APPLICATION OF SOIL BIOTECHNOLOGY FOR TREATMENT OF DOMESTIC WASTEWATER AND PERFORMANANCE MONITORING OF BENCH SCALE UNIT

A thesis submitted towards partial fulfilment of the requirements
For the degree of

MASTER OF ENGINEERING
In Water Resources and Hydraulic Engineering
Course affiliated to Faculty of Engineering & Technology

Jadavpur University

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my **Master of Engineering** in **Water Resources & Hydraulic Engineering** in the Faculty of Engineering & Technology, Jadavpur University during academic session 2022-2024.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

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ACKNOWLEDGEMENT

I express my sincere gratitude and thanks to my supervisor **Prof. (Dr.) Arunabha Majumder,** Emeritus Professor, School of Water Resources Engineering, Jadavpur University and **Dr. Gourab Banerjee,** Assistant Professor of School of Water Resources Engineering, Jadavpur University. Without their support and guidance, it was impossible for me to carry out this project.

I would also like to express my sincere gratitude to **prof. (Dr.) Asis Mazumdar**, Professor & Director, School of Water Resources Engineering, **Prof. (Dr.) Pankaj Kumar Roy,** Professor, School of Water Resources Engineering, **Dr. Subhasish Das,** Associate Professor, School of Water Resources Engineering, and **Dr. Rajib Das,** Assistant Professor, School of Water Resources Engineering, Jadavpur University for their valuable suggestions.

Moreover, I would like to express my sincere thanks to my seniors **Mr. Nilanjan Saha**, **Ankita Dutta**, **S M Hidayetullah, Rijurekha Dasgupta** for their support and help during my thesis work.

Thanks to all staff of School of Water Resources Engineering of Jadavpur University and the Regional centre for their help and support.

In addition, I express my very profound gratitude to my family members for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Most significantly, I would like to express my gratitude, thanks and gratefulness to my parents without whom I would not be able to do anything in my life.

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Abstract

Domestic wastewater contains organic contaminants and pathogenic organisms. Untreated wastewater may pollute river, lakes, canals and other water bodies as well as groundwater. Thus, wastewater or used water needs treatment. A sewage treatment plant aims to remove pollutants through bioremediation or phytoremediation process. Natural process for treatment of domestic wastewater follows either bioremediation or phytoremediation or both. Soil biotechnology is an energy efficient green process which can operate through bioremediation Principle and it necessary with the application of phytoremediation. The report also presents the results obtained from the research study carried to investigate the treatment or removal efficiency of pollutants from wastewater. From the experimental work, it was evident that SBT model brings about significant removal rate when design for optimum operating conditions. Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) removal efficiency more than 80%.TKN, total nitrogen and phosphates of this technique is good. Organic Loading Rate (OLR) is 0.075802 $kg/m^3/day$, which almost nearable of Standard Rate Trickling Filter (SRTF) and Hydraulic Loading Rate (HLR) is 0.505263 $m^3/d/m^2$. On the other hand, (Soil Biotechnology) SBT has low annual operation and maintenance cost, comparable to land-based systems and lower than conventional or advanced technologies. It does not produce any odorous bio-sludge and consumes the least energy.

Keywords: Wastewater, SBT, COD, BOD, TKN, OLR, HLR, SRTF

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SYMBOLS

º: Degrees

ºC: Celsius degrees

cm: centimetre

d10: 10% effective size diameter

d60: 60% passing diameter

dc: collector size or grain diameter, grain size

log: logarithm

m: meter

km: kilometre

lpcd: liters per capita per day

Uc: uniformity coefficient

Eps: Emerging Pollutant

ABBREVIATION:

SBT-Soil Biotechnology

BOD – Biochemical Oxygen Demand

COD – Chemical Oxygen Demand.

CPCB – Central Pollution Control Board.

CWs – Constructed Wetlands.

DO – Dissolved Oxygen.

FWS – Free Water Surface Systems.

IS – Indian Standard.

LPD – Litres Per Day.

MLD – Million Litres per Day.

NLCP – National Lake Conservation Plan.

NPCA – National Plan for Conservation of Aquatic Ecosystems.

NRCP – National River Conservation Plan.

NTU – Nephelometric Turbidity Units.

NWCP – National Wetland Conservation Programme.

SFS – Subsurface Flow Systems.

STPs – Sewage Treatment Plants.

TSS – Total Suspended Solids

OLR–Organic Loading Rate

HLR–Hydraulic Loading Rate

SLR–Surface Loading Rate

CHAPTER 1: INTRODUCTION

1.1. Background:

Global population growth, rising per capita consumption and the needs of the industrial and agricultural sectors are the main causes of the rising demand for fresh water. This tremendous demand for fresh water is a serious problem, especially in water-scarce regions. Water security is considered a major global concern, with water scarcity being suggested to lead to wars in the future. In India, 40% of untreated wastewater is directly discharged into rivers, heavily polluting major water resources (Gupta et.al. (2015). The two billion people worldwide are living in regions faced with water scarcity. By 2025, countries or regions facing absolute water scarcity will be home to 1.8 billion individuals, with two-thirds of the global population possibly living under water-stressed conditions (Mokal et.al. 2020). Out of many alternatives there, reclaiming wastewater could be the reliable option to maintain a balance between supply and demand. The Water (Prevention and Control of Pollution1974) Act was promulgated in the year 1974 in India to address wastewater treatment and disposal-related challenges faced by the then India. One of the challenges in those days was associated with regulating disposal of the sewages and industrial trade effluents in the nearby receiving bodies including lakes, rivers, estuaries, creak as well as in the ocean (Asolekar et al., 2013). Reclaimed domestic wastewater reuse has recently become more popular as a potential non-traditional supply to meet the water's rising demand (Bahri, 1999). Unclean water contributes to 1.7 million deaths worldwide each year, with over 90% of those deaths occurring in underdeveloped nations and almost half are children. It also increases the risk of opportunistic diseases, diarrhoea, and malnutrition. Therefore, it is very dangerous to use untreated wastewater for non-portable purposes or discharge it directly into the water body. Wastewater must properly treat to avoid health hazards and environmental damage, which is directly related to rising water usage. Since several activities do not require water of potable quality, reuse of reclaimed water and nutrient recycling may be substituted for conventional resources. Treated wastewater effluents may be reused for different purposes such as landscape irrigation (parks, green areas, golf courses, etc.), recreational activities, firefighting, reclamation of urban streams and rivers, groundwater recharge, and industrial uses (Asano T. and Levine A.D.1996). The availability and quality of water resources is one of the major environmental challenges facing the increasing demands of domestic and industrial sectors of India (Saravanane 2014). Until now, the wastewater treatment approach has mainly been focused on the conventional mechanized treatment systems. Since such system typically bears significant capital investments and energy inputs, this approach for small rural communities seems marginally inappropriate. This has led to the stimulation for the development of alternative wastewater treatment systems, efficient and less expensive to operate, than conventional wastewater treatment systems. Sustainability of sanitation systems should be related to low cost and low energy consumption and, in some situations, low mechanical technology requirements. Decentralised and low-cost processes are considered a better choice for rural areas (Lens et al., 2001) one of the emerging technologies to this alternative is the natural treatment system. A class of sewage treatment technologies that mimics natural processes such as interaction of soil-micro-organisms with pollutants as well as interaction of plants and other life in natural settings with pollutants in wastewaters are called as natural treatment systems (NTSs).It is well known that the engineered natural treatment systems render quite effective environmental services by treating biodegradable carbonaceous

pollutants and by separating suspended loads of particulates (Reinhold et al., 2010).This class of treatment systems typically incorporate river banks, wet-zones and their modified versions such as constructed wetlands (CWs), waste stabilization ponds (WSPs), sewage-fed, aquaculture ponds, hyacinth and duckweed ponds, oxidation ponds, algal-bacterial ponds, lemma ponds, polishing ponds, Karnal Technology (KT) for on-land disposal of wastewater etc. (Chaturvedi et al., 2014).Natural methods are favoured for nutrient removal from wastewater due to their low cost and environmentally friendly nature Initially, in the early days when it comes to wastewater treatment engineering, it is believed that natural treatment was the only known remedy for wastewater treatment (Darweesh et.al. 2021). During the earlier days of humanity, treatment of wastewater was not even an objective and neither the processes were understood. The wastewaters generated from the communities were simply allowed to flow to the nearest water carrying bodies or natural water resources like nearest river, lake which ever was available. As the communities grew, the pollution level in the carrying water eventually exceeded, which began to arise waterborne complications, which in turn caused interference with public health and effects on normal functioning of environment and its services. It was than these issues, which made humankind realize the need for treatment of wastewater prior to discharge to environment. Then, natural treatment systems were not able to handle the increased pollution load. The trend of mechanized treatment of wastewater took over to meet the required treatment needs. Eventually in due course of time, with advancement in research and development of natural treatment systems, it again came back into debate, considering its cost effectiveness for achieving the mandated treatment levels than which was available using existing mechanized treatment systems. The study focuses on increase the removal efficiency, cost effective by Application of Soil Biotechnology for Domestic Wastewater Treatment and Performance Monitoring in Bench Scale Unit.

1.2. Wastewater Concept and Management through Ages:

Before we proceed with the design and starts portraying wastewater treatment and its management strategies, it is very much essential for us to understand first, the concept of wastewater or in other word what does wastewater term really mean. Well-defined to its simplest of its form, a wastewater is nothing “but a used or a waste generated in the form of liquid from various activities of communities which contains contaminants in an excess amount permitted by statutory than regulating bodies”. Technically delineating, it can be defined as any waster or liquid, which contains pollutants/contaminants in the form of solids, liquids and gases or their combination in such concentration that may be harmful when discharged to the environment. The impurities that are present in wastewater are diverse in nature. They may be in the form of solid, which may be further organic or inorganic, suspended, colloidal or in dissolved form or in their various combination forms. Much has been articulated about the history of wastewater and water supply system and their correlation. Although it is very surprising to learn that the corresponding wastewater management is quite immature. For most of the centuries, almost in every culture, the wastewater generated was disposed in the open environment with no management solutions and tactics**.** Considerable historians and economists have reported the evolution of wastewater management practices over the ages {wastewater treatment history refers). But they have often lacked an engineering minds et. Fig:1. Below shows, the timeline for evolution of sanitation practices in due course of periods. Wastewater Management therefore means handling wastewater to protect the environment to ensure public health, economic, social and political soundness (Metcalf and Eddy, 1991).

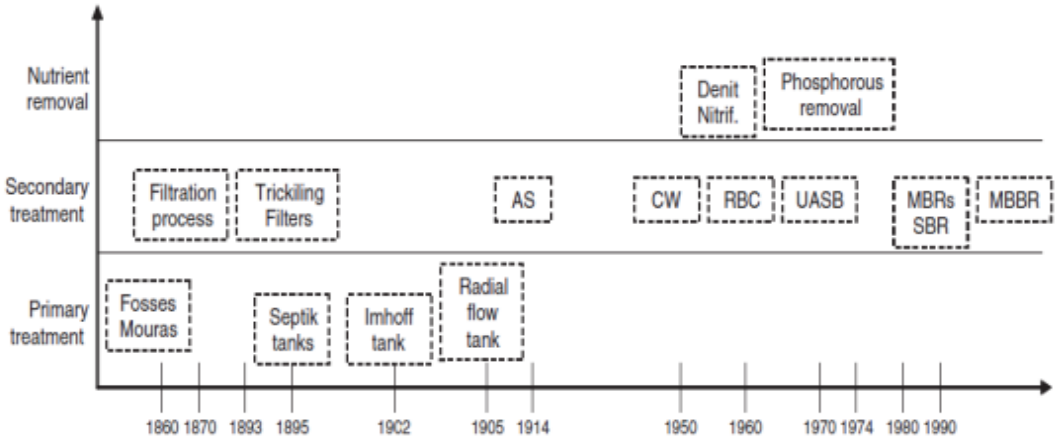


Fig.1: Evolution of wastewater treatment (Source: nyruralwater.org)

1.3. Indian Wastewater Scenario:

India's urban centres are witnessing unprecedented growth, propelled by new economic reforms and migration. Its population, 1.38 billion (as on 2020), is now fast converging on cities in search of a better source of income generation and quality of life. According to recent estimates, 35% of the total population (483 million) is concentrated in urban centres (United Nations, 2019). According to Census 2011, as many as 53 cities in India had a population above a million. At this current growth rate, the urban population is estimated to reach 607 million by 2030; and it is estimated that by 2050, 50% of the country's population (877 million) will be urban cities. This unsustainable increase in urban population exerts enormous pressure on city planners, especially for provisioning utility services, particularly for clean and affordable water. Allocation of water for such urban cities will eventually take water from the common pool where multiple sectoral demands exist. Sectoral water demands are reaching new heights where irrigation, household supply, energy and industry constantly seek increased volumes to meet growing needs. The 2050 projections for India report that it will require 1,447 km^3 of water, of which 74% is identified for irrigation, while the rest is for drinking water (7%), industry (4%), energy (9%) and others (6%) (Amerasinghe et al., 2013). However, with the aforementioned rapid urban growth in Indian cities and towns, the demand for drinking water is also rising and has a higher priority than competing rural water needs, including irrigation. Water transfers from rural and peril-urban regions to urban cities are increasing. A large number of these growing cities are located in major river basin catchments, taking freshwater away and discharging wastewater back into the catchments and thus polluting irrigation water as well as posing major challenges for urban and rural planners, especially concerning urban wastewater management.

1.4. Wastewater Treatment Status: Indian Scenario:

In India, the sewage generation in the urban centres, as per the recent assessment by Central Pollution Control Board (CPCB), was 72,368 million Litres per Day (MLD) for the year 2020-21. Currently, the installed sewage treatment capacity is 31,841 MLD, but the operational capacity is 26,869 MLD, which are much lower than the load generated. Of the total urban sewage generated, only 28% (20,236 MLD) was the actual quantity of wastewater treated. This

implies that 72% of the wastewater remains untreated and is disposed of in rivers/lakes/groundwater. There are some increases in infrastructure e.g., another 4,827 MLD sewage treatment capacity, has been proposed. If this is added to the existing installed capacity, even then, there is a gap of 35,700 MLD (i.e., 49%) between the wastewater generated and the capacity available for treatment (CPCB, 2021b). Looking more closely at the city-scale wastewater generation, the estimated wastewater generation from Class I cities and Class II towns (as per the 2001 census) is 29,129 MLD, which is expected to be 33,212 MLD at present, assuming a 30% decadal growth in urban population. Against this, the installed sewage treatment capacity is only 6,190 MLD. There remains a gaps of 79% (22,939 MLD) between sewage generation and installed sewage treatment capacity. Another 1742.6 MLD wastewater treatment capacity is under the planning or construction stage. If this is added to the existing capacity, there still is a gap of 21,196 MLD (equal to 73%) in sewage treatment capacity (CPCB, 2021c)

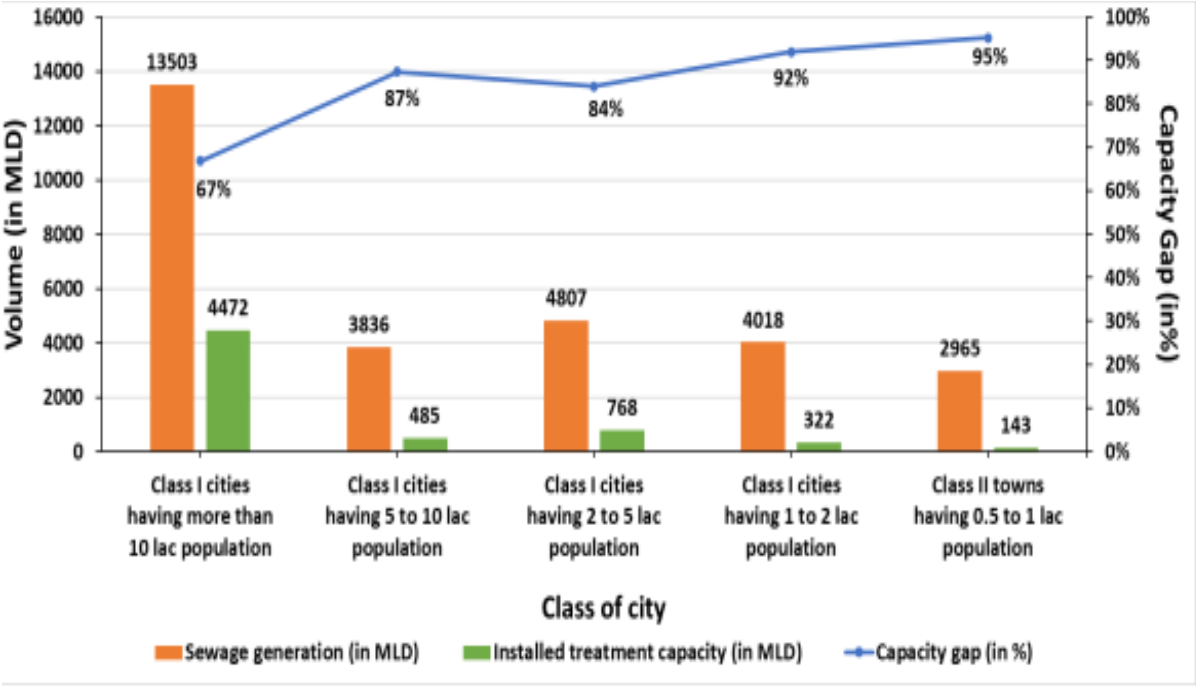


Fig.2: Wastewater treatment scenario of India (Source: CPCB, 2022)

1.5. Current State of Sewage and Septage Management in Kolkata Metropolitan Area:

The state of sewage and septage management in Kolkata Metropolitan Area presents a multifaceted challenge driven by rapid urbanization, inadequate infrastructure, and limited access to sanitation services. As one of India's most densely populated urban areas, Kolkata Faces significant pressures on its sewage and septage management systems, leading to public Health risks, environmental degradation, and social inequalities. Kolkata Metropolitan Area A network of sewage treatment plants (STPs) (30 operational) with a total serve (KMA) Treatment capacity of 455MLD and faecal sludge treatment plants (FSTPs) (2) capacity of 65

KLD designed to treat sewage and septage generated by urban households, industries, and commercial establishments. These treatment facilities vary in size, capacity (5-45MLD), and technology (including both conventional and advanced technologies), with some located within the city limits and others in peri-urban areas. In addition to this, the East Kolkata Wetlands (EKW), a distinguished Ramsar designated site of international importance, situated in the eastern fringes of the Kolkata Metropolitan Area (KMA). Spanning over an impressive expanse of 125 km^2 and plays a pivotal role in the eco-infrastructure of the region, particularly in the treatment of sewage generated within the KMA. Functioning as a natural filtration system, the EKW effectively processes approximately 900 MLD of sewage (EKWMA and WISA, 2021), thereby alleviating the burden on conventional treatment facilities. This eco-friendly mechanism harnesses the inherent qualities of wetland ecosystems to cleanse and purify wastewater before it is eventually discharged into the River Vidyadhari. The primary objective of sewage treatment of KMA is to remove contaminants and pathogens from wastewater and sludge before discharging into river Ganga/Vidyadhari.

1.6. Selection of the sample collection area:

The large network of sewage canals criss-crossing Kolkata Metropolis carry considerable sewage load of about 4.5 million people (The study area is situated between 22°30'08.0"N 88°23'22.1"E. Covering Sapuipara, Uttar Purbachal, Garfa, Kayasthapara, Kalikapur and parts of Haltu.

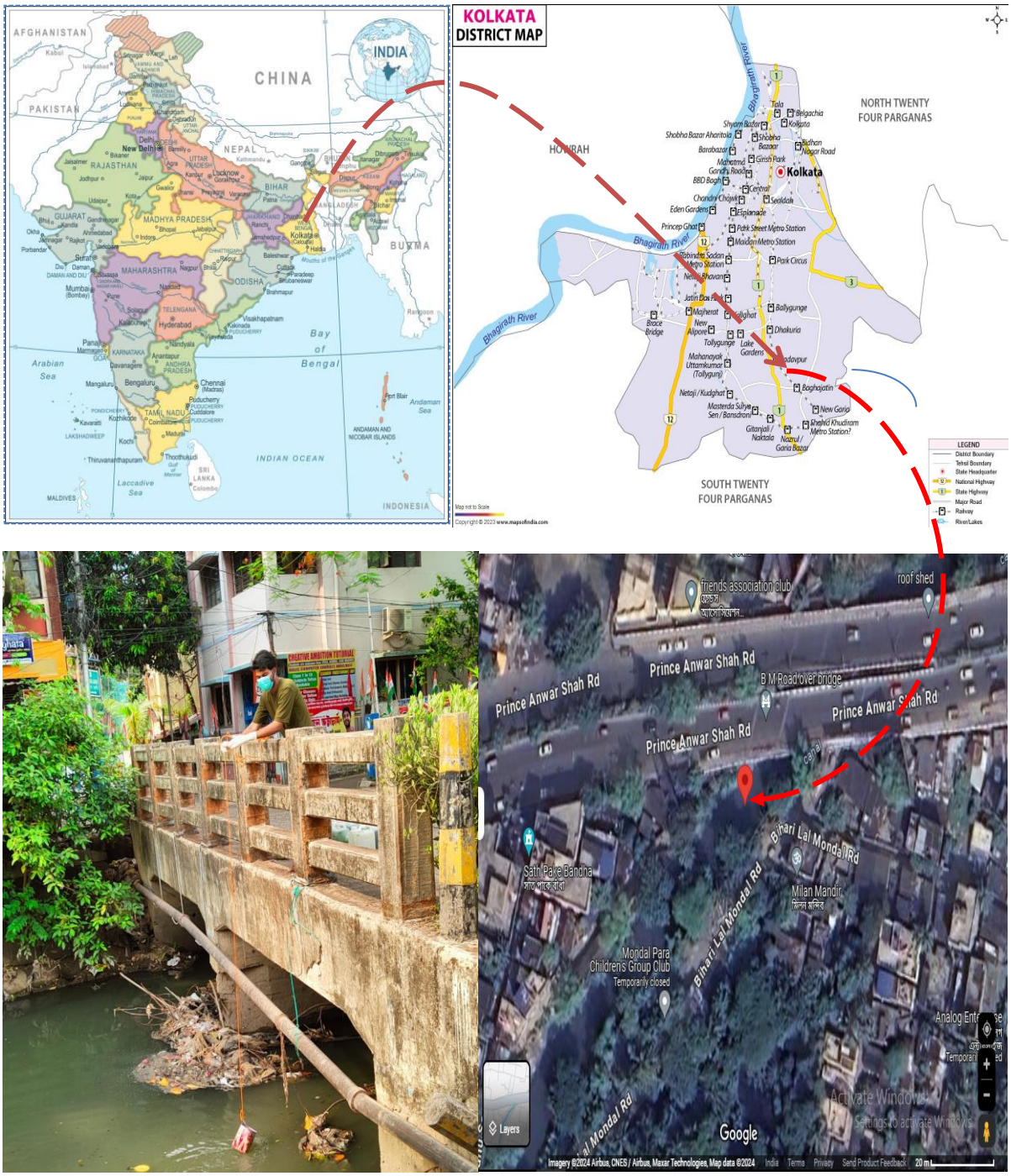


Fig.3: Selection of Sample Collection Area (Source: Google Map)

1.7. Research Gap:

Wastewater treatment using soil biotechnology methods involves the utilization of microorganisms and biological processes present in soils to remove or degrade various contaminants and pollutants from wastewater. However, there are several research gaps are present. Soil biotechnology (SBT) focuses only for metropolitan domestic wastewater treatment where most researcher focuses on conventional pollutants. Therefore, there is a need to evaluate how SBT handles emerging contaminants like pharmaceuticals and micro plastics that are increasingly prevalent in wastewater. The effectiveness of SBT for treating wastewater from different sources (industrial vs. municipal) needs further investigation. Optimizing the microbial communities for specific contaminants might be necessary. More LCAs that are comprehensive are needed to fully understand the environmental impact of SBT compared to conventional methods. This would include factors like energy consumption and greenhouse gas emissions.

