive into the analysis of the collected data. The following section will discuss the author's recommendation based on the assessed data. Lastly, the concluding remarks will reflect on ways to achieve the proposals and scopes of further research.

2. METHODOLOGY

To investigate the local housing provision in the selected context, the researcher sought to understand the construction techniques employed to build the prefab houses of *"Ghorer Hat"*. On the other hand, to understand the users' perspectives and expectations, it was vital to observe how local people utilize different features of these houses in their daily lives. Achieving the goals of this research required documenting a production process and understanding people's views. Because of this, the researcher followed qualitative methodology and adopted participatory strategies. The research began with secondary data collection through a review of existing literature. After that, primary data collection took place through a field survey. The data collection method included observation, transect walk, semi-structured interviews, focus group discussion, hands-on workshop, audio and video recording, photography, architectural mapping, and sketching. The field survey included the survey of "Ghorer Hats" and homestead surveys. For the survey of "Ghorer Hats," markets were selected from Louhajang Upazila in Munshiganj, ensuring varieties of annual production, sale, size, and experience. For homestead surveys, the researcher studied fifty dwelling units and adjacent neighborhood tissue for three months. The household selection process relied on ensuring a variety of land ownership, owner's occupation, social status, rural origin, homestead pattern, and size of the dwellings. The convenience sampling method was used for homestead sample selection. The users' preferences for various features of their purchased dwelling models were documented through participatory discussions. To analyze the collected data, thematic and narrative analysis methods were used to comprehend people's views, opinions, and experiences. Various participatory approaches employed in collecting data helped connect with the stakeholders involved in the process. The application of the aforementioned methodologies to analyze the acquired data resulted in documentation of the production process, classification of house models, and identification of user-preferred characteristics of different dwelling models.

3. LITERATURE REVIEW

The search for published journal articles and conference proceedings from reputed sources revealed a significant research gap in this context. However, information about the location and available products of the "Ghorer Hats" can be found in news articles published in various reputed newspapers. An article published in Daily Bangladesh revealed that these tin-wood houses are the tradition of Munshiganj. The report stated that depending on the design, type of wood, and size, the house price ranges from 2 lakhs to 30 lakhs [6]. Another article published in Shomokal informed that masons come from different parts of the country to build the houses. Many have been living in Munshiganj for 4-5 years for the convenience of constructing houses. Their wages are 35-60 thousand taka for building different types of houses [7]. According to an article from The Business Post, these houses' lifespan is 50-80 years, but this local industry received a massive blow during the Covid-19 pandemic [8]. The author extracted information about the materials used in producing these houses from the reviewed news articles. In a recently published article in Architexturez, an international newsletter, the author described these houses as "inhabitation designed for a shifting landscape" [9]. Bangladeshi architect Marina Tabassum conducted research commissioned by Sharjah Architecture Triennial in 2019 which focused on inheritance along the Padma-Meghna bank, where the delta is subjected to dynamic shifts [10]. As part of her research, she erected three prefabricated houses at the Sharjah Architecture Triennial to exhibit the families' struggle to relocate their homes due to river erosion [11]. In her essay "Inheriting Wetness," she concluded that adaptation to instability of the erosion-prone areas might be the only strategy left [12]. A scale model of a "Ghorer Hat" house is currently on display at the entrance of Munich's famous museum Pinakothek der Moderne in Germany as part of the exhibition 'Marina Tabassum Architects: In Bangladesh' [13]. Although the world is getting a glimpse of this local innovation through her exhibitions and research, this local housing provision demands further extensive investigations for future innovation.

4. FIELD SURVEY

The literature review documented information about the locations of "Ghorer hats," available products, prices, materials, and longevity. However, the studied document needed to include information about the construction process, the classification of houses, and local people's views. Participatory tactics used in the documentation process aided in developing an understanding between the researcher/architect and the local people/artisans, allowing them to express their experiences and concerns. The author performed extensive field research in the chosen housing markets and homesteads. The study conducted in the local marketplaces known as "Ghorer Hat" assisted in learning about the process of building these houses, the varieties of homes available in the market, construction processes, manner of delivery, and so on. Physical surveys carried out in the homesteads revealed the dialogue between the houses and its surrounding, users' activity in the spaces offered by these dwellings, preferred features, etc. The following subsections discuss the findings from the field surveys.

4.1 "Ghorer Hat" survey

In Munshiganj, house markets have sprung up in different locations to satisfy the housing need of local people. Here are some market locations in different Upazilas of Munshiganj

- Munshiganj Sadar Upazila: Katakhali, Hatimara, Bojrojogini
- Tongibari Upazila: Paikpara, Bettka
- Sirajdikhan Upazila: Malkhanagar, Kuchiamora
- Louhajang Upazila: Kathpotti, Ghordour, Konkosar [14].

Aside from markets in these areas, some families use the free spaces of their homestead and erect two to three wooden houses at a time to sell. For this study, house markets of the Louhajang area were selected and studied, ensuring annual production, sale, size, and experience varieties. Figure 1 shows the typical entryway of a house market displaying the products and a "house for sale" sign.



Fig. 1: Entryway of a typical *"Ghorer Hat"*

Significant findings from the house market survey included documentation of the construction process of these prefab dwellings and the classification of the available products.

4.1.1 Construction process

The first step of production of the "Ghorer hat" houses is sourcing the raw materials. The owner of a "Ghorer hat" source wood locally from the trees locally known as "Lohakath" and buy CI sheets from local vendors. The next step is to process the raw materials so that the production of components can begin. The large "Ghorer Hat" industries have their sawmill, and they can extract wood sections from large round tree sections in their sawmill. The local builders extract 3.25" x3.25" square sections for columns, 3.25" x1.15" for frames and beams, and 8" x6' rectangular sections for floorings. Smaller "Ghorer Hats" do not have their sawmill. They buy necessary wood sections from the local material market. Production of the components is briefly discussed here-

- Components for structure, wall, roof, door, window, and stair are produced simultaneously by local builders. Their workspace is inside a house market compound, usually open to the sky, scattered around the already-built houses displayed for sale. The artisans join wooden sections using Tenon mortice to make frames for the walls. Then they add plain white CI sheets as panel Infill. Decorative wooden bits are added to reduce and prevent water seepage.
- After the structure is fixed, as shown in Figure 2, wall panels are added to the structure using spikes. The floor panels are laid and individually nailed to the structure. After that, roof frames are pulled into position using ropes, and the builders fix the angle of the roof. Then corrugated sheets are added.
- The construction is finished by adding premade wooden doors and windows to the wall frame and placing stairs or a ladder inside. The finished products are displayed in the house markets.

