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Exploring Feasibility of Natural and Point of Use System for Sewage Treatment

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Abstract: ***This study presents an innovative approach to address the sewage treatment problem in Delhi, India, by combining natural and Point of Use PoU systems. The research focuses on the design and efficiency of a three-member series of waste stabilization ponds, which demonstrate a 97.45 efficiency in Biological Oxygen Demand BOD removal. The study also proposes the use of a Point of Use technology to further improve the quality of the effluent, making it suitable for human consumption and other uses. The proposed system is compared with the Rajokri Lake project, a government initiative for sewage treatment. The findings suggest that the proposed system outperforms the Rajokri Lake project in all effluent characteristics. However, the practical feasibility of the system is yet to be tested. The study concludes that if proven feasible, this system could be adopted on a large scale in areas lacking sewage systems, despite the potential drawback of requiring a significant amount of space.***

Keywords: Sewage Treatment, Waste Stabilization Ponds, Point of Use Systems, Biological Oxygen Demand, Rajokri Lake Project

1. Introduction

Water is an essential element of nature and plays a crucial role in our daily life. However, in developing countries like India there are various problem related to water. The lack of clean drinking water and pollution of rivers are some of the major ones.

One of the major contributors of river pollution is the unregulated disposal of wastewater and sewage which is the result of direct disposal of untreated sewage in rivers. The primary reason the waste remains untreated is the non-availability of sewage lines and sewage treatment systems.

To get a deeper understanding of the problem let's look at the situation of Delhi;

The United Nations estimates the population of Delhi at 28 million (World Cities, UN, 2018). It was shown in a study that 18% of this population doesn't get piped water supply (DownToEarth, 2018).

The minimum water requirement for a single person in a city with population greater than 200 thousand is 135 litres (NBC 2016, BIS). Therefore, the daily requirement of the people not connected to the piped system is 680 Million litres daily.

Another fact is that around 40% of Delhi households are not connected to proper sewage line (Times of India, 2019). The resulting sewage finally goes to Yamuna without proper treatment which is required for sewage before disposal.

Delhi generates 3268 million litres (MLD) of sewage per day, however only roughly 2083 MLD gets processed, despite a treatment capacity of 2756 MLD (ENVIS centre on Sanitation, 2020). Despite numerous attempts to treat more sewage, none of them have proven successful. Some plants are not getting enough sewage to meet their design requirements, resulting in capacity underutilization.

Many sewage treatment plants are not operating at full capacity, and reporting and response systems are inadequate. Hence, there is a dire need to treat the sewage and solve this problem.

2. Objective and Scope

This study is an effort to ideate a generalised solution to the sewage problems by the development of Sewage treatment system which can treat wastewater and provide clean water in small colonies of Delhi or any place.

The treated effluent if it is of permissible quality can be used in houses where piped water connection is not available for various uses such as drinking, bathing etc.

This study proposes a combination of natural and a man-made Point of Use (PoU) system which can treat the sewage to a suitable extent.

We'll take BOD, Pathogens and Solids as our primary parameters which our system will try to remove to a limit which is deemed fit for consumption and other human uses.

We'll also compare our system's efficiency with the Rajokri Lake project which is a project carried out by Delhi Govt. to treat sewage and convert the effluent into lake water and revitalise the nearby lake.

2.1 Review of Waste Stabilization Ponds

Open basins built to treat sewage and give extensive detention periods ranging from a few to several days are known as stabilisation ponds. The organic material in sewage is stabilised in the pond during this time.

In comparison to traditional approaches, pond systems are less expensive to build and operate. They also don't require highly trained operational personnel, and their performance is consistent from day to day.

2.1.1 Classification of Ponds

Aerobic

Aerobic ponds are meant to keep the air thoroughly oxygenated. The ponds are kept shallow, with a maximum depth of 0.5 metres. These types of ponds encourage a lot of algae development and have only been utilised as a test.