By addressing these research gaps, scientists and engineers can refine SBT technology and make it even more effective and reliable for wastewater treatment.

1.8. Research Objectives:

The primary research objective is to harness the natural processes and microbial communities in soil to effectively treat domestic wastewater, focusing on developing and optimizing integrated soil-based treatment systems. This includes combining biological, physical, and chemical processes for efficient contaminant removal. The study aims to monitor the performance and efficiency of a bench-scale soil biotechnology unit under varying organic and hydraulic loading rates. Additionally, optimization techniques will, refine design parameters, and establish a cost-effective natural wastewater treatment solution.

1.9. Methodology Adopted for Research:

Soil biotechnology (SBT) is a green engineering approach for wastewater treatment and recycling. The methodology adopted for research in this field typically involves the following steps. First studied the various national and international journal and books, find several research gaps for domestic wastewater treatment by Soil Biotechnology, and made a Soil Biotechnology model. Collected the wastewater and discharge through the model, monitoring the flow velocity uniformly through the active media and collected the treated water. Recycling the treated water as per treatment specification. Collected the sample like raw water, treated water for laboratory analysis, and checked the removal efficiency of various chemical parameter like BOD, COD, TSS, TN, TC & FC, TP, pH and other treatment parameter like OLR, HLR. Results of Various Physicochemical Parameters of Sewage at Inlet and Outlet of SBT model along with Discharge Standards.

1.10. Outline of The Thesis:

The thesis consists of 9 chapters. Chapter 2 consists of Literature review from national and international journal about SBT for treatment of wastewater various type of wastewater and their characteristics. Chapter 3 consists brief discussion about wastewater. Chapter 4 consists

of Discussion of the various type of natural treatment process of wastewater treatment. Chapter 5 consists methodology of this research and design and construction of SBT in lab scale model as well as field scale. Chapter 6 consists various type test in laboratory for checking removal efficiency. Chapter 7 consists of result and data analysis for performance checking. Result analysis of the various parameter like BOD, COD, TSS, TC-FC, pH. Chapter 8 consists of conclusion, future scope and recommendation references.

CHAPTER: LITERATURE REVEIW

2. Literature Review:

During the literature review several research papers, books, data are found for the waste water management and technology option, but unfortunately very few papers can be found for the natural waste water treatment so during the study collection of those data, technology option are the main challenging work to analysis the scenario of waste water management system .The literature review has been carried out consulting various natural based as well as international journal to acquire knowledge in the natural treatment technology for municipal waste water. The literature review section of this thesis on the application of the soil biotechnology for the treatment of domestic wastewater and performance monitoring of bench scale unit is a crucial part of this research, in this section, it is providing an overview of the exiting knowledge, research gaps and relevant studies related to the topic.

Shankar et.al. (2002) described the Soil Biotechnology (SBT) is characterized as an environmentally friendly technology for processing waste, utilizing a system that treats both solid organic wastes and wastewater with the help of bacteria, earthworms, and mineral additives in settings resembling gardens. The formulation of this system relies on soil media that incorporate micro and macro-organisms for water and wastewater treatment. The study of hydrodynamics and rate-limiting factors in the SBT system employs Computational Fluid Dynamics (CFD), with simulations conducted across various bioreactor configurations to compare against laboratory and field experimental data. Such a CFD model aids in predicting and understanding the behavior of the water treatment process within SBT, facilitating the optimization of bioreactor design and operational conditions prior to real-world application. The system enhances carbon and nitrogen cycles naturally, resulting in treated water quality that surpasses state pollution control board standards by reducing Chemical Oxygen Demand (COD) and nitrates significantly compared to other Sewage Treatment Plant (STP) methods. Soil Biotechnology is lauded for its low life cycle cost, longevity, minimal operational expenses, green ambiance, modularity, multi-level and greenhouse designs, and its capacity for purifying water, wastewater, solid waste, and air, thereby offering reusable water.

Gawad et.al. (2020) stated that Water is recognized as a precious natural resource, essential for the survival of all living things, making life without it unimaginable. In India, reliance on monsoons is vital to fulfil the annual water demand, with efforts to reduce total water supply needs through the reclamation and reuse of wastewater. In cities with populations exceeding one hundred thousand, 35,558 units of non-potable water are produced, which are directed into septic tanks, transforming into wastewater. This waste is treated using soil biotechnology (SBT), a method that employs living organisms to undertake the necessary filtration, aeration, and biochemical processing. This processing effectively removes various contaminants including biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, phosphates, suspended solids, and eliminates colour, odour, and bacteria, making it ecologically safe. SBT distinguishes itself by utilizing only natural materials and processes, such as respiration, photosynthesis, and nitrogen fixation, and does not require the periodic sludge removal necessary in traditional sewage treatment plants or septic systems, as all waste material is completely consumed within the system. The wastewater undergoes treatment in a bioreactor for approximately five hours, depending on the load and capacity, after which the treated water is collected.

Shrivithal et.al. (2021) stated that a novel green technology known as SBT is characterized by its use of natural processes such as respiration, mineral weathering, and photosynthesis to purify air and water as well as process organic solids. This technology employs a system that incorporates bacteria, earthworms, and mineral additives for the processing of organic wastes and the treatment of wastewater in a green infrastructure that mimics a garden. Despite its seemingly simple facade, the complex biochemistry underlying SBT allows it to effectively diminish levels of BOD, COD, and TSS in treated water by over 90%. Up to 95% of the water treated can be recovered and recycled, with about 99.99% of bacteria being eliminated, thus ensuring healthier environments. This technology, which operates efficiently within ambient temperatures ranging from 10°C to 35°C, stands out for its energy efficiency and economic advantage over traditional wastewater treatment methods. Its design negates the need for flooding and renders it impervious to monsoons, facilitating its suitability for ground water recharge through the utilization of constructed soil filters. Capable of removing organics from both industrial and domestic sewage, SBT can treat wastewater to conform to groundwater recharge standards, aiding in the replenishment of wells and groundwater levels. In contrast to conventional methods, SBT concludes its process without generating waste, instead producing beneficial by-products such as bio-fertilizer and reusable water.

Mokal et.al. (2020) discussed the two billion people worldwide are living in regions faced with water scarcity. By 2025, countries or regions facing absolute water scarcity will be home to 1.8 billion individuals, with two-thirds of the global population possibly living under water-stressed conditions. There is a significant demand for water in every domestic area. To reduce these demands and meet the requirements, an efficient and economical wastewater treatment system is necessary. Soil biotechnology (SBT) represents a green engineering approach for the treatment and recycling of wastewater, employing sedimentation, infiltration, and biochemical processes to eliminate suspended solids, organic, and inorganic contents from the wastewater. This technique is characterized by a specific mineral constitution, a culture of native micro-flora, and bio-indicator plants, encompassing soil, formulated granular filter media, and selected cultured plants. The wastewater requires collection, analysis, and treatment, initially assessing pH, Turbidity, DO, Solids & BOD, etc., to decide upon and design the treatment process. The construction of treatment plants is estimated and cost-calculated based on these analyses. Sewage treatment plants, deemed necessary facilities, receive wastewater to remove harmful materials for both public health and the environment. Our study aims to minimize freshwater intake for college use, with the treated effluent designated for flushing and plantation purposes, and the resulting solid waste (or treated sludge) considered suitable for reuse as farm fertilizer.

Kamble et.al. (2017) stated that the only renewable resource among all other renewable resources that cannot be replenished is water, which is vital for food production, economic development, and life itself. Soil biotechnology (SBT) is an oxygenation engine similar to conventional technologies like the activated sludge process (ASP), sequential batch reactor (SBR), membrane bioreactor (MBR), and moving bed bioreactor. Life cycle assessment (LCA) has been conducted to evaluate the environmental impacts of the construction and operation phases of SBT. This technology can achieve a removal of more than 90% for chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Additionally, the nutrient removal proficiency (nitrate, nitrite, ammonia nitrogen, TKN, total nitrogen, and phosphates) of this technique is considered good. On the other hand, low annual operation and maintenance costs are incurred by SBT, which are comparable to land-based systems and lower than conventional

or advanced technologies. From the life cycle impact assessment, the main contributors for the overall impact from the plant were identified as electricity consumption, discharges of COD, $P\text{-}PO_4$ and $N\text{-}NH_4$ +, and disposal of sludge. It was found that the construction phase had significantly more impact than the operation phase of the plant. It is suggested by this study that plant I is not relatively as efficient enough regarding sanitation. Several benefits are provided by SBT over other conventional technologies for wastewater treatment. It is based on a bioconversion process and is practically maintenance-free. The least energy is consumed by it, and it does not produce any odorous bio-sludge.

Ekta et.al. (2016) described that the treatment of petrochemical wastewater with a high chemical oxygen demand (COD) range of 5000 to 6000 mg/l using soil biotechnology was examined in the study. This approach involves a system with soil, granular filter media, and earthworms as the selected macro-organisms. The key points are: The treatment of COD by 81-82% after 6 hours of detention time, and 88-91% after 12 hours of detention time was found to be done by earthworms acting as a 'bio filter'. The wastewater treatment occurs through the mechanisms of 'feeding' and 'biodegradation' by the earthworms. The hydraulic conductivity and natural aeration are increased by grinding the soil particles by earthworms. In the study, the effluent passed through the top layer of the filter, and the removal efficiency of COD was evaluated. This process, eliminating the need for additional expenditure on land filling and disposal, does not generate sludge. The process is described as odour-free, eco

RAJU et.al. (2020) stated that an emerging decentralized wastewater treatment technology suitable for small communities is Soil Biotechnology (SBT). A column experimental study was conducted to evaluate the required depth of locally available over burnt brickbats as the contact media for treating domestic sewage at different flow rates (0.5 - 2.5 L/hr). The required depth of locally available over burnt brickbats as the contact media for treating domestic sewage at different flow rates (0.5 - 2.5 L/hr) was evaluated in a column experimental study. The column setup consisted of a 100mm diameter PVC pipe filled with the brickbat media at depths of 1.5m, 2.0m, 2.5m and 3.0m. The removal percentages of BOD and COD were measured at each depth for the different sewage flow rates. At each depth, the removal percentages of BOD and COD for the different sewage flow rates were measured. At 3.0m depth, 81.2-94.2% BOD and 78.4-90.7% COD removal was achieved across the flow rates tested. Across the flow rates tested, 81.2-94.2% BOD and 78.4-90.7% COD removal was achieved at 3.0m

Kamble SJ et.al. (2017) investigated that high removal rates (over 90%) for chemical oxygen demand (COD) and biochemical oxygen demand (BOD) in wastewater can be achieved by SBT, an environmentally friendly (green) engineering approach. Nutrients like nitrates, nitrites, ammoniacal nitrogen, total Kjeldahl nitrogen (TKN), and phosphates can also be effectively removed by it. Electricity consumption, discharges of COD, phosphates, and ammoniacal nitrogen, as well as sludge disposal were identified as the main contributors to the overall environmental impact by the life cycle assessment (LCA). The construction phase of the SBT plants had a significantly higher environmental impact compared to the operation phase. One of the assessed plants (Plant I) was found to be relatively less efficient in terms of sanitation. Compared to conventional or advanced wastewater treatment technologies, SBT has several advantages, including low annual operation and maintenance costs, being a bioconversion process, maintenance-free operation, no odorous bio-sludge production, and low.

Gupta et.al. (2015) discussed the water security is considered a major global concern, with water scarcity being suggested to lead to wars in the future. In India, 40% of untreated

wastewater is directly discharged into rivers, heavily polluting major water resources. Challenges are faced by many Indian industries in installing or maintaining wastewater treatment plants. A solution involving recycling and reusing wastewater is proposed using existing treatment technologies like the activated sludge process and up flow anaerobic sludge blanket process. The comparison of conventional wastewater treatment technologies with an innovative soil biotechnology (SBT) developed at IIT Bombay is made in the passage. Sewage treatment via activated sludge vs SBT and effluent treatment via rotating biological contactors vs SBT are evaluated. Parameters including BOD, COD, TDS, TSS as well as economic and environmental aspects are compared. The aim is to explore SBT as a potentially more effective solution for treating and recycling wastewater in India.

Khan et.al. (2021) stated that a green engineering approach for wastewater treatment and recycling that aims to reuse contaminated water in an environmentally friendly manner is known as SBT. Wastewater is first passed through tube settlers, then through bioreactors filled with aggregates, bricks, and a bio media of earthworms. These layers act as natural filters to treat the water through harmless biological processes as the wastewater flows through them by gravity. Several benefits are offered by SBT over conventional processes, such as minimal power usage, while still effectively treating the water. Analysis of the domestic wastewater and treated water was done measuring parameters like pH, TDS, TSS, BOD, COD, and ammoniacal nitrogen following standard methods. SBT is considered a cost-effective, eco-friendly modern technology that utilizes soil, gravel, sand, earthworms.

Darweesh et.al. (2021) described the Water scarcity and inadequate wastewater treatment combined with increased industrial activity have led to contamination of water bodies in developing countries. Contamination of water bodies in developing countries has been led by water scarcity and inadequate wastewater treatment combined with increased industrial activity. Many common wastewater treatment techniques are not practical in these countries. In these countries, many common wastewater treatment techniques are not practical. Biotechnological approaches using biological methods are considered important for wastewater treatment in developing nations. Wastewater treatment in developing nations is considered important for biotechnological approaches using biological methods. Biological methods are favoured for nutrient removal from wastewater due to their low cost and environmentally friendly nature. Due to their low cost and environmentally friendly nature, nutrient removal from wastewater is favoured by biological methods. These methods can contribute to integrated environmental protection strategies. Integrated environmental protection strategies can be contributed to by these methods. The authors are from universities in Egypt researching environmental, biological and genetic aspects related to this issue. The authors from universities in Egypt are researching environmental, biological, and genetic aspects related to this issue. The useful tools of biotechnology to wastewater treatment such as activated sludge, membrane bioreactors, media filters, anaerobic.

Kanani et.al. (2017) described that a wastewater treatment process, SBT, is based on a bioconversion process where fundamental reactions of nature, namely respiration, photosynthesis, and mineral weathering take place in a media housing micro & macro-organism, which bring about the desired purification. An oxygen supplying biological engine is SBT and the process can treat so all types of water – domestic, municipal, and industrial. Soil biotechnology (SBT) is an eco-friendly and cost-effective technology for treating wastewater using natural materials like soil, gravel, sand, earthworms, bacteria, and plants. It

is useful in areas without access to sewer systems. In this project, alluvial soil, E-fetid earthworms, and aloe Vera plants were used to treat domestic wastewater. Wastewater analysis was conducted using IS 3025 methods, measuring parameters like pH, TDS, TSS, BOD, COD, and ammonia nitrogen. Experiments were done with hydraulic retention times (HRT) of 6, 8, and 10 hours. The removal efficiency ranged from 65-75% for TDS, 64-74% for TSS, 75-90% for BOD, 75-92% for COD, and 55-65% for ammoniacal nitrogen. The treated water met the discharge norms of the pollution control board. Noise pollution is eliminated in this SBT system as there.

Anjali et.al. (2021) examined that Soil Biotechnology is a terrestrial wastewater treatment system that operates on the principle of a trickling filter. Physical processes like sedimentation and infiltration are combined with biochemical processes carried out by microorganisms to remove suspended solids, organic matter, and inorganic compounds from wastewater. It is also known as a Constructed Soil Filter (CSF). The system consists of components like a raw water tank, bioreactor containment, treated water tank, piping, and pumps. It can be constructed using materials like RCC, stone masonry, or soil bunds. An environmentally friendly technology that harnesses the bioenergy present in organic wastes by integrating elements of a productive soil ecosystem including soil bacteria, earthworms, plant species, and mineral nutrients is utilized. An integrated system for processing both solid organic wastes and treating wastewater using bacteria and earthworms in a garden-like setup is offered by it. The natural activities of microbes and earthworms are utilized in the treatment process to break down and stabilize the organic matter present in the wastewater. Soil Biotechnology (SBT) is an environmentally friendly waste process technology that offers systems for processing of both solid organic wastes and wastewater treatment using bacteria.

Goti (2022) stated that the soil biology-based wastewater treatment process is characterized by the use of enzymes and microorganisms, which carry out the fundamental reactions of nature, namely respiration, photosynthesis, and mineral weathering, in a media that resembles soil. It is these microbial and macro-organisms that achieve the purification, which is the main aim of an SBT process. An SBT process is a biological engine that can provide oxygen to water, and as a result, all types of water - domestic, municipal, and industrial can be treated. Treatment of all types of water is possible using SBT, which is solely an aerobic process. In areas such as pharmaceuticals (dairy), distillery, and petroleum refinery wastes, as well as compost and landfill lactates, fishpond discharge, this technology is used for municipal and industrial wastewater treatment.

Panchal et.al. (2019) investigated that the SBT is an environmentally friendly system for treating municipal wastewater and industrial effluents. Soil, filter media, and selected macro and microorganisms like earthworms are used in the process. A major advantage of SBT is that sludge is not produced at the end. Instead, vermicomposting is generated as a useful product. A more sustainable and cost-effective approach is offered by SBT compared to conventional energy-intensive wastewater treatment technologies. Natural bioconversion processes like respiration, photosynthesis, and mineral weathering occurring in the media containing micro and macro-organic form the basis of it. Various types of water - domestic, municipal, and industrial can be treated by it, as an oxygen supplying biological system. Water quality and quantity can be conserved and enhanced through treatment and reuse of wastewater from different sources without contributing to global warming. In essence, an eco-friendly, efficient,

and cost-effective alternative to conventional wastewater treatment is presented by SBT through harnessing natural biological processes and generating useful by-products.

Minhas et.al. (2017) stated the process of converting polluted wastewater into an effluent that can be safely released back into the water cycle or reused with minimal environmental impact is known as wastewater treatment. Various technologies are available for wastewater treatment, and the selection of the best technology depends on factors such as space requirement, initial cost, operating and maintenance costs, power requirement, and the quantity and quality of sludge produced. The main technologies studied are Moving Bed biological Reactor (MBBR), Sequencing Batch Reactor (SBR), and Soil Biotechnology (SBT). SBT is a biological process that mimics natural processes like respiration, photosynthesis, and mineral weathering by utilizing micro and macro-organisms. The organisms through bioconversion reactions occurring in the treatment media facilitate the desired purification of wastewater. SBT is an oxygen-supplying biological system, enabling it to treat various types of wastewaters - domestic, municipal, and industrial. Its applications include heavy metal removal, treatment of hospital waste and industrial effluents, as well as air purification. By harnessing fundamental natural processes with the help of diverse organisms, an effective biological approach for comprehensive wastewater remediation and air treatment is provided by SBT. Water is treated for reuse rather than disposal through Soil Biotechnology, which utilizes the biological energy in organic matter to facilitate this process. It is recommended for apartments and communities in urban areas as a solution to apartment water problems since the treated water can be reused rather than discarded, making it an eco-friendly and sustainable approach.

Singhet.et.al. (2021) discussed the comparative analysis of three popular wastewater treatment techniques is being conducted. The main technologies studied are: (1) Sequencing Batch Reactor (SBR), (2) Rotating Biological Contractor (RBC), and (3) Soil Biotechnology. In SBR, BOD reduction is carried out aerobically through a suspended growth process known as the Improvised Activated Sludge Process. The organic matter is brought in contact with bacteria in suspension. In RBC, the attached growth process involves circular disks on a horizontal shaft, and in SBT, BOD reduction takes place aerobically without generating excess sludge. No media are required in SBR, but in RBC, a biological slime or 'zoogleal film' is grown on the media containing the bacteria and microorganisms that provide wastewater treatment. In SBT, it is formulated from soil with primary minerals of suitable size and composition. In the SBR treatment system, sludge is active, so an anaerobic (or aerobic) digester is required for complete destruction of biomass. This increases plant cost and operator attention compared to low production of sludge in SBR. However, SBT produces no sludge in the process and needs more power than SBT, although the power required is more than SBT and almost similar to SBR. Less power is consumed in the process compared to SBR; only power is used for operating the pumps. More area is needed than RBC and SBT require no maintenance and operations, while other systems need maintenance and operations.

Pachori et.al. (2018) examined the determination of quality was carried out by various parameters including pH, chemical oxygen demand, biological oxygen demand, TSS, TDS, and Total Kjeldahl Nitrogen through the soil biotechnology method. Both samples were also subject to analysis using Atomic Absorption Spectroscopy (AAS) to detect the concentration of Sodium, Potassium, and heavy metals like Nickel, Copper, and Aluminium. Microbial analysis was conducted to identify the presence of bacteria, fungi, yeast, etc. The fundamental principle of soil biotechnology derived from the operation of a terrestrial ecosystem, and

wastewater or used water is processed through a combination of biological and physical processes involving resistant control, soil, formulated coarse filter media, and a select culture of organisms such as plants and earthworms. The natural bio-geochemical cycle of nature is utilized, making it the most effective eco-friendly technology for wastewater treatment.

