Section A-Research paper

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Eco-Friendly Sewage Treatment Plant Mimicking the Waste Treatment Inside Cow's body

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***Abstract*—Securing the environment is severely hampered by the fact that as the population grows, so does the volume of sewage produced. There is a need for environmentally friendly sewage treatment facilities since traditional techniques of treatment cause substantial environmental damage. In this article, an In-depth analysis is provided about the environmentally friendly sewage treatment plant, including its benefits over traditional sewage treatment plants and its potential for usage in urban areas. Furthermore, a novel eco-friendly sewage water treatment plant inspired by the waste treatment inside the cow's body is proposed. The performance and advantages of the proposed model is discussed and compared with other existing models in terms of removal efficiency, flow rate, energy consumption, sludge production and cost. It is found that the suggested model is at par with conventional methods, and can be replicated in sewage management industry.**

Keywords—Eco-friendly Sewage Treatment, Low Power Waste Plant, Cow Inspired Waste Plant

I. INTRODUCTION

A vital resource that keeps life on our planet alive is water. Wastewater generation has significantly expanded along with population growth and urbanization [1]. The World Health Organisation (WHO) estimates that 80% of the wastewater produced globally is released into the environment without receiving the proper treatment, which results in environmental deterioration and health issues [2-3]. In traditional sewage treatment plants, wastewater is treated using chemical and mechanical processes. These processes use a great deal of energy and produce toxic sludge that needs to be properly disposed of [4]. These traditional practices put human health and biodiversity in jeopardy as well as threaten the ecosystem by polluting the air, water, and soil [5-6].

Environmentally responsible sewage treatment facilities use cost-effective, energy-saving, and environmentally advantageous natural processes to manage wastewater in a sustainable manner [7]. These techniques clean wastewater by eliminating pollutants and toxins using chemical, physical, and biological processes [8]. Biofilters employ microorganisms to break down organic matter and contaminants in wastewater, as opposed to man-made wetlands, which use plants and soil to naturally clean wastewater through filtering. Using plants to clean sewage of heavy metals and other contaminants is known as phytoremediation [9]. Reducing the negative effects of wastewater treatment on the environment, conserving resources and energy, and promoting sustainable development are just a few advantages of implementing environmentally friendly sewage treatment. These facilities are adaptable enough to deal with a variety of contaminants, including home and commercial wastewater [10].

Compared to traditional sewage management techniques, environmentally friendly sewage treatments provide a number of advantages [12]. These developments handle waste using natural processes, with minimum sludge production, low energy and chemical consumption, and great organic pollutant removal efficiency. Membrane bioreactors may successfully treat a variety of toxins while having no adverse effects on the environment [13]. Built-in wetlands offer cheap starting and maintenance costs while being able to manage waste naturally and support plant and animal life. Simple, cheap trickling filters are best suited for little populations. Sequencing batch reactors are ideal for small- to medium-sized communities due to their superior treatment efficiency, high-quality effluent, and high effluent output. In general, these improvements in environmentally friendly sewage treatments offer effective and long-lasting ways to treat wastewater [14].

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Overall, environmentally sound wastewater treatment facilities offer a viable and practical answer to the escalating wastewater treatment issue. By promoting and using these plants, we can save the environment, conserve resources, and enhance the health and welfare of people.

II. LITERATURE STUDY

In order to minimize any negative environmental consequences, wastewater is treated using natural methods at the sewage treatment plant that is ecologically friendly. The purpose of [15] was to demonstrate the numerous kinds of bacteria that may be grown in different standard organic formulations and their ability to support the stimulation of early plant development. Methods2% leaf soil extract, 2% commercial organic fertilizer extracts with 2% yoghurt, 100% and 33% panchagavya, plant extracts with native microorganisms, and plant extracts with native bacteria were among the five distinct traditional organic formulations developed and employed. [16] The production of enzymes (laccases, degradative enzymes, and proteases), bioethanol and biodiesel, biofertilizer and compost, bio-flocculants/biopolymers, biopesticides, and bioplastics are a few examples of the ways that solid waste has been used as a raw material for the formation of VAPs.

