DESIGN OF SUSTAINABLE WASTEWATER TREATMENT PLANT UTILIZING RECYCLED WATER RESOURCES

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ABSTRACT

The concept of recycling and reusing wastewater has gained prominence as a sustainable solution to alleviate water scarcity and reduce pollution. This abstract presents a comprehensive design of a wastewater treatment plant that employs advanced technologies for treating and recycling wastewater, thereby harnessing the potential of recycled water resources. The proposed wastewater treatment plant incorporates a multi-step treatment process, encompassing physical, chemical, and biological treatment units. The primary treatment stage involves the removal of large debris and solids through processes such as screening and sedimentation. Subsequently, secondary treatment employs activated sludge processes, biofiltration, and membrane bioreactors to efficiently biologically degrade organic matter and eliminate pathogens. Advanced treatment units, including anaerobic digesters and nutrient removal systems, facilitate the recovery of biogas and valuable nutrients like nitrogen and phosphorus. The biogas generated from anaerobic digestion can be utilized as an energy source to power the treatment plant, while nutrient recovery supports sustainable agricultural practices. The heart of the plant design lies in its water recycling and reuse scheme. The recycled water is subjected to microfiltration and reverse osmosis processes, achieving a high degree of purification suitable for non-potable applications. The reclaimed water can be employed for various purposes, including industrial processes, landscape irrigation, and even indirect potable reuse, following stringent water quality standards. The integration of smart monitoring and control systems enables real-time optimization of treatment processes, minimizing resource wastage and ensuring consistent water quality.

Keywords: *wastewater treatment plant, recycled water resources, sustainable design, water scarcity, pollution reduction, advanced treatment technologies, resource recovery, water recycling, non-potable applications, environmental impact, smart monitoring, control systems.*

I. INTRODUCTION

Rainwater, a natural and essential element of the Earth's water cycle, becomes a source of concern when it runs off impervious surfaces, gathering contaminants and pollutants along its path. This runoff, often referred to as "stormwater runoff" or "rainwater wastewater," carries a mix of sediments, chemicals, bacteria, pathogens, nutrients, and debris from urban environments into our waterways, adversely affecting water quality, aquatic ecosystems, and public health. Rainwater, initially clean as it falls, interacts with human-impacted surfaces, making it a significant contributor to water pollution. To mitigate the detrimental environmental and health impacts of this rainwater runoff, effective management strategies, including stormwater control practices, erosion prevention, public education, and regulatory frameworks, are essential for cleaner and more.

Objectives:

- **Environmental Stewardship:** The primary objective is to establish a wastewater treatment plant that upholds the principles of environmental stewardship. This includes minimizing the impact on local ecosystems, reducing greenhouse gas emissions, and protecting natural water bodies from contamination.

- **Water Resource Conservation:** To effectively manage and conserve water resources, with an emphasis on reducing water wastage and reusing treated wastewater for non- potable purposes, such as industrial processes, irrigation, and cooling systems.

- **Water Quality Improvement:** Improve the quality of wastewater effluent to meet stringent water quality standards and ensure that the discharged water poses no harm to the environment or human health. This involves advanced treatment processes, such as filtration and disinfection.

- **Resource Recovery:** Maximize resource recovery from wastewater, such as energy generation through anaerobic digestion or the production of fertilizers from nutrient- rich sludge. This contributes to the economic sustainability of the plant.

- **Adaptation and Scalability:** Design the wastewater treatment plant with the flexibility to adapt to changing demands, including population growth and evolving regulatory requirements. Scalability is essential for long-term sustainability.

- **Community Engagement:** Promote community awareness and engagement regarding responsible water use, recycling, and the role of the treatment plant in ensuring clean water. This includes education programs and public outreach initiatives.

- **Economic Viability:** Conduct cost-benefit analyses to ensure that the wastewater treatment plant remains economically viable, balancing initial capital investments, operational costs, and the benefits it provides to the community and environment.

Scope:

- **Wastewater Source Segregation:** The project scope encompasses the segregation of different wastewater sources, such as residential, commercial, and industrial, to facilitate appropriate treatment processes.

- **Multi-Stage Treatment:** Design and implement a multi-stage treatment process that includes primary treatment (screening and sedimentation), secondary treatment (biological and nutrient removal), tertiary treatment (advanced filtration and disinfection), and a specific process for recycling water to meet non-potable demands.