Patidar et.al. (2012) assessed under laboratory the performance of an uncultured soil bioreactor in a laboratory to treat wastewater was reported in the present study. A new approach for contaminant removal from municipal wastewater using a constructed soil filter (CSF) in laboratory scale was demonstrated. Results showed that the pH of the effluent was found to be in the natural range (7.8-7.95). The bio-chemical oxygen demand (BOD) was reduced from 70 to 20 mg/L, with a removal percentage of around 50%, and alkalinity reduced from 157 to 122 mg/L, with a removal percentage of around 11%. In this experimental work, a constructed soil filter system (CSF) was configured for the treatment of soil ecosystem for wastewater purification. No pre-treatment was required, resulting in higher removal efficiency and very low energy requirement.

Desye et.al. (2022) investigated that the reduction of contamination and pollution of natural waters, as well as the improvement of aquatic ecosystem health, is contributed to by wastewater treatment. The efficiency of waste stabilization pond (WSP) technology for wastewater treatment in Ethiopia was evaluated in the study using a laboratory-based analysis of 60 wastewater samples. Significant removal efficiencies were observed for BOD_5 (up to 75.3%), COD (up to 56.5%), total nitrogen (up to 79%), total phosphorus (up to 69.2%), phosphate (up to 71%), total coli forms (up to 99.99%), and faecal coli forms (up to 94.3%). The overall treatment efficiency of the WSP was found to be 73.5%, and a water quality index of 30 was recorded for the effluent, indicating unsuitability for direct discharge into the environment. To greatly reduce the WSP's efficiency and ensure adequately treated water is produced, recommendations were made for adequate preliminary treatment, design modifications, dislodging, additional treatment steps, and frequent monitoring and maintenance. Despite the limitations, the WSP technology was found to be considered a promising wastewater treatment method, especially for developing countries like Ethiopia, where only a small proportion of wastewater is currently being treated.

Santo et.al. (2021) described the Waste stabilization ponds (WSPs) are commonly used for sewage treatment, consisting of anaerobic, facultative, and maturation ponds in series. While effective at removing organic matter and pathogens, they have disadvantages like long retention times, biogas release, and inability to remove nutrients. A promising alternative is the replacement of the anaerobic and facultative ponds with an up flow anaerobic sludge blanket (UASB) reactor, which greatly reduces retention time and allows for biogas capture. The post-treatment ponds after the UASB reactor are capable of producing oxygen, consuming CO_2, and raising the pH, which facilitates nitrogen and phosphorus removal. The experimental results showed that pathogen decay and pH increase for better nutrient removal were accelerated by using the post-UASB ponds in a sequential batch regime instead of continuous flow. High quality effluent low in organic matter, nutrients, and pathogens is produced by this modified UASB sequential batch pond system, without energy consumption or chemicals, and with a much smaller area than conventional WSP.

Tom et.al. (2021) examined the ppopulation growth, resource depletion, and environmental degradation are included in the major global challenges. A critical issue is presented by food

scarcity due to climate change. An important role in addressing global food scarcity is played by aquaculture, with aquaculture's share of fish for human consumption projected to rise to 58% by 2028. Water quality is adversely impacted and secondary pollution damaging aquatic resources caused by traditional aquaculture systems. For sustainable aquaculture systems, improving water recycling and reducing wastewater discharge are crucial. Recirculating aquaculture systems that replace only 10% of water daily are more sustainable than conventional systems. Highly efficient at removing nitrogen compounds from wastewater are constructed wetlands. Cumulative energy demand has been reduced by around 50% compared to conventional units by coupled aquaponics systems. Environmental impacts of fish farming can be reduced while producing biomass and lipids by using microalgae as feedstock. Output and profitability of shellfish are improved by integrated multi-tropic aquaculture combining fed aquaculture with extractive aquaculture. Sustainable aquaculture contributing to water-food-energy sustainability can be ensured by developing efficient reactors and an integrated approach.

Li et.al. (2020) discussed the development of intensive industrial aquaculture must prioritize the avoidance and mitigation of the introduction of harmful effluents into the environment in order to greatly reduce pollution impacts. The researchers to efficiently remove nutrients from effluent wastewater constructed a novel field-scale aquaculture wastewater treatment system (FAWTS) involving three-stage purification. However, the mechanisms of nutrient attenuation in the FAWTS were found to be unclear. Microbial metabolic activity, microbial composition, and their metabolic potential were tested by using microplate culture and 16S rRNA gene amplicon sequencing. The results showed that high removal efficiencies for chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP were displayed by the FAWTS. Microbial metabolic activity for various carbon sources was greatly enhanced in FAWTS biofilms. Denitrifying and phosphorus-removing bacteria like Rhizobacteria were enriched in these biofilms, and genes involved in denitrification and phosphorus metabolism were greatly increased in the biofilm communities.

Kotaik et.al. (2021) stated the Constructed wetlands (CWs) are considered an eco-friendly and efficient technology for wastewater treatment that integrates water security, energy potential, and environmental protection. Reasonably high contaminant removal efficiency and ecological benefits have been demonstrated by CWs at both laboratory and field scales, making them a promising technology for cost-effective and low-impact wastewater treatment. The role of individual wetland components, such as macrophysics (aquatic plants) and biofilms, and their impact on treatment efficiency is focused on by the review. The interface between pollutant removal, root radial oxygen loss, root iron plaque, endophyte-macrophyte assisted treatment, and prospects of energy harvesting from macrophysics in CWs is explored. The effect of biofilms on treatment efficiency, their composition, and factors affecting them is also examined. Recent advances and developments in alternative low-cost substrate materials, including industrial by-products, organic waste, mineral-based, and hybrid materials, and their effects on target pollutants are discussed. The concerns and applicability of CWs for treating various types of wastewaters, such as municipal, industrial, agricultural, and farm wastewater are addressed. The practical relevance and significance of these aspects, incorporating recent developments, to inform future research and development directions related to CWs are aimed to be analysed

Parde et.al. (2021) investigated that factor like the wetland type, vegetation, hydraulic loading rate, and media used in the bed influence the performance of constructed wetlands. The use of constructed wetlands for treating various types of wastewaters, such as textile, dairy, industrial, piggery, tannery, petrochemical, and municipal waste is reviewed in this paper. Different types of constructed wetlands are summarized in the review, considering aspects like media, vegetation, removal efficiency, construction cost, maintenance cost, and land area requirement using life cycle cost analysis. Constructed wetlands are compared with other wastewater treatment technologies in terms of treatment efficiency, payback period, and cost-effectiveness. The lack of proper guidelines for selecting media and vegetation in constructed wetlands is highlighted. Typhus Latifolia and Phragmites Australia are found to have better removal efficiency than other plant species. Lightweight Expanded Clay Aggregate (LECA), sawdust, zero-valiant iron, and gravels when used as media can effectively remove organic matter, phosphorus, sulphate, and arsenate. Constructed wetlands with low Hydraulic Loading Rate (HLR) perform exceptionally well, removing 80-91% Biochemical Oxygen Demand (BOD), 60-85% Chemical Oxygen Demand (COD), and 80-95% Total Suspended Solids (TSS). They require very low operation and maintenance compared to other technologies. Further research and development related to land area, media, plants, engineering design, and automation of treatment units for constructed wetland.

Costa et.al. (2016) studied the potential of Duckweed ponds for the removal of nutrients like nitrogen and phosphorus from domestic and agricultural wastewater effluents is being investigated. Unlike conventional treatment systems that emit greenhouse gases like CO_2 and CH_4, nutrients can be removed by duckweed ponds while also fixing CO_2. Greenhouse gas emissions and CO_2 fixation were evaluated by operating two pilot duckweed ponds in series treating real wastewater at a flow rate of 200L/day. Over a period of 123 days, the ponds achieved high nutrient removal efficiencies of 92.6% for total nitrogen and 84% for total phosphorus, as well as 79% removal of organic matter (COD).

After the literature review, several research papers, books, data are found for the wastewater management and technology option, it's said that,

Soil biotechnology relies on natural biological, physical, and chemical processes to treat wastewater.

Soil bacteria and fungi play a crucial role in breaking down organic matter and removing pollutants.

Soil acts as a natural filter, removing suspended solids and some dissolved contaminants.

This technology is often used in constructed wetlands, reed beds, and other nature-based wastewater treatment systems.

It is generally low-cost, environmentally friendly, and requires minimal energy input compared to conventional treatment methods.

CHAPTER 3: BASIC PRINCIPLE AND CURRENT SCENARIO OF WASTEWATER

3.1. Wastewater:

Wastewater or sewage is the by-product of many uses of water. There are the household uses such as showering, dishwashing, laundry and, of course, flushing the toilet. Additionally, industries and commercial enterprises use water for these and many other purposes, including processes, products, and cleaning or rinsing of parts. After the water has been used, it enters the wastewater stream, and it flows to the wastewater treatment plant.

3.2. Types of Wastewaters:

Wastewater can be described as in the figure below:

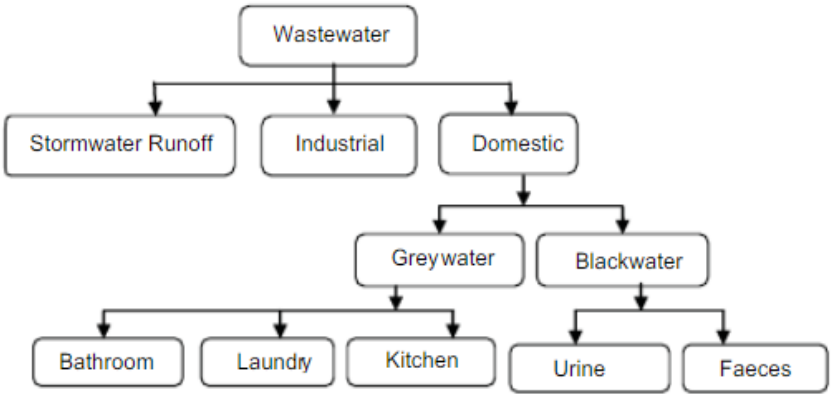


Fig.4: Types of wastewaters.

- **Storm water Runoff** is water from streets, open yard etc. after a rainfall event, which run through drains or sewers.

- **Industrial wastewater** is liquid waste from industrial establishments such as factories, production units etc.

- **Domestic wastewater** also known as municipal wastewater is from residences (homes), business buildings (e.g. hotels) and institutions (e.g. university). It can be categorized into greywater and Blackwater.

- **Greywater** or sullage is liquid waste from washrooms, laundries, kitchens which does not contain human or animal excreta.

- **Blackwate**r is wastewater generated in toilets. Blackwater may also contain some flush water besides urine and faeces (excreta). Urine and faeces together are sometimes referred to as night soil.

3.3. Constituents in Wastewater:

Water when used for different purpose like domestic commercial, industrial etc., receives impurities and become wastewater. Thus, wastewater is used water, and it has physical, chemical, and biological Impurities in it, wastewater is a general term.

3.3.1. Physical Characteristics:

The Physical Characteristics of water are determined using the physical method of analysis:

- ✓ **Colou**r: Colour of sewage indicates its strength and age. Fresh domestic sewage is grey in colour, but septic sewage is dark in colour. When industrial effluent is mixed it give characteristic colour to sewage.



Fig.5: Colour of sewage (Sapuipara sewage canal)

- ✓ **Odour:** Fresh domestic sewage is almost odourless. Septic or stale sewage is putrid in odour, which is due to generation of H2S during anaerobic decomposition of organic matters. When industrial effluent is mixed, it gives characteristics Odour to sewage.
- ✓ **Temperature:** Temperature of sewage depends upon season. However, temperature is slightly higher than that of ground water. High temperature of sewage is due to evolution of heat during decomposition of organic matter in sewage.
- ✓ **Turbidity:** Sewage is highly turbid. Turbidity of sewage is due to dissolved substances, colloidal matters, suspended solids and microbial cells.

3.3.2. Chemical Characteristics:

The Chemical Characteristic of sewage helps in indicating the stage of sewage decomposition, its strength, and extent and type of treatment required for making it safe the chemical characteristics of sewage include.

- ✓ **Solids:** Solids normally contain 99.9 % water and only 0.1 % of total solids present in the sewage may be in any of the four: suspended solids, dissolved solids, colloidal solids, and settle able solids. Suspended solids are those solids, which remain floating in sewage, dissolved solids, are those, which remain, dissolved in sewage just as a salt in water. Colloidal solids are finely divided solids remaining either in solution or in suspension. Settle able solids are that solids which settle out, if sewage is allowed to remain undisturbed for a period of 2 hrs. Solids can be organic or inorganic. About 45 % of total solids are

organic and the remaining 55 % is inorganic. Inorganic matter consists of minerals and salts like sand, gravel, dissolved salts, chlorides, sulphates, etc. Organic matter consists of carbohydrates like cellulose, cotton, starch, sugar, etc. Fats and oils received from kitchens garages, etc. Nitrogenous compounds like protein and their decomposed product, including wastes from animals, urea, fatty acids etc. Generally, presence of inorganic solids in sewage is not harmful. Mechanical units in treatment plants can remove them. But the suspended and dissolved organic solids are responsible for creating nuisance if disposed of without treatment

- ✓ **pH:** The fresh sewage is alkaline, with past of time pH tends to fall due to production of acid by bacterial action in anaerobic or nitrification processes. However, with treatment of sewage the pH tends to rise.

- ✓ **Nitrogen Content:** The presence of nitrogen in sewage is an indication of the presence of the organic matter and may occur in one or more of the following forms: Free ammonia called ammonia nitrogen, Albuminoidal or Organic Nitrogen, Nitrites, Nitrates. Albuminoidal nitrogen indicates the quantity of nitrogen in sewage before the decomposition of organic matter. Nitrates indicates the presence of fully oxidized organic matter in sewage. The nitrites thus indicate the intermediate stage of conversion of organic matter of sewage into stable forms, thus indicating the progress of treatment.

- ✓ **Chlorides Contents:** Chlorides are generally found in sewage and are derived from kitchen wastes, human faces and urinary discharges. The normal chloride content of sewage is 120 mg/lit, whereas the permissible limit of chloride content in water is 250 mg /lit.

- ✓ **Fat, Oils and Greases:** Fats, oils and greases are derived in sewage from the discharge of animals and vegetable matter, or from the garages, kitchens of hotels and restaurants, etc.



Fig .6: Fat, oils and grease of wastewater (KMC sewage manhole)

- ✓ **Heavy Metals:** Metals can, and do, exist naturally in watercourses, and many animals, plants and humans are depending on metals for their survival. However, high concentrations of some metals, and especially heavy metals, can

be extremely dangerous for living Organics Effluents from industries, textile, tannery, pigment etc. Contains considerable amounts of metal ions, among which some are extremely toxic. Metals can bio accumulates in the food chain, which means that the toxic effect is more pronounced in animals at the higher levels. Metals can also enter the environment from storm water runoff, and areas with highways and dense traffic have shown to increase levels of Ca (calcium), Cu (copper) and Zn (zinc).

- ✓ **Sulphides, Sulphates and Hydrogen Gas:** Sulphides and sulphates are formed due to the decomposition of various sulphur containing substances in sewage. This decomposition also leads to evolution of hydrogen sulphide gas, causing bad odours, besides causing corrosion of concrete sewer pipes.
- ✓ **Dissolved Oxygen (DO):** Due to high level of microbial cells and biodegradable organic matters, sewage have very low level of dissolved oxygen. In some sewage, DO is completely absent. Level of Do depends on age and condition of sewage. Low level DO is also due to lower solubility of oxygen in sewage. Oxygen is only 95% soluble in sewage than in pure water).
- ✓ **Biochemical Oxygen Demand (BOD):** is defined as the amount of oxygen required by the microorganisms (mostly bacteria) to carry out decomposition of biodegradable organic matter under aerobic condition. The BOD test is widely used to determine the pollution strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses. It is the one of the most important tests in stream pollution control activities. It is also useful in design of wastewater treatment plant and to measure the efficiency of some treatment processes. The 5 days period is generally chosen for the standard BOD test, during which oxidation is about 60 to 70 % complete, while within 20 days period oxidation is about 95 % to 99 % complete. A constant temperature of 200 C is maintained during incubation. The BOD value of 3-Day incubation period is commonly written as BOD_5 or simply as BOD.
- ✓ **Chemical Oxygen Demand (COD):** Chemical oxygen demand (COD) is the total amount of oxygen consumed by strong oxidants present in the wastewater during the decomposition and chemical oxidation of organic/inorganic matter. COD can be used to identify the sensitivity of particulate matter toward the oxidation process as well as to determine the amount of inorganic chemical material present in the wastewater sample. The rise in COD levels of the wastewater is a result of accumulation of solid waste, soluble organic compounds, antifreeze, residual food waste, emulsified oils and the dying bacterial cells that are responsible for the decomposition and release of DOC in the wastewater, which in turn increases the COD.
- ✓ **Chemical oxygen demand/nitrogen (COD/N) ratio**: COD/N ratio is one of the important governing factors for the growth of microorganisms and plays a major role in nitrification and denitrification (Meng, Yang, Liu, & Meng, 2008). This parameter can also be correlated to fouling in water treatment plants where a COD/N ratio of 10:1 remarkably reduces the rate of fouling compared to the ratio of 5:1 (Feng et al., 2012). It is also investigated in a study that increasing the COD/N ratio from 100:1 to 100:1.8 improved membrane performance and

with a longer operational period (Hao, Liss, & Liao, 2016). However, the performance of water treatment under anoxic/oxic conditions with different COD/N ratio found more fouling at higher COD/N ratio due to higher production of humid acids, carbohydrates, and proteins (Han et al., 2015). Lower level of fouling is also reported at lower COD/N ratio of 3.5 simply by filtration and back flushing (Yang et al., 2014).

- ✓ **Total Organic Carbon:** TOC test consists of acidification of the wastewater sample to convert inorganic carbon to CO_2 which is then stripped. The sample is then injected into high temperature furnace where it is oxidized in presence of a catalyst. The CO_2 that is produced is measured by means of infrared analyser and converted instrumentally to original organic carbon content. The test is accurate and correlates to BOD well. Certain types of organic matter are oxidizing in TOC test, so its valve is less than BOD test. For a typical domestic wastewater, BOD_5/ TOC ratio varies from 1.0 to 1.6. TOC is not widely used because of the cost of the instrument and the skill necessary in its operation.
- ✓ **Theoretical Oxygen Demand (ThOD)**: The oxygen required to oxidize the organic matter present in a given wastewater can be theoretically computed. If the organics present in the wastewater are known. Thus, if we know the chemical formulas and the concentrations of chemical compounds present, we can easily calculate the theoretical oxygen demand of each of these compounds by writing the balance reaction for the compound with the oxygen to produce CO_2 and H_2O and oxidized in organic compounds. But in actual practice it is virtually impossible to know the details of the compounds present in any natural raw water or wastewater.

3.3.3. Biological Characteristics:

The sewage contains many microorganisms like bacteria, algae, fungi, protozoa, etc. bacteria being the most predominant. Most of the bacteria found in the sewage are harmless non-pathogenic bacteria. They are helpful in oxidation and decomposition of sewage. A little no of bacteria, however, are disease-producing pathogens, which are the real danger to the health of the public. In case of sewage samples, the routine bacteriological tests, as performed for water samples, are generally not performed, because of the high concentration of bacteria present in it. But at the time of outbreak of epidemics, certain tests may be done to find the type of pathogens.

3.4. Harmful effect of Wastewater:

Water quality issues due to pollution by human and chemical waste are common in India, where urbanization often grows faster than drainage infrastructure. Ingesting sewage-polluted water may have dire results and may give birth to numerous waterborne diseases. Here, we shall list some diseases resulting from sewage water contamination in India.

1. **Cholera:** Vibrio cholera is a type of bacteria that causes cholera, which leads to an infection. Infection through contaminated water, especially with sewage, is a significant means of transmission. This is diarrhoea and severe dehydration.

2. **Typhoid Fever:** Water contaminated with human faeces provides a habitat for Salmonella tophi, the microbe causing typhoid fever. Inadequate sanitation facilitates its transmission.
3. **Hepatitis A:** Hepatitis A — a virus aimed at your liver. The virus has been spread by water or food contaminated with faeces in regions without a sound water system.
4. **Dysentery:** Dysentery arises from infection due to bacteria such as Shigella and parasites such as Endamoeba histolytic leading to bloody diarrhoea and abdominal pain. Sewage-contaminated water typically leads to that result.
5. **Polio (Poliomyelitis):** Polio was caused by the poliovirus, for example, in sewage. If insufficient sewage is treated correctly and proper sanitary hygiene practices are not maintained, cholera can become a disabling disease.
6. **Gastroenteritis:** Gastroenteritis, featuring symptoms such as diarrhoea, vomiting, and stomach cramps, can be caused by several pathogens in water polluted with sewage, such as rotavirus and norovirus.
7. **Amoebiasis:** Amoebiasis is caused by Endamoeba histolytic, a common parasite found in sewage. If taken through contaminated food and water, it can bring up intense intestinal illnesses.
8. **Diarrheal Diseases:** Sewage-contaminated water contains a variety of pathogens, including Escherichia coli (E.coli) and Campylobacter, which can cause many diarrheal diseases, particularly in children.
9. **Ascariasis:** Ascariasis is an infection caused by roundworms or ascariasis that affect the lower part of the human digestive system. When human waste is not well-managed, they spread pathogens by making them present in the water resources.
10. **Skin Infections:** Sewage-contaminated water can result in skin irritations such as contact dermatitis, fungal infections and cellulitis due to exposure to pathogenic organisms.

CHAPTER 4: NATURAL TECHNOLOGY FOR WASTEWATER TREATMENT

4. Introduction:

Worldwide, around 2.4 billion people lack access to improved sanitation facilities, and 2.1 billion have inadequate sanitation where wastewater drains directly into surface waters. This poses major public health and environmental risks. An estimated 80% of wastewater is discharged untreated globally. There is growing interest in low-cost, nature-based solutions (NBS) for wastewater treatment that harness natural systems are actions that protect, manage or restore ecosystems to address societal challenges while providing benefits for human well-being and biodiversity, according to the IUCN (International Union for Conservation of Nature) definition. NBS can be applied in traditional grey infrastructure wastewater treatment systems or used to treat various wastewater types like municipal, agricultural, industrial effluents and storm water. NBS aim to develop engineered systems mimicking natural ecosystems using elements like plants, soil, and bacteria to remove pollutants like solids, organics, nutrients and pathogens from wastewater. NBS can also remove emerging contaminants like hormones, personal care products and pesticides. Different NBS can be combined to achieve desired treatment efficiencies. Using NBS for wastewater treatment contributes to healthier environments by improving water quality and enhancing biodiversity and ecosystem services.