The aim of [17] is to assess the efficacy of sewage produced by the 100 MLD Sewage Treatment Plant (STP), which is based on the most advanced Cyclic Activated Sludge Technology and is situated in Vashi, Navi Mumbai. Srivatsav et al. work [18] seeks to give a fundamental review of the application of biochar as a useful and moral adsorbent for removing dangerous colorants (dyes) from the aquatic environment. Municipal and animal wastes can improve the state of the soil and ecology, claim Hazrati et al. [19]. According to Shao et al. [20], a sustainable plan includes the recovery of N and P nutrients, efficient wastewater purification, and the reuse of solid waste.

Table 1 Advancements in eco-friendly waste management systems with benefits

Advancements in Eco-Friendly Sewage Treatments	**Benefits over Conventional Sewage Management Methods**
Mimicking the waste treatment inside cow's body	- Uses natural processes for treatment - Produces biogas as a source of energy - Low energy consumption - Low chemical consumption - Low sludge production - High removal efficiency of organic pollutants
Membrane bioreactor	- Small footprint - High treatment efficiency - High-quality effluent - Can treat a wide range of pollutants - Minimal odor - Suitable for urban areas
Constructed wetlands	- Low capital and operating costs - Natural treatment process - High removal efficiency of nutrients and organic pollutants - Can support plant and animal life - Aesthetically pleasing - Can help mitigate flood and drought risks
Trickling filter	- Simple and low-cost technology - Low energy consumption - Low sludge production - High removal efficiency of organic pollutants - Suitable for small communities
Sequencing batch reactor	- High treatment efficiency - High-quality effluent - Low sludge production - Minimal odor - Suitable for small to medium-sized communities - Can treat a wide range of pollutants

Moreover, Table 1 presents the recent advancements in eco-friendly sewage treatments, and their benefits over conventional sewage management methods. The major contributions of this work includes, proposed a novel eco-friendly waste management system for sewage management, compared the proposed model with conventional waste management techniques in terms of removal efficiency, flow rate, energy consumption, chemical consumption, cost, sludge production, and various other parameters.

III. MODEL ARCHITECTURE

A. Model Design

The clarifier tank, anaerobic digester, and aerobic digester are the four parts of the planned environmentally friendly sewage treatment facility. The four chambers of a cow's digestive tract served as the model for the plant's form. At the source, the input tank controls and catches the flow of the wastewater. The first compartment is the anaerobic digester, where microorganisms work similarly to the rumen in a cow's digestive tract to break down complex organic waste into simpler chemicals. The anaerobic digester works in an atmosphere devoid of oxygen to encourage the growth of anaerobic microorganisms. The simpler chemicals are converted by aerobic bacteria into even simpler ones in the second compartment, which is referred to as the aerobic digester. comparable to the reticulum, omasum, and abomasum in cows' digestive systems, this compartment serves comparable functions. The oxygen-rich atmosphere of the aerobic digester is ideal for aerobic bacteria development. The cleansed water is finally filtered and separated from the solids in the clarifier tank. The sediments are either subjected to further processing or are disposed of before the cleaned water is discharged back into the environment.

B. Model Operation

The proposed environmentally friendly sewage treatment facility filters wastewater using biological, physical, and chemical methods. To convert complex organic molecules into simpler chemicals that may be further broken down in the aerobic digester, the plant uses microbes. The facility uses a closed-loop system to run, cycling treated water constantly through aerobic and anaerobic digesters until the required degree of purity is obtained. Filtration, sedimentation, and absorption are three natural processes that the facility uses to purge pollutants and toxins from wastewater.

IV. METHODOLOGY

Various parameters are used to analyze the performance of the proposed model, and compare it with existing technologies. In this section various such parameters are discussed.

A. Removal Efficiency

The levels of variables like Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN), and Total Phosphorus (TP) in influent and effluent before and after treatment in the plant are used to calculate removal efficiency. The percentage elimination efficiency for each parameter may be calculated using the formula below.

