Environmentally Sustainable Sewage Management Strategy-A Case of Jamshedpur, India

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ABSTRACT

With the rapid growth of urbanization and industrialization, the generation of municipal sewage is increasing on a time scale. Presently, there are no treatment facilities available in majority of class 1 and 2 towns in India. Consequently, sewage water is either being discharged into rivers, natural water courses or on low lying lands thereby polluting the water resources and causing various diseases. There exists a strong need to address this problem on a scientific scale with integrated and sustainable approach. An effort has therefore been made by the authors of the present paper to carry the case study of Jamshedpur, India in which population trends along with forecasting is done. Similarly, trends of sewage generation and forecasting on a time scale were done. An attempt has also been made to highlight the waste water treatment methods with focus on the design of Aerated lagoon method to treat the municipal sewage. An approach has been adopted to make it environmentally sustainable.

INTRODUCTION

Wastewater is considered to be a major part of the water management cycle, yet used water is considered to be an unnecessary load and is expected to be discharged as soon as possible or often ignored. With the rapid increase in population and the increase in the water demand the wastewater becomes a great alternative source of water. Due to this, the approach towards the wastewater changes completely, which is the shift from the concept of treating and disposing it off to reusing it, recycling it and recovering its resources. An overall observation of sewage treatment globally concludes that almost 70% of the wastewater is being treated in high income countries, whereas in middle income countries out of the total generated wastewaters only 38% of it undergoes treatment and it further reduces in lower income countries, 8% of the entire generated wastewater. If we accumulate the data, then it concludes that approximately 80% of the wastewater remain untreated. The major reasons for sewage waste treatment are improvement of environment quality and using the wastewater as an alternate source of energy in order to reduce water scarcity this concept mostly works for developed countries. Whereas, in developing countries release of untreated waste waters in open is very common. This is mainly because of the lack of proper infrastructure, technology, capacity building and finances as well [1]. If considered region wise, one of the biggest problem in Africa as far as wastewater management is considered is its lack of proper infrastructure for collecting and treating the wastewater which results into the pollution of limited surface and groundwater resources. In some Middle Eastern states (or Arab states) wastewater has been safely treated and reused and has become one of the main reasons why the water table did rise, which is one of the main component of water resource management plans. In 2013, around 71 percent of the wastewater has been treated in Arab states out of which 21 percent of wastewater has been used for irrigation purpose and groundwater recharge. In Asia and Pacific regions, due to lack of human and

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financial resources the municipalities and the urban local bodies are unable to imply the environmental regulations concerned to wastewater management and to reuse its resources to get environmental benefits [2].

In India with the increase in the population and urbanisation there is also a rapid increase in the domestic water supply and also to the amount of grey or wastewater generated. According to CPHEEO almost 70%-80% of the water that is being used for domestic purposes is generated as wastewater [3]. The class I and class II towns which represent almost 72% of the entire urban population of India generates wastewater of 98 litres per capita per day. Whereas, the National Capital Region Territory-Delhi alone generates wastewater of more than 220 litres per capita per day, which is 3,663 million litres per day out of which 61% of wastewater is treated [4]. Thus overall as per CPCB, total wastewater generated from the 498 class I cities is 35,558 million litres per day and 410 class II cities generates 2,696 million litres per day. Overall 70% of the total population is provided with sewerage facility as compared to 48% in 1988 [5]. Almost 63% of the total wastewater generated from the entire country is generated from Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat [6]. As per an estimation by UNESCO and WWAP (2006) India has one of the lowest industrial water use productivity, 3.42 to be approximate, which is 1/30th of that of Japan and that of Republic of Korea [7]. As per the future projections of 2050, India would generate wastewater of 48.2 billion cubic meters (132 billion liters per day) which have a potential to meet 4.5% of the total irrigation water demand, which would further increase the gap between reuse, supply and demand [8]. In India there 234 STPs for waste water treatment and are mostly located in cities or towns along the banks of major rivers. Other than domestic sewage in India, nearly 13468 million liters per day of Industrial wastes is generated, out of which nearly 60% of waste water is being treated [3,9].