Anaerobic
Municipal sewage is occasionally pre-treated in completely anaerobic ponds. To save land, these ponds are built with a depth of 2.5 to 5 metres. Due to the discharge of sulphide gases, they have an odour problem.

Facultative
At the surface of the facultative pond, aerobic conditions prevail, while anaerobic conditions prevail at the bottom. The sulphide gases are oxidised by the aerobic top layer, which prevents bad odours. Because the facultative pond is so widely utilised, the use of ponds will be confined to these ponds only.

2.1.2 Mechanism of Purification
Both aerobic and anaerobic processes stabilise sewage organics. The non-stable and dissolved organic matter in the incoming sewage is oxidised to carbon dioxide and water at the top aerobic layer, where oxygen is supplied by algae photosynthesis.

The dissolved and suspended organics in the bottom layers, as well as the settled sludge mass coming from raw waste and microbial synthesis in the aerobic layer, are stabilised by conversion to methane, which escapes the pond as bubbles.

2.1.3 Reactions
In a facultative pond, the depth of the aerobic layer is determined by sun radiation, waste properties, and temperature. As the organic loading increases, algae produce less oxygen than is required, and the depth of the aerobic layer declines. The oxygen that diffuses from the top layers is promptly and totally consumed.

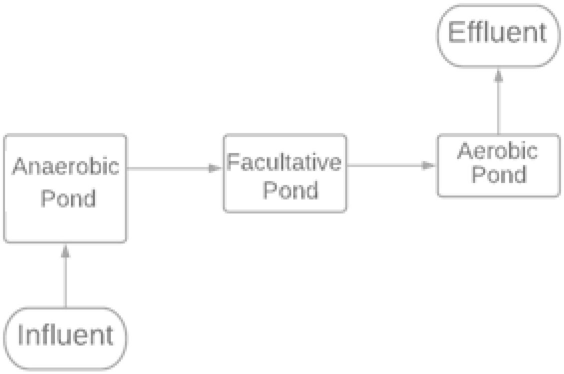

Figure 2.1: Schematic of Waste stabilisation Ponds

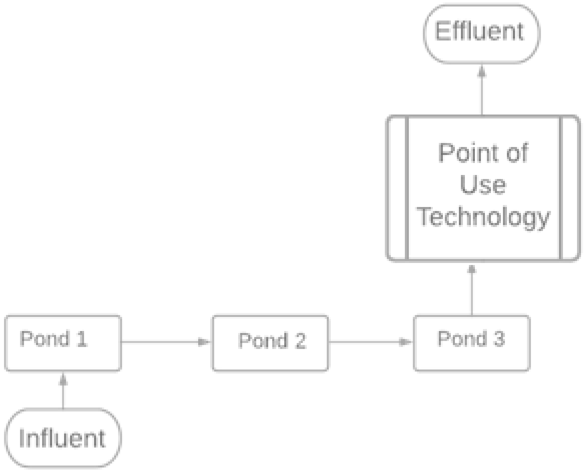

Figure 2.2: Proposed Sewage Treatment System Schematic

3. Methodology

This research paper concentrates on finding a feasible and effective solution to the sewage problem in Delhi. This is done in three sections. First section contains the data which is collected from various research papers and also the project of Lake Revitalisation of Rajokri Village, New Delhi. The second section contains the designing of the waste stabilisation ponds which are first part of the two part sewage treatment system proposed in this paper. Third section contains the information about the Point of use technology which is the second and final part of the system.

3.1 Data Collection through Literature Review

3.1.1Data of the sewage influent quality
This data will give us a rough estimate of the expected parameters of the Influent sewage.

For this, The data is taken from a research paper on **Rajokri Lake project** (Shrivastava and Prathna, 2021). The project was done to revitalise a dry water lake in Rajokri, a village at the Delhi-Gurgaon Highway.

Rajokri's WWTP has a capacity of 0.6 MLD. It made use of the "scientific wetland with active biodigester" (SWAB) technology, which was created to treat domestic wastewater before being utilised to fill the lake.