- **Resource Recovery Facilities:** The scope includes the establishment of resource recovery facilities, including anaerobic digestion units for energy recovery and the production of fertilizers from nutrient-rich sludge.

- **Storage and Distribution Infrastructure:** Develop infrastructure for the storage of treated water in reservoirs or tanks and a distribution system for recycled water to various end-users, industries, and irrigation areas.

- **Monitoring and Control Systems:** Implement real-time monitoring and control systems to ensure the efficient and consistent operation of the treatment plant and to address any deviations promptly.

- **Environmental Impact Mitigation:** The project scope encompasses the integration of sustainable technologies and green infrastructure to minimize the environmental footprint of the treatment plant, such as energy-efficient equipment and environmentally friendly construction materials.

- **Data Management and Reporting:** Establish a comprehensive data management and reporting system to monitor and improve plant performance, including compliance with water quality and environmental regulations.

- **Emergency Response Planning:** Develop comprehensive emergency response plans to address potential emergencies, such as system failures, natural disasters, or extreme weather events.

- **Regulatory Compliance:** Ensure strict adherence to local, state, and federal water quality and environmental regulations, with a commitment to ongoing compliance.

- **Research and Innovation:** Stay updated on the latest advancements in wastewater treatment technology and research for potential improvements in plant operation.

- **Long-Term Sustainability Planning:** Consider the long-term needs of the wastewater treatment plant, including potential expansion options, to adapt to changing demands and ensure its continued role as a sustainable and environmentally responsible facility.

Water Pollution:

Water pollution in India is a pressing environmental issue with far-reaching consequences for public health, ecosystems, and sustainable development. The country's rapidly growing population, urbanization, industrialization, and agricultural practices have led to the contamination of its water bodies, including rivers, lakes, and groundwater. This article explores the sources, effects, and measures to combat water pollution in India, highlighting the need for comprehensive strategies and increased awareness.

Sources of Water Pollution in India

- Industrial Effluents:
- Agricultural Runoff:
- Sewage and Domestic Wastes

- Mining Activities:
- Urbanization:
- Groundwater Contamination:
- Religious and Cultural Practices:
- Ship breaking Industry

II. LITERATURE REVIEW

- **NURALHUDA ALADDIN JASIM (2020)** the design of waste water treatment plant with GPS x modeling There is correlation between sludge age and the mixed liquor suspended solid (MLSS). The value of the observed yield has been noticed, with values ranging from 0.2 to 0.6 kgVSS/kg (BOD5). The sludge retention time is equal to 27.7 day and the sludge produce is 3339.18 Kg/day.

- **SAUD JAFFER AL (2018)** waste water treatments and sludge production occur in variety of economic, social and technological contexts types of analysis, numbers of the sample, purification method, types of the microbial agent, and rates of microbial agent removal was entered into the checklist. Also the removal rate of the microbial agent mention in study was compare with the united states environmental protections agencies (USEPA) standard

- **ELSAYED ABDEL-REOUETA (2012)** problems of the fresh water scarcity affects people all over the world One of possible solution for this issue is for purify industrials wastewaters so that it can be used in agriculture by eliminating harmful contaminants and renewable and environmentally friendly sources for developing new materials

- **JAYASHREE DHOTEETA (2009)** numerous water resources are pollute by the anthropogenic in source including the agricultural and household waste as well as industrial process environmental impacts of waste water pollution increased. To eliminate the pollutants, many traditional wastewater treatments strategies, such as activated sludge, chemical coagulation and adsorption, have used; however, there're still few limitations, particularly in terms of high operating costs. Because of its low operating and maintenance cost, aerobics waste water treatment as reductive medium is gaining

III. METHODOLOGY

The size and capacity of wastewater treatment systems are determined by the estimated volume of sewage generated from residences, businesses, and industries connected to sewer systems as well as the anticipated inflows and infiltration (I&I). The selection of specific on-lot, clustered, or centralized treatment plant configurations depends upon factors such as the number of customers being served, the geographical scenario, site constraints, sewer connections, average and peak flows, influent wastewater characteristics, regulatory effluent limits, technological feasibility, energy consume the operations and maintenance costs involved.