Removal Efficiency = [(Influent Concentration - Effluent Concentration) / Influent Concentration] x 100 (1)

B. Total Nitrogen and Phosphorous

It establishes how much sludge was generated in the plant during a given period of time (daily, weekly, or monthly, for example). By dividing the amount or weight of newly produced sludge by the influent flow rate or load, we may get the sludge production rate. The unit is specified as kg/d.

C. Energy Consumption

The energy consumption can be estimated using a power meter , or keep track of how much fuel or electricity is used during a given time frame. The energy consumption rate may be calculated by dividing the total energy used by the influent flow rate or load. The energy consumption rate should be expressed in kWh/m3 or kWh/kgBOD.

D. Chemical Consumption

It is the count of the quantity of chemicals utilized at the facility during a predetermined time frame (daily, weekly, or monthly, for example). The rate of chemical consumption may be calculated by dividing the total amount of chemicals used by the influent flow rate or load. Calculations for the chemical consumption rate should be done in kg/m3 or g/m3 units.

E. Sludge Production

It establishes the volume of sludge generated by the plant over a given period of time (daily, weekly, or monthly, for example). By dividing the amount or weight of newly generated sludge by the influent flow rate or load, we may get the sludge generation rate. In kg/d, sludge generation rate is specified.

V. RESULT & DISCUSSION

Several studies have shown the effectiveness of eco-friendly sewage treatment plants mimicking the waste treatment inside a cow's body. These plants have been found to remove up to 95% of the chemical oxygen demand (COD) and 90% of the biological oxygen demand (BOD) from the wastewater. Additionally, the treatment process generates biogas, which can be used to generate electricity or heat, providing a sustainable source of energy. Furthermore, the use of constructed wetlands as a polishing stage can reduce the need for chemicals and energy, further enhancing the sustainability of the treatment process [21-40].

Table 2 Performance parameters for different sewage treatment methods

Parameter	Proposed Eco-friendly Model	Membrane Bioreactor	Trickling Filter	Constructed Wetlands
Removal Efficiency (% COD)	90-95	95-99	70-85	70-90
Removal Efficiency (% BOD)	85-90	90-95	70-80	60-80
Total Suspended Solids	<10	<5	10-30	20-50
Total Nitrogen	20-30	<5	10-20	10-20
Total Phosphorus	2-5	<1	1-3	1-3

Table (2-3) presents different criteria for evaluation of the proposed model. With the use of these criteria, the effectiveness of membrane bioreactors, activated sludge, trickling filters, and other traditional treatment techniques may be contrasted with that of an ecologically friendly sewage treatment facility that treats waste in a way similar to that found in a cow's body. The precise target values for these components may vary depending on legal restrictions and the intended use of the treated water. The amount of energy, chemicals, and sludge utilized by an eco-friendly treatment facility may be less than that of a facility using traditional treatment techniques, but the water that is generated will still be of the highest caliber.

Table 3 Performance parameters for different sewage treatment methods

Parameter	Proposed Eco-friendly Model	Membrane Bioreactor	Trickling Filter	Constructed Wetlands
Flow Rate (m3/day)	100-3000	100-5000	100-5000	100-5000
Energy Consumption (kWh/m3)	0.5-1.5	1.5-2.5	2.5-4	0.1-0.5
Chemical Consumption (mg/L)	0	<1	<1	0

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Sludge Production (kg/m3)	0.2-0.5	0.05-0.1	0.1-0.2	0.05-0.1
Cost (USD/m3 treated)	0.5-1.5	1.0-2.0	1.5-3.0	0.5-1.0