4.1. Use of Natural technologies of Treatment:

(a)Constructed treatment wetland:

Horizontal surface, combination of surface and horizontal subsurface flow	Wastewater and contaminated surface water treatment in favourable climatic conditions.
Horizontal subsurface flow	Sewage treatment; year-round operation
Vertical flow downwards	Sewage treatment; year-round operation
Vertical flow up	Wastewater Treatment, predominantly in the summer.
Vertical flow with intermitted flow	Sewage treatment; year-round operation

(b)Waste Stabilization Ponds:

Aerobic low-loaded	surface runoff and wastewater treatment
Aerobic high-loaded	Wastewater treatment in climatic favourable areas
Aerobic continuously with aeration	Intensive wastewater treatment, continuous aeration
final purification	Final treatment of wastewater after biological treatment steps
Anaerobic	Anaerobic treatment pre-ranked aerobic treatment

(c)Aquatic plants systems:

Pond and aquatic plants systems	Wastewater treatment and treatment by means of duckweed, algae, cyanobacteria
Combination of aquaculture with aquatic plants systems	Municipal and Industrial wastewater treatment
Bio eliminations	Wastewater treatment tanks with submersed meshes for algae biomass attaching

(d)Soil Biotechnology system:

Utilizes microorganisms attached to a medium to remove organic matter from wastewater.	domestic wastewater treatment

4.2. Constructed Treatment Wetlands:

Constructed wetlands are engineered facilities, which make use of aquatic vegetation for purification of effluents. The important characteristic used to define wetlands is the absence and presence of aquatic plants. Thus, the aquatic macrophysics are considered an indispensable component of these ecosystems. This macrophysics possess and perform several functions in the wetlands. To name few, the plants provide functions such as filtering effect, velocity reduction, prevention of medium clogging, foundation space for microbial linkage, nutrient plant uptake (Phytoremediation). These processes help in degradation and mineralization of organic matters present in the wastewater. The major mechanisms acting in the process of transforming and eliminating enough of the nutrient in wastewater moving through CWs are adsorption by plants and Microbial degradation.

Types of CWs: CWs are subdivide into free water surface systems (FWS) and subsurface flow systems (SFS). Depending on the directions of water flow, sub-surface flow can subdivide into horizontal flow (HF) Vertical flow (VF)

➤ **Horizontal Flow (HF) wetland:**

- Wastewater flows horizontally through a filter media having sand or grave as a filter medium and the water level is kept below the surface.
- Anaerobic degradation process prevails due to water-saturated conditions.
- Clogging may be the one issue, so primary treatment must need to remove particulate materials to prevent clogging.
- Emergent Macrophysics are used.
- Preferable for secondary or tertiary treatment due to clogging problem.

➤ **Vertical flow (VF) wetland:**

- Water is sometimes loaded on filter media surface and vertically percolates through the media.
- Air enters into the pores of the filter during reloading of water. So aerobic degradation process prevails.
- Preferable for secondary or tertiary treatment due to clogging problem

➤ **Free Surface flow:**

- it is look like natural wetland, preferable for tertiary treatment
- Large area required and generally, lightly loaded.
- Different plant genus can be used. a) Emergent: Typhus, Phragmites, Scarps, (b) submerged: Pogamoggan, Elodea, etc., (c) floating Eichhornia (water hyacinth), Lemma (duckweed).

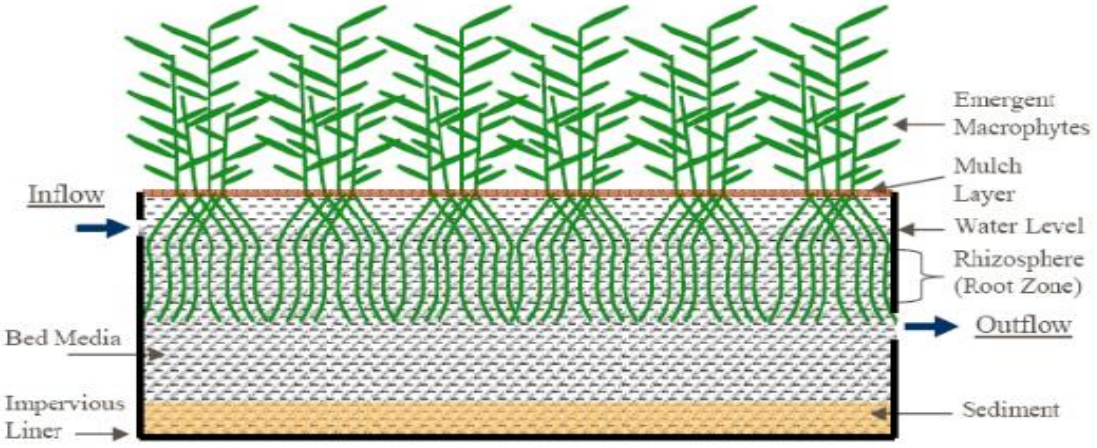


Fig.7: horizontal flow (HF)

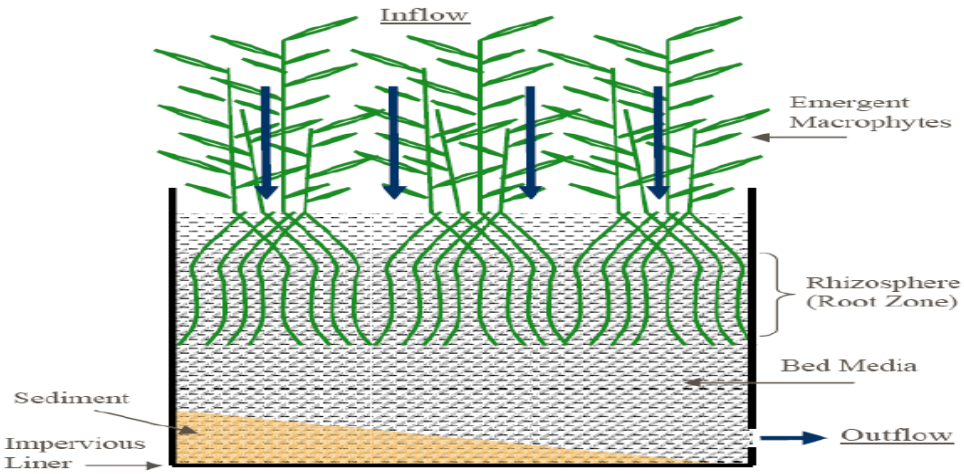


Fig.8: Vertical flow (VF) wetland

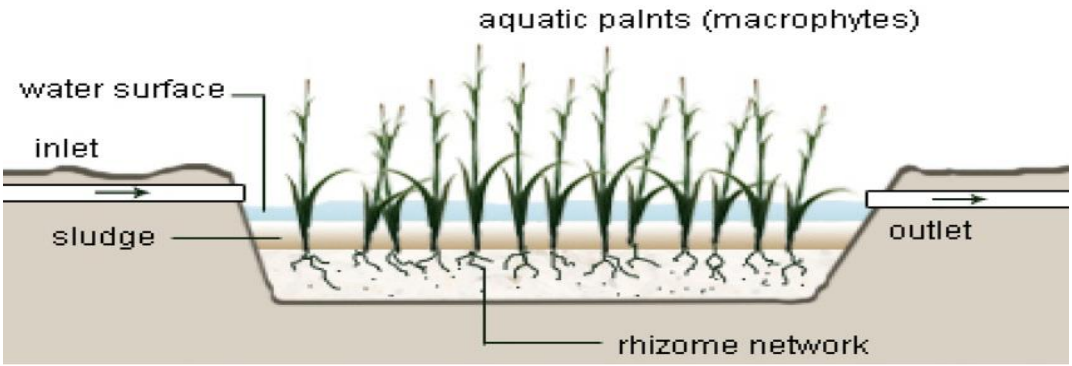


Fig.9: free water surface systems (FWS)

➤**Removal efficiency of Constructed wetland:**

Parameter	Horizontal flow	Vertical flow	Free water surface flow
Main application	Secondary	Secondary	Tertiary
TSS	>80%	>90%	>80%
Organic demand (measured as oxygen demand)	>80%	>80%	>80%
Ammonia nitrogen	20-30%%	>90%	80%
Total nitrogen	30-50%%	<20%	30-50%
Total phosphorus	10-20%	10-20%	10-20%
Coliforms	$2\log_{10}$	2-4 $\log_{10}$	$2\log_{10}$

➤**Advantages of CTW:**

- Aesthetic integration into the environment, increase in biodiversity of the landscape by creating an artificial wetland
- They favourably affect the microclimate in the immediate vicinity due to the relatively significant evaporation of water by vegetation
- Very energy-saving treatment element, it can function without electricity supply.
- Operation costs are low.
- A relatively simple construction, it is possible to construct it on the self-help basis, or with the use of human resources and machinery of municipalities and communes.
- The proper design can achieve high treatment effects of insoluble substances, organic and bacterial contamination.
- Pulse emptying, or filling of filters may sufficiently provide oxygen saturation of the environment and the removal of ammonia nitrogen
- The removal of ammonia nitrogen is sufficient even during the implementation of constructed wetland filter with the vertical flow when the filtration environment is not still saturated with water
- Continuously washing filters, permanently filled with water with the anaerobic environment may serve to denitrification of wastewater – removal of nitrate nitrogen.
- When there is an appropriate arrangement, it is possible to backwash particularly smaller filters by treated wastewater without the necessity of filter material extraction

➤**Disadvantages of CTW:**

- When used as the main treatment stage, there is the high surface demand (depending on the design from 2 to 5-meter square per capita equivalents in case of the request for the removal of insoluble substances, ammonia, organic and bacterial pollution)

- In the basic configuration – the filter with the continuous horizontal flow, permanently filled with water has the low effectiveness in removing ammonia nitrogen
- Stable removal of phosphorus from water is only possible by using special filtration materials with elevated sorption capacity with limited potential of P removal (Arias et al., 2001; Vohla et al., 2011; Jenssen et al., 2010)

4.3. Waste Stabilization Ponds:

- Waste stabilization ponds (WSPs) are the simplest biological techniques for treatment of wastewater.
- It is most appropriate when high quality effluent is not required and there is a large area available for the treatment.
- It a natural process, so no requirement of operating skills and equipment.
- Highly recommended for warm climate regions.

Types of WSP: Based on their depth and biological reaction occur in the pond, stabilization pond can be classified in three types. They are-

- Anaerobic waste stabilization ponds
- Facultative waste stabilization ponds
- Maturation ponds

- ✓ Generally, ponds are constructed in the earthwork having relatively very small in depth compared to their large surface areas.
- ✓ It can be utilized individually or in a series to improve treatment quality.
- ✓ To increase treatment effectiveness, WSPs should be linked in a series of three or more ponds where effluent will flow from anaerobic pond to facultative pond and at last, to the maturation pond.

➤Anaerobic ponds:

- Depth of these ponds are generally kept in the range of 2.5 to 5.0 m.
- Anaerobic conditions prevail throughout the depth of the ponds except few centimetres of surface zone.
- A layer of scum forms at the surface of the ponds, which helps to maintain the anaerobic conditions throughout the whole depth as Scum layer prevents the penetration of sunlight inside the ponds and thus prevents the photosynthesis action.
- Stabilization of sludge involves decomposition of organic matters into CO_2, H_2S and CH_4 through anaerobic digestion and their precipitation.

➤Facultative ponds:

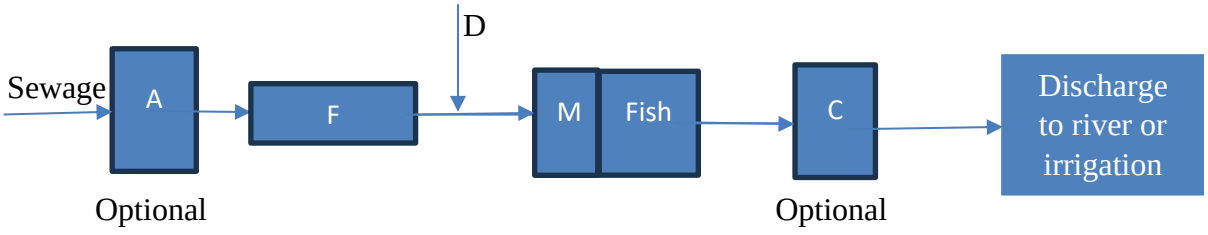
- Depth of these ponds are varying in the range of 1.5 to 2 m
- There are three zones exists throughout the depth of the ponds. Aerobic zones at the top surface, At the bottom there is anaerobic zone and facultative zone at the middle of the pond.
- As the sunlight helps in photosynthesis, the oxygen level is highest during the day and drop at night and thus, during day, facultative zones are predominantly aerobic.

- In the upper part of the top and intermediate layers, the soluble organic matters are oxidized the microorganisms present in the wastewater under aerobic and facultative condition using the oxygen supplied by the photosynthesis metabolism of algae present in the pond.
- The solids settled at the bottom and anaerobic bacteria decomposed them to a stable product.

➤Maturation ponds:

- These ponds are generally 1 to 1.5 m in depth (for sunlight penetration and mixing)
- Hydraulic retention time is 3 to 10 days/
- Aerobic conditions exist throughout the depth.
- The main objective of this pond is to achieve natural die-off of bacterial at the desired level.

❖ **Layout of Waste Stabilization Pond system:**



A-Anaerobic F-Facultative M-Maturation D- Disinfection C-Contact Tank

Fig.10: schematic diagram of WSP system

4.4. Duckweed Pond:

Duckweed based wastewater treatment is potentially suitable for small-scale application at rural level and for medium-sized facilities at community, (peril-) urban level. Duckweed is a group name belonging to botanical family Lemnaceae that consists of four genera namely- Spiro Della, Lemma, and Woolfell; first 3 genera are commonly found in India. It is cosmopolitan and found everywhere in organic nutrients rich stagnant water. It has a very high growth rate; at optimum nutrient environment, it doubles within 2-3 days. It tolerates a wide range of temperature- between 100-460C, depending upon the genera. The size of the plant is very small. Wolf Ville is the smallest plant having pinhead size, while Spiro Della is the largest one, having its size of 2-3 cm only. The most important feature of this plant is that it contains up to 30 % edible protein, vitamins A and C. It is a complete feed for certain species of fish like Grass carp, silver carp, Common carp, Rehu and Mrigal. High yield of fish has a direct linkage with economic return and thus, Employment Avenue with the system. The system is being adopted in several developing countries (Sascha Iqbal, 1999). Since duckweed grows very fast in wastewater, its uptakes nutrients from wastewater very quickly and form green mat over water. Thus, in addition to normal settling of wastewater, there is bioaccumulation of nutrients in duckweed. Duckweed has the ability to bio accumulate up to 99% of the nutrients, dissolved solids and even heavy and toxic elements of wastewater up to a certain extent. These are permanently removed from wastewater as plants are harvested. Hence, it reduces Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids,

bacterial and helminthic pathogens, some organic compounds, ions of potassium, nitrogen, phosphate and even heavy metals of wastewater to a level, quite safe for disposal. Duckweed pond size is depending on the quantity of wastewater. In 1 ha of pond 0.5 ha for duckweed and 0.5 ha for a fishpond. For green mat overlap of wastewater, it reduces the chance of mosquito to breed in wastewater. Since duckweed grows very fast, regular harvesting is required. 25% of the area of duckweed pond should be harvested daily. It can be harvested manually through a simple net device attached to bamboo. Freshly harvested duckweed is filled into a wickerwork basket, where it remains for some time to allow some water drainage and pathogen removal by sunlight irradiation. The Duckweed Pond is particularly applicable for large land area is available after facultative pond system. Cheap labor is available for the maintenance of the pond system.



Fig.11: Duckweed pond

4.5. Soil Biotechnology for wastewater treatment:

Soil biotechnology for wastewater treatment refers to the use of microorganisms and their activities to remove or degrade pollutants and contaminants present in wastewater. It involves the exploitation of biological processes and organisms, such as bacteria, fungi, and algae, to treat and purify wastewater before its discharge into the environment or reuse.

4.5.1. Soil Biotechnology alias SBT approach for sewage remediation:

Soil biotechnology (SBT) is a green engineering approach for wastewater treatment and recycling. It is an oxygenation engine similar to conventional technologies like activated sludge process (ASP), sequential batch reactor (SBR), membrane bioreactor (MBR) and moving bed bioreactor (MBBR). However, contrary to them where aeration is achieved mechanically which is very energy intensive; this technology is based on a bioconversion process where fundamental reactions of nature, namely respiration, photosynthesis, nitrogen fixation, nitrification and denitrification, take place in a media housing micro- and macro-organism, which bring about the desired purification. SBT uses natural geological media of suitable mineral constitution and culture containing native microflora and plants as bio indicator. Its natural ingredient makes is an ideal candidate for natural remediation technique. Its treatment performance with respect to COD, BOD, Suspended Solids, Ammonia removal has been found

to be at par with any international as well national recycle standards. The processed water can also be utilized to recharge groundwater using rainwater-harvesting recharge wells. Very low hydraulic loading time (HRT) (0.5–2.0 h), high hydraulic loading, no pre-treatment, no chemical usage, absence of moving parts, high dissolved oxygen levels in the effluent, no bio sludge generation, natural aeration, odour free, low energy requirement and green aesthetic environment are other unique features. On the other hand, SBT has low annual operation and maintenance cost, comparable to land-based systems and lower than conventional or advanced technologies.

4.5.2. SBT technology's features:

- It is environmentally friendly.
- There isn't any further aeration required
- Consumption of minimal energy.
- No development of bio-sludge.
- Removal of pollution load in a timely manner.
- The most efficient use of available space and the creation of natural ecosystems.
- One-time set-up of media.
- An extended period of existence.
- Few mechanical and electrical devices are available.

4.5.3. SBT treatment plants have many advantages over other technologies:

- Energy consumption is less than other technologies, so it saves money over time.
- Unlike other technologies, it can handle varying loads much better than other technologies.
- The water can be treated without the use of chemicals in just one pass without the need for chemicals.
- This water purification system provides comparable water quality to international standards within 0.5 to 2.0 hours after starting up.
- On the other hand, it produces no bio sludge at all in comparison with other technologies.
- As opposed to mechanical aeration, a natural ecosystem is able to do the job of purifying the water by generating its own oxygen.
- The operating and maintenance costs of traditional technologies are considerably higher than those of modern technologies and no labourers are needed.

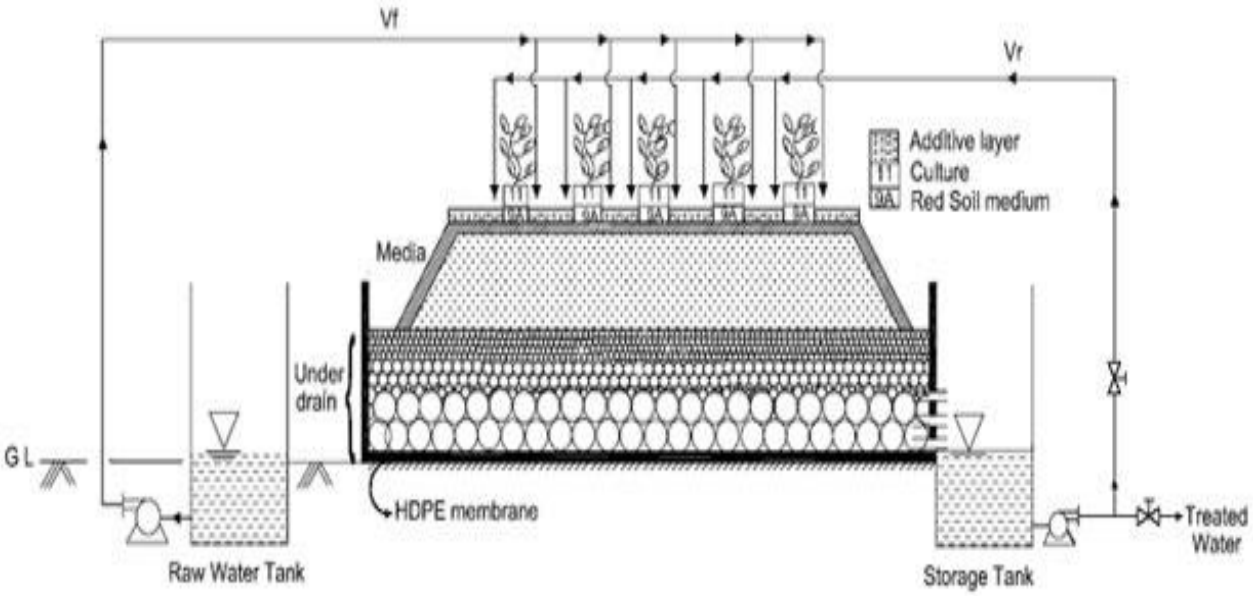


Fig.12: Layout of SBT (Source: Sugam Paryavaran Vikalp Pvt. Ltd.)