When a buyer buys a house, it is dismantled, delivered to the buyer's homestead, and reassembled by the builders. The production flow can be summarized as raw material collection, raw material process, parallel components production, assembling the components, display, delivery to the buyer's homestead, and reassembly at the site.

4.1.2 Classification of available products

There are many variations in the areas and volumes of the houses available in "Ghorer Hats." Aside from area and height variations, different kinds of forms are available in these house markets. The typology documented here is not solely based on area or height. It is a combination of space and size and describes the difference noticed in the forms of houses available in the various "Ghorer Hats" of this district. From the field survey experience, available houses can be classified as

- Small (S): These are the smallest available product according to both area and volume. They only have a rectangular monospace. Attic space is absent in this model. That is why during flood season, these structures are the most vulnerable. Sometimes an extra room is added in front of these small one-story houses.
- Medium (M): Medium-sized houses are two-storied. These houses vary in volume. Builders manipulate the height of the upper floor by changing the height of windows, adding extra panels above or below windows, and so on. These variations are locally known as “Shoa Ektola,” “Dertola,” “Dui-Tola,” etc.
- Large (L): These houses have an extra room in front of the two-storied mass. This room is locally known as the “cabin.”
- Extra Large (XL): These houses used to be popular 12-15 years ago among joint families. A luxurious verandah encircled the upper floor. These are no longer sold in the markets, but upon custom order, one can attain one of these grand two-storied wooden houses with verandah.

There are many variations observed within the classification of these houses. Some models have corrugated sheets as panel infills instead of plain white sheets. People choose decorative motifs for door and window designs according to their affordability. The quality of wood also varies from market to market. Figure 3 illustrates detailed information about the identified house typologies.

4.2 Homestead survey

After production of the houses, they are delivered to the buyer's homestead to be reassembled and occupied for several years. A typical homestead in this area is usually courtyard centric and includes single or multiple prefab houses used as living areas. These houses are rectangular and usually have one to two rooms. The rooms are used for sleeping, resting, dining, and several multipurpose uses. Generally, the homestead has other structures such as a kitchen, toilet, vegetable garden, etc. These prefab houses are accepted and cherished by people from all economic strata. Although homestead survey revealed that people from different economic tiers have diverse requirements and demands.