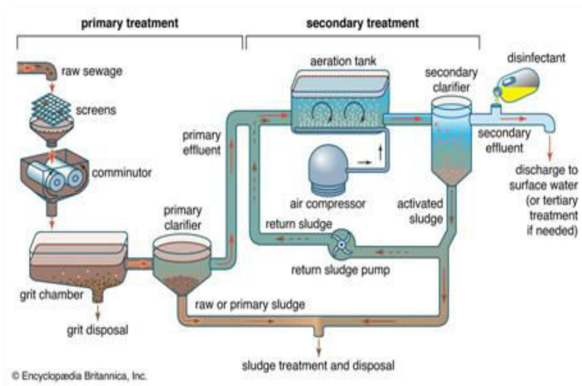

Figure 1 Treatment process

The predominant method of wastewater disposal in large cities and towns is discharge into a body of surface water. Suburban and rural areas rely more on subsurface disposal. In either case, wastewater must be purified or treated to some degree in order to protect both public health and water quality. Suspended particulates and biodegradable organics must be removed to varying extents. Pathogenic bacteria must be destroyed. It may also be necessary to remove nitrates and phosphates (plant nutrients) and to neutralize or remove industrial wastes and toxic chemicals. The degree to which wastewater must be treated varies, depending on local environmental conditions and governmental standards. Two pertinent types of standards are stream standards and effluent standards.

Stream standards, designed to prevent the deterioration of existing water quality, set limits on the amounts of specific pollutants allowed in streams, rivers, and lakes. The limits depend on a classification of the "maximum beneficial use" of the water. Water quality parameters that are regulated by stream standards include dissolved oxygen, coli forms, turbidity, acidity, and toxic substances. Effluent standards, on the other hand, pertain directly to the quality of the treated wastewater discharged from a sewage treatment plant. The factors controlled under these standards usually include biochemical oxygen demand (BOD), suspended solids, acidity, and coli forms.

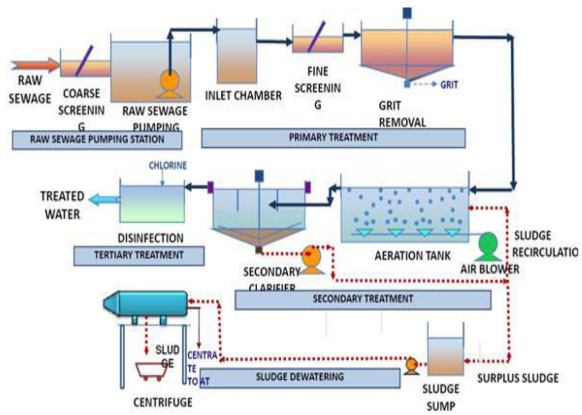

Figure 2 process of Treatment

IV. PRIMARY TREATMENT

Primary treatment removes material that will either float or readily settle out by gravity. It includes the physical processes of screening, comminuting, grit removal, and sedimentation. Screens are made of long, closely spaced, narrow metal bars. They block floating debris such as wood, rags, and other bulky objects that could clog pipes or pumps. In modern plants the screens are cleaned mechanically, and the material is promptly disposed of by burial on the plant grounds. A comminutor may be used to grind and shred debris that passes through the screens. The shredded material is removed later by sedimentation or flotation processes.

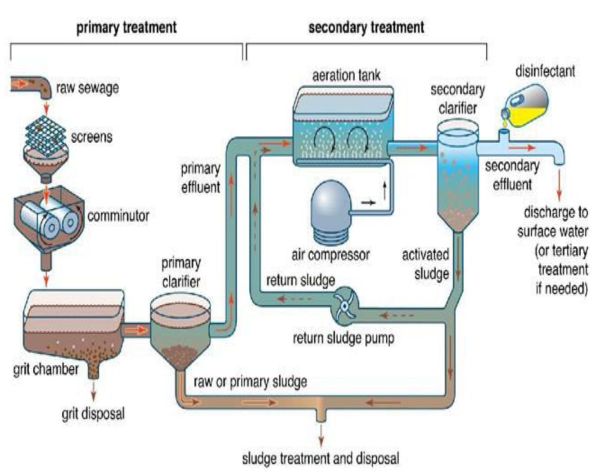

Figure 3 Activated sludge process

V. TREATMENT METHODS

Treatment of sewage sludge may include a combination of thickening, digestion, and dewatering processes.