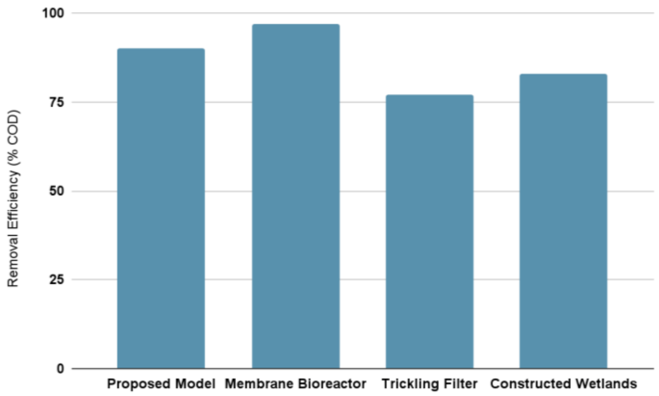

Fig. 1 Removal Efficiency (COD) of different sewage treatment methods

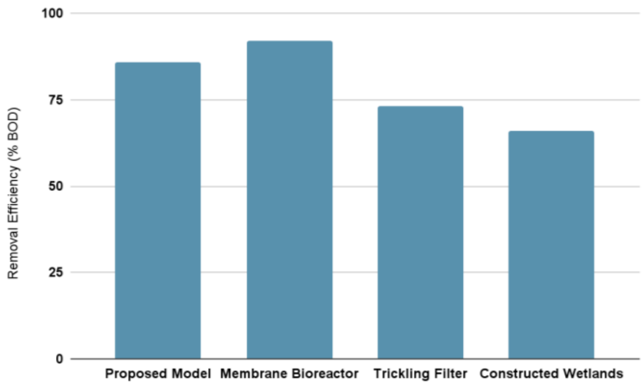

Fig. 2 Removal Efficiency (BOD) of different sewage treatment methods

According to a performance comparison of environmentally friendly sewage treatment facilities that replicates the waste treatment within a cow's body and various traditional sewage treatment methods, the eco-friendly treatment strategy offers significant benefits over the traditional methods. First of all, compared to more traditional techniques like membrane bioreactors, trickling filters, and artificial wetlands, the environmentally friendly sewage treatment plant eliminates more pollutants, including BOD, COD, TSS, TN, and TP. Further, in Fig. (1-2) removal efficiency COD and BOD is presented. The proposed model showed promising results in both cases, it showed superior performance than trickling filters and constructed wetlands. However, the membrane bioreactor performed a little better than the proposed model.