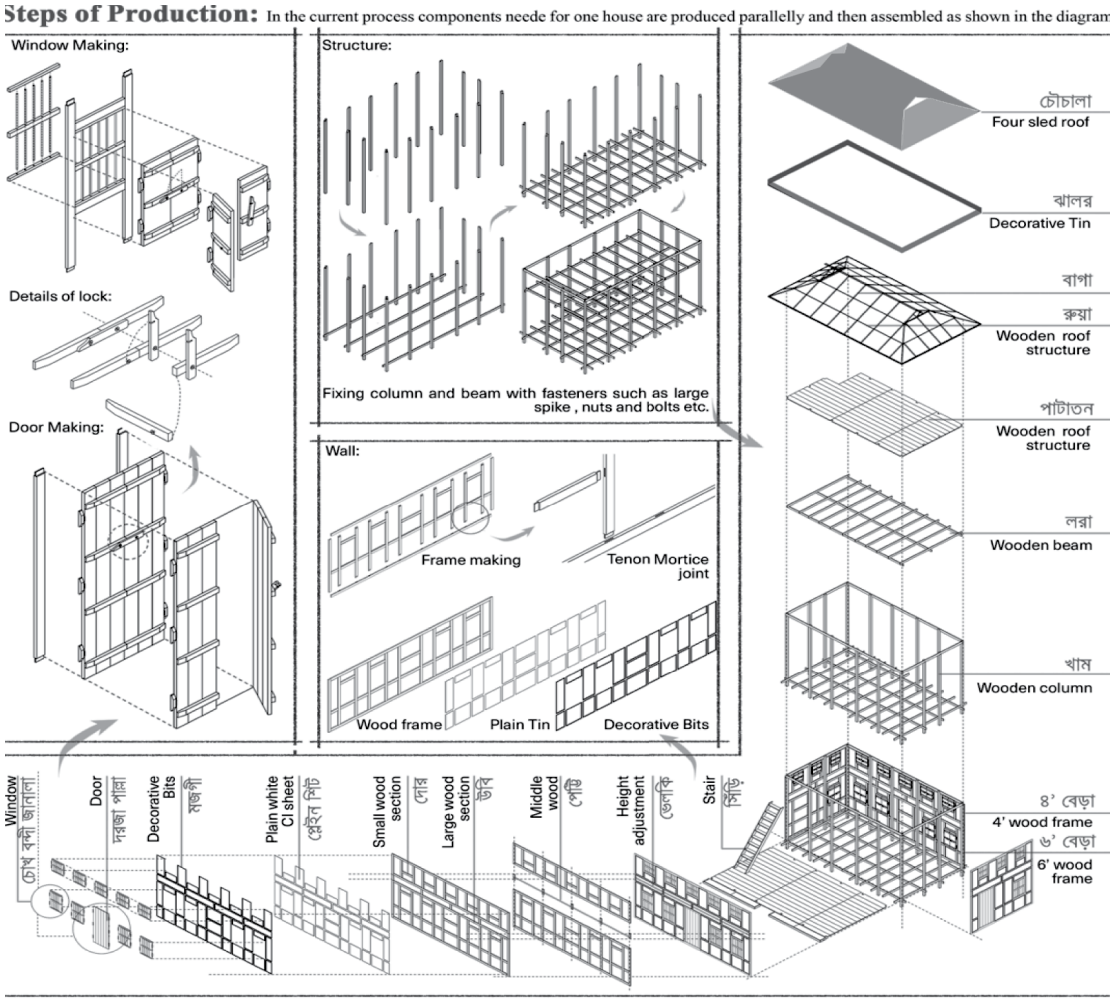

Fig. 2: Steps of production of the prefabricated components and assembly process

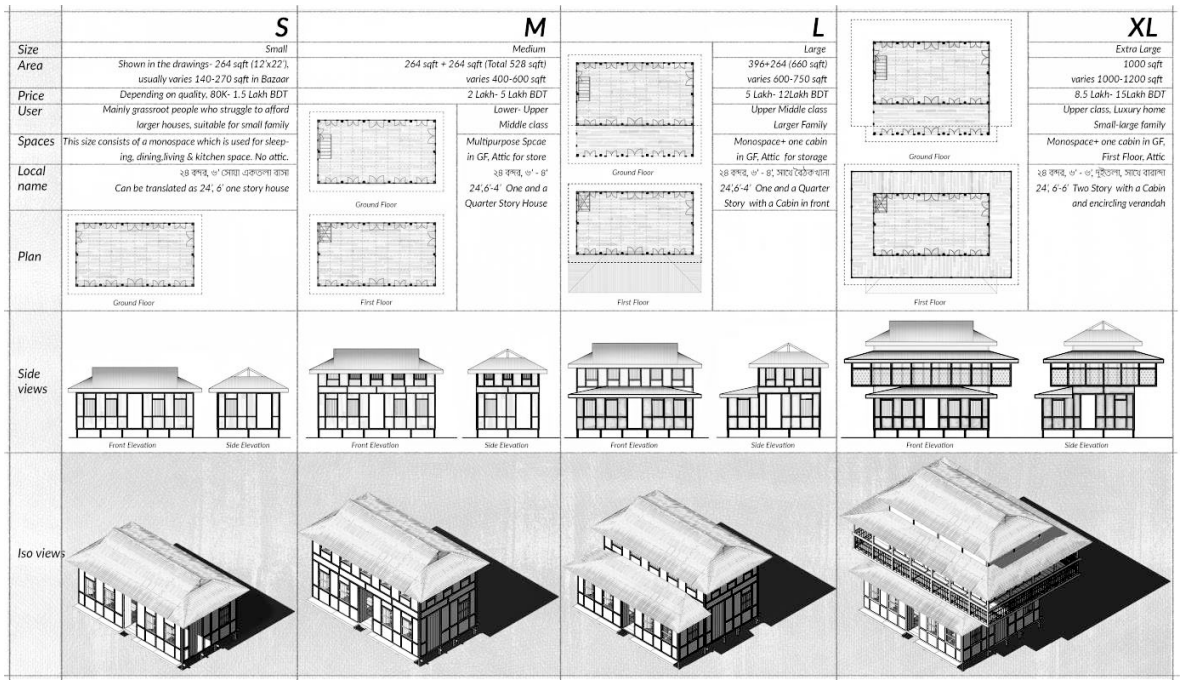

Fig. 3: Typology of available prefab dwelling models

Another interesting finding of the homestead survey is the classification of land ownership. When people face river erosion, they generally move to somewhere safe. They tend to settle inland, away from the riverbank, to save themselves from future miseries. If the affected family is well-to-do, they buy new land and settle there. But the most general response is to take shelter in a relative's house, which might be near the victims' area or in another Upazila. Relatives or not, the people of Munshiganj empathize with the victim's loss and try their best to temporarily accommodate the affected family in their land. If the migrated family wishes to stay there permanently, tenures are ensured. These activities lead to land or house renting, which creates variation in land ownership.

During the homestead survey, four types of ownership were observed (Figure 4).

- Landowner: Local people build their homesteads adjacent to their agricultural lands. To the local people, a spacious wooden house is an investment. As wood prices increase exponentially, the owners can profit by reselling old homes. Homesteads of landowners usually have multiple prefab dwellings added as their family grows.
- House Rent: House Rent system is observed near the Padma Multipurpose Bridge as people migrate here from other parts of the country searching for work. The tendency to rent houses is also observed near high-density areas where land renting is not profitable. House rent varies from one location to another depending on site forces and the type of house.
- Land Rent: Land rent is the most common form of tenancy observed on the site. After losing their land and shelter, river erosion affected people who generally rent land adjacent to where they used to live. Sometimes the whole neighborhood shifts together. After renting land, a family generally buys a new "Ghorer Hat" house to reside in or occupy an existing structure with the landowner's permission.

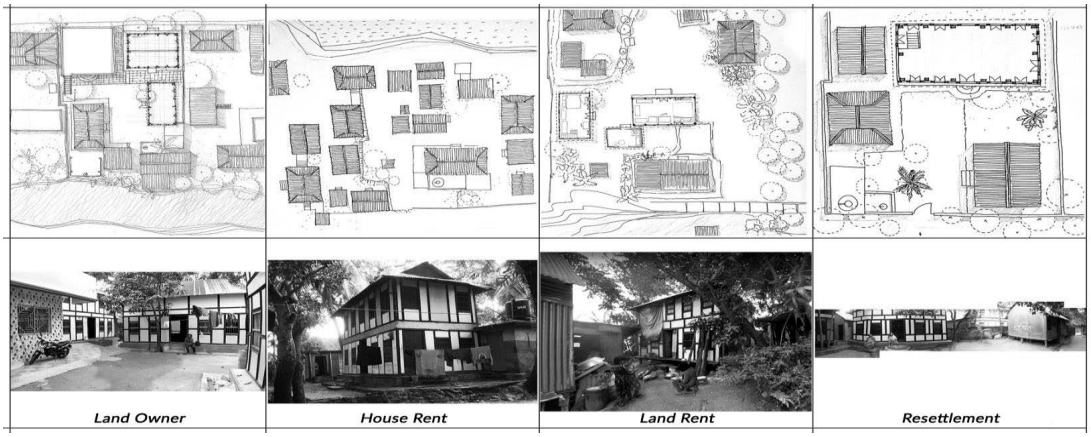

Fig. 4: Homestead layout and images of prefab houses belonging to various ownership typologies

Either way, they maintain the homestead and protect it from land grabbing if the owner is absent.

- Resettlement: Due to the construction and implementation of Padma Multipurpose Bridge project, procedure, approximately 3,000 people on both sides of the river were displaced by the land acquisition [15]. At the rehabilitation site, the author observed that people are building "Ghorer Hat" houses with cement-finished plinths and other permanent structures. It suggests that they believe this will be their long-term address. The courtyards are smaller as the provided plots are much smaller than their previous lands.

Variation in ownership creates diverse demands among the local people. Opinions and views of the occupiers were documented using focus group discussions and semi-structured interviews.