CHAPTER 5: METHODOLOGY

5.1. Methodology:

In this chapter, the methodology adopted for the research study has been discussed below -

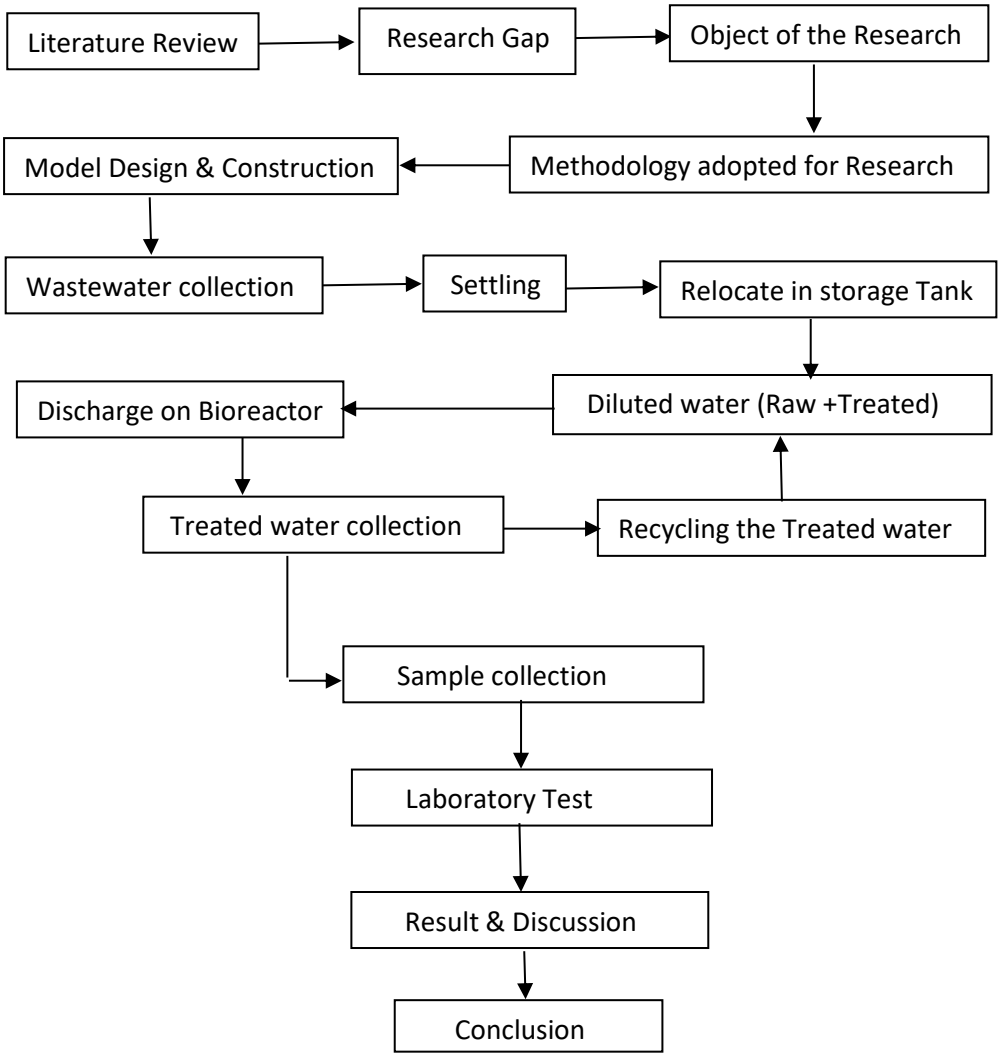


Fig.13: Methodology Flow chart

5.2. Design and Construction of SBT model:

The pilot set-up consists of three main parts (i) Raw water storage tank (ii) SBT bioreactor (iii) Treated water collection bucket



Fig.14: pilot set up for SBT model

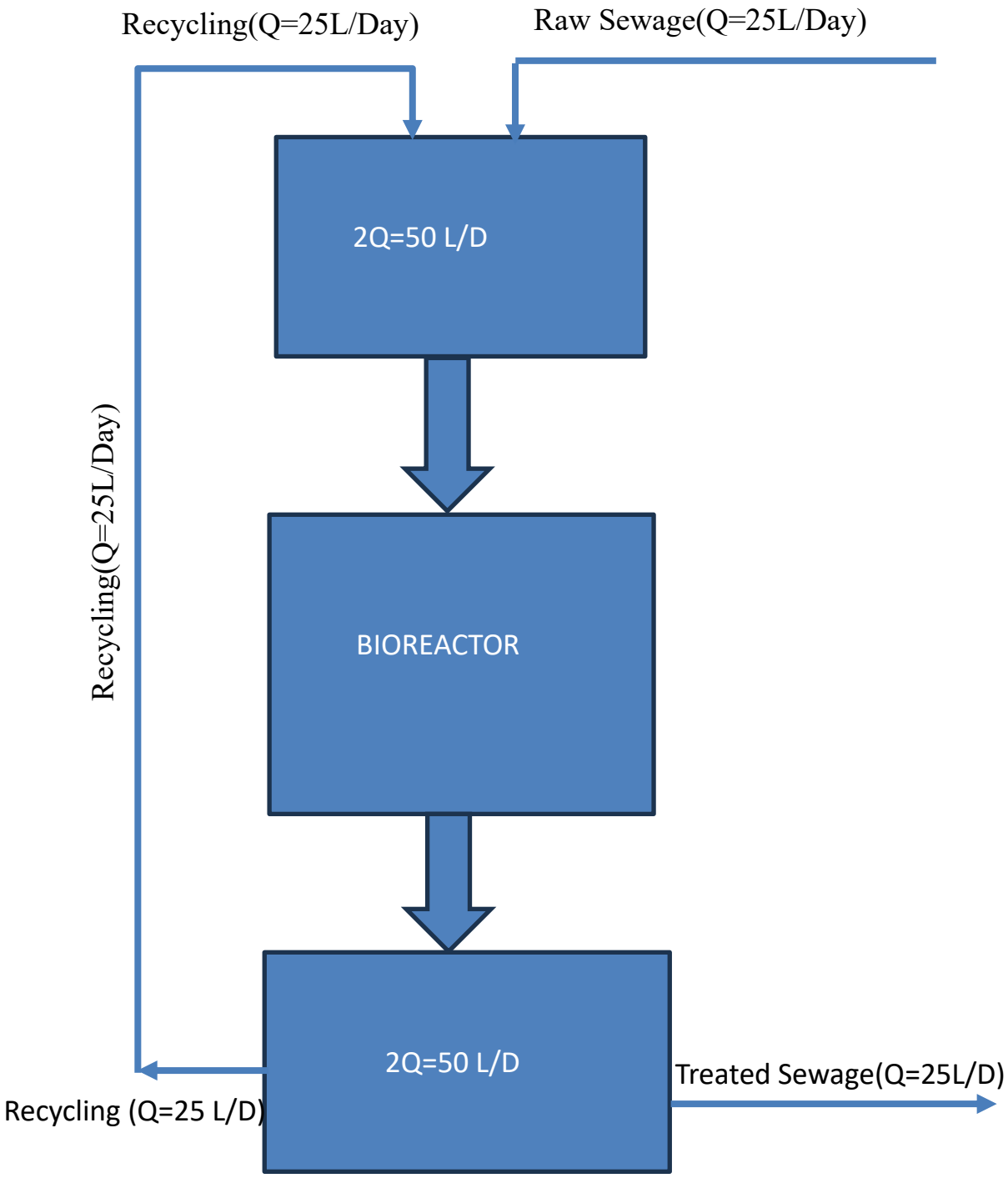


Fig.15: Schematic Diagram of Whole Setup

5.3. Design of SBT model in Lab scale:

The design of the SBT model consists of (i) Raw water storage tank (ii) SBT bioreactor (iii) Treated water collection bucket

(i)Raw water storage tank design:

Operation time=24 hours

Height of Tank (H)=560 mm (measured with measuring tape) =0.560 m

Diameter of Tank (D)=330 mm

Radius of Tank(r) =0.165mm=0.165 m

Volume= πr^2×H=π× $(0.165)^2$ × (0.560) m^3=48 litres

(ii) Design of SBT bioreactor:

Total Wastewater treated through Filter in 24 hours=43.20 litres

Length of Tank=560 mm

Diameter of Tank=330 mm

Area of flow=$A = \pi r^2$=π× $(0.165)^2$=0.08548 m^2

Average Inlet flow rate=30 ml/minute

Hydraulic Retention Time (HRT) =$\frac{\text{Discharge in one day}}{\text{Inlet flow rate}}$=$\frac{43.20\times1000}{30}$=24.00 hours

(iii) Design of Treated water collection bucket:

Total treated water collection in 24 hours operations (average) =37 litres

Outlet flow from Bioreactor=25.5ml/minutes

Volume of Bucket =66 litres> 37 litres.....OK

5.4. Design of SBT in Field:

Design of village-based wastewater treatment unit following Soil Biotechnology:

Design Population:1000

Domestic water supply:55 lpcd

Total water supply:55×1000=55000 Liters/day

Black water=20% of 55 lpcd =11 Lt/c/d

(To be used in two pits pour flush toilet as flushing and allusions water)

Wastewater/used water generated =80% of 55 lpcd

=44 lpcd

It may be also termed as “Grey Water”

Total wastewater generated =1000×44=44000 Lt/day

(1) Design of Screen:

Wastewater generated =44000 Lt/day

=44 m^3/day

=1.833 m^3/hr

=0.00051 m^3/sec

=0.51 lps

Considering peak factor=4

Peak flow=0.00204 m^3/sec

Velocity at peak flow=0.6 m/sec

Net area of screen = $\frac{0.00204}{0.6}$ =0.0034 m^2

Providing Coarse Screen,

Hence width of the bar=10 mm

Depth of the bar=50mm

Clean opening=25 mm

Consideration of least screen=0.0034×$\frac{35}{25}$ = 0.00476 m^2

Angle of inclination = 75°

Gross Area= $\frac{0.00476}{\text{Sin}75°}$ =0.00493 m^2 = 0.005 m^2 (assuming)

Depth of water=80 mm=0.080 m

Width=80 mm=0.080 m

Considering free board=0.040 m

Width of screen=0.80 m

Depth of screen=0.12 m

Size of Screen:

1) Width=0.080 m
2) Depth=0.12 m

(2) Design of Sedimentation Tank:

A Sedimentation tank will be provided after screen for allowing settling of suspended solids.
Detention time= 4 hours
Volume of sedimentation tank=1.833 m^3/h ×4 h = 7.34 m^3

(3) Design of Soil Bioreactor Unit:
After settling, the wastewater will be flow to Soil Bioreactor unit.
As the Laboratory, model study,
The Organic Loading Rate (OLR) has nearest (average) as 0.075802 kg/m^3/day
Now BOD loaded in Soil bioreactor unit to be calculated
The settled wastewater characteristics may be as following,
pH :7.4
Suspended solids:10 mg/l
BOD: 40 mg/l
COD: 75 mg/l
Flow rate: 44 m^3/day
Now, BOD load = $44\times10^{-3}\times40\times10^{-3}$
=1760 gm/day
Organic Loading Rate (OLR) = 0.075802 kg/m^3/day
= 75.802 gm/ m^3/day
(Where OLR of Standard Rate Trickling Filter is 0.08 to 0.32 kg/m^3/day)
Hence, Volume of active media (prepared soil) = $\frac{1760}{75.802}$ =23.22 m^3
Considering 1.2 m depth of active media,
Area of Active media of Soil bioreactor unit = $\frac{23.22}{1.2}$ = 19.3 m^2
The size of the unit may,
= 4.4 m ×4.4 m
Length = 4.4 m
Width = 4.4 m

Checking for Hydraulic Loading,
Hydraulic Loading Rate (HLR) = $\frac{44}{4.4\times4.4}$= 2.27 m^3/day/m^2
(Where HLR of SRTF=1.13-4.5 m^3/day/m^2)
Hence, the calculated HLR is within 1.12 to 4.5 m^3/day/m^2 so it's acceptable

The Rate of Flow of this Soil biotechnology unit = 1833 Lt/hr
=0.51 Lt/sec

The wastewater will be distributed uniformly of the surface of the active soil media.

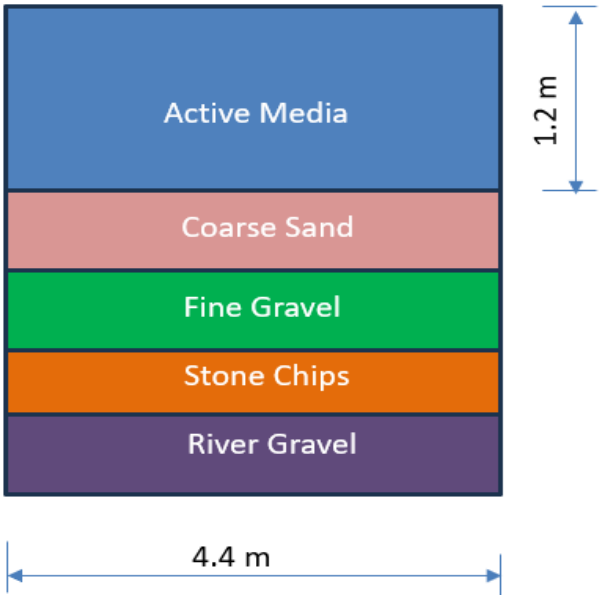
The treated wastewater will be collected from the bottom of the Soil biotechnology unit into a collected tank.

Size of the treated water collection tank,

Volume of the tank=2×1.833 m^3 =3.666 m^3 = 3670 Lt (say)

(2 hrs detention time or holding time)

The treated wastewater will require disinfection by chlorination. Disinfection is to be done for removal of coliform organism. Chlorine is to be added as per chlorine demand to be measured at the field. Coliform organism in effluent will be kept bellow 230 MPN/100 ml after disinfection. Contact time around 30 minutes will be maintained for proper disinfection. A residual chlorine amount 0.5 mg/l will be kept after disinfection. The treated wastewater can be reused for kitchen gardening, plantation, flushing of the toilets etc.



- Following diagram of domestic wastewater treatment unit:

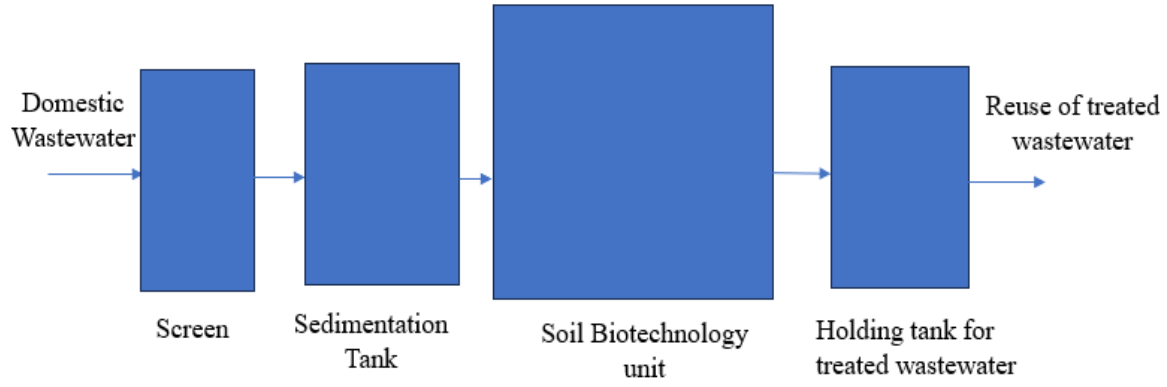


Fig.16: Schematic diagram of SBT plant in field

5.5. Construction Materials:

For construction of the bioreactor in lab scale model we use different sizes gravel, sand, sandy soil and micro bacteria.

Materials	Specification
	Name: River Gravel (Coarse) Size :60 mm Sp Gravity:2.4 – 2.7 (according to Road Research Laboratory (26) Source: Purulia district
	Name: Stone chips Size-20 mm Sp. Gravity:2.6(AASHTO T 85) Source: Purulia District
	Name: Fine gravel Size:4.75 mm Sp. gravity:2.65(AASHTO T 85) Source: Purulia District

	River Coarse sand Size: 0.85-1 mm Sp gravity:2.65-2.67(IS :2386, part-3) Source: Purulia District
	Name: Prepared Sandy soil Sp. Gravity:2.41-2.48(based on ASTMD854) Source: Purulia District

Fig.17: Material and specification

5.6. Construction of Bioreactor:

The reactor is made in a plastic drum of 330 mm diameter and 560 mm height. The reactor bed is made up of different layers of gravel, river sand, sandy soil with Bacteria. At first, we filled the bottom-most layer with 50-60mm of gravel and thickness of layer is 120 mm, above this layer other layer of aggregate 25 mm and thickness of this layer is 60 mm, above this layer another layer of sandstone which size is 5mm and thickness of this layer is 60 mm, above this, the layer of sand passing from 2mm IS Sieve is introduced thickness10 mm. The topmost layer consists of a mixture of sandy soil and bacteria which thickness is 280 mm. 30mm of freeboard is kept for distribution of wastewater. All portion filled with very smoothly and carefully.



Fig.18: Construction of Bioreactor



Fig.19: Micro bacteria (Source: Titagarh STP)



Fig.20: Preparation of soil layer

5.7. Sample Collection for Pilot setup:

Whole operations methodology for pilot setup of SBT model in Lab scale describe below:

➤**Wastewater collection:** To collect the wastewater we use ten number of jars, each jar carrying 10 litres of wastewater. We collect the wastewater twice a week.

So total wastewater collection in one time=Number of Jar× Volume of each Jar in litres

=10×10=100 litres

Total wastewater collection in a week=100×2=200 litres



Fig.21: Wastewater collection from Sapuipara canal

Settling of the collected wastewater: Before relocating collected wastewater in Raw Water Tank, needed to settle ‘so minimum two hours kept for settling.

➤**Experimental set-up operation in SBT Bioreactor**: The treatment performance of the SBT based on the trickling filter principal. Then after diluted the water is transferred towards the biotechnology filter through pipe. To achieve the natural aeration, the water is sprinkled over the model and soil media over the filter with hydraulic loading typically about 0.02-0.04 $m^3/m^2/h$. Now here biological action of bacteria and microorganisms takes place. The water is filtered through this media and picked up in storage tanks near the filter. operation

total 50 litters diluted water (25L wastewater and 25 litters of treated water) are required in every day. For maintain the inlet flow rate, we are checking the flow after every one hour. For whole

➤**Treated Water collection& Recycling:** for 24 hours, successfully operation of 50L diluted water (25L wastewater +25L treated water) we get around 45 to 46 L treated water, which is 92% of the diluted water. Again, 25L of treated water relocate to the diluted storage tank as recycle water for next 24 hours' operation.

- ✓ Total diluted wastewater passing through model =1765 Litres
- ✓ Average flow rate=30 ml/min
- ✓ Average diluted water passing though bioreactor in one day =43.20 Litres
- ✓ Average Treated water collection per day=37 Litres

➤**Observation During Experiment:**

- ✓ During the experiment, some aquatic plants growing in soil layer are usually called macrophytes. These aquatic plants enhance the removal of pollutants by absorbing in the form of plant nutrients. Plants are capable of decreasing all tested indicator of water quality to level that permit the use of the purified water for irrigation.
- ✓ Another observation we noticed that Earthworms growing in the bioreactor during experiment. Earthworms can physically handle most organic wastewater and potentially at a fraction of the cost of conventional methods of wastewater treatment. They are very useful in treatment of wastewater as well as sludge. They are also useful for treatment of wastewater from industries as well as domestic and residential sewage.



Fig.22: Plant growing on Bioreactor

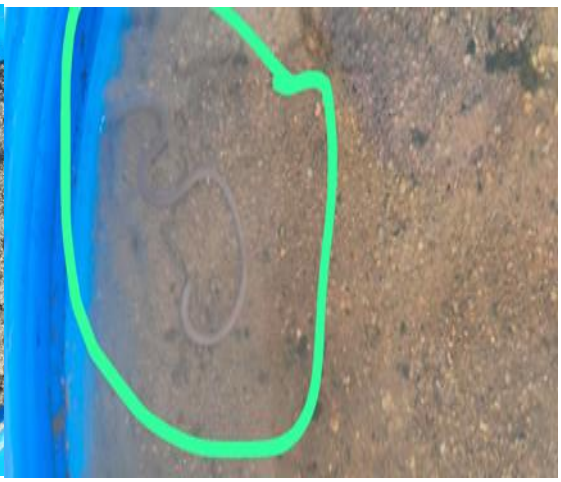


Fig.23: Earthworms on Bioreactor

➤**Sample collection:** The sampling was carried out in two way (i) Directly from Sapuipara canal (ii) From our experimental set up. The samples were collected in a pre-cleaned one-litter bottle. The samples were transported immediately to the lab for different water quality parameters testing. There is not significant time lag between sampling and testing. It was ensured that the entire tests were carried on the same day.



Fig.24: Sample collection from experimental set up

CHAPTER 6: LABROTARY TEST

6.1. Mechanical analysis of topmost layer sandy soil:

Introduction: The properties of an aquifer material related to its storage function are its porosity and specific yield. Porosity is the ratio of the volume of voids or pores in a soil mass to its total volume. Shape, size and packing of the grains affect the porosity of granular material. The grain size distribution of the formation or aquifer material can be determined by conducting a mechanical analysis test in a nest of standard sieves with the course on top and finest at the bottom, covered with lid on the top and bottom pan as receiver. A representative sample, about 150-500 gm, is taken in the laboratory by quartering, oven dried and an exact weight poured into the top sieve and covered with lid. The whole nest is shaken through a mechanical sieve shaker (hand operated /electrical) for about 5 minutes, the material retained on each sieve, and bottom pan is accurately weighed. Percentage of material passing through each sieve gives a point on the grading curve.

Description:

Sieve diameter (d): In most cases a series of sieves is used for separation of sediment into various size grades provided particles are larger than 0.0625 (= 1/16) mm in diameter. Sieve openings are square. Since a long particle with a very small cross-sectional area can pass through a sieve, sieves classify particles based on their least cross-sectional area and thus this classification is not based purely on size. Sieve diameter "d" of a particle is the size of the sieve opening through which a given particle will just pass.

Nominal diameter (dn): of a particle is defined as the diameter of a sphere which is having the same volume as the particle. Sedimentation diameter is the diameter of the sphere of the same relative density and the same terminal settling velocity as the given particle in the same sedimentation fluid under the same condition.

Triaxle size: Several geologists and hydraulic engineers have defined particle size based on measurement along three mutually perpendicular axes of a particle. If a is the longest or the major axis, by the intermediate axis and c the shortest or the minor axis, then one can take the intermediate axis b as the index of size. In such a case, correlation can be found between the shape of the particle, nominal diameter and the intermediate axis b. Since, the axes are perpendicular, values of a, b and c for a given particle depend on axis is chosen first.

Size terms for particles: It is essential to standardize the terms related to particle size so that they could be used to convey definite ideas regarding the size. The sizes given in Table 1 are in terms of triaxle size (b) for boulders, cobbles and up to coarse gravel, and in terms of sieve diameters (d) for medium gravel to very fine sand; for the finer material sedimentation diameter is recommended.