Sewage disposal system is another integral part of Jamshedpur city and the entire connected network of the area under its services proves to be quite beneficial. The wastewater and sewage is connected to a state-of-the-art plan that treats sewerage at a level more than satisfactory and is being recycled. The city is now in the process of recycling and reusing of the treated sewage water into other purposes such as irrigation. The main objective behind it is to reduce the river water use and to achieve the zero liquid discharge within the city planning area. Some of the wastewater solutions implemented within the city in the over the years include portable sewage treatment plants which is used to treat sewage water and reuse them for irrigation and other activities. A geographic information system and SCADA system is installed and used for real time data analysis and corrective measures for the sewage disposal system [10].

LITERATURE REVIEW

Wastewater treatment comprises of breakdown of complex organic compounds present in the wastewater in simpler stable and problem free compounds by physical, chemical or biological treatments. There are adverse and alarming effects on the environment when untreated wastewater is being discharged in groundwater, surface water or on land. The effects include the release of poisonous and malodorous gases into the environment, eutrophication of the water bodies due to the growth of aquatic plants and algal blooms so on and so forth [6].

Municipal Bodies reuse the wastewater after treatment in places such as parks, road plantations, parks, golf courses, playgrounds and used for flushing in toilets [11]. The Industrial uses of wastewater reuse include cooling of the industrial machineries and systems, used efficiently in food processing industries and other industries which involve high rate of water uses and finally most prominently used for agriculture (irrigation and aquaculture) [12,13]. In Middle eastern countries due to scarcity of groundwater, in the coming future installation of a dual distribution system would help to provide efficiently treated effluents which can be used for flushing in toilets of hotels and office buildings etc. [14]. At present, in India the treated wastewater is reused for gardening, irrigation, cooling of air conditioners, flushing, and in industries used in boilers and also as processed water as well [15]. China has developed a national policy that encourages reusing the treated wastewater for irrigation at first and then in industries and for municipal uses [16]. As far as Japan is concerned, the treated wastewater is used in toilet flushing, for industrial uses and stream restoration and flow augmentation to create “urban amenities” such as green areas, playgrounds, open spaces etc. [13].

A successful wastewater management should be initialized from the household level and is majorly dependent on the technologies (software) and the human resources [12]. Support from urban local bodies and other local bodies during treatment and recovery of wastewaters during wastewater management provides positive changes and also helps the pro-active institutions and the vertical support from the governments [6].

Some of the methods of Waste Water Treatment as far as hazardous waste are concerned, include use of gravity and reverse osmosis for physical method. For chemical method pH neutralization, oxidation, reduction and precipitation is to be considered. For Biological treatment the micro-organisms are used for degradation. For Thermal methods incineration and pyrolysis is commonly used. Sustainability of the Water Treatment Technologies depends on the functional performance, adaptability, durability, flexibility, maintenance, economic factors, environmental emissions, resource utilization and social indication of water quality [17].

CASE STUDY OF JAMSHEDPUR

Jamshedpur is a significant industrial city of the state Jharkhand. Including the urban agglomeration the city has a total population of 13,39,400 (as per census 2011). The city mainly has three water bodies, among which one is a lake known as Dimna lake and the other two are the rivers flowing within the city (Kharkai and Subarnarekha).

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In order to make a sewage disposal much more we very much need to consider the amount of sewage that is being generated and the amount of sewage is to be generated in future depending on the future population projection. Thus in order to find out the projected decadal population the present population as per census 2011 is to be considered. The projected decadal population is calculated mainly using three methods, that are Arithmetic Progression (AP), Geometric Progression (GP) and Incremental Method (**Table 1**).

In order to calculate the total sewage generation firstly we need to calculate the total water consumption based on the assumptions we make for the projected years. Thus the assumed water consumption for the existing year 2011 is taken to be 125 litres per person per day and it is increased by 10 litres per person per day in each decade. (**Figure 1, Table 2**)

The total water consumed by the entire projected population within a decade per day is calculated utilizing the assumed water consumption for each decade. (**Table 3, Figure 2**)

Table 1. Population projection shows the decadal population projections from 2021-2051 by Arithmetic Progression, Geometric Progression, Incremental method and finally the average of it, depending on the existing population of 2011.