5. ANALYSIS

For analysis of the collected data, thematic and narrative analysis was used. Analysis of collected data gives a greater understanding of the identified problem. The analysis is conducted in the following sections-

5.1 Analysis of production process

The manufacturing process documentation acts as a resource for future research opportunities. It also showed areas for improvement in the production method to make it more efficient and sustainable. The current production method operates on a "house by house" rather than a "component by component" basis. A home-by-house procedure means that builders build one house at a time. As a result, the prices of the dwellings are not uniform. A medium-sized home may be constructed in 15 days if the decorations are simple, or if the wood carvings and detailing are elaborate, it might take months. At first glance, the buildings dotting Munshiganj may appear uniform, yet no two houses follow the same manufacturing procedure. This non-standardized system creates many issues rather than addressing the existing ones. Such as

- There is no price limit for a particular sized product. The price may vary depending on the quality of the material used, but purchasers should be provided with truthful information regarding the price range.
- There is no standard component dimension. Each market relies on its builders' sense of proportion; most measurements are taken by sight.
- Furthermore, the user-seller connection must be more transparent. There is always a propensity for eyewash and bargaining rather than focusing on structural integrity and product durability.

5.2 Analysis of available dwelling models

The classification of housing models revealed the "Ghorer hat" business owners' appraisal of current customer demands in the Munshiganj environment. This evaluation must be updated on a regular basis in order to fulfill the demands of users appropriately. The issues identified here can be summarized as-

- Because medium-sized houses are currently in high demand, company owners engage in creating them and offering variants. People who wish to acquire a huge or extra-large house must place a bespoke order, which costs more money.
- The author discovered that business owners prioritize profit over consumer demands. They cater to upper-class clientele while providing inferior-quality items to others.

5.3 Analysis of user preference

People in Munshiganj who live near erosion-prone regions face involuntary displacement on a regular basis. That is why locals invest in Ghorer Hat prefabricated dwellings. This area is also prone to seasonal floods. These prefabricated dwellings are built on stilts to make the floor space usable during the rainy season. However, severe rain might cause floodwaters to rise above the stilts. That is why people choose to buy houses with attics. Several flaws were discovered in the existing production system while studying user comments, including-

- During a flood, individuals in medium-sized houses can shift their essentials to the upper-story attic area, minimizing loss. As a result, the preference for medium-sized homes is the most widespread across all types of ownership. Smaller properties on the market are less expensive but lack attic room. On the other hand, people from lower socioeconomic levels can seldom afford medium or larger dwellings. If a family loses their home due to erosion, it is difficult for them to purchase a new home immediately. Often, they opt to rent a house. However, this is only a temporary solution. Locals expressed a need for a starting home with an attic room that they could purchase in this circumstance.
- They also raised the issue of these residences' expansion. When the family expands, and additional space is required, they have to purchase another home. If the wall panels of these dwellings could be modified, they could add a room on any four sides of the house, and the house could expand with the family.
- The users of these residences are dissatisfied with the vendors' lack of transparency. They accused the dealers of supplying low-quality timber, which hampered the disassembling process.
- Locals also urged that the construction and disassembly processes be shortened. They frequently need more time to remove the entire house and have to leave with whatever bits they can salvage.

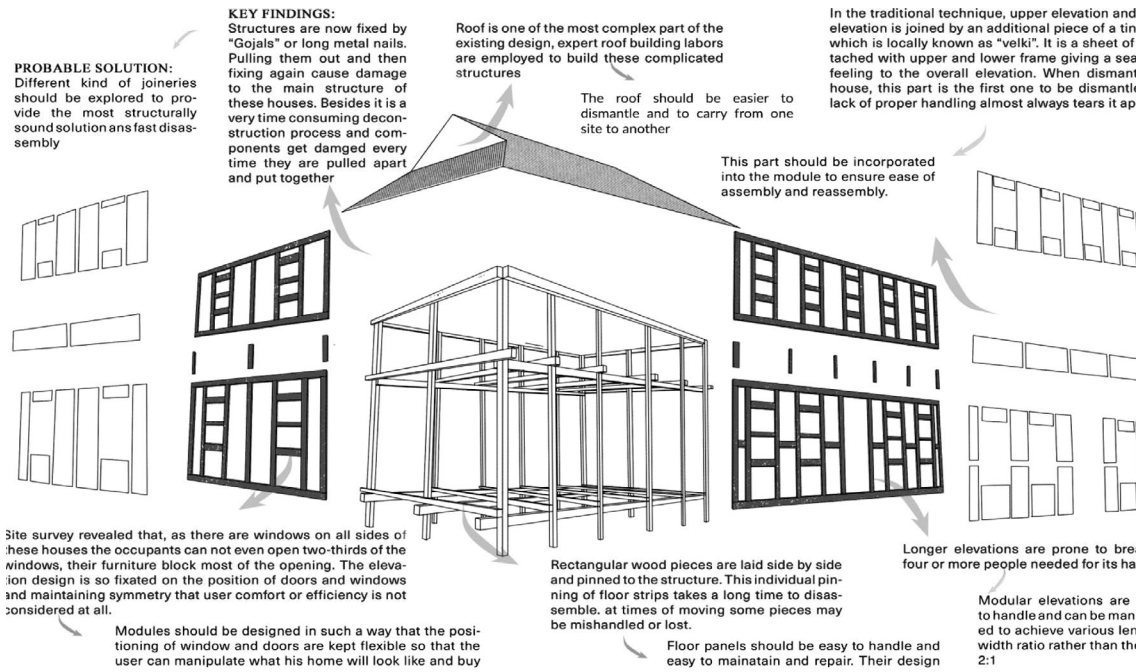

Fig. 5: Recommendation for future improvement

6. RECOMMENDATIONS

The The preferred features of the prefab houses bought and sold in Ghorer Hat in Munshiganj are their portability, ability to move with the shifting landscape, promise of progress, and flood-resistant qualities. The author suggests the following recommendations to retain these qualities and address the issues uncovered through the analysis of collected data.

6.1 Recommendation for production process

The construction procedure should follow the "component by component" method to make the process more efficient. These industries need a lot of space to display the houses. Rather than constructing all the homes for sale, they might exhibit a range of houses on their property while preserving the components required to build various-sized dwellings. People may then select their homes by studying the displayed alternatives, and parts required for building their chosen homes can be supplied to their location. Therefore, the time spent erecting the dwellings in the "Ghorer Hat" compound can be reduced. The owners can thus run their industry in much smaller compounds.

Construction process standardization will assist company owners in mitigating loss. As previously said, the whole business incurred significant losses during the pandemic. It's time to speed up the pace. The material quality, size of utilized components, and pricing of various house models should be standardized.

Creating a transparent relationship between the supplier and the user is also critical. All user groups should have access to high-quality content. If all stakeholders can collaborate, the present process can be improved.