Table 1: Grade Scale for Size Terms

Range in mm	Class name	Range in mm	Class name	Range in mm
4096-2048	Very Large Boulders	**1-½**	**Coarse Sand**	**1– 0.5**
2048-1024	Large Boulders	**½-¼**	**Medium Sand**	**0.5–0.25**
1024-512	Medium Boulders	**¼-1/8**	**Fine Sand**	**0.25–0.125**
512-256	Small Boulders	**1/8–1/16**	**Very Fine Sand**	**0.125–0.0625**
256-128	Large Cobbles	1/16–1/32	Coarse Silt	0.0625–0.03125
128-64	Small Cobbles	1/32–1/64	Medium Silt	0.03125–0.015625
64-32	Very Coarse Gravel	1/64–1/128	Fine Silt	0.015625-0.007813
32-16	Coarse Gravel	1/128–1/256	Very Fine Silt	0.007813-0.003906
16-8	**Medium Gravel**	1/256–1/512	Coarse Clay	0.003906-0.001953
8-4	**Fine Gravel**	1/512–1/1024	Medium Clay	0.001953-0.000977
4-2	**Very Fine Gravel**	1/1024–1/2048	Fine Clay	0.000488-0.000224
2-1	**Very Coarse Sand**	1/2048–1/4096	Very Fine Clay	0.000224-0.000112

- ✓ The **effective size** (***d_{10}***) is the size corresponding to10 percentage of the material being finer and 90%coarser (i.e., the size corresponding to p = 10%) and an index of fineness of the soil.
- ✓ The **uniformity coefficient (C_u)** is the average slope of the grade curve between10% and 60% size sand is given by Cu= $\frac{d60}{d10}$

And gives an idea of the grading or particle size distribution in the material. Lower values C_u<2 indicate more uniform material or poor grading, and higher values indicate well graded material.

Another term to indicate the effective distribution of grain size is the '**range sizes' C_r** defined on the basis of the mean slope of the grain size curve. And gives an idea of the grading or particle size distribution in the material. Lower values C_u<2 indicate more uniform material or poor grading, and higher values indicate well graded material. Another term to indicate the effective distribution of grain size is the ***C_r*** defined based on

the mean slope of the grain size curve. A uniformly graded sand has a higher porosity than a less uniform, fine and coarse mixture because in the latter the fines occupy the voids in the coarse material. Wider the range in size, lower the porosity.

Instruments/Apparatus required:

1. **Mechanical/Vibrating Sieve Shaker** (Carries up to 7 sieves, driven by 1/4th H.P. Motor. A pair of rods and a holder are supplied, operation on 230 Volts)
2. **Test Sieves** (IS460) Brass Frame, diameter 200 mm with a stainless-steel wire machine made:33 numbers
3. **Available sizes of the sieves are** 11.2 mm, 5.60 mm, 4.75 mm, 3.35 mm, 2.3 mm, 1.70 mm, 850-micron, 500-micron, 300-micron, 250 micron, 120-micron, 90-micron, Lid (top cover) and Pan (Receiver). *(1 micron = 1 µm = 1/1000 mm)*
4. **Hot Air Oven**
5. **Rubber pestle and Mortar** (for crushing the soil if lumped or conglomerated)
6. **Electronic Digital Balance** (The balance, to be used, should be sensitive to the extent of 0.1% of total weight of sample taken).

Test Procedure:

1. Take a representative oven dried (at 1050C for 24 hours) sample of soil that weighs about 500 gm. (this is normally used for soil samples the greatest particle size of which is 4.75 mm).

2. If soil particles are lumped or conglomerated crush the lumped and not the particles using the pestle and mortar.

3. Determine the mass of sample accurately. Wt. (gm)

4. Prepare a stack of sieves. Sieves having larger opening sizes (i.e. lower numbers) are placed above the ones having smaller opening sizes (i.e. higher numbers). In case of sandy soil, the very last sieve is 0.075 mm, and a pan is placed under it to collect the portion of soil passing 0.075 mm sieves. Here is a full set of sieves. 4.75mm and 0.075 mm should always be included).

5. Make sure sieves are clean; if many soil particles are stuck in the openings try to poke them out using brush.

6. Weigh all sieves and the pan separately. (Fill in column 3)

7. Pour the soil from step 3 into the stack of sieves from the top and place the cover, put the stack in the sieve shaker and fix the clamps, adjust the time on 5 minutes (Theoretically 10 minutes) and get the shaker going.

8. Stop the sieve shaker and measure the mass of each sieve + retained soil. (Fill in column 4)

9. Weigh the sand retained by each sieve to the nearest 0.01 gm. This is done in a cumulative way – this means that you add what is remaining on the coarsest sieve on top to the container on the scales and measure the weight. Following this, you add the material from the second sieve down, and again note the combined weight of both samples. Continue in this way for the whole set. When finished, check that the final weight corresponds to the initial weight of the sample.

10. Clean each sieve as it is emptied and returns the soil to the stock.

11. Enter the results in Table. From this, you can calculate the percentage retained on each sieve, and correspondingly, the percentage passing.

12. Plot the results on 3-cycle logarithm graph paper:



Fig.25: Sieve analysis

6.2. Total suspended solids (TSS):

TSS of the samples has been measured with the help of vacuum pump using filtration method. Glass-fibre filter paper, Whitman grade 934AH was placed in a glass dish and dried in over at 104±1°C for 1 hour and then kept in the desiccators for stabilizing temperature Initial weight of dry filter paper (Wi) was measured before placing it on the funnel. Generally, the inlet samples contain TSS in large amount as compared to that of outlet samples. So, for determining TSS of inlet sample, 100 ml volume was taken and allowed to pass through the filter paper. The vacuum pump was used to speed up the filtering effect. After the completion of filtration process, the filter was carefully removed from the funnel and placed in the glass dish. The paper was left for oven drying overnight and the final weight of paper after drying (W_f) was measured the next day.

$$\text{Total Suspended Solids} = \frac{(Wf - Wi) \times 1000}{\text{ml of sample used}}, \text{ mg/l}$$



Fig.26: Test for TSS

6.3. Biochemical Oxygen demand (BOD):

The amount of oxygen, taken up by the microorganisms that decompose the organic waste matter in wastewater is known as biological oxygen demand or biochemical oxygen demand. Therefore, it is used to measure the amount of certain type of organic water pollution BOD is calculated by keeping a sample of water containing a known amount of oxygen for three days at 27°C. The oxygen content is measured again, and BOD is calculated. A high BOD indicates the presence of a large number of microorganisms, which indicates a high level of pollution in wastewater. Oxygen demand is associated with the biodegradation of the carbonaceous portion of wastes and oxidation of nitrogen compounds such as ammonia. The following equations simplify the process of biodegradation:

Organic matter + O_2 + microorganisms CO_2 + H_2O + new microbial cells

Ammonia + O_2 + microorganisms NO_3 + H_2O+ new microbial cells.

➤Apparatus:

1. BOD meter with probe for measurement of dissolved oxygen in 300 mL BOD bottles

2. 300 mL BOD bottles

3. Incubator, capable of maintaining 27 +/ 1°C

4. 250 mL graduated cylinders

5. 100 mL graduated cylinders

6. 25 mL measuring pipettes (wide mouth)

7. 10 mL measuring pipettes (wide mouth)

8. 100 mL beaker

9. 1000 mL beaker

10. 250 mL Erlenmeyer flask

11. Burette graduated to 0.1 mL

12. Dilution water bottle of suitable volume for the number of tests to be performed

13. Pipette bulb

➤Reagents: Test reagents are as follows:

1. Phosphate Buffer Solution: For preparing the phosphate buffer solution, the following

Chemicals in the quantity are used:

Potassium dihydric phosphate (KH_2PO_4) :8.5g

Dipotassium hydrogen phosphate ($K_2 HPO_4$):21.75g

Disodium hydrogen phosphate ($Na_2 HPO_4 .7H_2O$):33.40g

Ammonium chloride (NH_4Cl):1.7g

Mix and dissolved these above chemicals in about 500 mL distilled water and diluted to 1 L. Adjusted the pH value of the solution to 7.2 by adding 1N, NaOH solution.

2. Magnesium Sulphate ($MgSO_4.7H_2O$) Solution: Dissolve 22.5 g $MgSO_4.7H_2O$ in distilled water and diluted to 1 L.

3. Calcium Chloride Solution ($CaCl_2$): Taken 27.5g of anhydrous calcium chloride, mix and

Dissolve it in distilled water and diluted it to 1.0 L

4. Ferric Chloride ($FeCl_3.6H_2O$) Solution: Take 0.25g of Ferric chloride, mix and dissolve it in distilled water and diluted it 1L.

5. Manganous Sulphate Solution: Dissolve manganese sulphate (480 g of $MnSO_4.4H_2O$) in freshly boiled and cooled water, filter and made 1000 ml.

6. Acid and Alkali Solution:1N sodium hydroxide and 1N sulphuric acid for neutralization of samples.

7. Alkaline Iodide Solution: Dissolve 500 g of sodium hydroxide (or 700g of potassium hydroxide) and 135 g of sodium iodide (or 150 g of potassium iodide) in freshly boiled and cooled water and diluted to1L.

8. Sulphuric Acid, Concentrated

9. Starch Indicator: Dissolve 2g of starch and 0.2g of salicylic acid as preservative, in 100 ml of hot distilled water.

10. Sodium Thiosulphate Stock Solution: Dissolve approximately 25g of sodium thiosulphate

($Na_2S_2O_3.5H_2O$) in boiled distilled water and made up to 1000 ml. Added 1 g of sodium hydroxide to preserved it.

11. Standard Sodium Thiosulphate Solution: Dissolve 250 ml of stock solution in boiled distilled water and made up to 1L.

➤Procedure:

Preparation of Dilution Water:

Aerate the required volume of distilled water in a container by bubbling compressed air for 8 to 12 hours to attain dissolved oxygen saturation. Let it stabilize for 4 h at room temperature (around 27°C). At the time of use, added 1 ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride for each Litre of dilution water. Added 2 to 5 ml of treated sewage per litre of dilution water for seeding purpose.

Dilution of Sample and Incubation:

Neutralization: Neutralize the sample to pH around 7.0 using alkali or acid of such strength the quantity of reagent does not dilute the sample by more than 0.5 percent.

Sample Volume and Dilution Techniques:

Based on chemical oxygen demand (COD), determine expected BOD. Use the following formula for calculating sample volume:

$$\text{Sample volume in ml, per litre dilution} = \frac{X}{Expected\ BOD} \times 1000$$

For keeping 2 dilutions take X = 2.5 and 4.0. For single dilution take X = 3.0 or 3.5. Round off to nearest convenient volume fraction. In case of high BOD samples, prepare primary dilutions with distilled water and then make the final dilution

Taken requisite quantity of sample in one-litre volumetric flask. Diluted to the mark with the dilution water by siphoning from the container. Mix well. Rinse three BOD bottles with the diluted sample and fill up these bottles with the diluted sample. Stopper the bottles immediately after removing the air bubbles. Samples of natural surface water bodies like river, lake and marine, generally do not require seeding and dilution due to naturally available microbiological population and low BOD values. For such samples which are likely to have BOD less than 5 mg/l, BOD determination may be carried out as such (100 percent) without any dilution.

Determination of Initial Dissolved Oxygen (DO):

Determine initial DO for one bottle and keep two bottles for incubation at 27°C ± 1°C for 3

Days. Prepare six blanks by siphoning out dilution water directly into the bottles. Determine

Initial DO in two bottles and incubate remaining four bottles at 27°C ± l°C for 3 days.

Determination of Final DO:

After 3 days incubation at 27°C ± 1°C, determine final DO in incubated bottles.

➤Calculation:

When Sample is Undiluted: BOD, mg/l = (DO before incubation −DO after incubation.)

When Dilution Water is seeded: BOD, mg/1= $\frac{D1-D2}{P}\times 1000$

When Dilution Water is seeded: BOD, mg/l = $\frac{D1-D2-(B1-B2)f}{P}\times 1000$

D_1 = Initial DO of sample in mg/l,

D_2 = DO of sample after incubation in mg/l,

B_1 = DO of seed control before incubation in mg/1,

B_2 = DO of seed control after incubation in mg/1

f = ratio of seed in diluted sample to seed in control; (percent seed in diluted sample): (percent seed in seed control),

P = percentage dilution of sample (sample volume in ml/10).

Glucose Glutamic Acid Check:

BOD being a bioassay test is greatly influenced by factors like toxicants, poor seeding, etc. For periodical checking of these factors, use a mixture of 150 mg glucose and 150 mg glutamic acid per litre as a standard check solution. Determine the 3 days 27°C BOD of 2 percent dilution of the glucose-glutamic acid standard check solution as in Sample Volume and Dilution Techniques. If the BOD value of the check is outside the range of 200 ± 37 mg/l, reject any BOD determinations made with the seed, dilute water, and seek the cause of the problem.



Fig.27: Sampling for BOD Test



Fig.28: Titration after 3days Incubation of Sample



Fig.29: BOD incubator

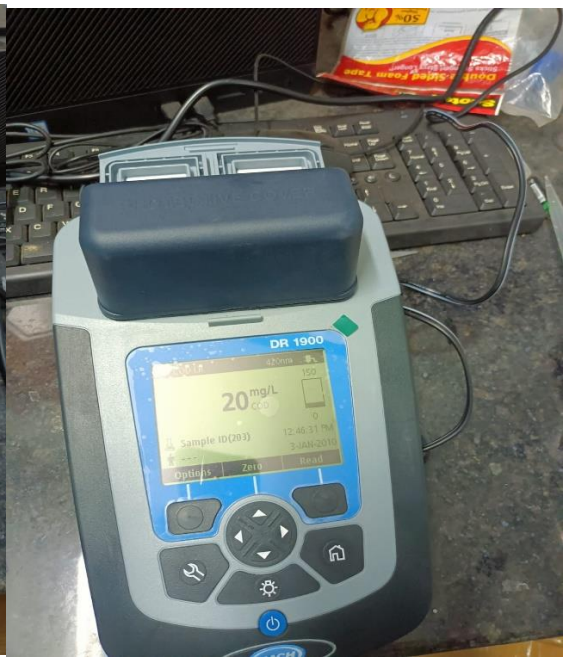
6.4. Chemical Oxygen Demand (COD):

Chemical oxygen demand test is carried out to indirectly determine the number of organic compounds as pollutant that is present in the wastewater. It is the measure of oxygen content in water consumed in the chemical oxidation of pollutants and is expressed in milligram per litter (mg/l). In our laboratory, COD Measurement in Wastewater (Rapid-Digestion Method) done by in analytical method with COD digester.

➤**Apparatus**: COD digester, spectrophotometer, Reagents, micro pipet



(i)



(ii)



(iii)



(iv)

Fig.30: (i) COD digester, (ii) Spectrophotometer, (iii) Reagent, (i) micro pipet

➤**Test Procedure:** The chemical oxygen demand (COD) test is a widely used method for determining the number of organic pollutants present in wastewater. It measures the amount of oxygen required to chemically oxidize the organic matter in a sample of wastewater. The COD test is typically performed using a COD digester, which is a specialized instrument designed for this purpose. Here is a general overview of the COD test using a COD digester:

1. Sample preparation: A sample of wastewater is collected and prepared for analysis. This may involve filtering, diluting, or pre-treating the sample, depending on the specific procedure and the nature of the wastewater.
2. Reagent addition: The prepared sample mixed with a strong oxidizing agent, typically potassium dichromate ($K2Cr_2O_7$), along with other reagents such as sulphuric acid (H_2SO_4) and a catalyst (e.g., silver sulphate). The reagents are added in specific amounts according to the test procedure.
3. Digestion: The mixture of the sample and reagents is placed in a sealed digestion vial or tube, which is then loaded into the COD digester. The digester maintains a high temperature (typically around 150°C) for a specified duration (usually 2 hours) to facilitate the oxidation of organic matter by the potassium dichromate.
4. Cooling: after the digestion, process is complete; the vials are removed from the digester and allowed to cool to room temperature.
5. Measurement: The amount of unreacted potassium dichromate remaining in the digested sample is determined, typically by colorimetric or titrimetric methods. This measurement is inversely proportional to the amount of organic matter present in the original sample.
6. Calculation: Based on the measured amount of unreacted potassium dichromate, the COD value of the wastewater sample is calculated using a predefined formula or calibration curve. The COD value is usually expressed in milligrams per litre (mg/L) or parts per million (ppm).

The COD digester plays a crucial role in the COD test by providing the controlled high-temperature environment necessary for the oxidation of organic matter. Different types of COD digesters are available, including block digesters, which heat multiple vials simultaneously, and small-scale digesters suitable for individual sample analysis.

It's important to note that the COD test provides a measure of the total oxidizable organic matter present in the wastewater sample, but it does not differentiate between specific organic compounds or their biodegradability. The results of the COD test are often used in conjunction with other wastewater quality parameters, such as biochemical oxygen demand (BOD), to assess the overall organic load and treatment requirements of the wastewater.

6.5. Total Coliform and Faecal Coliform Test:

TC FC stands for Total Coliform (TC) and Faecal Coliform (FC) test, which is a common analysis performed on wastewater samples to determine the presence and levels of coliform bacteria. Coliform bacteria are a group of microorganisms that are found in the intestines of warm-blooded animals, including humans, and their presence in water is an indication of potential faecal contamination. The TC FC test measures the levels of two subgroups of coliform bacteria:

1. Total Coliforms (TC): This group includes a wide range of coliform bacteria found in soil, water, and on plants, as well as those from faecal sources. The presence of total coliforms in water does not necessarily indicate the presence of faecal contamination, but it can suggest the possibility of pathogenic organisms.
2. Faecal Coliforms (FC): This subgroup is more specific and is composed of coliform bacteria that are found primarily in the intestines of warm-blooded animals and humans. The presence of faecal coliforms in water is a strong indication of faecal contamination and the potential presence of pathogenic organisms.

The TC FC test is crucial in wastewater treatment processes and environmental monitoring because it provides insights into the effectiveness of disinfection methods and the potential health risks associated with water sources. The results of this test help determine if the treated wastewater meets regulatory standards for safe discharge or reuse. The TC FC test is typically performed by filtering a water sample through a membrane and incubating the membrane on selective media. After incubation, the colonies of coliform bacteria are counted, and the results are reported as colony-forming units per unit volume (e.g., CFU/100 mL). It important to note that while the TC FC test is widely used and provides valuable information, it does not directly test for the presence of specific pathogenic organisms. Further testing may be required if the results indicate potential contamination or if there are specific concerns about the presence of particular pathogens.

6.6. pH Test of wastewater:

For conducting a pH test on wastewater, will need the following materials:

1. pH test strips or a pH meter
2. Clean glass or plastic containers for collecting wastewater samples
3. Gloves and safety glasses (for protective equipment)

Here is a general procedure for testing the pH of wastewater:

1. Collect a representative sample of the wastewater in a clean container. Make sure to follow proper sampling techniques to ensure an accurate result.
2. If using pH test strips, dip the strip into the wastewater sample and hold it for the recommended time specified by the manufacturer. Compare the colour change on the strip with the colour chart provided to determine the pH value.
3. If using a pH meter, calibrate it according to the manufacturer's instructions. Then, rinse the electrode with distilled water and gently blot it dry with a soft tissue. Immerse the electrode in the wastewater sample and record the pH value once it stabilizes.
4. Repeat the test with multiple samples from different locations or at different times to ensure consistency and accuracy.
5. Record the pH values along with the sample information (date, time, location, etc.) for documentation and future reference.
6. It's important to note that the pH of wastewater can vary depending on the source and composition of the waste. Typically, neutral pH is around 7, while acidic conditions are below 7, and alkaline conditions are above 7. The pH of wastewater can affect various treatment processes and the potential for corrosion or scaling in pipes and equipment.



Fig.31: pH test of wastewater

6.7. Total Nitrogen and Total Phosphorus Test:

The total nitrogen and total phosphorus tests are crucial for assessing the nutrient content in wastewater and determining the effectiveness of wastewater treatment processes. These tests are typically performed on wastewater samples to monitor and regulate the discharge of nutrients into receiving water bodies, as excessive levels of nitrogen and phosphorus can lead to eutrophication and other environmental problems.

1. Total Nitrogen Test: The total nitrogen test measures the sum of all forms of nitrogen present in the wastewater sample, including organic nitrogen, ammonia, nitrite, and nitrate. The test typically involves the following steps:

a. Sample preparation: The wastewater sample may require pre-treatment, such as digestion or oxidation, to convert all forms of nitrogen into a single, measurable form (e.g., nitrate).

b. Analysis: Various analytical methods can be used to measure total nitrogen, including:

- Persulfate digestion method: The sample is digested with persulfate to convert all nitrogen forms to nitrate, which is then measured calorimetrically or by ion chromatography.
- Kjeldahl method: This method involves digesting the sample to convert organic nitrogen to ammonia, which is then distilled and measured.
- Combustion method: The sample is combusted at high temperatures, and the resulting nitrogen oxides are measured using chemiluminescence or other detection methods.

2. Total Phosphorus Test: The total phosphorus test measures the sum of all forms of phosphorus present in the wastewater sample, including orthophosphates, polyphosphates, and organic phosphorus compounds. The test typically involves the following steps:

a. Sample preparation: The sample may require digestion or oxidation to convert all phosphorus forms into orthophosphate, which is the measurable form.

b. Analysis: Several analytical methods can be used to measure total phosphorus, including:

- Persulfate digestion method: The sample is digested with persulfate to convert all phosphorus forms to orthophosphate, which is then measured calorimetrically or by ion chromatography.
- Acid hydrolysis method: The sample is treated with acid to hydrolyse polyphosphates and organic phosphorus compounds into orthophosphate, which is then measured.
- Inductively coupled plasma (ICP) method: The sample is analysed using ICP spectrometry, which can directly measure total phosphorus content.

The results of the total nitrogen and total phosphorus tests are typically reported in milligrams per litre (mg/L) or parts per million (ppm). These values are compared to regulatory standards and used to assess the efficiency of wastewater treatment processes in removing nutrients before discharge into water bodies

CHAPTER 7: RESULT AND DISCUSSION

7.1. Sieve analysis of topmost layer:

The generated particle size distributed on graph, which can be obtained from performing sieve analysis, can be used in various ways including finding out the soil grading as well as percentage content of course and fine material in the soil sample.

