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A Case Study on Design of Sewage Treatment Plants and Methods of Improvement

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Abstract: Sewage treatment plants are vital infrastructures that safeguard public health and protect the environment by treating and purifying wastewater. The design of these plants plays a crucial role in ensuring efficient and effective treatment processes. This research paper focuses on the design principles and considerations for sewage treatment plants and explores various methods for improving existing facilities. By implementing innovative design strategies and adopting optimization techniques, wastewater treatment plants can enhance their performance, increase treatment capacity, and achieve higher levels of environmental sustainability.
Keywords: sewage treatment plant, waste water

I. INTRODUCTION

Sewage is the term used for wastewater that often contains faces, urine and laundry waste. It also carried in solution or suspension, that is intended to be removed from a community . Also known as domestic and industrial waste water, It is more than 99.9% liquid waste and 0.1% solid waste is characterized by volume or rate of flow, physical conditions, chemical and toxic constituents, and its bacteriologic status. It consists mostly of greywater ,black water ,soaps, detergents and toilet paper and also contains surface runoff depends on the sewer system. It is generated by residential ,institutional, commercial and industrial establishments. It includes household waste liquid from toilet, baths, showers, kitchens and sinks draining into sewers. In many areas, sewage also includes liquid waste from industry and commercial places. Sewage is composed of many materials that are broken down into three general areas. These areas are the physical, chemical , and biological characteristics of waste water. The physical characteristics of waste water includes those items that can be detected using physical senses.

They are temperature, color, odor ,and solids. The chemical characteristics of sewage helps in indicates the stage of sewage decomposition, its strength, extent and type of treatment required for making its safe, they include solids are present may be four types suspended solids, dissolved solids, colloidal solids, settleable solids, pH, nitrogen contents, chloride content, DO. The biological characteristics of sewage contains many microorganisms like bacteria, algae, fungi, protozoa, etc. Bacteria being most predominant (1) The resulting water pollution causes the quality of the water to deteriorate and affects ecosystems. Pollutants can also seep down and effect of ground water deposits. Sewage and industrial wastes are discharged into the rivers. Because of our environment and for our own health.

There are lot of good reasons why keeping our water clean is an important priority. The treatment and proper disposal of sewage are critical in order to maintain public health and preserving the integrity of our environment. Sewage treatment plants serve as vital role in infrastructures that play a crucial role in treating and purifying wastewater before it is discharged back into water streams or reused for various other purposes.

The design and execution of a sewage treatment plant are of utmost importance for educational institutions like colleges, to ensure the efficient management of wastewater and the preservation of the local surrounding. As Our college experience significant water consumption due to academic activities, residential facilities, and other campus operations, it becomes essential to establish a sewage treatment plant that meets regulatory standards and contributes to sustainable practices. The design of these plants significantly influences their efficiency, effectiveness, and overall performance. Additionally, existing sewage treatment facilities often require improvements and upgrades to address evolving challenges and meet growing demands.

The design and implementation of a sewage treatment plant within a college campus are essential for effectively managing wastewater and promoting environmental sustainability. As educational institutions grow and evolve, the need for an efficient and reliable sewage treatment system becomes increasingly critical. A college sewage treatment plant not only ensures the protection of public health and the environment but also serves as an educational resource, demonstrating the institution's commitment to sustainable practices.

II. OBJECTIVES OF THE STUDY

The objective of this research paper is to explore the design principles and considerations of sewage treatment plants and investigate various methods for improving existing facilities. By examining the unique requirements and challenges faced by educational institutions, we aim to provide valuable insights into the design process and contribute to the development of environmentally conscious and resource-efficient wastewater management systems.

In the initial sections we will explore the fundamental design principles necessary for the successful implementation of a sewage treatment plant on a college campus. This includes site selection and layout considerations, hydraulic and process flow analysis, primary, secondary, and tertiary treatment design, as well as effluent discharge and environmental impact assessment. Understanding these design principles is crucial for developing treatment plants that are effective in removing pollutants, minimizing energy consumption, and meeting regulatory standards.

Building upon these design principles, we will explore innovative design strategies that can be incorporated into the planning and construction of sewage treatment plants. These strategies encompass the utilization of advanced treatment technologies, the adoption of decentralized treatment systems, the integration of green infrastructure, and the implementation of modular and expandable designs. By embracing these innovative approaches, new treatment plants can be designed to optimize efficiency, enhance resource recovery, and reduce the overall environmental footprint.