6.2 Recommendation for dwelling models

The dwelling models can be developed to be expandable. As the walls are already removable, if the house markets start providing standardized components, people can buy additional parts and expand their homes according to their needs. The house markets should start providing starter homes for disaster-affected families. These homes can be half the size of the smaller houses, which can be expanded to become regular-sized houses. These prefab houses have windows on all sides. The occupants do not open most windows as their furniture blocks them. The elevation design is fixated on the position of doors and windows to maintain symmetry. User comfort and efficiency should be taken into account. The design of the prefab dwellings should be modified to make the dismantling process less time-consuming.

6.3 Recommendation for incorporating user feedback

Sellers should conduct surveys to learn about consumers' preferences from various income strata. After all, it is the consumers who keep this local sector afloat. Sellers can begin offering feedback forms and monitoring their delivered items regularly. The needs of the locals will alter over time. The local housing business must

adapt to their evolving requirements. The comments of users should be integrated into the design of the home models. Belongingness will be generated if local people are involved in developing new models. They will become the industry's active protectors, assisting in the preservation of its tradition. Additional recommendation for future improvement is illustrated in Figure 5.

7. CONCLUSION

This study investigates the local prefabrication house industry, production steps, classification of the existing product, understanding users' perspectives, identification of issues, and scopes for upgradation. Wooden houses are a cultural expression of Munshiganj. The author recommends ways of modification of the existing system that can maintain the cultural identity sought by its local people and ensure variety to address everyone's need for belongingness and growth. The suggestions will help to establish a transparent relationship between local industry & local people. It can also ensure the dissemination of local construction techniques. The researcher recommends collaboration among the architect, the producers (local industry owners), the builders (local masons), and the users (local people) to scrutinize the existing situation and to propose a flexible, adaptable, contextual solution that can be periodically modified through users' review. The documentation of the process will lead to the parallel sharing of knowledge and inspire researchers to explore local materials and construction techniques to innovate and overcome climatic vulnerabilities.

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Feasibility Study of Rainwater Harvesting for Official and Residential Consumption in Mymensingh Engineering College, Bangladesh.

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ABSTRACT

Heavy rainfall causes flooding in the low-lying areas of a country. Rainwater Harvesting (RWH) systems can become one of the solutions to this problem. Rainwater is very clean and safe if the location is far from pollution. The growing population, industries, and agricultural practices need a lot of water. So the huge consumption of water is causing the reduction of available water. In such a situation, rainwater harvesting is a very effective way of utilizing water. Collecting rainwater from the roof, storing it, and using this for the purpose of water consumption throughout the whole year is the main idea of the study. The study area is the official and residential buildings of the Mymensingh Engineering College where the existing water supply system depends on groundwater. Providing an RWH system in this area will open a new way of water supply system which will reduce the dependency on groundwater and also help to increase the level of groundwater by allowing excessive rainwater flows into the soil. The study includes developing an RWH system for official and residential uses, proposing a filtration process, cost analysis, determination of existing building dimensions, the whole pumping process, and proposing the future design considerations of the system. The study shows that not only the quality of rooftop harvested water is good but also the amount of water is enough for 260 people per building for official uses and 4 people per unit of the five-story residential building of the study area of Mymensingh city.

Keywords: Rainwater harvesting system; Effective consumption; Storage tank sizing; Rooftop harvest.

1. INTRODUCTION

The main sources of water are surface water, groundwater, and rainwater. Saltwater accounts for approximately 97.5% of all water on Earth, leaving only groundwater, surface water, and atmospheric water. [1]. So, it is clear that fresh water is a limited resource. On the other hand, rainwater is a relatively clean water source, and with the necessary caution, it can be even used for consumption. But in most cases, rainwater is wasted because eventually, it falls into the ocean. In this situation of water scarcity, by using the Rain Water Harvesting System, a good amount of rainwater can be used for consumption which can reduce the pressure on the main water supply. Rain Water Harvesting is a simple technique for collecting rainfall immediately so that it does not flow off to a river or stream, sink into the earth, or get contaminated. [2].

In Bangladesh rapidly increasing population withdraws groundwater at a faster rate and both industrial and humans are contaminating surface water continuously. Those emerging problems can be mitigated through rooftop rainwater harvesting because high rainfall happens in the country [3]. Rainwater harvesting, a practice of collecting and utilizing precipitation from a catchment area that dates back to the dawn of civilization, is seen as an alternate option for water supply in Bangladesh. [4]. Rooftop, paved, and unpaved areas available rainwater goes to waste. This water can be stored in a tank and used directly or indirectly by diverting to recharge the aquifer [5]. Bangladesh's climate is subtropical in the center-north and tropical in the south, with a pleasant, mild, and sunny winter from November to February, a short hot spring between March and May, and a protracted wet season owing to the summer monsoon from June to October. The average annual precipitation ranges from 5,690 mm in the northeast region to 1,110 mm in the western region. [6].

Mymensingh, which constitutes one of the administrative districts of Mymensingh division, is geographically situated in the central part of Bangladesh. It shares its borders with various neighboring regions, including the Meghalaya state of India and Garo Hills to the north, Gazipur district to the south, Netrokona and Kishoreganj districts to the east, and Sherpur, Jamalpur, and Tangail districts to the west. The district headquarters are located in Mymensingh town. The district covers an area of 4,363.48 sq. km. and consists of several small valleys between high forests. The research site is Mymensingh Engineering College which is situated in, a newly formed Mymensingh City Corporation. In this area, the water supply system fully depends on groundwater whereas, during the entire year, Mymensingh aggregates up to 2249 mm of precipitation. So, when it rains, there are several opportunities for rainwater collecting. The key objective of this study is to construct an RWH system in Mymensingh Engineering College for academic and residential consumption to reduce the pressure on groundwater.

2. IMPORTANCE OF ROOFTOP WATER HARVESTING

Rooftop water harvesting (RTWH) is a strategy that involves the optimal utilization of rainwater that falls on the roofs of buildings, especially in urban areas where roofs are often impervious and take up significant land space, and where the availability of municipal water is insufficient. RTWH includes capturing the runoff from the roofs of individual structures and storing it for later use, which can be a cost-effective solution in regions where water is scarce and supply costs are high. Industries and large institutions in urban areas located in arid and semi-arid regions have adopted RWH systems in response to water scarcity and high supply costs. The effectiveness of an RTWH system depends on the quality of water, efficient and economical collection and storage methods, and the potential for groundwater recharge. The design of an RTWH system is determined by the characteristics of rainfall in the region, such as its intensity, duration, the nature of the rainfall season, and the average number of rainy days. [7].