Table-2: Grain Size Distribution

Sieve Analysis				
Sample Weight: 1000. Gram				
Pan Weight: 371.23gms				
Sieve Size (mm)	Weight Retained (grams)	Cumulative Weight Retained (grams)	% of Cum. Wt. Retained	% Finer
11.2	14.81	14.81	1.49	98.51
4.75	60.57	75.38	7.56	92.44
3.35	21.2	96.58	9.69	90.31
2.3	23.69	120.27	12.07	87.93
1.7	44.07	164.34	16.49	83.51
0.85	230.9	395.24	39.65	60.35
0.5	197.5	592.74	59.46	40.54
0.3	395.99	988.73	99.19	0.81
0.12	0.08	988.81	99.19	0.81
0.09	0.16	988.97	99.21	0.79
Pan	7.88	996.85	100.00	0.00
Total	=996.85			

	Curve Value	Trend Value		Curve Value	Trend Value
D60	0.89	0.843797468	D50	0.7	0.667140506
D10	0.39	0.346246117	D30	0.52	0.446940579
	Cu	2.436987525		Cc	0.683717105
		2.282051282			0.779026217

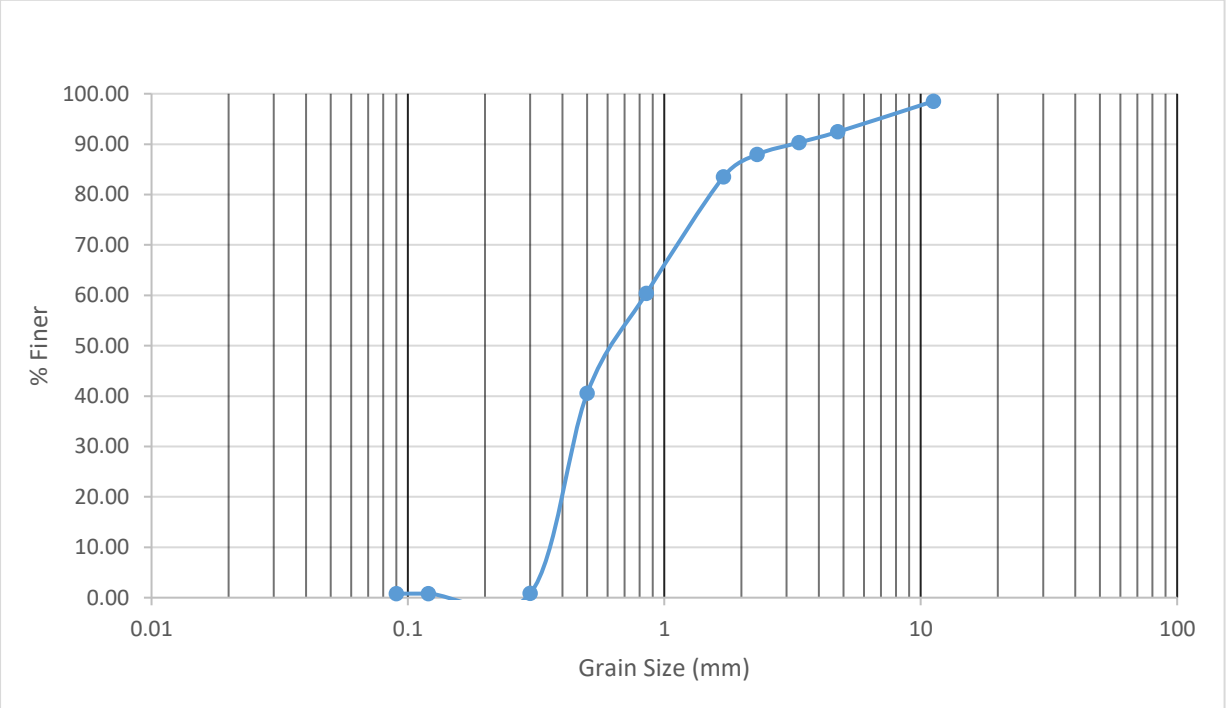


Fig.32: Sieve analysis graph

7.2. Performance Monitoring of SBT Unit:

Samples of row wastewater were collected in and tested. In the present study, tests conducted are pH, BOD, COD, TSS, TN, TP, TC &FC etc. Conducted tests were performed as per the standard procedures according to IS 3025 (Part 44): 1993 (Methods of sampling and test (Physical and Chemical) for water and wastewater: Part 44 biochemical oxygen demand (BOD) (First Revision), pH, TN, TP, TSS measure as per guideline of APHA, 23rd Edition in laboratory

7.2.1. Biochemical Oxygen Demand (BOD):

The removal mechanism for BOD primarily includes degradation by Microorganisms. The removal efficiency varied from 82.05% to 87.09%, so the removal performance of bioreactor is very good.

Table.3: BOD removal efficiency

Date	Inlet(mg/l)	Outlet(mg/l)	Removal Efficiency
12.02.2024	39	5	82.05%
29.02.2024	37	5	86.48%
21.02.2024	44	7	84.09%
28.03.2024	40	6	85.00%
23.04.2024	30	<5	83.33%
04.05.2024	62	8	87.09%
11.05.2024	42	6	85.71%

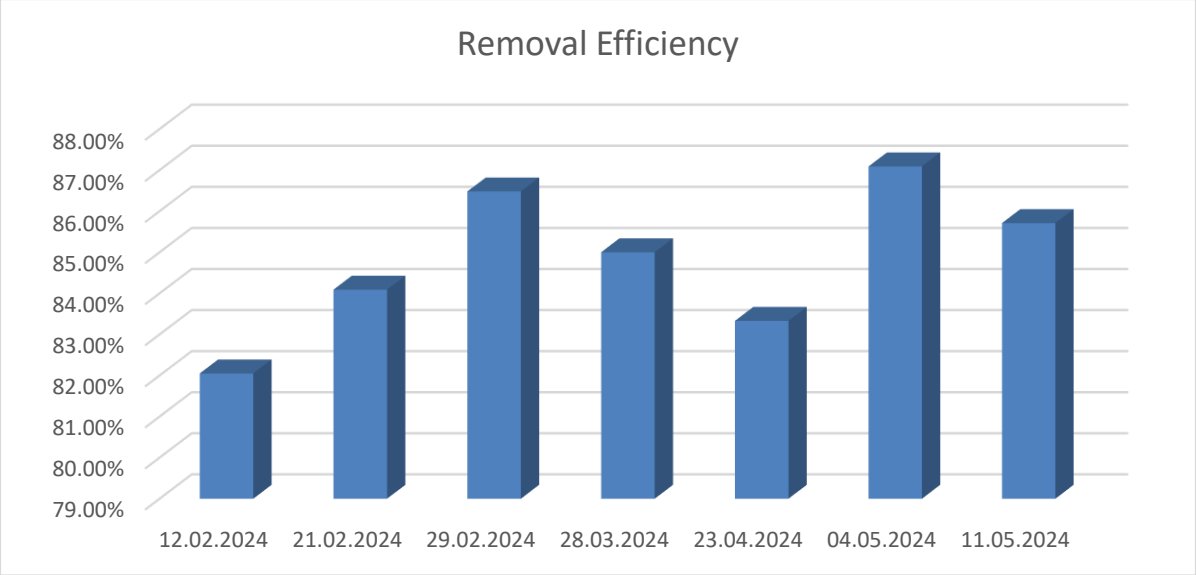


Fig.33: BOD Removal efficiency Bar Chart

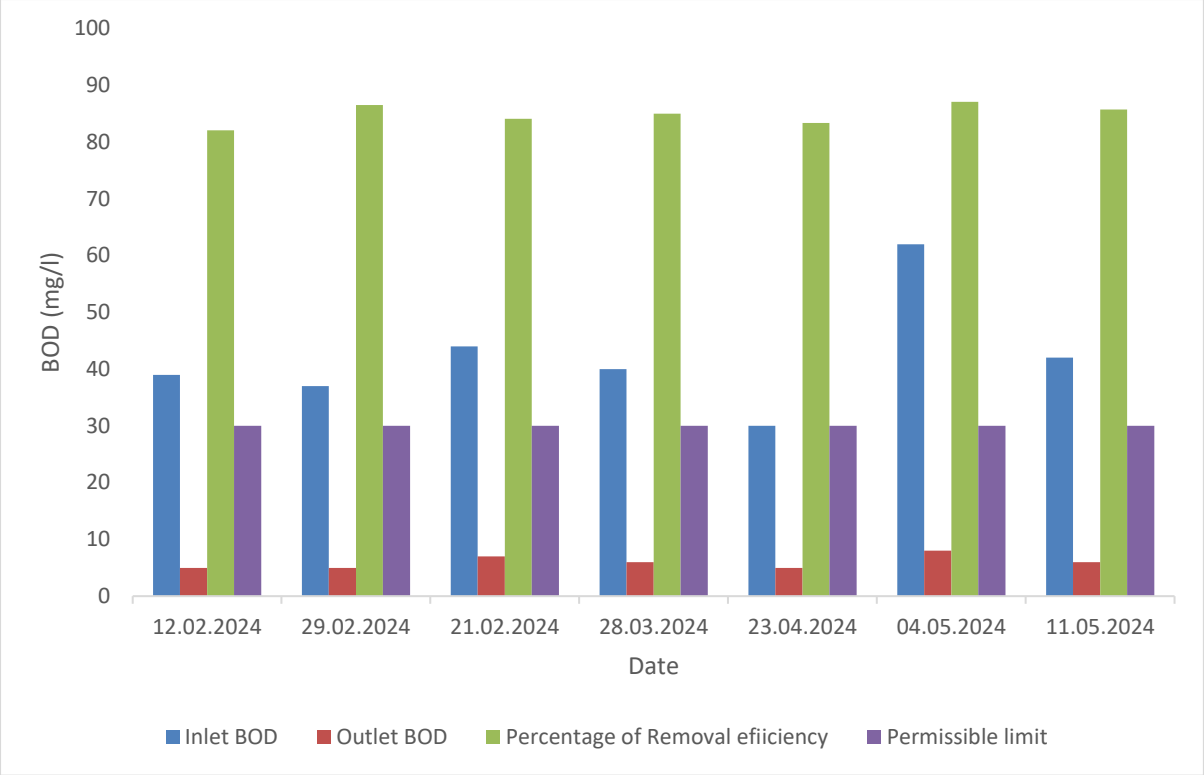


Fig.34: monitoring the removal profile of inlet, outlet, removal efficiency and permissible limit of BOD level of the SBT model

7.2.2. Chemical Oxygen Demand (COD):

COD was developed as a rapid means of measuring BOD and as a means of measuring industrial or trade wastewaters. COD test done in our laboratory with COD digester and spectrophotometer. Result shown the removal efficiency varied from 84.73% to 88.09%, so performance of the bioreactor is significantly good

Table.4: COD removal efficiency

Date	Inlet(mg/l)	Outlet(mg/l)	Removal Efficiency
12.02.2024	84	10	88.09%
21.02.2024	80	13	83.75%
29.02.2024	77	11	85.71%
28.03.2024	81	12	85.18%
23.04.2024	66	8	87.87%
04.05.2024	131	20	84.73%
11.05.2024	84	12	85.71%

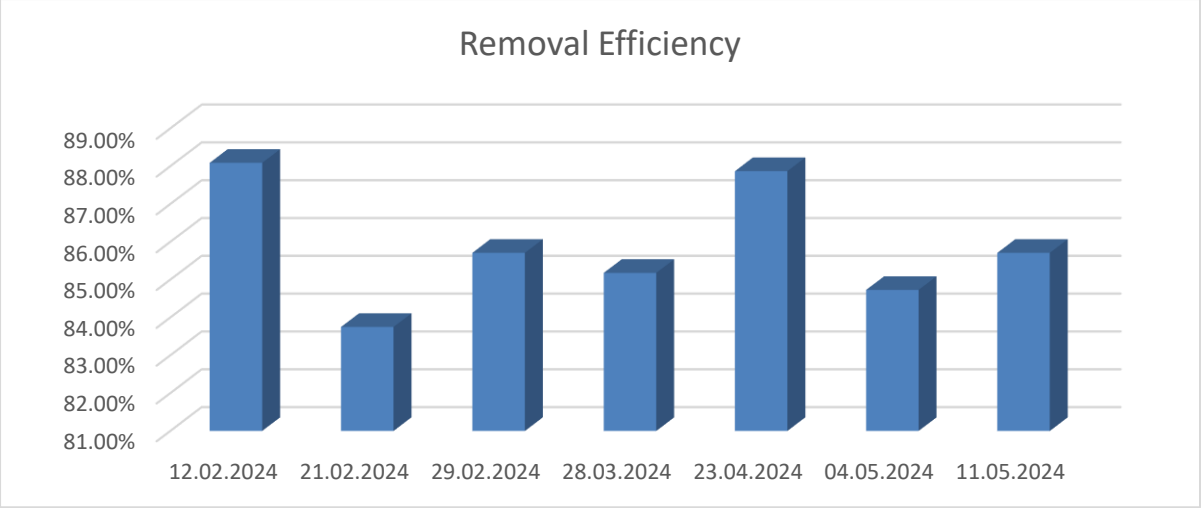


Fig.35: COD Removal efficiency Bar Chart.

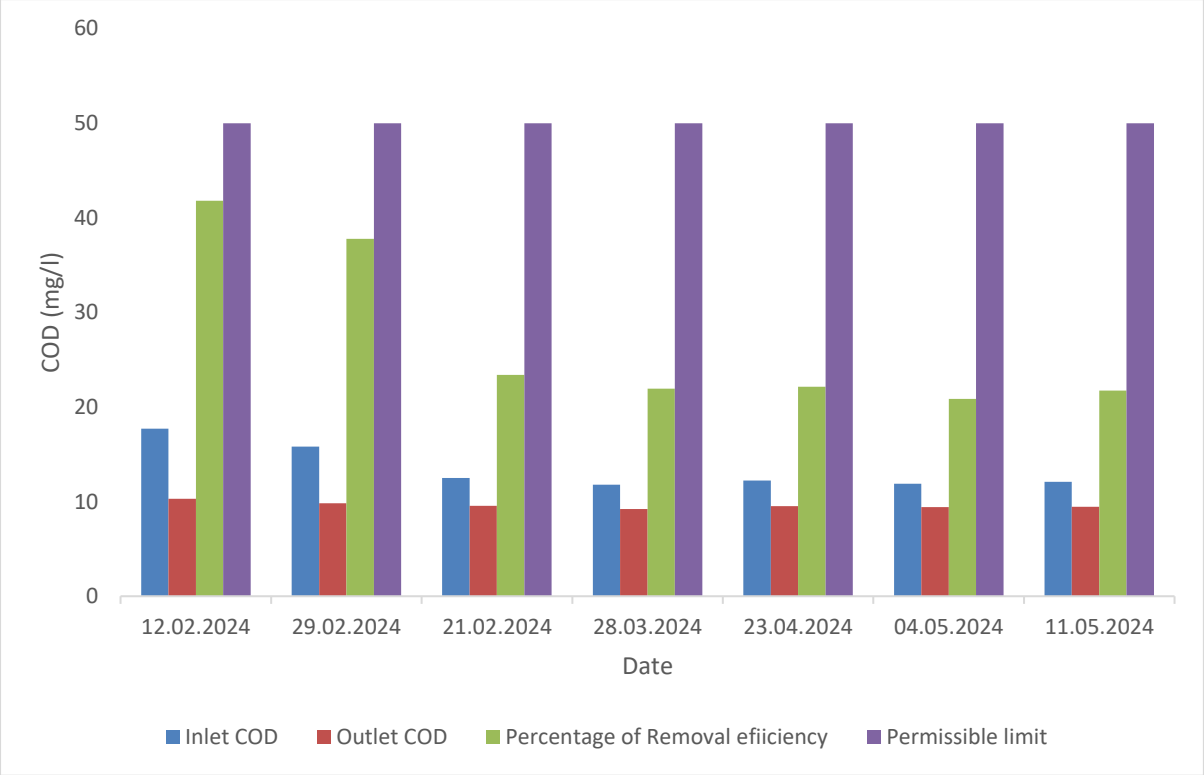


Fig.36: Monitoring the removal profile of inlet, outlet, removal efficiency and permissible limit of COD level of the SBT model.

7.2.3. Total Suspended Solids (TSS):

The removal processes of TSS in the bioreactor are mainly attributed to the filtration and sedimentation. Some other factors such as the hydraulic behaviour of the system and microbiological features contribute to TSS reduction. The TSS value of the inlet wastewater is significantly low for this study. The reason being collected wastewater kept for settling for two hours just before the wastewater allowed flowing into the bioreactor. The TSS removal efficiency varied from 86.36% to 91.18%.

Table.5: TSS removal efficiency

Date	Inlet(mg/l)	Outlet(mg/l)	Removal Efficiency
12.02.2024	88	12	86.36%
21.02.2024	82	10	87.80%
29.02.2024	81	10	87.65%
28.03.2024	83	11	86.74%
23.04.2024	77	8	89.61%
04.05.2024	74	6	91.18%
11.05.2024	80	10	87.5%

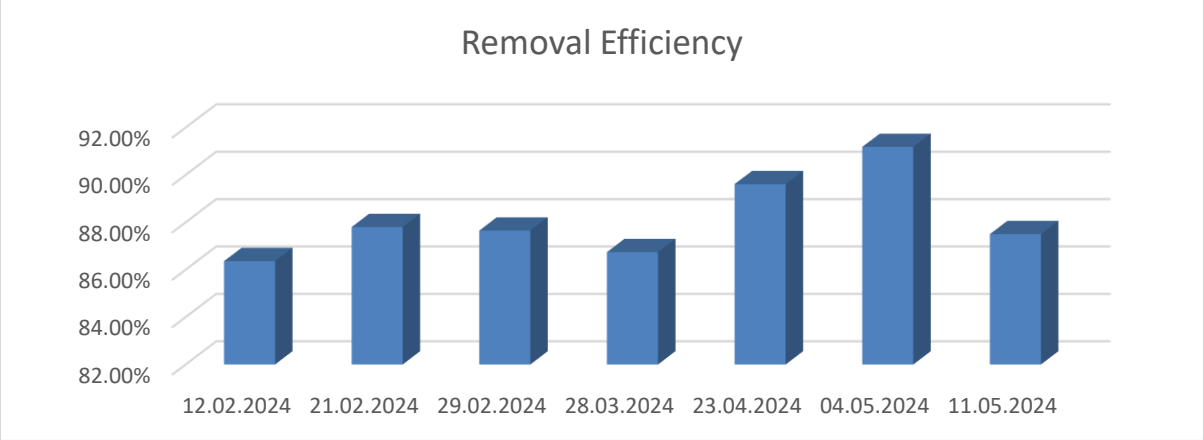


Fig:37: TSS Removal efficiency Bar chart

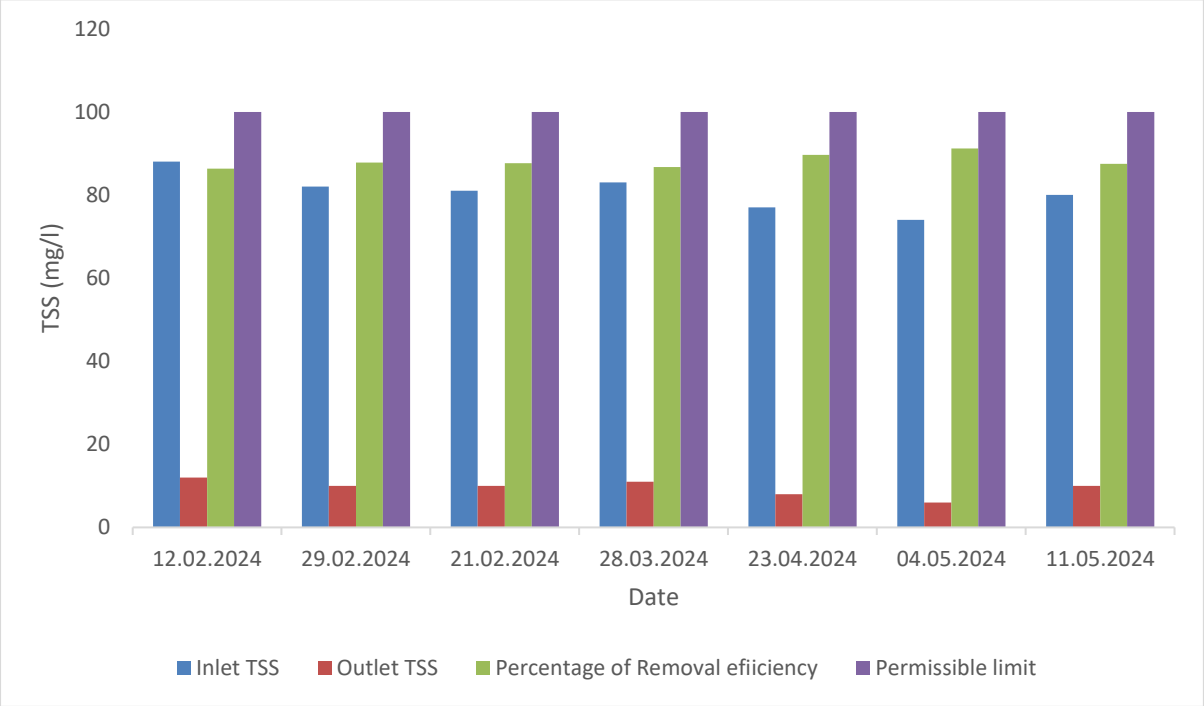


Fig.38: Monitoring the removal profile of inlet, outlet, removal efficiency and permissible limit of TSS level of the SBT model

7.2.4. pH:

pH serves as one of the important parameters because it may reveal contamination of a wastewater or indicate the need for pH adjustment for biological treatment of the wastewater. Effluent pH from fish processing is usually close to neutral. The pH measured in laboratory with pH meter (as per guideline of APHA,23rd Edition-H+B) and the treated water value is slightly more than raw water. Direct measurement of pH of wastewater effluent may vary dramatically due to change in temperature, water flow and any substance present in water. Therefore, for the accurate measurement of the pH value of wastewater, the accurate value of temperature is additionally required.

