Design of a Non-Mechanized Plant (Natural Method) For Treating Sewage for a Small Town Pethapur

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Abstract— Pethapur is a medium sized municipal town in Gandhinagar District with 2011 census population of 2,20,000 currently under consideration for developing its sewerage system. As a suitable sewage treatment plant and disposal facilities will be needed immediately on completion of the conveyance system, it is intended to develop an appropriate design of a sewage treatment plant for the town to be developed in phases. This paper presents the Non mechanized means of treating domestic sewage i.e. natural way of treating sewage; which will be robust and comparatively cheap, easy to operate to obtain desired quality of treated sewage for disposal into a farming land nearby with a bypass arrangement to a natural drain.

Key words: STP; Sewage; Stabilized Pond; Facultative Pond.

I. INTRODUCTION

A. General

Many settlements in India are not served by public sewers. Residents in these areas are therefore required to provide their own sewage treatment facilities. Piped sewage conveyance Systems are being developed gradually in many areas with the help of private designers and consulting engineers. It is therefore desirable that engineers who have the right education and interest in the subject come forward and provide necessary assistance to the nodal agencies in developing suitable treatment plants in the above project area.

The function of an STP is for treating collectively any wastes of the kind that are ordinarily discharged from toilets, water closets, baths, showers, sinks, basins and other sanitary and kitchen fitments.

B. The composition of wastewater

Human waste or more technically referred to as ‘excreta’ is defined by Chamber’s Concise 20th Century Dictionary as “useless matter discharged by animal alimentary”, animals being humans in this context. Excreta is made up of a solid matter, faeces, and a liquid matter, Urine and is essentially an organic compound. The constituents making up the compound are carbon, nitrogen, phosphorous, sulphur and hydrogen. Also present are fats, carbohydrates, enzymes, proteins, trace elements, pathogens and many different bacteria.

C. The need to treat sewage

It is unhealthy for humans, pets, and wildlife to drink or come in contact with surface or ground water contaminated with wastewater. Inadequate treatment of wastewater allows bacteria, viruses, and other disease-causing pathogens to enter groundwater and surface water. Hepatitis, dysentery, and other diseases may result from bacteria and viruses in drinking water. Disease-causing organisms may make lakes or streams unsafe for recreation. Flies and mosquitoes that are attracted to and breed in wet areas where wastewater reaches the surface may also spread disease.

Inadequate treatment of wastewater can raise the nitrate levels in groundwater. High concentrations of nitrate in drinking water are a special risk to infants. Nitrate affects the ability of an infant’s blood to carry oxygen, a condition called methemoglobinemia (blue-baby syndrome).

The total management of wastewater can be separated into four categories:

1. Wastewater collection,
2. Wastewater treatment,
3. Treated wastewater disposal and,
4. Sludge management.

Wastewater only becomes non-hazardous to human health and marine life after treatment.

D. Wastewater Treatment

“The term treatment means separation of solids and stabilization of pollutants. In turn stabilization means the degradation of organic matter until the point at which chemical or biological reactions stop. Treatment can also mean the removal of toxic or otherwise dangerous substances (for e.g. heavy metals or phosphorous) which are likely to distort sustainable biological cycles, even after stabilization of the organic matter.” The wastewater treatment can be by mechanized sewage treatment plant i.e. STP or by non-mechanized plant.

E. Early Historic Times

The use of sewers is not new. In the Indus city of Mohenjo-Daro (located in Pakistan) the wealthy as well as some of the peasants used latrines and cesspools. These were connected to drainage systems in the streets from whence the liquid flowed to cesspools or through drains to the nearest river. In some cases terracotta pipes were used to connect second-floor bathrooms to street sewers. Archaeologists have found four separate drainage systems at King Minos’ Royal Palace at Knossos (Crete), which dates from 1700 BC. The wastewater drained through terracotta pipes which were joined with cement into stone sewers. Rainwater-fed cisterns and stone aqueducts tapped available water sources to deliver a continuous flow of water through the bathrooms and latrines which eventually discharged to the Kairatos River. From 2000 BC the island of Crete had a drainage system made up of terracotta pipes with bell and spigot joints sealed with cement. The system conveyed mainly storm water but also some human waste. Water stored in large jars was used to fill the system periodically. Wolfe (1999) states that many of the drains are still in use today. There was a recent discovery of a stone lavatory with running water in a royal tomb from the Western Han
dynasty (206 BC to AD 24) in the central province of Henan, China (Rennie 2000).

F. Objective
The project aims at designing a suitable non mechanized for the domestic sewage for reuse in agriculture. This will enhance the standard of living of the people of the town through better sanitation.

II. DATA COLLECTION
General design considerations: We are treating only Domestic Sewage.

A. Project area characteristics
We selected Pethapur town for designing the STP.

- Terrain features: generally flat
- Climate: Hot and arid
- Nearby River: Sabarmati
- Type of Soil: Granular

B. Data collected:

<table>
<thead>
<tr>
<th>Designed Population (2031)</th>
<th>2,20,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD₅</td>
<td>200mg/l</td>
</tr>
<tr>
<td>TSS</td>
<td>180mg/l</td>
</tr>
<tr>
<td>Ph</td>
<td>7.5</td>
</tr>
<tr>
<td>Ground water Infiltration</td>
<td>15%</td>
</tr>
<tr>
<td>COD</td>
<td>300mg/l</td>
</tr>
</tbody>
</table>

Table 1: From GUDCL (Gujarat Urban Development Company Ltd.)