2.1 Harvesting practice in Bangladesh

Rainwater harvesting has emerged as a viable option for augmenting freshwater supplies in the coastal areas of Bangladesh. In recent years, numerous initiatives and programs have been implemented by government bodies and non-governmental organizations, with financial support from international donor agencies, to promote and install various household and community-based rainwater harvesting systems. The primary objective of these efforts has been to provide an alternative water source in areas affected by arsenic contamination and to alleviate the increasing burden on underground aquifers in densely populated urban centers such as Dhaka. It is estimated that approximately 1000 rainwater harvesting systems have been installed across rural regions of the country since 1997, with the aim of impacting the lives of thousands of families. In 2009, Coca-Cola partnered with UN-Habitat to launch The Safe Drinking Water and Sanitation Project, which seeks to showcase rainwater harvesting, alongside other water conservation and storage technologies, to a larger audience. Given that Dhaka receives an average annual rainfall of 2540 mm, which could potentially serve as a source of vertical recharge for underground aquifers, rainwater harvesting systems could prove to be a crucial element in ensuring sustainable water management in the region.

3. RESEARCH METHODOLOGY

3.1 Data collection

For continuing our research twelve years of mean rainfall data (2007-2018) of the Mymensingh city corporation area was collected from the Department of Irrigation and Water Management, Bangladesh Agricultural University. The harvesting area was measured from the research site (Academic and residential building from Mymensingh Engineering College, Mymensingh). In academic and residential buildings, water consumption demand was collected from the college authority. This demand was also checked with WHO guidelines. The chemical composition of groundwater and rainwater data was collected from secondary sources and also tested in the laboratory. Sources of these secondary data were research papers/govt. water reports on water chemistry [3,6,10].

3.2 Hydrological analysis

This study analyzed twelve years' worth of rainfall data to determine the highest and lowest rainfall amounts as well as the instances of insufficient rainfall throughout the year. The minimum amount of rainfall needed each month to meet monthly water consumption requirements solely from rainfall was established as the critical rainfall amount. The Monthly Factor of Insufficiency (MFI) was calculated as the ratio of the difference between monthly rainfall and critical rainfall to critical rainfall. Monthly rainfall and critical rainfall were used to determine MFI. The research revealed that the highest rainfall amount occurred in 2014, whereas the lowest was recorded in 2012, providing insight into the rainfall intensity pattern shown in Fig 1.

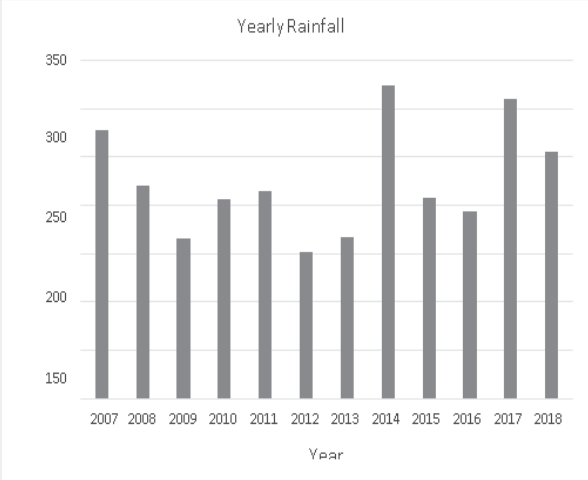

Fig. 1: Yearly rainfall of 2007-2018

When analyzing an annual series, the primary objective of frequency analysis is to establish a correlation between the size of an event and the likelihood of it being exceeded. The process of probability analysis can be conducted through empirical or analytical methods, both of which aim to determine the probability of the event occurring based on its magnitude. Having several methods, we used the Weibull formula:

$$P = m/(N+1) \qquad (1)$$

where N = number of years of record. m = Order number

This formula uses to calculate the probability *P*. Having calculated *P* (and hence, *T*) for all events in the series, the variation of the rainfall magnitude is plotted against the corresponding *T* on a semi-log graph [7].

$$T = 1/P \qquad (2)$$

By using frequency analysis, the study gets the following equation and graph as shown in Fig. 2.

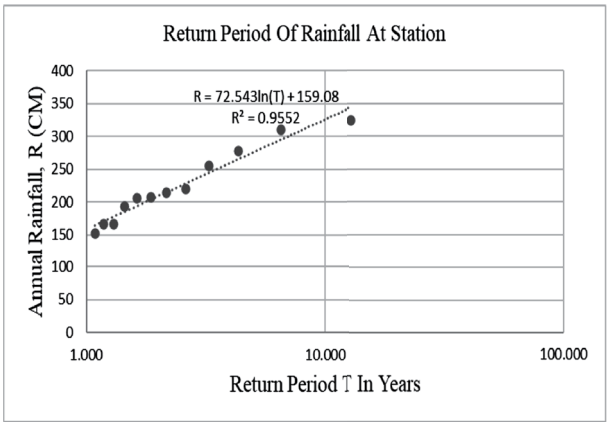

Fig. 2: Return period of annual rainfall

The design period of any construction is normally 50 years or 99 years. From the above equation after 50 years and 99 years the rainfall data will be respectively 442.87 cm and 492.42 cm which clearly declares the increasing amount of rainfall.

3.3 RWH system for research site

An RWH system consists of Roof Catchment, Gutters, and Downpipes, a First flush diverter and leaf catcher, a Filter chamber, a Storage tank (underground), and a Supply system. The studied residential building is a five-storied building having a concrete roof and the approximate size of the harvesting area is 2044.563ft^2 each academic building is also five storied building and the harvesting area is approximately 4587.058ft^2 as shown in Fig.-3 and Fig.-4 respectively. Fig.-3 and Fig.-4 give the overall view of the harvesting site. The roof runoff coefficient varies significantly on the basis of roof material, the slope of the roof, and so forth as we used 0.8[8].

In the studied area, PVC (polyvinyl chloride) pipe can be used for gutters because of its rigid and flexible form, and the dimension should be 10-15% more than the required one according to MH and PWD, 2002. In the research site, Rapid Sand Filter (RSF) filter can be used which has three layers of filtration system. In Saidabad Water Treatment Plant, Dhaka, Bangladesh, water is also filtered with Rapid Sand Filter. There are 24 units of rapid sand filter each with a 121m^2 surface area and filtration rate of 6.56 m/h. In the research area, for the RWH system, an underground R.C.C storage tank can be used.