Year	Projected Population by AP	Projected Population by GP	Projected Population by Incremental Method	Average projected Population
2011	-	-	-	13,39,400 (existing)
2021	1525800	1601458	1550680	15,59,313
2031	1712200	1914788	1786840	18,04,609
2041	1898600	2289421	2047880	20,78,634
2051	2085000	2737354	2333800	23,85,385

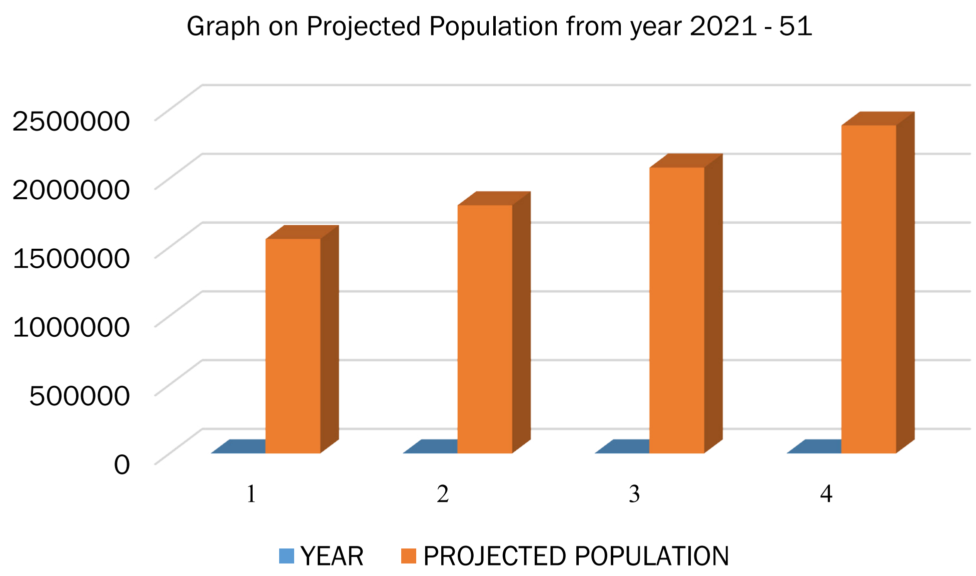

Figure 1. Population projection-The graph shows the decadal population projections from 2021-2051.

Table 2. Shows the considered water consumption which would be utilised to calculate the total projected water consumption depending upon its population.

Year	Water Consumption	Unit
2011	125	Litres/person/day
2021	135	Litres/person/day
2031	145	Litres/person/day
2041	155	Litres/person/day
2051	165	Litres/person/day

Table 3. Shows the total projected water consumption in each decade per day as per the projected population.

Year	Water Consumption (as per population)	Unit
2011	125 × 13,39,400=16,74,25,000	Litres/day
2021	135 × 15,59,313=21,05,07,255	Litres/day
2031	145 × 18,04,609=26,16,68,305	Litres/day
2041	155 × 20,78,634=32,21,88,270	Litres/day
2051	165 × 23,85,385=39,35,88,525	Litres/day

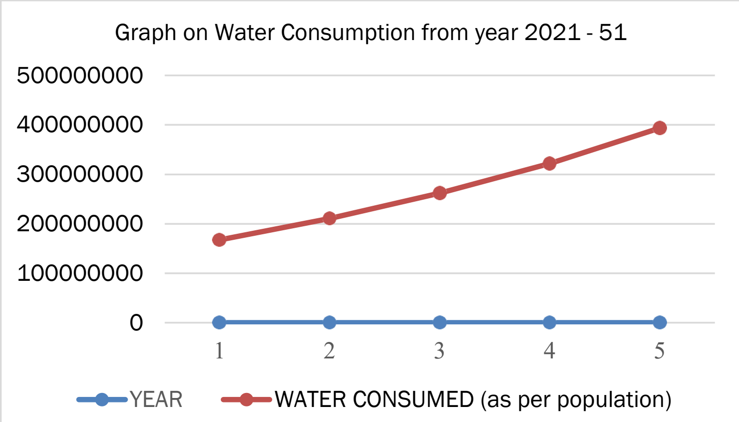

Figure 2. The Graph show the projected decadal water consumptions from 2021-2051.