III. DESIGN:

A. Estimation of sewage flow for Pethapur:

Per capita water supply rate =135 lpcd

Average daily demand=135×2, 20,000

=29.7 mld

=0.34375 m³/s

Assumed 80% of water supplied discharged as sewage=80%×0.34375

=0.275 m³/s

Peak factor=2 , for population above 2,00,000

Infiltration rate=15%

So, peak discharge=0.275×2+0.15×0.275

=0.59m³/s

- Non mechanized plant:

It includes following units:

(1) Screen Chamber
(2) Grit chamber
(3) Facultative stabilization pond

B. Bar screens:

- Purpose:

To remove large objects (sticks, cans, etc) which may cause flow obstructions. Depending on the size of the plant, bar screens are either hand or mechanically cleaned. Hand cleaned is used for this plant. Excessive screen channel width which results in shallow depth of flow should be avoided.

- Design:

Bars of 10 mm ×50mm are used with 10mm dimension facing the flow.

Assume velocity through screening =0.8 m/s

Net area of screening = 0.59/0.8

=0.737m²

Number of bars =10

Center to center spacing between bars=40mm

Gross area= Net area [Clear spacing + bar thickness]

=0.737×[40+10]/40

=0.92125 mm²

Screening is at 45 degree inclination with horizontal

=0.92125/sin45

=1.3755mm²

C. Grit chamber:

- Purpose:

To remove inorganic material referred to as grit. Grit includes sand, eggshells, bone chips, coffee grounds, etc. that may clog channels. Grit chambers are, infect, nothing but like sedimentation tanks, designed to separate the intended heavier inorganic materials by the process of sedimentation due to the gravitational forces & to pass forward the lighter organic material.

The grit chambers are usually placed after the fine screens, to remove particles of size up to 0.2 mm or so.

- Design of Grit Chamber:

Length of the tank=velocity detention time

=0.2×(2×60)

=24 m

Cross section area required=0.59/0.2

=3m²

Assuming the water depth in tank=1.2m

Width of tank=area of cross section/depth

=3/1.2

=2.5m

Free board=0.3 m (assumed)

Thus the overall depth of tank =1.2+0.3+0.45

=1.95m

Grit chamber (rectangular) =24×2.5×1.95

D. Stabilization pond

Technology - sometimes also called Facultative pond technology - is a natural method for wastewater treatment. Facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. They are often about 1 to 2 m in depth. The aerobic layer acts as a good check against odour evolution from the pond.

E. Mechanism of purification:

The functioning of a facultative stabilization pond and symbiotic relationship in the pond are shown below. Sewage organics are stabilized by both aerobic and anaerobic reactions. In the top aerobic layer, where oxygen is supplied through algal photosynthesis, the non-settleable and dissolved organic matter is oxidized to CO₂ and water. In addition, some of the end products of partial anaerobic decomposition such as volatile acids and alcohols, which may permeate to upper layers are also oxidized periodically. The settled sludge mass originating from raw waste and microbial synthesis in the aerobic layer and dissolved and suspended organics in the lower layers undergo stabilization through conversion to methane which escapes the pond in form of bubbles.
production by algae falls short of the oxygen requirement and the depth of aerobic layer decreases. Further, there is a decrease in the photosynthetic activity of algae because of greater turbidity and inhibitory effect of higher concentration of organic matter.

Gasification of organic matter to methane is carried out in distinct steps of acid production by acid forming bacteria and acid utilization by methane bacteria. If the second step does not proceed satisfactorily, there is an accumulation of organic acids resulting in decrease of pH which would result in complete inhibition of methane bacteria. Two possible reasons for imbalance between activities of methane bacteria are: (1) the waste may contain inhibitory substances which would retard the activity of methane bacteria and not affect the activity of acid producers to the same extent. (2) The activity of methane bacteria decreases much more rapidly with fall in temperature as compared to the acid formers.

Thus, year round warm temperature and sunshine provide an ideal environment for operation of facultative ponds.

G. Detention Time

The flow of sewage can approximate either plug flow or complete mixing or dispersed flow. If BOD exertion is described by first order reaction, the pond efficiency is given by:

For plug flow: \( L/L_1 = e^{-kt} \)

For complete mixing: \( L/L_1 = \frac{1}{1+k_1t} \)

For dispersed flow the efficiency of treatment for different degrees of intermixing is characterized by dispersion numbers. Choice of a larger value for dispersion number or assumption of complete mixing would give a conservative design and is recommended.

Depth: Having determined the surface area and detention capacity, it becomes necessary to consider the depth of the pond only in regard to its limiting value. The optimum range of depth for facultative ponds is 1.0 - 1.5 m.

H. Design:

Organic loading= 200 kg/ ha. /day

The quantity of sewage to be treated = 0.59 cubic meter per second

The BOD Content per day= 0.59×200

=118 Kg

Surface Area Required= BOD content per day ÷ Organic loading

=118÷200

=0.59 Ha

=5900 square meter

Ratio of length /width=2

Area= Length × Width

5900=2 (B×B)

Hence B=54 meter

L=2(B)

=108 m

Using effective depth of tank=1.2 m

Hence the capacity of tank provided=108×54×1.2

=7000 cubic meter

I. Merits of Non mechanized plant over Mechanized plant

- In a tropical country like India there, sun shines almost 320-330 days from 365 days. Hence a non-
mechanized plant is a good option for our town Pethapur.
− Non mechanized plant is operated by solar energy.
− A Non mechanized plant is much cheaper than Mechanized plant.

IV. CONCLUSION
Sewage treatment plan designed in this report will be useful for the purpose of disposal of the sewage to be generated from Pethapur town in future. This design also be taken up with Gujarat Urban Development company Ltd. (GUDCL) in case they are interested to use our professional service. No cost estimation has been carried out.

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REFERENCES
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