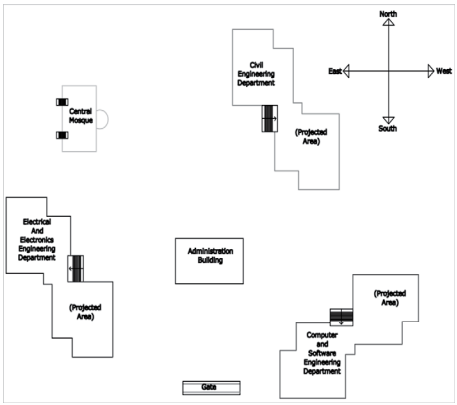

Fig. 3: Academic area

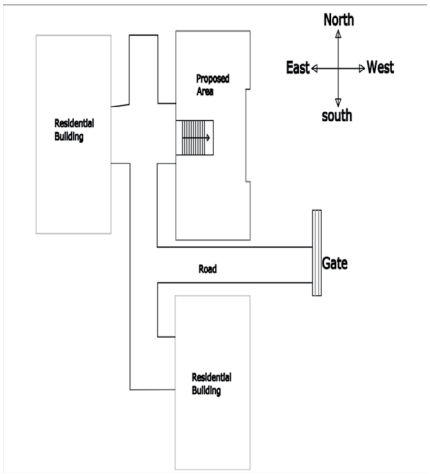

Fig. 4: Residential area

3.3.1 Sizing formulae

The size of the storage tank is determined by the following procedure proposed by Choudhury [3]:

For academic building:

Step 1: Determine monthly water consumption:
Different ways of water use (Data was collected from college authority and FAO and WHO guidelines):
• Drinking purpose - 2910 gallons/ month
• Washroom (including toilet + hand wash) - 5850 gallons/ month
• Laboratory use - 20 gallons/ month
• Cleaning (floor + classroom + laboratory) - 20 gallons/ month So, total monthly consumption in gallons,
MC = 2910 + 5850 + 20 + 20 = 8800 gallon/ month

Step 2: Determine critical rainfall Determine catchment area in sqft., A = 4587.058 ft^2
Determine runoff factor, for concrete roof, ROF = 0.8
Determine critical rainfall in inches per month, CRF = (MC × 12 × 8.33) / (A × ROF × 62.4)
= (8800 × 12 × 8.33) / (4587.058 × 0.8 × 62.4)

= 3.84 inch

Step 3: Determine the total amount of rainwater available in a year:
Find out the mean annual rainfall,
ARF = 7.36 inches
Find out monthly factors of insufficiency for 12 years, MFI
Adding the MFI's to determine yearly factors of insufficiency, For

2007, YFI = 3.555
2008, YFI = 4.405
2009, YFI = 6.01
2010, YFI = 4.33
2011, YFI = 5.51
2012, YFI = 5.41
2013, YFI = 5.01
2014, YFI = 3.43
2015, YFI = 4.77
2016, YFI = 5.17
2017, YFI = 3.4
2018, YFI = 4.446

Determine the maximum factor of insufficiency,
$YFI_{max} = 6.01$
Determine the monthly supply required, $TS = YFI_{max} = 6.01$

Step 4: Determine storage factor, SF
When water supply is completely dependent on rainwater, SF will be 1. In our research site, the dependency is assumed to be 70%, so
SF = 0.7

Step 5: Determine leakage factor, LF
The used material for the cistern is concrete in the research site, so LF = 0.01

Step 6: Calculate storage volume in gallons,
$V_{gal} = MC \times TS \times (1 + LF) \times SF$
$= 8800 \times 6.01 \times (1+ 0.01) \times 0.7$
= 37391.816 gallons.

Step 7: Calculate storage volume in cubic feet
$V_{cft} = (V_{gal} \times 8.33) / 62.4$
$= (37391.816 \times 8.33) / 62.4$
= 4991.567 cft
For three academic building, $V_{cft} = 4991.567 \times 3$
= 14974.70 cft
≈ 15000 cft
Lobby = (5 × 5 × 10) × 5 × 3 = 3750 cft
Others = 15000 – 3750 = 11250 cft Underground of mosque, Proposed area, A = 1500 sqft 1500 × h = 11250
h = 7.5 ft
= 7.5 ft + 3.5ft (for filter)
= 11 ft
So, the storage height should be 11 ft, on the underground floor of the mosque, where the rainwater will be stored for the three academic building's water uses purposes.

For residential buildings:

Step 1: Determine monthly water consumption Different ways of water use (Data was collected from college authority and FAO and WHO guidelines):

• Drinking - 840 gallons/month
• Washroom (including toilet) - 41250 gallons/month
• Kitchen - 270 gallons/month
• Cleaning - 60 gallons/month Total monthly consumption in gallons,
MC = 840 + 41250 + 270 + 60 = 42420 gallon/month

Step 2: Determine critical rainfall Determine catchment area in sqft, A = 2044.5637 ft^2
Determine runoff factor, for concrete roof ROF = 0.8
Determine critical rainfall in inches per month, CRF = (MC × 12 × 8.33) / (A × ROF × 62.4)
= (42420 × 12 × 8.33) / (2044.5637 × 0.8 × 62.4)
= 41.54 inches

Step 3: Determine the total amount of rainwater available in a year:
Find out the mean annual rainfall,
ARF = 7.36 inches
Find out monthly factors of insufficiency for 12 years, MFI
Adding the MFI's to determine the yearly factor of insufficiency, Like as the information is given in academic building's calculation, YFI max = 6.01
Determine monthly supply required, TS = YFI max = 6.01

Step 4: Determine storage factor, SF
For residential purposes rainwater dependency is assumed to be 40% SF = 0.4

Step 5: Determine leakage factor For concrete material, LF = 0.01

Step 6: Calculate storage volume in gallon, $V_{gal} = MC \times TS \times (1+ LF) \times SF$
$= 42420 \times 6.01 \times (1+ 0.01) \times 0.4$
= 102997.46 gallons.

Step 7: Calculate storage volume in cubic feet, $V_{cft} = (V_{gal} \times 8.33) / 62.4$
$= (102997.46 \times 8.33) / 62.4$
= 13749.500 cft ≈ 14000 cft

On porch, a storage tank's volume,
= 15 × 15 × 10 = 2250 cft

Others = 14000 – 2250 = 11750 cft

Underground of building, Proposed area = 2000 sqft 2000 × h = 11750
h = 5.88 ft + 3.5 ft (for filter) = 9.38 ft

So, the storage height should be 9.38 ft which is in the underground floor of that residential building.