As per the standards, out of the total water consumed in one day 70% of it is secreted as sewage. Thus from the decadal projected water consumption we can project the decadal sewage generation as well. (**Table 4, Figure 3**)

Table 4. Shows the total projected water consumption in each decade per day as per the projected water consumption.

Year	Sewage generated	Unit	Sewage generated	Unit
2011	16,74,25,000 × 0.7=11,71,97,500	Litres/day	117198	Cubic meters/day
2021	21,05,07,255 × 0.7=14,73,55,078.5	Litres/day	147355	Cubic meters/day
2031	26,16,68,305 × 0.7=18,31,67,813.5	Litres/day	183168	Cubic meters/day
2041	32,21,88,270 × 0.7=22,55,31,789	Litres/day	225532	Cubic meters/day
2051	39,35,88,525 × 0.7=27,55,11,967.5	Litres/day	275512	Cubic meters/day

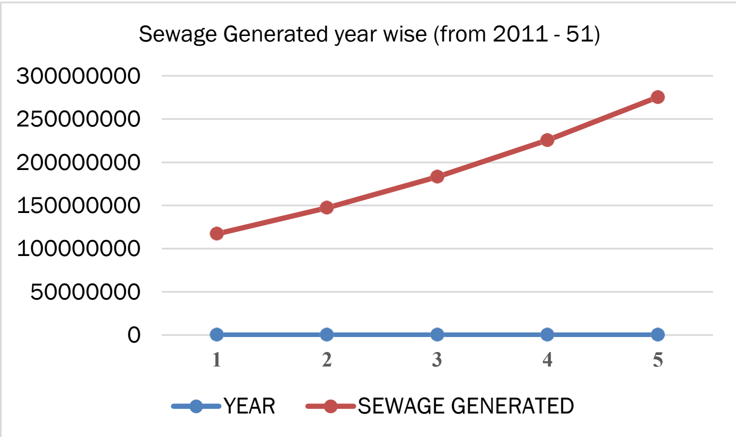

Figure 3. Projected sewage generation the graph shows the projected decadal water consumptions from 2021- 2051.

DESIGNING OF A WASTEWATER TREATMENT PLANT

Wastewater treatment can be divided majorly into four steps, that is:

- Preliminary Treatment–This treatment involves Bar screening and Grit removal
- Primary Treatment–This treatment involves use of Primary Clariier
- Secondary Treatment–This treatment involves the use of Aeration tank and Secondary Clariier
- Tertiary Treatment–Filtration, Disinfection and Nutrient removal

After the Tertiary treatment the water is ready to be reused for functional purposes such as irrigation or for domestic purposes or is disposed of to the nearest water body to raise the surface water level. Apart from the treated water the Activated sludge which is being generated during the primary and the secondary treatment proccess is being disposed off (**Figure 4**).

DESIGNING OF SCREEN CHAMBER

Screen Chamber is made up of rectangular bars and is a part of the preliminary treatment in the wastewater treatment