However, the focus of this research paper is not solely on the design of new sewage treatment plants. We also recognize the significance of improving existing facilities to address issues such as aging infrastructure, increasing population, and stricter regulatory requirements. Therefore, we will discuss various methods for improving and upgrading existing sewage treatment plants. These methods encompass process optimization and retrofitting, upgrading primary and secondary treatment units, incorporating advanced treatment techniques, and enhancing disinfection and effluent discharge systems.

III. LITERATURE REVIEW

1) "Advances in Wastewater Treatment Technologies" by Hasan Ozturk et al. (2019): This review paper discusses various advanced treatment technologies such as membrane bioreactors, advanced oxidation processes, and constructed wetlands. It highlights their efficiency in improving wastewater treatment performance and suggests their potential application for upgrading existing sewage treatment plants.
2) "Process Optimization in Sewage Treatment Plants" by Fernando Sampaio et al. (2020): This review paper focuses on process optimization techniques to improve the performance of existing sewage treatment plants. It discusses approaches like model-based control, real-time monitoring, and sensor networks to enhance operational efficiency, nutrient removal, and energy consumption.
3) "Innovative Approaches for Sludge Management in Sewage Treatment Plants" by Cristina Partesotti et al. (2018): This review paper explores innovative sludge management strategies for existing sewage treatment plants. It discusses techniques such as anaerobic digestion, thermal hydrolysis, and sludge drying technologies, which can improve the sludge reduction, biogas production, and resource recovery.
4) "Emerging Contaminants in Wastewater: Occurrence, Fate, and Removal" by Ana Gomes et al. (2018): This literature review focuses on emerging contaminants in wastewater and their impact on existing sewage treatment plants. It discusses the occurrence of pharmaceuticals, personal care products, and microplastics, and evaluates different treatment technologies like activated carbon adsorption, advanced oxidation, and membrane filtration for their removal.
5) "Sustainability Assessment of Sewage Treatment Plants: A Review" by S. Sharuddin et al. (2016): This review paper provides an overview of sustainability assessment methodologies for sewage treatment plants. It discusses environmental, social, and economic aspects of sustainability, including energy consumption, greenhouse gas emissions, social acceptance, and life cycle cost analysis.

"Smart Technologies for Sewage Treatment Plants: A Review" by M. Anand et al. (2017): This review paper explores the application of smart technologies in sewage treatment plants for improving efficiency and performance. It discusses the use of sensors, automation, real-time monitoring, and data analytics to optimize operational parameters, reduce energy consumption, and enhance maintenance practices. "Decentralized Wastewater Treatment Systems: A Review of Current Trends and Challenges" by Alok Kumar Patel et al. (2020): This review paper discusses decentralized wastewater treatment systems as an alternative or supplement to centralized sewage treatment plants. It evaluates different technologies such as constructed wetlands, sequencing batch reactors, and membrane systems, highlighting their advantages and challenges for improving wastewater treatment at a smaller scale.

IV. METHODOLOGY

Sewage treatment can be categorized in n following manner –

A. *Physical Characteristics*

1) *Odour* – It is recognized as a quality factor/indicator acceptability of water , organic and inorganic substance takes contribution to taste or odour .
2) *Colour* - It is present in water due to the presence of natural metallic ions such as Fe or Mg , humus and peat materials , weeds and planktons .
3) *Floatables* – In waste water two types of floating materials are present , particulate materials like grease balls or the liquid thin visible layers .
4) *Temperature* – Temperature of sewage is maximum time greater than temperature of water .

B. *Chemical Characteristics*

1) pH – Expressed on a scale of 1 to 14 . The permissible limit of treated wastewater should be between 6.5 to 9.0 .
2) Gases – There are a lot of dissolved gases present in wastewater . Typical domestic wastewater contains oxygen in very low concentrations , carbon dioxide and hydrogen sulfide .
3) Presence of fats , greases and oils – These are present in wastewater due to the sewage from the discharges available of animals , kitchens of hotels and industries etc.

C. *Biological Characteristics*

1) *Bacteria* – They may be of following types pathogenic bacteria, non-pathogenic bacteria ,aerobic bacteria,anaerobic bacteria , Facultative bacteria .
2) *Microorganisms* – Algae, fungi, protozoa helps the process of decomposition of sewage be photosynthesis or by breaking the organic compounds .
3) *BOD (Biochemical oxygen demand)*– It is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to breakdown organic material present in given water sample at certain temperature over a specific time period .