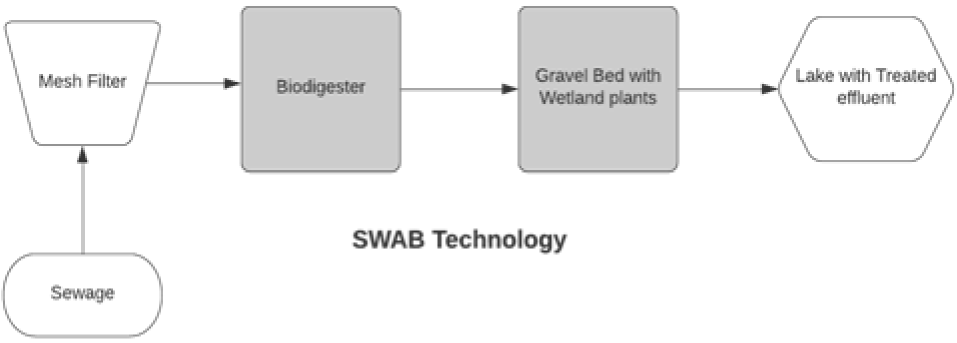

Figure 3.1: Rajokri Project Schematic

The tank functions both to remove relatively large particles by sedimentation and initiate anaerobic digestion as it contains a mix of microorganisms isolated from centralized WWTPs. The partially treated water flows on to a gravel bed for further treatment.

The partially treated effluent is transported from the sedimentation tank to the gravel bed by solar-powered pumps (wetland system). From top to bottom, the pebbles in the gravel bed increase in size. Natural auxins were used to promote the bioremediation of *Cyperus alternifolius and Canna indica*. To give further treatment, these wetland plants are cultivated in the gravel bed.

The initial and resultant parameters of its influent and effluent are:

Table 3.1: Data of Rajokri lake (Shrivastava and Prathna, 2021)

Parameter	Influent	Effluent
BOD (mg/l)	124	17
TSS (mg/l)	116	16
Coliform (MPN/ml)	1.1×10^7	6.1×10^3

3.1.2 BOD permissible limits for various water uses

The value of BOD for drinking water should be less than 2 (mg/l) for 20 degrees for 5 days (CPCB, 2019). Ideally it should be zero.

For bathing, the value should be less than 3 (mg/l).

The BOD for safe disposal of treated effluent into water bodies is 20 mg/l (CPCB, 2019).

3.1.3Groundwater Quality of Delhi

The groundwater parameters are also important for the project and these values are obtained from a research paper on Hydro-Chemical Survey of Groundwater in Delhi.

Table 3.2: Data of Delhi's groundwater (Alam et al, 2008)

Parameter	Lower Limit	Upper Limit
BOD (mg/l)	0.44	3.9
TDS (ppm)	190	1430

3.1.4 TDS, TSS and Coliform removal by Waste stabilisation ponds

The efficiency of Waste stabilisation ponds system in removing TDS, TSS is between 90-97% (Nwankwo et al. 2019) , while Coliform reduction achieved is around 6 log (Verbyla et al. 2017).

3.1.5 TDS in Sewage wastewater

The range of TDS was observed to be between 1700-2500 ppm in a research conducted by Indian Agricultural Research Institute, Delhi (Sharma and Khan, 2013). The average was 2107 and standard deviation was 356.9 (Sharma and Khan, 2013).

3.4 Designing of Waste stabilisation ponds

For preparing a real life model, the ponds will be based on the Rajokri Data. The WWTP in Rajokri created a STP of 0.6 MLD.

We'll have 3 facultative ponds in series as the flow of wastewater is neither plug flow nor complete mix which is both the ideal cases. This model will represent the flow which will be somewhere in between these flows.

The design of the ponds will be based on the BOD parameter as it is the only parameter which has empirical formulas in the waste stabilisation ponds system.