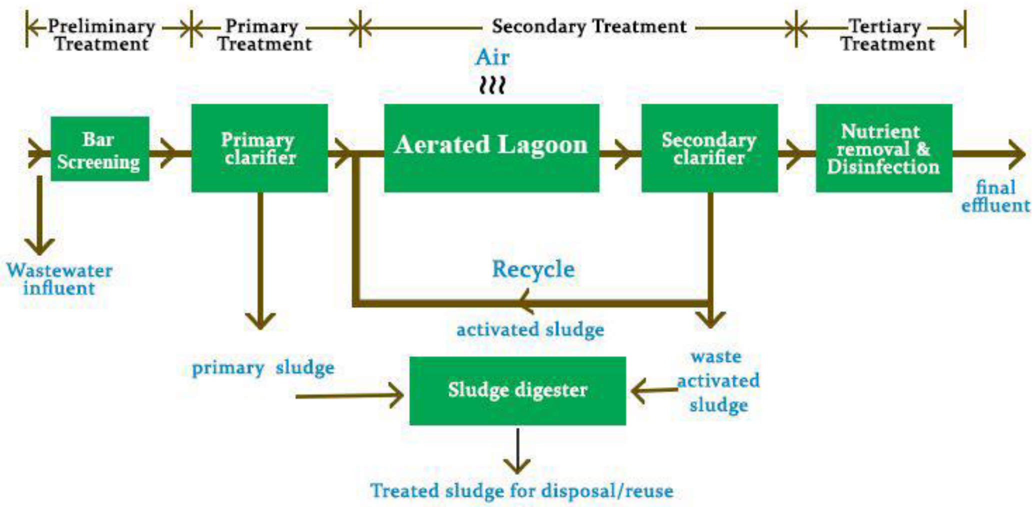

Figure 4. Shows the wastewater treatment proccess and the various stages involved.

plant. It is one of the initial stages of wastewater treatment. Screen chambers is a mechanical filter and is used to remove large objects such as rags, plastic, metal containers etc (**Figure 5**).

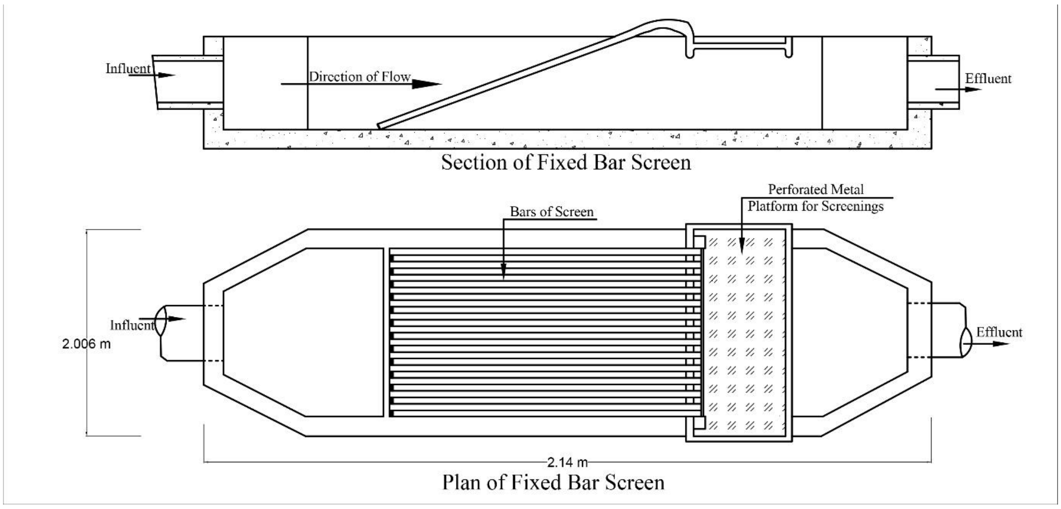

Figure 5. Shows the Plan and section of the proposed Screen Chamber.

In order to design a screen chamber the projected sewage of a particular projected decadal year needs to be considered. In this case, we are considering the projected population and the sewage generated of the year 2021. Thus the calculations ar as follows:

Volume of the amount of sewage being produced in the year 2021 is=147,355 m^3/day

Assuming the design rate flow is 1.5 times of the average regular flow.

Hence, the total volume to be handled by the screen chamber is=1.5 × 147,355=221,032.5 m^3/day

=2.56 m^3/sec

The velocity assumed for the ideal velocity flow throughout is 0.6 m/s.

Total area required to accommodate the wastewater flow=0.77/0.6=4.3 m^2

Depth of the wastewater flow=0.706 meter

Let the width of the opening of the chamber with rectangular bars be 1.55 meters=1550 mm

Using 12 mm rectangular bars at 50 mm centre to centre distance and

Clear opening=40 mm

End clearance=40 mm

Let number of bars in the screen chamber be n

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Total width of opening=(n+1) × 40

or, 1550=(n+1) × 40

therefore, n= 37.75=38 numbers

Henceforth,

Total width of the screen chamber= 155+38 × 1.2=200.6 cm=2.006 m

Total length of the screen chamber= 4.3/2.006=2.14 m

DESIGNING OF PRIMARY CLARIFIER

After the preliminary treatment the wastewater inserted into a sedimentation tank also known as primary clarifier. Thus, a Primary Clarifier is used for the removal of solids physically by using gravity and allows the solids and organic matter to settle down. Primary clarifier is a apart of primary treatment (**Figure 6**).