V. DESIGN OF SEWAGE TREATMENT PLANT CORRESPONDING TO 0.3MLD

A. *Screening*

Maximum Flow = 0.30 MLD
= 0.0030 cumec
Velocity of flow (0.6m/sec-0.9m/sec) = 0.8 m/sec
Hence . Net submerged area of screen openings = maximum flow/velocity of flow
= 0.0030/0.8 = 0.0044 sqm
Gross vertical area required = net submerged area*Sin60
=0.0044*sin 60 = 0.0038 sqm
Providing a depth of 0.003 m
Width of channel = Gross vertical area / depth
= 0.0038/0.003 = 1.2700 m
The velocity of flow in screen chamber = Maximum flow/(Providing depth*Width of channel) = 0.0030/(0.003*1.27) = 0.92 m/sec
Shape of bars : MS Bars
Size of bars : 10*50 mm2
Clear spacing : 30 mm (6-40mm for medium screens)
No. of bars required = 32 bars
Actual width of screen = No of bar*(clear spacing + dia. of bar) = 1.28 m
Actual depth of sewage flow = Gross vertical area/Actual width of screen = 0.0038/1.28 = 0.003m
Providing free board = 0.0050 m
Total depth of screen = 0.0080 m
Size of screen = 1.28*0.0080 m

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B. Primary Treatment Unit

1) Grit Chamber

To prevent scouring of already deposited particles the magnitude of "v" should not exceed critical horizontal velocity Vc .
The critical velocity , Vc , can be given by the following equation (Rao and Dutta , 2007)

$Vc = \sqrt{(8g/f \ \beta(Gs -1) d)}$

Where ,
β = constant
= 0.04 for unigranular sand
= 0.06 for non-uniform sticky material
f = Darcy weisbach friction factor = 0.03 for gritty matter
g = gravitational acceleration
Gs = specific gravity of the particle to be removed (2.65 for sand)
d = diameter of the particle

$Vc = \sqrt{(((8*9.81*0.06*(2.65-1)*0.2))/((0.03*1000)))} = 0.228$ m/sec

The grit chambers are designed to remove the smallest particle of size 0.2 mm with specific gravity around 2.65. For these particles, using above expression the critical velocity comes out to be Vc = 0.228m/sec
Keeping horizontal velocity 0.2m/s (<0.228m/s) to prevent scouring and detention time 60 sec (vary from 40-60s)
To lower the velocity, hydraulic structures like Sutro weir and Parshall flume should be provided.
Length of grit chamber = velocity of flow x detention time= 12.00 m
Volume of grit chamber = discharge x detention time
0.2100 sqm
Cross section area of flow = volume of grit chamber/length= 0.0175 sqm
Providing width of grit chamber = 3.00000 m
Depth of grit chamber = 0.0058 m
Now assuming Grit Generation (0.05 m3 per 1000 m3 of sewage) = 0.05 m3
Grit storage provided for average flow = 8.00 hr.
Storage Volume required = 0.01 m3
Grit storage depth = 0.29m
Providing free board = 0.50 m
Total depth of Grit chamber = 0.79 m

2) Skimming Tank

Detention time = 3 to 5 minutes
Compressed air required = 300 to 600 m3
Surface area required = A=0.00622q/Vr
Where ,
Q = Rate of flow of sewage in m/day
Vr = minimum rising velocity of greasy material to be removed in m/minute = 0.25 m/minute
Surface area required = 7.46 sqm
Side of tank = 3.00 m
Actual area of tank = 3.00*3.00 m

3) Primary Sedimentation Tank

Continuous flow tank is to be provided
Detention time (1-2hrs) = 2.00 hr.
Quantity of sewage treated = 25 m3
Assuming that the low velocity through the tank = 0.30 m/minute
The length of tank required = Velocity of flow * Detention time = 36.00 m
Cross section area of the tank required = capacity of the tank/length of the tank= 1.00 sqm
Assuming that the water depth in the tank = 5.50 m
Width of the tank required = Area of cross section/Depth = 0.18 m

Since the tank is provided with mechanical cleaning arrangement , no space at bottom is required for sludge zone .
Providing free board = 0.50 m
Overall depth of the tank = 6.00 m
Rectangular sedimentation tank = 36.00*0.18*6.00 m