- **Thickening:** Thickening is usually the first step in sludge treatment because it is impractical to handle thin sludge, slurry of solids suspended in water. Thickening is usually accomplished in a tank called a gravity thickener. A thickener can reduce the total volume of sludge to less than half the original volume. An alternative to gravity thickening is dissolved-air flotation. In this method, air bubbles carry the solids to the surface, where a layer of thickened sludge forms.

- **Digestion:** Sludge digestion is a biological process in which organic solids are decomposed into stable substances. Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge. Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.
- **Dewatering:** Digested sewage sludge is usually dewatered before disposal. Dewatered sludge still contains a significant amount of water—often as much as 70 percent—but, even with that moisture content, sludge no longer behaves as a liquid and can be handled as a solid material. Sludge- drying beds provide the simplest method of dewatering.

- **Disposal:** The final destination of treated sewage sludge usually is the land. Dewatered sludge can be buried underground in a sanitary landfill. It also may be spread on agricultural land in order to make use of its value as a soil conditioner and fertilizer. Since sludge may contain toxic industrial chemicals, it is not spread on land where crops are grown for human consumption.

VI. SAMPLE COLLECTION AND TESTINGS

- ***Collection of Wastewater:***

  Sample and Analysis Results The collection of wastewater samples and subsequent analysis of the results are critical steps in assessing water quality, identifying pollutants, and ensuring the effectiveness of wastewater treatment processes.

Figure 4 Collection of water sample 1 and 2

- ***Laboratory Testing:***

Wastewater samples are typically sent to a laboratory for analysis. The laboratory should follow standardized testing methods, such as those recommended by the Environmental Protection Agency (EPA) in the United States or other relevant regulatory bodies in your region.

Figure 5 Turbidity test and Water samples

Figure 6 hardness test and PH test

Wastewater Characteristics:

Refer to the physical, chemical, and biological properties of the wastewater that need to be understood for proper treatment. These characteristics help in selecting treatment processes and equipment. Common wastewater characteristics include:

Description of Parameter	Value	Unit
Quantity of Sewage Generated	4000000.00	Lpd
	4.00	MLD
	4000.00	Cum/day
Raw Sewage Characteristics		
Average Effluent flow entering the treatment plant	4000000.00	Lpd
Assumed Peak Factor	1.20	
Peak Effluent flow entering the treatment plant	4800000.00	Lpd
COD	3000.00	mg/l
BOD	1500.00	mg/l
TDS	1800-2000	mg/l
TSS	750.00	mg/l
pH	6.50	

Table 1 Characteristics of wastewater samples Treatment scheme and size

VII. THE TREATMENT SCHEME

typically includes preliminary treatment to remove large debris and grit, followed by primary treatment in clarifiers to allow Description of Parameter Value Unit Quantity of Sewage Generated 4000000.00 Lpd 4.00 MLD 4000.00 Cum/day Raw Sewage Characteristics Average Effluent flow entering the treatment plant 4000000.00 Lpd Assumed Peak Factor 1.20 Peak Effluent flow entering the treatment plant 4800000.00 Lpd COD 3000.00 mg/l BOD 1500.00 mg/l TDS 1800-2000 mg/l TSS 750.00 mg/l pH 6.50 32 for the settling of solids. Secondary treatment, which may involve aeration tanks for biological treatment or fixed-film processes, further refines the wastewater. Tertiary treatment processes, such as filtration or chemical treatment, can be added if necessary. Disinfection is employed to kill pathogens, and sludge generated in the treatment process is managed through thickening, digestion, dewatering, and disposal. The sizing of each component is determined by various factors, including the design flow, water quality objectives, regulatory standards, and local conditions. The design and sizing of a wastewater treatment plant are complex processes that require the expertise of wastewater engineers and environmental specialists to ensure efficient and effective treatment while meeting environmental standards and regulations.

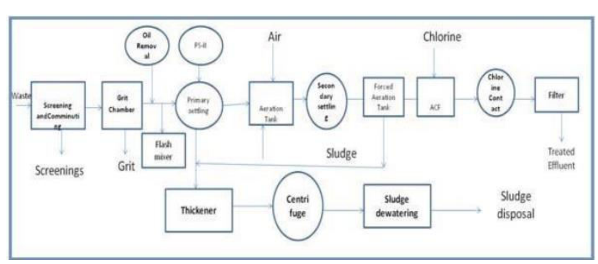

Figure 7 Treatment process

- ***Clari - Flocculator :***
  A clarifier is a key component in wastewater treatment plants used for the separation of solid particles from water or wastewater.