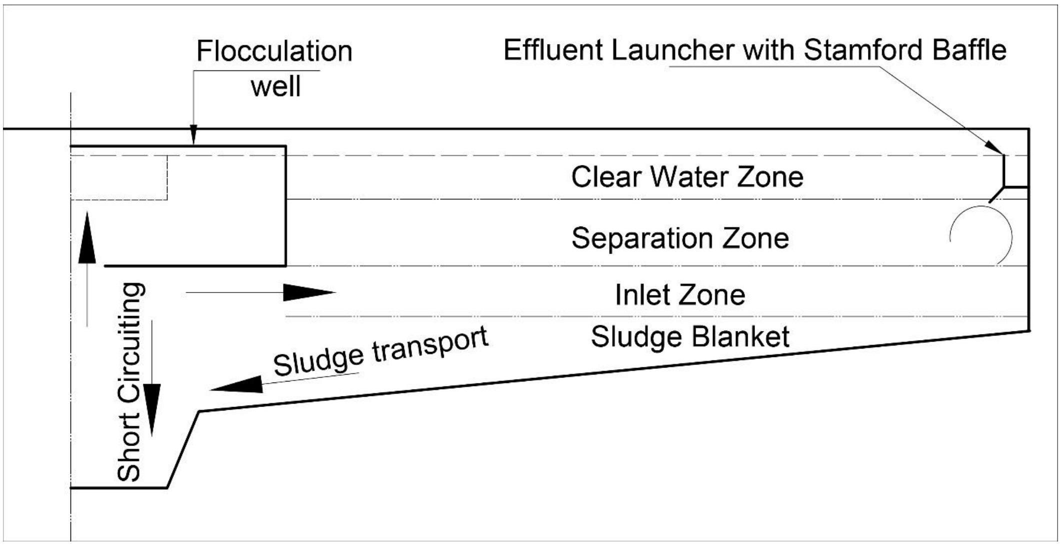

Figure 6. Shows the section of the proposed primary clarifier.

While designing primary clarifier, following assumptions are taken into considerations,

High performance flow rate=20 m^3/m^2/day and

Clear water depth=3 meters

Design Calculations

Assume the number of clarifier to be 20

Sewage Production=Wastewater quantity/No. of clarifiers

= 221,032.5/20=11051.62=11052

Loading rate=20=Sewage Production/(π/4) × D^2

=11052/(π/4) x D^2 (Where, D is the Depth)

Therefore, D=26.53 meters=26 meters

Volume of clariier=20 × (π/4) x D^2=10,618.58 m^3=10,619 m^3

Since, Waste water quantity=221,032.5 m^3/day=221,032 m^3/day

So, Detention time=Volume in m^3/Waste water quantity

= 2671/221

032=0.048 days=1.15 hours

The primary clarifier removes almost 30% of the influent BOD and 80% of the suspended solids.

Hence, BOD after passing from the primary clarifier = 0.7 × 283=198 .1 mg/l=200 mg/l

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DESIGNING OF AERATED LAGOON

Aerated Lagoon or Aerated pond is a part of the secondary treatment of the wastewater treatment system. It consists of a pond that provides artificial aeration that promotes biological oxidation of wastewaters. Thus the proccess and the considered factors of designing an Aerated Lagoon is as follows (**Figure 7**):