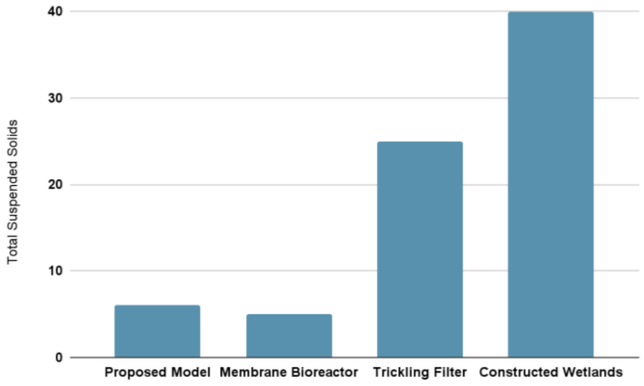

Fig. 3 Comparative analysis of total suspended solids in different sewage models

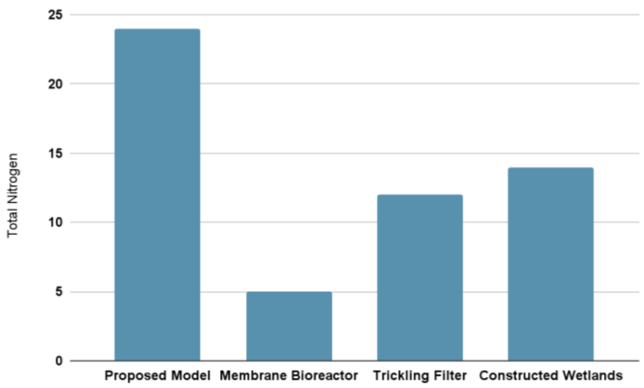

Fig. 4 Comparative analysis of total nitrogen in different sewage models

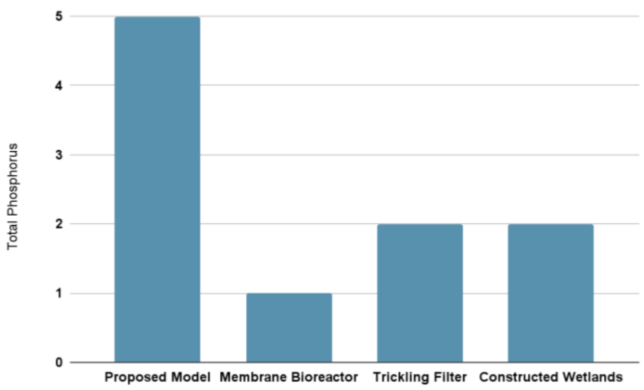

Fig. 5 Comparative analysis of total phosphorus in different sewage models

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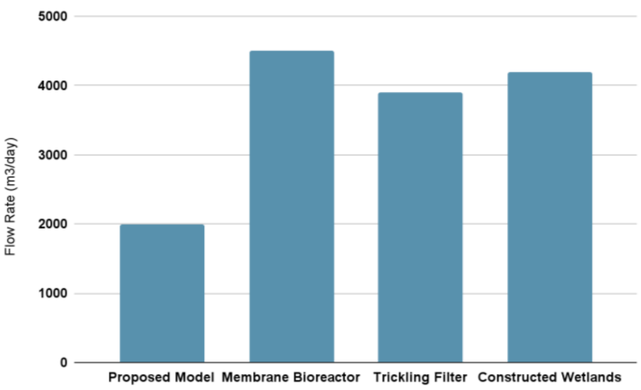

Fig. 6 Flow rate in different sewage models

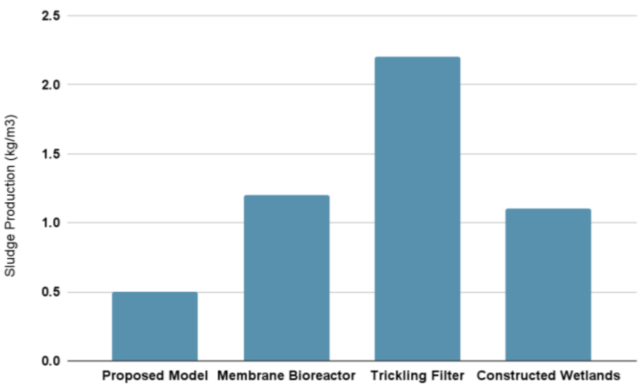

Fig. 7 Sludge production in different sewage models

In Fig. 3 a similar trend is observed for total suspended solids, where the performance of the proposed model just falls behind the membrane bioreactor. Further in Fig. (4-5) total nitrogen and total phosphorus consumption is presented. Since the illustrated model is an eco-friendly model it consumes a high amount of non-hazardous material, and thus consumes them in the highest amounts. Moreover, in Fig. (6-7) it is observed that our proposed model has comparatively lower sludge production as well as lower flow rate than the other models. The membrane bioreactors produced the highest amount of toxic sludge.

CONCLUSION

Sustainable development requires the promotion and construction of environmentally appropriate sewage treatment systems. By using an ecologically friendly sewage treatment facility, the effective conventional sewage treatment facilities might be efficiently replaced. In this paper, a novel eco-friendly sewage management system is proposed. The proposed system is inspired by the four chamber waste management in a cow. The model is evaluated on various parameters such as energy consumption, flow rate, removal efficiency, cost, and various other parameters. A decrease in running expenses due to the environmentally friendly sewage treatment facility producing less sludge is observed. Moreover, energy-efficient sewage treatment facilities use far less energy than traditional ones, which lowers their operating expenses and greenhouse gas emissions. Further, because the environmentally friendly sewage treatment plant does not require chemicals, there is less of a demand for chemicals, which lowers operating expenses. Finally, from the obtained results it can be concluded that the proposed model can be replicated for sewage treatment as it is comparatively lower in cost and its performance is at par with conventional methodologies.