Formula of BOD used (Sperling, 2007):

$$S = \frac{S_o}{\left(1 + \frac{Kt}{n}\right)^n} \#(3.1)$$

Where;
S = Final BOD;
S_o = Initial BOD;
n = number of ponds in series
K = BOD removal coefficient (d^{-1})
t = time (d) = HRT

$$\textbf{Hydraulic Retention Time (HRT)} = \frac{V}{F} \#(3.2)$$

Where;
V= Volume of Container
F= Influent flow rate

BOD removal coefficient formula

$$K_T = K_{20}.X^{(T-20)} \qquad (3.3)$$

Where;
K_T= BOD removal coefficient at a temperature T (d^{-1})
K_{20}= BOD removal coefficient at a temperature of 20°C (d^{-1}) = 0.3
T = liquid temperature (°C)
X = Temp. Coefficient = 1.05

- Assuming Delhi's average temperature = 30^0 C
  K_{30} = 0.49
- n = 3 (3 ponds in series)
- t = detention time in the system = 15 days (assumed)

As we're designing for 0.6 MLD system;
F = 0.6 MLD = Influent flow rate
Total volume of ponds = 9 ML
Volume of each pond = 3 ML = 3000 m^3

As the Recommended height for facultative ponds is between 1.5 – 3 m. Let **H = 3 m.**
Therefore, length x breath of pond = 1000 m^3
Keeping L/B = 2.5
L = 50 m; B = 20 m; H = 3 m

3.2 Addition of Point of Use Technology

For making the effluent of the system usable for activities like Drinking, Bathing and Gardening the TDS, coliform and BOD quality has to improve further.

For that a Point of use technology has to be used.

The requirement of the proposed system is a system which can have a capacity of 0.6 MLD.

Kemflw Pvt. Ltd is one such company which offers this type of product. It offers industrial level RO systems which can help reduce the desired parameters.

A product which can have a capacity of 0.6 MLD will be used in the proposed system.

For the calculation of the efficiency of parameters removal rate of this system, we can use the values of Groundwater water as these make groundwater fit for potable uses.

Therefore the Point of Use technology can make water of equal parameters as groundwater i.e.; BOD 0.5 – 4 mg/land TDS 1400 ppm (Alam et al, 2008) and make it fit for consumption by reducing these parameters to negligible levels.

4. Results

4.1Dimensions of Ponds

Height = 3 m, length = 50 m, breadth = 20 m

The ponds will be of 3000 m^3 volume each.

4.2Effluent Characteristics

BOD removal if there are only n ponds.

Table 4.1: BOD removal with different number of ponds

Pond (n)	Days	Effluent BOD
1	15	15.12
2	15	5.86
3	15	3.15

Hence, **BOD of final effluent from Waste Stabilisation Pond = 3.15 mg/l**
Efficiency = 97.45% BOD removal
Effluent TDS = 210 ppm (assuming 90% efficiency)
Effluent TSS = 11.6 ppm (assuming 90 % efficiency)
Effluent Coliform = 11 MPN/ml (assuming 6 $\log_{10}$ efficiency)

4.3Parameters removal from Point of Use Technology

As the effluent lies in the range of groundwater, our POU technology can treat this water and it can be used for human purposes.

4.4 Comparison with Rajokri WWTP

The waste stabilisation pond system outperforms the Rajorkri WWTP in every effluent characteristic.

5. Summary and Conclusion

The combination of natural and point of use technology can convert wastewater into usable form.

3 member series of waste stabilisation pond has efficiency of 97.45 % in removing BOD.

Even if, the point of use technology is not used the natural system converts sewage in to water can be safety disposed in rivers.

If this model turns out to be practically feasible it should be adopted in a large scale in places where sewage lines don't exist.

The only drawback of this system is that it may require large amount of space to function owing to the large pond size required. However, this model can work in most of the villages as they don't have sewage systems and abundant free land.

6. Future Work

A mini version of this system can be made and put to use to check its efficiency in practical scenario.

A comprehensive list of the settlements in Delhi where this system might work should be prepared based on the data of non-availability of piped water supply, land availability and absence of sewage systems.

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