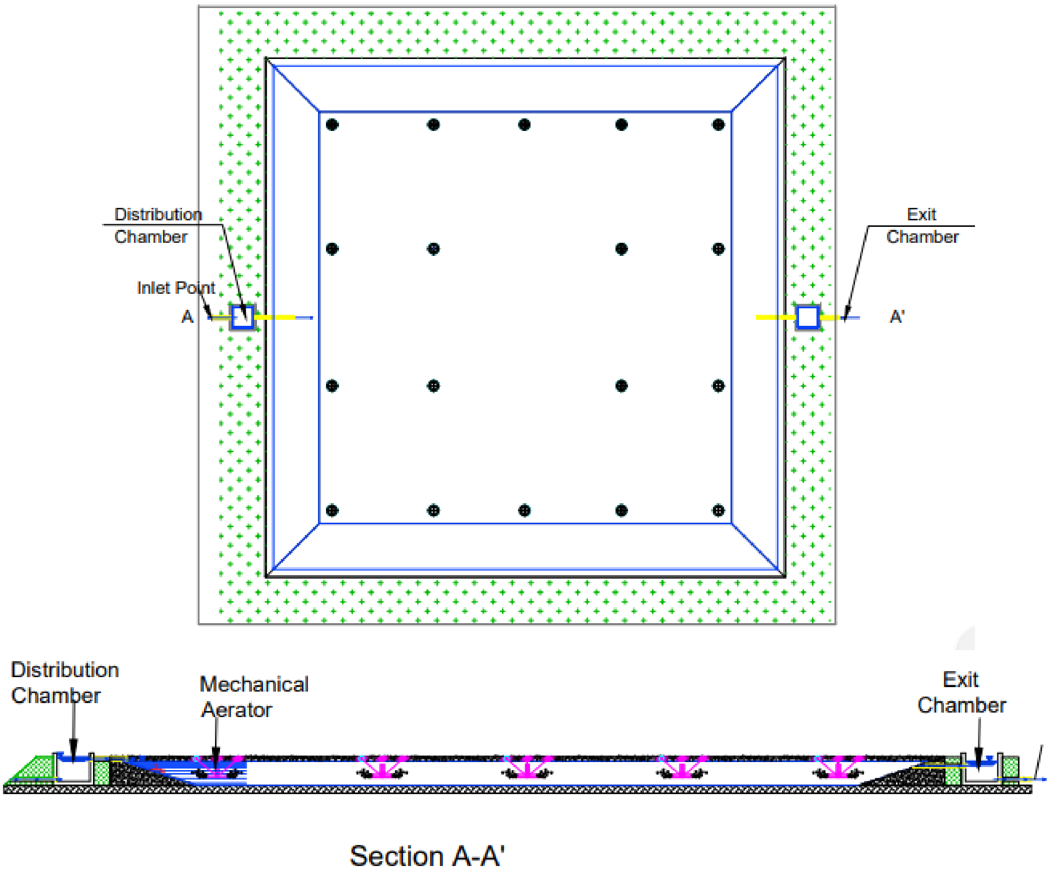

Figure 7. Shows the Plan and section of the Aerated Lagoon

Influent BOD entering the Aerated Lagoon from the Primary Clarifier=Li=200 mg/l

System Rate Constant=K=0.12/day

Oxygen requirement for 90 percent removal of BOD=1.4 kg/day

Oxygen capacity of surface aerators=1.36 kgO_2/H. P/hr

Depth of the Liquid=3 meters

Width of the Free Board=0.3 meters

Since Aerated Lagoon is rectangular in shape, henceforth,

The ratio of Length: Breadth=2:1 and Side Slope=1 vertical:1 horizontal

Effluent BOD after treatment through Lagoon=Le=83 mg/l

Design calculations for the size of the Aerated Lagoon

Detention time, t= log (Li/Le)/K

=3.18 days=4 days approximately

Volume of the lagoon, V=Quantity of Sewage Production × Detention Time=Q × t

=221,032.5 × 4=884,130 m^3

As in total 8 Aerated Lagoons are being provided of equal size, Thus

Volume of each Lagoon=Va=884,130/8=110,516.25 m^3=110,516 m^3

Since, Va=110,516=[((2a × a)+(2a-6)(a-6)) × 3] /(8)

Therefore, a=273.68 meters

Henceforth, width of each Lagoon=274 meters

Assuming that BOD reduction is 90% and

Since, oxygen requirement=1.4 kg/day of BOD applied

Therefore, Total amount of BOD applied=221,032.5 × 283 × 200/10^6=12,510.44 kg/day

Total Oxygen required in the process = 1.4 × 12510 kg O_2/day=729.75 kg/hr=730 kg/hr

Horse power requirement

Assuming surface aerators capable of transferring 1.36 kg of O2/HP/Hour at lagoon condition

Therefore, Total Horse Power required =730/1.36=536.76 HP

Thus, by providing 8 aerators of 67.1 HP capacity each, each aerated lagoon compartment is supposed to have 4 aerators.