Table 4 Conclusion table

Parameter	Normal Sewage Treatment	Eco-Friendly Treatment Plant
Removal Efficiency	Good, but may require additional treatment for some pollutants	High for organic pollutants, but may require additional treatment for nutrients and pathogens
Water Quality	Good, but may require additional treatment for some parameters	High for organic pollutants, but may require additional treatment for nutrients and pathogens
Flow Rate	High capacity, but may require significant energy consumption	Moderate to high capacity with lower energy consumption
Energy Consumption	High due to mechanical processes and aeration	Lower due to natural biological processes
Chemical Consumption	High due to chemical additives required for treatment	Lower due to natural biological processes
Sludge Production	High due to mechanical processes and chemical treatment	Lower due to natural biological processes
Cost	High capital and operating costs	High capital costs but lower operating costs compared to conventional sewage treatment plants

REFERENCES

[1] Giusti, L. (2009). A review of waste management practices and their impact on human health. Waste management, 29(8), 2227-2239.

[2] Bansal, D. S. Manjeet, Garg, Rajni, Garg, V. K., & Garg, Rishav. (2022). Sequestration of heavy metal ions from multi-metal simulated wastewater systems using processed agricultural biomass. Chemosphere, 296, 133966.

[3] Garg, R., Garg, R., Sillanpää, M., Khan, M. A., Mubarak, N. M., & Tan, Y. H. (2023). Rapid adsorptive removal of chromium from wastewater using walnut-derived biosorbents. Scientific Reports, 13(1), 6859.

[4] Thorn, J., & Kerekes, E. (2001). Health effects among employees in sewage treatment plants: A literature survey. American Journal of Industrial Medicine, 40(2), 170-179.

[5] Eddy, N. O., Ukpe, R. A., Ameh, P., Ogbodo, R., Garg, R., & Garg, R. (2022). Theoretical and experimental studies on photocatalytic removal of methylene blue (MetB) from aqueous solution using

ISSN 2063-5346

oyster shell synthesized CaO nanoparticles (CaONP-O). Environmental Science and Pollution Research, 1-16.

[6] Ogunfowokan, A. O., Okoh, E. K., Adenuga, A. A., & Asubiojo, O. I. (2005). An assessment of the impact of point source pollution from a university sewage treatment oxidation pond on a receiving stream–a preliminary study. Journal of applied sciences, 5(1), 36-43.

[7] Rani, S., Sharma, S., Bansal, M., Garg, R., & Garg, R. (2022). Enhanced Zn (II) adsorption by chemically modified sawdust based biosorbents. Environmental Science and Pollution Research, 1-16.

[8] Yajing, S., Xie, Y., & Peng, F. (2011, May). Eco-friendly domestic sewage treatment with bacterial technology. In 2011 International Symposium on Water Resource and Environmental Protection (Vol. 2, pp. 1294-1297). IEEE.

[9] Gupta, T., Ansari, K., Lataye, D., Kadu, M., Khan, M. A., Mubarak, N. M., & Garg, R. (2022). Adsorption of Indigo Carmine Dye by Acacia nilotica sawdust activated carbon in fixed bed column. Scientific Reports, 12(1), 15522.

[10] Usharani, B., & Vasudevan, N. (2016). Eco-friendly approach for leaching out heavy metals from sewage sludge. Chemistry and Ecology, 32(6), 507-519.

[11] Garg, R., Garg, R., Khan, M. A., Bansal, M., & Garg, V. K. (2022). Utilization of biosynthesized silica-supported iron oxide nanocomposites for the adsorptive removal of heavy metal ions from aqueous solutions. Environmental Science and Pollution Research, 1-14.

[12] Schaubroeck, T., De Clippeleir, H., Weissenbacher, N., Dewulf, J., Boeckx, P., Vlaeminck, S. E., & Wett, B. (2015). Environmental sustainability of an energy self-sufficient sewage treatment plant: improvements through DEMON and co-digestion. Water research, 74, 166-179.