C. Secondary Treatment Unit

1) Aeration Tank

BOD of sewage aeration tank = 189.00 mg/L
BOD left in the effluent = 25.00 mg/L
BOD removed in activated plant = 86.77%
BOD upto 85%-92% conventional aeration process adopted
Volume of the aeration tank can be designed by assuming a suitable value of MLSS and θc (or F/M ratio)
MLSS (between 1500-3000 mg/L) = 2500.00 mg/L
F/M ratio (between 0.3 to 0.4) = 0.30 YO XT
F/M= Q/V X (Y)/X
V = 75.60 m3
Adopt an aeration tank of Liquid Depth = 5.00 m
Width of tank = 20.00 m
Length of tank = V/B*D = 0.76 m
Provide two aeration tank , each of lengths = 0.38 m
Check for volumetric loading (0.4-0.7) = Q*YO/V 0.75
OK
Check for Return Sludge Ratio = QR/Q
Assuming SVI (50-150 ml/gm) = 100.00 ml/gm
Check for Return Sludge Ratio(0.25-0.5) = 0.33ml/gm
OK
As all the parameters of design are coming in range , Hence design is OK
Providing free board = 0.50 m
Aeration Tank = 0.38*20.00*5.50 m

2) Secondary Clarifier

No. of secondary clarifier = 1.0 no
Average flow = 300.00 m3 /day
Recirculated flow (assuming 50%) = 150.00 m3 /day
Total inflow = 450.00 m3 /day
Volume of tank = 37.5 m3
Assume liquid depth = 0.05 m
Area (=volume/depth) = 750.00 m2
Surface loading rate of average flow (25-35 m3/m/hr)
Surface area to be provided = 10.00 m2
Taking area whichever is higher = 750.00 m2
Dia of circular tank (d) = 30.90 m
Check for weir loading
Average flow = 300.00 m3/day
Recirculated flow (assuming 50%) = 150.00 m3/day
MLSS in tank = 25.00 mg/l
Total solid in inflow = 11.25 kg/day
Solid loading = 1.1250 kg/day/m
Providing freeboard = 0.005 m
Overall depth = 0.055 m

VI. CURRENT CHALLENGES FACED BY SEWAGE TREATMENT PLANT

1) One of the primary challenges faced by Sewage Treatment Plants is managing the capacity to handle the incoming wastewater. Some of the STP is operating beyond its designed capacity which can lead to inadequate treatment and potential environmental issues.
2) The few Sewage Treatment Plants have aged infrastructure which has lead to leaks, blockages, and equipment failures that have affected the proper functioning of the treatment plant.
3) Operation of various units of sewage plant such as aeration, pumping, sludge treatment is energy intensive which reduces the overall efficiency and increase energy usage
4) Many STP struggles with effective removal of nutrients like nitrogen and phosphorus from the wastewater. These nutrients, if not properly treated, can lead to water pollution and ecosystem imbalances in receiving bodies of water.
5) Sewage treatment produces sludge as a byproduct. This Sludge digestion and beneficial reuse is a biggest challenge faced by many plant due to regulatory requirements and environmental concerns.
6) Sewage treatment plant is generating unpleasant odor which create nuisance to nearby residents and students.
7) There is no accurate Monitoring Equipment, quality protocols and regular audits to ensure compliance with environmental regulation and quality standards.

VII. SCOPE OF IMPROVEMENT OF SEWAGE TREATMENT PLANT

1) Upgrading and expanding the plant's infrastructure can be done in case the treatment plant is working beyond its capacity .
2) In case of leaks, blockage or equipment failure, inspection and repair or replacement of damaged pipes, pumps and valves should be done. Also, proper maintenance practice should be done.
3) Finding ways to optimize energy usage and improve overall efficiency can help reduce operational costs and environmental impact. Implementing energy-efficient technologies or exploring alternative energy sources, such as solar or biogas, can be potential solutions.
4) Implementing advanced treatment processes like biological nutrient removal (BNR) or enhanced tertiary treatment methods may be required to effective nutrient removal.
5) Developing effective sludge management strategies, such as sludge dewatering, anaerobic digestion, or composting, can help reduce disposal costs and promote sustainable practices leads to proper sludge management.
6) Implementing odor control measures, such as covering tanks, improving ventilation systems, or using chemical neutralizers, can help mitigate the odor-related issues.
7) Installing and maintaining accurate monitoring equipment, establishing rigorous quality control protocols, and conducting regular audits can help identify any deviations and enable timely corrective actions.
8) Some effluent can be used for the nearby irrigation purpose which can improve the surrounding environment.