DESIGNING OF SECONDARY CLARIFIER

Quiescent Settling Zone also known as Secondary Clarifier is a settling pond which uses the principles of sedimentation to remove suspended solids and turbidity from wastewater which is being created from the biological process while the wastewater passes through Aerated Lagoon. The factors considered and the process for designing the Setting basin is as follows:

This zone may be a diked-off portion of the aerated basin

Assuming detention time for quiescent settling=2 days

Thus, Volume of settling basin=8 × 221,032.5=1,768,260 m^3

Since one settling basin is provided for each aerated lagoon,

Hence, Volume of each basin=1,768,260/8=221,032.5 m^3

Assuming that the width of the basin=274 meters and Depth of the basin=3 meters,

Length of settling basin=221,032.5/274×3= 268.89 meters=269 meters

DESIGNING OF SLUDGE DISPOSAL UNIT

The residual by product that gets accumulated in Sewage treatment plants is called Sludge (or Bio solids) after the waste-water treatment process, it is mainly in the form of solids, semi- solids or slurry. Sludge can be classified into Primary Sludge and Secondary Sludge. Primary Sludge is extracted by chemical precipitation and sedimentation. Whereas, Secondary sludge is the biomass which is generated by biological treatment. Thus the amount of suspended solids and the volume of the settled sludge is given below.

Average suspended solids=633 mg/l (**Table 5**)

Assuming 80 percent removal of suspended solids from the Sludge extracted

Thus, Total Suspended solids removed=633 × 0.8=506 mg/l

Also, Quantity of settled solids=506 × 221,032.5 × 1000/106=105511.74 kg/day

Assuming, that Primary sludge contains 4% solids by dry weight

Hence, The volume of settled sludge=32286 × 100/4=422047 litres/day=4220.5 m^3/day

Table 5. Shows the characteristics of water of the sewage wastewater.

S.No.	Parameters	Concentration		
		Minimum	Maximum	Average
1	BOD in mg/l	176	390	283
2	COD in mg/l	308	760	534
3	TSS in mg/l	84	1182	633

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APPLICATION OF THE TREATED WASTEWATER

The treated wastewater has various applications which includes the development of green belts, vegetative cover in the vicinity of the wastewater treatment plant taking into consideration hydraulic loading concept. The treated waste water contains ample amount of nutrients and hence, the treated wastewater can be used for growing this vegetative cover without using the fertilizers. The selected plant species can be grown taking the local conditions into consideration. This enhances the green infrastructure within the city which helps in reduction of the odour produced from water treatment plant, and also in the water and air pollution. The greenhouse gases evolved from the waste are absorbed by this green belt and this also restricts the waste water to directly join the main water body flowing from the city.

The treated wastewater can also be used for irrigation and also can be used in flushing of toilets hotel buildings and other commercial buildings (**Figure 8**).

Figure 8. Green Belt around the Waste Water Treatment.

CONCLUSION

With rapid increase in urban population, the municipal sewage is increasing not only in India but on global scale. Such a huge quantity of sewage is being discharged untreated in majority of the countries. The treatments of sewage generated require huge money. But discharging of sewage untreated, caused multi-dimensional problems. It pollutes our surface water bodies, ground water, land, and responsible for various diseases caused to human beings. It would thus be proper to evolve environmental sustainable approach to address the problem. The sustainable approach would be achieved if technological plans are prepared on time scale with futuristic projections and the compatible technology linked with financial benefits. The authors of the present paper have tried on this sustainable approach having environmental benefits. The municipal authorities should also evolve sustainable approach to deal with such an emerging issue.

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