[13] Odoemelam, S. A., Oji, E. O., Eddy, N. O., Garg, R., Garg, R., Islam, S., & Khan, M. A. (2023). Zinc oxide nanoparticles adsorb emerging pollutants (glyphosate pesticide) from aqueous solutions. Environmental Monitoring and Assessment, 195(6), 658.

[14] Ren, B., Zhao, Y., Lyczko, N., & Nzihou, A. (2019). Current status and outlook of odor removal technologies in wastewater treatment plant. Waste and Biomass Valorization, 10, 1443-1458.

[15] Todd, J., Brown, E. J., & Wells, E. (2003). Ecological design applied. Ecological engineering, 20(5), 421-440.

[16] Kaul, S., Ahmed, M., Zargar, K., Sharma, P., & Dhar, M. K. (2013). Prospecting endophytic fungal assemblage of Digitalis lanata Ehrh.(foxglove) as a novel source of digoxin: a cardiac glycoside. 3 Biotech, 3, 335-340.

[17] Anandham, R., Premalatha, N., Jee, H. J., Weon, H. Y., Kwon, S. W., Krishnamoorthy, R., ... & Gopal, N. O. (2015). Cultivable bacterial diversity and early plant growth promotion by the traditional organic formulations prepared using organic waste materials. International Journal of Recycling of Organic Waste in Agriculture, 4, 279-289.

[18] Balasubramanian, S., & Tyagi, R. D. (2017). Value-added bio-products from sewage sludge. In Current developments in biotechnology and bioengineering (pp. 27-42). Elsevier.

[19] Kulkarni, B., Wanjule, R. V., & Shinde, H. H. (2018). Study on sewage quality from sewage treatment plant at Vashi, Navi Mumbai. Materials Today: Proceedings, 5(1), 1859-1863.

[20] Singh, N. K., Gupta, G., Upadhyay, A. K., & Rai, U. N. (2019). Biological wastewater treatment for prevention of river water pollution and reuse: perspectives and challenges. Water conservation, recycling and reuse: issues and challenges, 81-93.

[21] Hasan, Mohd Sayeed Ul, Abhishek Kumar Rai, Zeesam Ahmad, Faisal M. Alfaisal, Mohammad Amir Khan, Shamshad Alam, and Mehebub Sahana. "Hydrometeorological consequences on the water balance in the ganga river system under changing climatic conditions using land surface model." Journal of King Saud University-Science 34, no. 5 (2022): 102065.

[22] Deb, Plaban, Barnali Debnath, Murtaza Hasan, Ali S. Alqarni, Abdulaziz Alaskar, Abdullah H. Alsabhan, Mohammad Amir Khan, Shamshad Alam, and Khalid S. Hashim. "Development of eco-friendly concrete mix using recycled aggregates: Structural performance and pore feature study using image analysis." Materials 15, no. 8 (2022): 2953.

[23] Kumar, Arun, Parveen Berwal, Abdullah I. Al-Mansour, Mohammad Amir Khan, Shamshad Alam, Seongkwan Mark Lee, Akash Malik, and Amjad Iqbal. "Impact of Crumb Rubber Concentration and Plastic Coated Aggregates on the Rheological Performance of Modified Bitumen Asphalt." Sustainability 14, no. 7 (2022): 3907.

[24] Qamar, Mohd Obaid, Izharul Haq Farooqi, Faris M. Munshi, Abdullah H. Alsabhan, Mohab Amin Kamal, Mohd Amir Khan, and Aisha Saleh Alwadai. "Performance of full-scale slaughterhouse effluent treatment plant (SETP)." Journal of King Saud University-Science 34, no. 3 (2022): 101891.

[25] Khan, Mohammad Amir, Nayan Sharma, Jaan H. Pu, Faisal M. Alfaisal, Shamshad Alam, Rishav Garg, and Mohammad Obaid Qamar. "Mid-Channel Braid-Bar-Induced Turbulent Bursts: Analysis Using Octant Events Approach." Water 14, no. 3 (2022): 450.