VIII. RESULTS AND DISCUSSIONS

1) From all the above data and analysis we have seen the problems associated with the STP and also suggested some methods of improvements in the existing sewage treatment plant and the design will be implemented in future when the capacity of flow increase .
2) Wastewater Treatment performance now-a-days a very big problem for the society but by improving some methodologies we can solve it .
3) There are a lot of upcoming technologies which increases the performance and quality of waterwater in the plant
4) After following the designing procedure , the size of different treatment units required are as follows –

   Size of screen – 1.28m x 0.0080m
   Size of grit chamber – 12.00m x 3.00m x 0.79m
   Size of skimming tank – 3.00m x 3.00m
   Size of primary sedimentation tank – 36.00m x 0.18m x 6.00m
   Size of aeration tank – 0.38m x 20.00m x 5.50m
   Size of secondary clarifier – Diameter : 31m
   Depth : 0.055m

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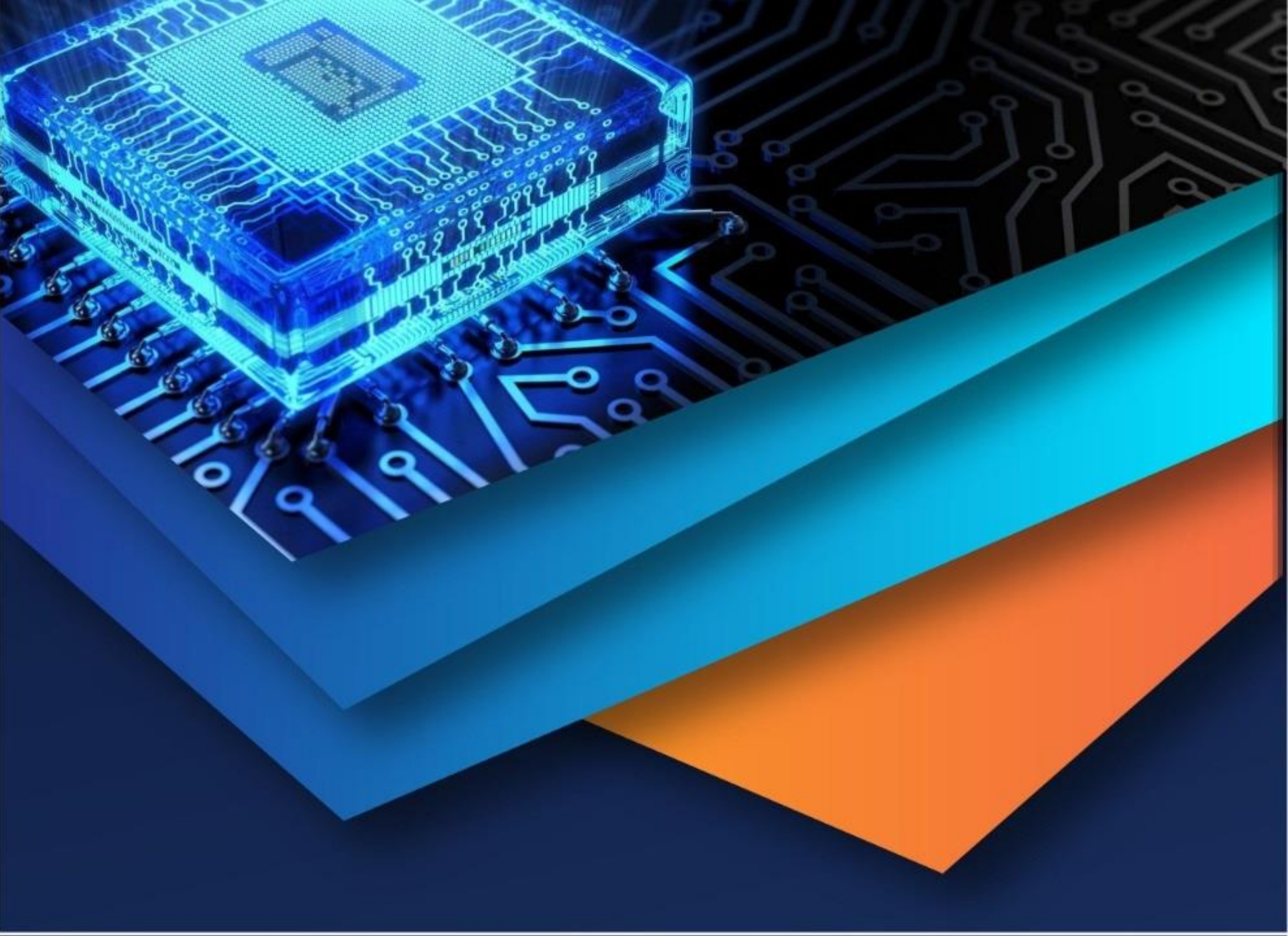

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