4. HARVESTING SYSTEM

The roof catchment area of the academic building is 4587.058 sqft, For academic purposes, three academic buildings are the research area which means 13761.174 sqft in total is the roof harvesting area for academic consumption. Rain water consumption rate is assumed to be 70%. Using this data, the study showed that a 15000 cft storage tank is needed. The underground floor of the proposed two-storied mosque is used as a storage tank which area is assumed as 1500 sqft and 11 ft height is measured for the storage tank in which 3.5ft is kept for the RSF filter. Also, the lobby is used for rainwater storage where a 250 cft tank is placed on each floor. After finishing the underground harvested water, lobby's stored water will be used. The existing academic 3D model are shown in Fig.-5 for visualization of RWH system.

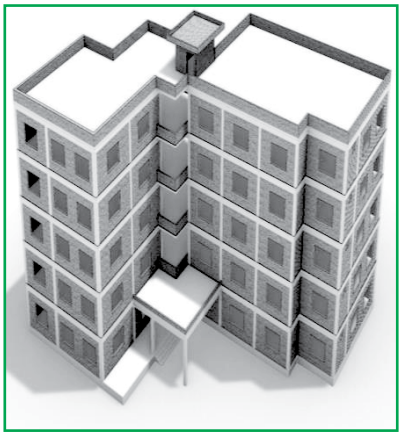

Fig. 5: Academic building

The residential building's catchment area is 2044.563 sqft. The ROC will be as similar to academic buildings and water consumption is assumed to be 40%. After the calculation process, it is found that the required storage tank is 14000 cft. The underground area of the building is assumed to be 2000 sft and on the porch, another storage tank will have to be placed which a volume is 2250 cft. So, storage height is measured as 9.38 ft where 3.5 ft is for filtration. The existing residential 3D model is shown in Fig.-6 for visualization of the RWH system.

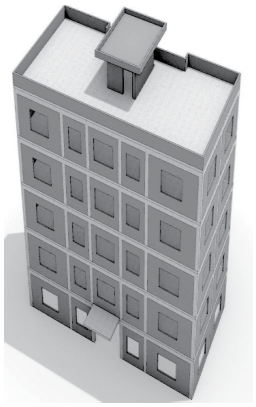

Fig. 6: Residential building

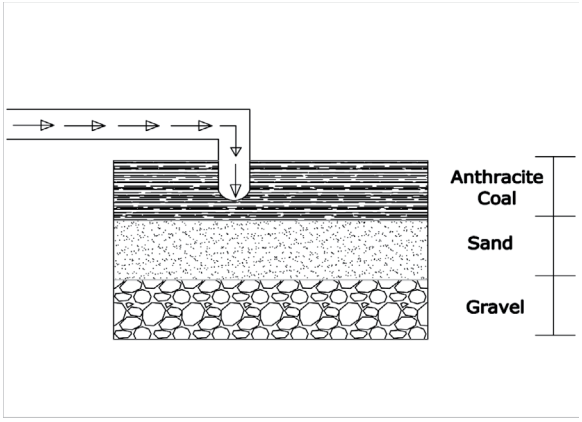

Fig. 7: RSF filter

In rapid sand filtration, the filtration rate is comparatively higher due to the use of larger and relatively uniform size sand particles as a filter medium. It has the capability of high removal of turbidity and color (80-85%) and bacteria (85-95%) [10]. The filtration process of the research site is stated below in Fig.7.

In Fig. 8 below, we can see that collected rainwater flow down to the underground storage tank through pipe, some amount of rainwater can store in lobbies storage tank. In underground storage, filtration process happens through RSF filter, then store in the storage tank. After using storage tank's water, we can use lobbies water. Same thing happen for residential building, after using underground water, we can use the water store in the porch.

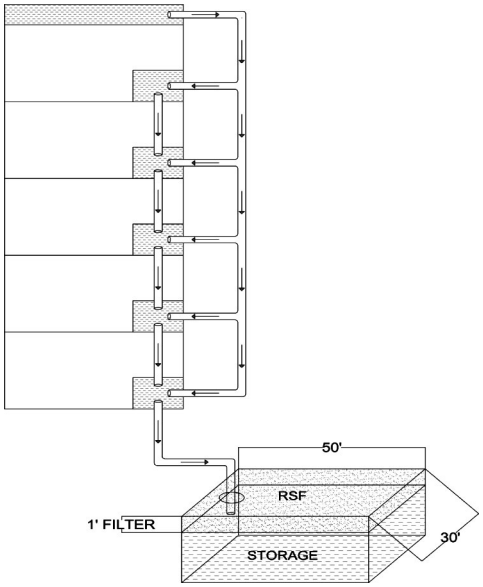

Fig. 8: Simple diagram to show rooftop rainwater harvesting system

From cost analysis, 70% of water consumption of rainwater will reduce some cost but this cost is equal to the pumping cost since 1 HP pump will be used to pump the stored water to the three-academic building for use. If in the future, City Corporation Authority (WASA) takes the responsibility for water supply system, then the RWH system will be beneficial for this study site according to cost as well as quality. Also, 40% water consumption cost from the ground is equal to the pumping cost. So, good quality water will be available from the RWH system. But if WASA is included in the future, the cost will reduce.

5. CONCLUSION

Rainwater harvesting system seems beneficial and sustainable in securing fresh water. From this study, it has been found that by taking proper storage and management system, rainwater could be utilized over the whole dry period of a year instead of only in the rainy season. By doing rainfall analysis, it was found that an adequate amount of rainfall occurs in Mymensingh city which should be used in an absolute manner.

The study shows that by installing an RWH system, rooftop rainwater will fulfill 70% of water consumption for the office building and will meet 40% of the water demand for the residential building which reduce the pressure on the groundwater. In addition to this, excessive rainwater can also be allowed to flow into the soil, which will increase the groundwater level.

Rooftop rainwater harvesting system will reduce the dependency on the authority (City Corporation or future WASA) as expected according to the objective.

By analysis of cost, the study shows that in the present situation, good quality water can be obtained from the RWH system with a similar cost of groundwater.

Thus, the rainwater harvesting system is feasible and ensures the suitable use of rainwater which reduce wastage.

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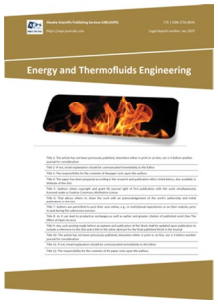

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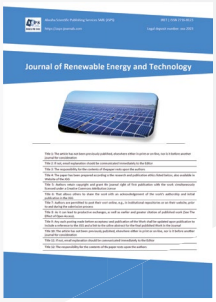

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