Table.6: pH value of inlet and outlet

Date	Inlet	Outlet	Removal Efficiency
12.02.2024	7.29	7.34	-
21.02.2024	7.65	7.87	-
29.02.2024	7.43	7.51	-
28.03.2024	7.32	7.6	-
23.04.2024	7.35	7.62	-
04.05.2024	7.4	7.65	-
11.05.2024	7.47	7.7	-

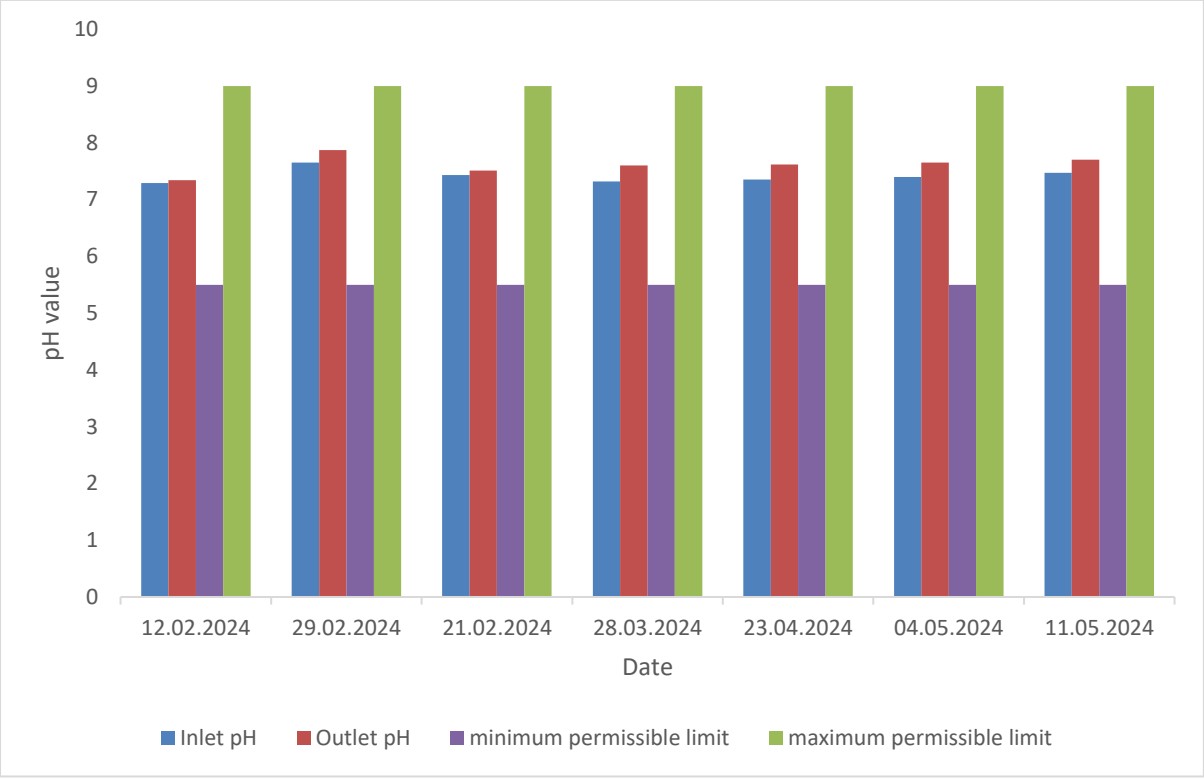


Fig.39: Monitoring the removal profile of inlet, outlet and permissible limit of pH value of the SBT model.

7.2.5. Total Nitrogen (T.N):

Total nitrogen (TN) is the sum of all forms of nitrogen in the water sample. In laboratory test (APHA 23rd Edition,4500-NO_3 D) result shown below the table.

Table.7: Nitrogen removal efficiency

Date	Inlet(mg/l)	Outlet(mg/l)	Removal Efficiency
12.02.2024	17.7	10.3	41.80%
21.02.2024	15.8	9.83	37.78%
29.02.2024	12.5	9.57	23.4%
28.03.2024	11.8	9.21	21.94%
23.04.2024	12.23	9.52	22.15%
04.05.2024	11.9	9.42	20.84%
11.05.2024	12.1	9.47	21.73%

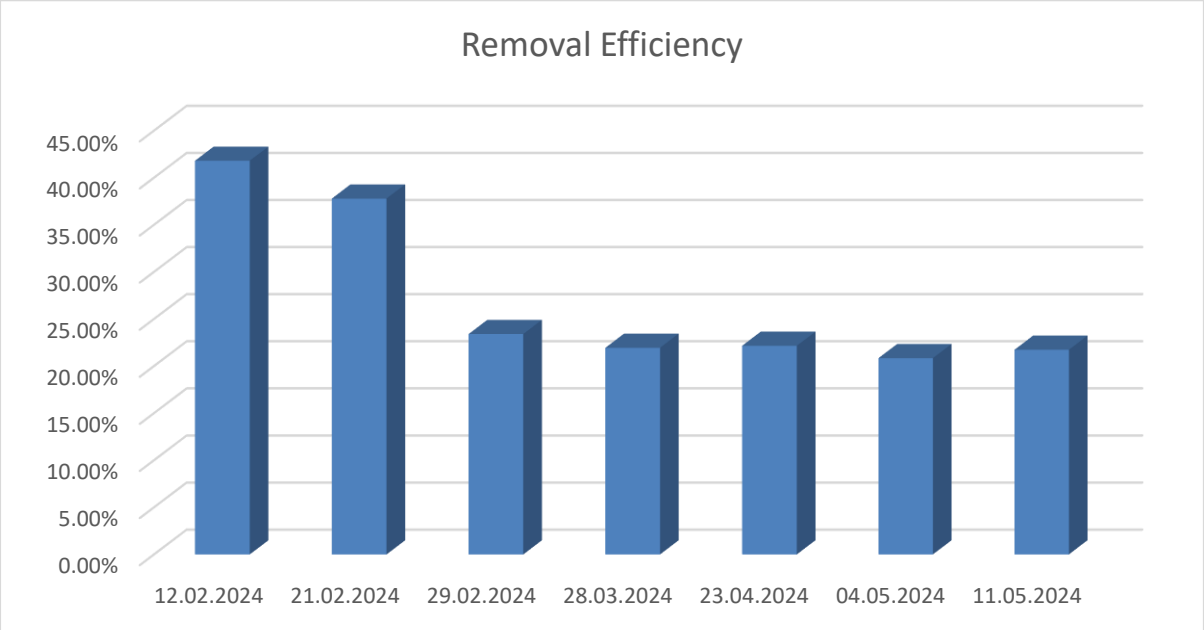


Fig.40:Total Nitrogen Removal efficency Bar Chart

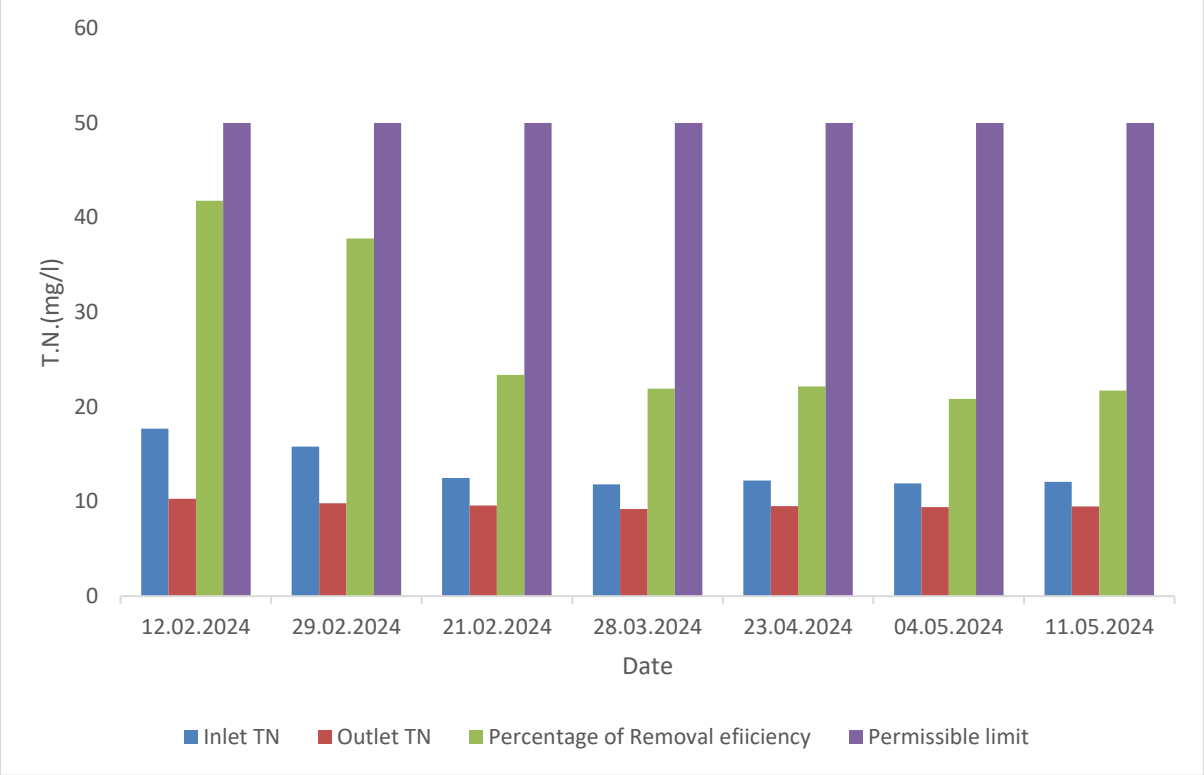


Fig.41: Monitoring the removal profile of inlet, outlet, removal efficiency and permissible limit of T.N. level of the SBT model.

7.2.6. Total Phosphorus (T.P):

The three basic forms of phosphorus found in wastewaters are Orthophosphates Polyphosphates, and Organic phosphates. In laboratory test (APHA 23rd Edition, 4500-P D) result shown below the table.

Table.8: Total Phosphorus removal efficiency

Date	Inlet(mg/l)	Outlet(mg/l)	Removal Efficiency
12.02.2024	3.52	1.1	68.75%
21.02.2024	2.6	0.70	73.07%
29.02.2024	3.12	0.93	70.1%
28.03.2024	3.1	0.95	69.35%
23.04.2024	2.86	0.83	70.97%
04.05.2024	2.81	0.80	71.53%
11.05.2024	2.75	0.79	71.27%

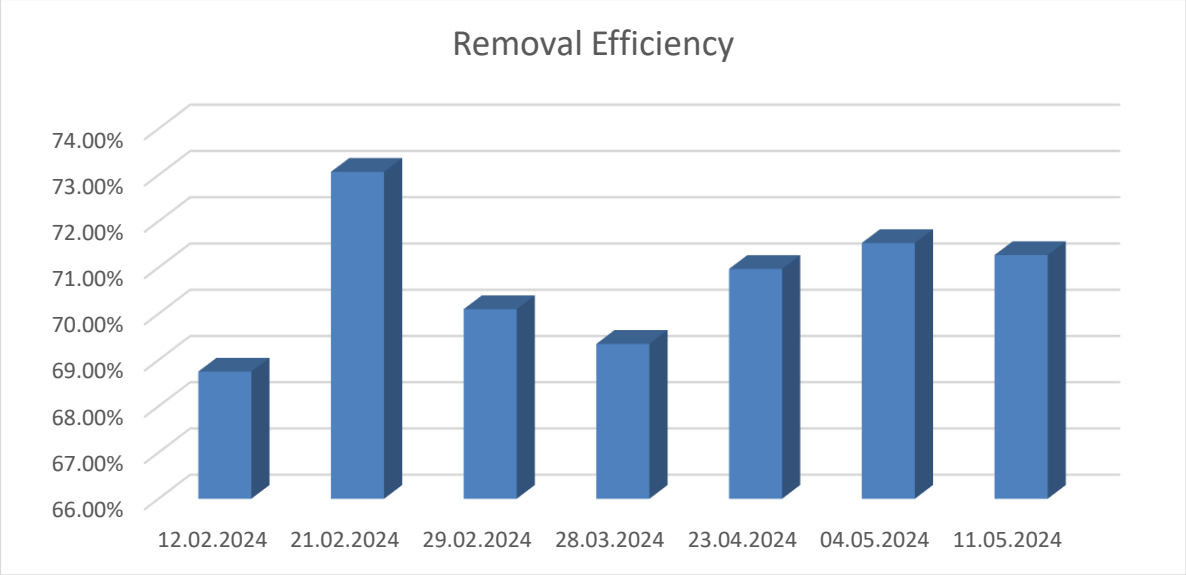


Fig.42:Total Phosphorus Removal efficency Bar Char

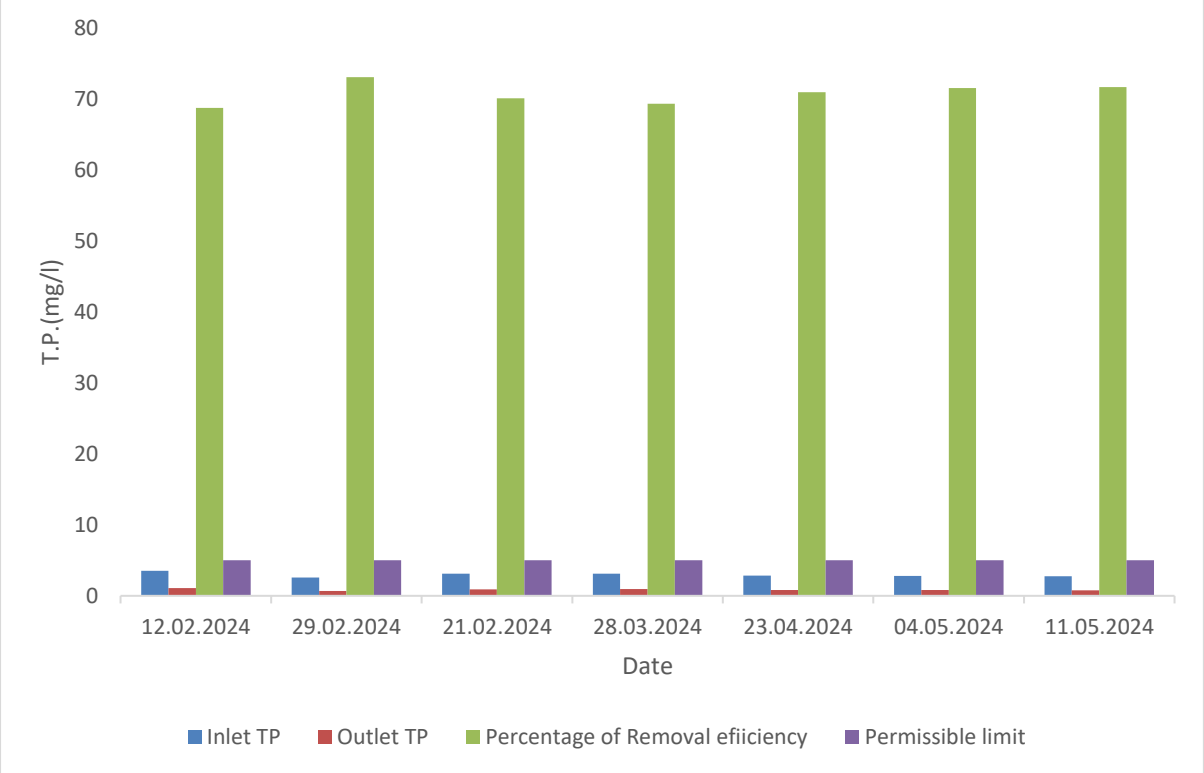


Fig.43: Monitoring the removal profile of inlet, outlet, removal efficiency and permissible limit of T.P. level of the SBT model.

7.2.7. Total Coliform & Faecal Coliform (T.C & F.C):

In laboratory test (APHA 23rd edition 9221B and 9221E) result shown below the table

Table.9: Total Coliform & Faecal Coliform (T.C & F.C)

	Inlet (MPN/100ml)	Outlet (MPN/100ml)
Total Coliform (MPN/100ml)	1.6×10^5	4.9×10^2
Faecal Coliform (MPN/100 ml)	1.1×10^4	1.8×10^2

In whole operation, total wastewater passing through to the Bioreactor was 1765 litres. The average inflow rate 30 ml/min so total days of operation successfully is (1765/30) =40.85 days. Hence total wastewater required in one day is 43.20 litres. The removal mechanism for BOD primarily includes degradation by Microorganisms. Highest BOD removal efficiency of 87.09% and lowest removal efficiency is 82.05%. Average removal efficiency in whole operation is 84.82%. Highest BOD shown 62 mg/l, and lowest is 30 mg/l and average BOD of Raw water is 42 mg/l. The highest removal efficiency of COD shown 88.09% and lowest removal efficiency shown 83.75% shown. Total suspended solids removal efficiency 91.18%. The overall pH range between7.29 to 7.65 for raw water and for treated water the range is 7.34 to 7.87 so saw that treated water pH is more than wastewater. Highest removal efficiency of Total Nitrogen is 41.80% and lowest removal efficiency is 20.84%. For Total Phosphorus, highest removal efficiency 73.07% and lowest removal efficiency 68.75%. Total Coliform in inlet 1.6×10^5 **(**MPN/100 ml) and in outlet 4.9×10^2**(**MPN/100 ml). So, we saw in whole operation the achievement of all parameter removal efficiency is very successfully.

7.3. Results of Varius Parameter along with Discharge Standard:

Results of Various Physicochemical Parameters of Sewage at Inlet and Outlet of SBT model along with Discharge Standards are given bellow:

Table.10: Compression of various parameter with standard value

Parameters	Mean of Raw influent	Mean of Treated Effluent	Mean Removal Efficiency (%)	Permissible Limit (CPCB)	Permissible Limit (USEPA)
pH	7.41	7.61	-	5.5-9	5.5-9
BOD (mg/l)	42	6	84.82%	30	30
COD (mg/l)	86.14	12.28	85.78%	250	90
TSS (mg/l)	80.71	9.57	88.12%	100	45
T.N. (mg/l)	13.43	9.61	27.08%	50	5
T.P. (mg/l)	2.96	0.87	70.72%	5	-
F.C.(MPN/100ml)	1.1×10^4	1.8×10^2	98.36	<1000	1000

7.4. Calculation Of various loading Parameter of Top layer (Soil):

- ✓ Length of the soil layer :280mm=0.280m
- ✓ Diameter:330 mm=0.330m
- ✓ Radius:0.165m
- ✓ Surface Area:$A = \pi r^2$=π×0.165^2 ·=0.0855 m^2
- ✓ Volume= πr^2×H=π×0.165^2×0.280=0.02393622 m^3
- ✓ Average BOD_5=42 mg/l
- ✓ Average flow rate=30 ml/mint
- ✓ Total wastewater passing through the bioreactor=1765 litres

- **Organic loading Rate:** Organic loading rate (OLR) is defined as the amount of organic waste fed per unit volume of the digester per day. It is an essential parameter

OLR=Total BOD_5 entering in model per day/Volume of Top layer

=($42\times10^{-6}\times43.20)/0.0239362=0.075802$ kg/m^3/day

(Where Standard Rate Trickling Filter OLR value 0.08 to 0.32)

- **Hydraulic Loading Rate:** Calculating the hydraulic loading rate is important to account for both the primary effluent as well as the recirculated filter effluent.

HLR=Discharge Passing Through Filter/Area of Layer

=($30\times10^{-6})/0.0855=0.505263$ m^3/day/m^2

CHAPTER 8: CONCLUSION

8.1. **Conclusion**:

Soil Biotechnology (SBT) is a process for processing of organic and inorganic matter. In these system fundamental chemical reactions of nature such as respiration, mineral weathering and photosynthesis takes place. For this research, we installed a SBT model in our Water Resources Engineering Department. From the experiment, observation and laboratory result analysis, results show that soil biotechnology achieves good performance in the removal of the impurities. Highest BOD removal efficiency 87.09 % and COD removal efficiency 88.09%, TSS removal efficiency 91.18%. The overall pH range between7.29 to 7.65 for raw water and for treated water the range is 7.34 to 7.87 so saw that treated water pH is more than wastewater. Highest removal efficiency of Total Nitrogen is 41.80% and lowest removal efficiency is 20.84%. Results showed that soil biotechnology achieves good performance, and the results were better than conventional wastewater treatment.

This research also carried out some key futures like

- Comparing with the conventional wastewater treatment systems, this technology can maintain better socioeconomic and environmental benefits and is usually considered one of the most promising green technologies to treat wastewater.
- No requirement of tertiary treatment such as activated carbon and sand filtration.
- Soil Biotechnology compared to other available technologies like Activated Sludge Process, SBR, Membrane Bio Reactor, constructed wetlands, the cost is very low.
- There are no greenhouse gas emissions (GHG), unlike other wastewater treatment methods.
- Semi-skilled manpower is sufficient for operation and maintenance
- Can be set up as decentralized units for small capacities (such as cluster of few houses) or centralized unit for large capacities (such as township, town or city)
- No sludge and no odour due to ecology at work
- SBT plants can be operated well even if power is available intermittently - This feature enables plant to be operated in situations wherein due to variable load plant is operated as and when required.
- Used water renovation for use in gardening, irrigation, agriculture, flushing, construction, road / car wash, etc.
- Applicable for Industrial wastewater treatment, Industrial air purification

- **Future Scope:**

Soil biotechnology (SBT) has emerged as a promising and sustainable approach for wastewater treatment. By harnessing the natural capabilities of microorganisms in soil, SBT offers several advantages over traditional methods. Here are some key areas where SBT is poised to make significant strides in the future:

Emerging Contaminants: SBT can be engineered to target emerging contaminants like pharmaceuticals, personal care products, and micro plastics, which are increasingly challenging to remove using conventional methods.

Heavy Metals: SBT can effectively remove heavy metals from wastewater through processes like bio sorption and bioaccumulation.

Nutrients: SBT can efficiently remove excess nutrients, such as nitrogen and phosphorus, from wastewater, reducing eutrophication in water bodies.

Optimization**:** Advanced techniques like metagenomics and meta transcriptomic can be used to identify and optimize microbial communities for specific wastewater treatment tasks, enhancing efficiency.

Reduced Operational Costs: SBT often requires less energy and chemicals compared to traditional methods, leading to lower operational costs.

Hybrid Systems: SBT can be integrated with other wastewater treatment technologies, such as membrane filtration or activated sludge, to create hybrid systems that offer complementary benefits.

Small-Scale Applications: SBT is well suited for decentralized wastewater treatment in rural or remote areas, where traditional infrastructure may be limited**.**

Greenhouse Gas Reduction: SBT can contribute to climate change mitigation by reducing greenhouse gas emissions associated with wastewater treatment, such as those from energy-intensive processes.

Carbon Sequestration: SBT can be used to sequester carbon dioxide from wastewater, helping to mitigate climate change.

- **Limitation of the Study:**

Soil biotechnology for wastewater treatment is an innovative and eco-friendly approach, but it does have some limitations. Here is a concise overview of the key limitations:

1. Limited capacity: These systems may struggle to handle very high volumes of wastewater or sudden surges in wastewater production.
2. Soil clogging: Over time, the accumulation of organic matter and biofilm growth can lead to soil clogging, reducing treatment efficiency.
3. Seasonal variations: The treatment efficiency may vary with seasons, particularly in regions with distinct wet and dry periods.
4. Time constraints: Soil biotechnology systems often require longer retention times compared to conventional treatment methods, which may not be suitable for situations requiring rapid treatment.

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