Solid conc. In settled sludge -%	0.8 to 0.9	%
Area Required for the Tank	80.00	Sq.m
Diametre Required for Secondary Settling Tank	10.09	m
Assumed Detention Period	3.10	hrs
	258.33	Cum
Depth of the Clarifier assumed	2.50	m
Area of the Clarifier	103.33	Sq.m
Provide Secondary Clarifier of Diameter	11.50	m
Surface Loading Rate	19.35	Cum/Sq.m/day
Assumed BOD reduction in Clarifier	20.00	%

Table 2 Clari-Flocculator

- ***Chlorination:***
  Chlorination is a water treatment process that involves the addition of chlorine or chlorine based compounds to water or wastewater. Chlorine is a highly effective disinfectant and oxidizing agent, and it is commonly used to achieve several water treatment objectives, including disinfection, oxidation of contaminants, and residual disinfection to protect against microbial regrowth.

Disinfection through Chlorination		
Bleaching powder Dozers, 1W+1SB	3500.00	litres/hour
or Vacuum Chlorinator 1 W+1 SB	1.00	Kg/hour
Chlorine Contact tank 15minute detention	8.1*8.1*4	m*m*m

Table 3 Disinfection through chlorination

- ***Sludge Lines:***
  Sizing sludge and sewer lines is a critical aspect of wastewater system design to ensure efficient and reliable conveyance of wastewater and sludge to treatment facilities or disposal points. Proper sizing helps prevent overflows, blockages, and system failures. Consulting with experienced wastewater engineers and adhering to local regulations and standards is essential in the design and sizing process.

Pipe Sizes (Diameter in mm)		
Gravity Lines		
Sludge line	160.00	mm
Sewage line	125.00	mm

Table 4 Pipe sizes

Filter press for Sludge Disposal to handle sludge off	2400	kg/day
	228571.43	Cum/day
	1904.76	Cum/hr
OR		
Population Equivalent	30000.00	Persons
area per person	0.03	Sq.m
Total Area required	750.00	Sq.m

Table 5 filter press for sludge disposal

- ***Hydraulic Calculation:***
  Hydraulic calculations in the context of wastewater treatment and conveyance systems involve the analysis of fluid flow through pipes, channels, and other components to ensure that the system operates efficiently and reliably. These calculations are essential for designing, maintaining, and optimizing the performance of water and wastewater systems.

Hydraulic Calculations		
Average Ground Level	100.00	m
Inlet Chamber		
Water Level in the Inlet Chamber be	200.00	m
Liquid Depth Provided in the Inlet Chamber	0.60	m
Bed Level of Inlet Chamber	199.40	m
Bar Screen Chamber		
Water Level in the Bar Screen Chamber be	199.35	m
Bed Level of U/s of Bar Screen Chamber	199.09	m
Bed Level of D/s of Bar Screen Chamber	198.84	m
Grit Chamber		
Water Level in the Grit Chamber be	198.74	m
Bottom Level of Grit Chamber	197.24	m
Silt Depoition Hopper bottom level	196.94	m
Equalization Tank		
Water Level in the Equalization tank	198.24	m
Bed Level of Equalization tank	193.24	m
Secondary Clarifier		
Water Level in the Secondary Clarifier	197.84	m
Bottom Level of secondary Clarifier	195.34	m
Treated Sewage Sump		
Water Level in the Sump	196.84	m
Bed Level of Treated Sewage Sump	192.74	m
Wall Top Level of Treated Sewage Sump	100.50	m
Pump House		
Size of the Pump House	100	Sq.m
Finished Floor Level of the Pump House above Treated Sewage Sump	100.65	m
Roof Bottom Level of Pump house	104.00	m

Table 6 Hydraulic calculations

VIII. CONCLUSION

Wastewater treatment plays an important role in water pollution control. Proper design, operation and maintenance only can give good removal efficiency of pollutants. The actual implementation and maintenance of this scheme will give proper idea of process handling and actual benefits. Through this project, it has been shown that it is feasible to have a common effluent treatment plant for an industrial estate. The conceptual design of the wastewater treatment plant described in this report is a very essential part of addressing current pollution problems. All the proposed treatment units were designed to achieve acceptable effluent characteristics in compliance with the national standards, using the least expensive, most traditional, and energy efficient technologies available.

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