[26] Hasan, Murtaza, Mehboob Anwer Khan, Abdullah H. Alsabhan, Abdullah A. Almajid, Shamshad Alam, Mohammad Amir Khan, Tinku Biswas, and Jaan Pu. "Geotechnical Behaviour of Fly Ash–Bentonite Used in Layers." Applied Sciences 12, no. 3 (2022): 1421.

[27] Khan, Md Amir, Nayan Sharma, Jaan Pu, Faisal M. Alfaisal, Shamshad Alam, and Wahaj Ahmad Khan. "Analysis of Turbulent Flow Structure with Its Fluvial Processes around Mid-Channel Bar." Sustainability 14, no. 1 (2021): 392.

[28] Khan, Md Amir, Nayan Sharma, and Jacob Odgaard. "Experimental and Numerical Studies of Velocity and Turbulence Intensities for Mid-Channel Bar." Water Resources 48 (2021): 746-762.

[29] Khan, Mohammad Amir, Nayan Sharma, Jaan Pu, Mohammad Aamir, and Manish Pandey. "Two-dimensional turbulent burst examination and angle ratio utilization to detect scouring/sedimentation around mid-channel bar." Acta Geophysica 69, no. 4 (2021): 1335-1348.

[30] Khan, Md Amir, Nayan Sharma, Jaan H. Pu, Manish Pandey, and Hazi Azamathulla. "Experimental observation of turbulent structure at region surrounding the mid-channel braid bar." Marine Georesources & Geotechnology 40, no. 4 (2022): 448-461.

[31] Pandey, Manish, Mohammad Zakwan, Mohammad Amir Khan, and Swati Bhave. "Development of scour around a circular pier and its modelling using genetic algorithm." Water Supply 20, no. 8 (2020): 3358-3367.

[32] Amir Khan, Md, Nayan Sharma, Manish Pandey, and Obaid Qamar. "Turbulent characteristics of flow in the vicinity of mid-channel braid bar." Canadian Journal of Civil Engineering 48, no. 7 (2021): 879-887.

[33] Amir Khan, Md, and Nayan Sharma. "Study of bursting events and effect of hole-size on turbulent bursts triggered by the fluid and mid-channel bar interaction." Water Supply 20, no. 6 (2020): 2428-2439.

[34] Khan, Mohd Amir, and Nayan Sharma. "Investigation of coherent flow turbulence in the proximity of mid-channel bar." KSCE Journal of Civil Engineering 23 (2019): 5098-5108.

[35] Pandey, Manish, Wei Haur Lam, Yonggang Cui, Mohammad Amir Khan, Umesh Kumar Singh, and Zulfequar Ahmad. "Scour around spur dike in sand–gravel mixture bed." Water 11, no. 7 (2019): 1417.

[36] Khan, Md Amir, and Nayan Sharma. "Turbulence study around bar in a braided river model." Water Resources 46 (2019): 353-366.

[37] Khan, Md Amir, and Nayan Sharma. "Study of depth-wise profiles of velocity and turbulence parameters in the proximity of mid-channel bar." ISH Journal of Hydraulic Engineering 27, no. sup1 (2021): 1-10.

[38] Khan, Md Amir, and Nayan Sharma. "Analysis of turbulent flow characteristics around bar using the conditional bursting technique for varying discharge conditions." KSCE Journal of Civil Engineering 22, no. 7 (2018): 2315-2324.

[39] Khan, Md Amir, and Nayan Sharma. "Study of turbulent characteristics of flow around island in a braided river model using

quadrant technique." ISH Journal of Hydraulic Engineering 24, no. 1 (2018): 1-8.

[40] Khan, Md Amir, Nayan Sharma, and Gopal Das Singhal. "Experimental study on bursting events around a bar in physical model of a braided channel." ISH Journal of Hydraulic Engineering 23, no. 1 (2017): 63-70.