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Environmentally Sustainable Waste Water Treatment Management - A case study of Kanpur, 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 Kanpur, 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.

KEYWORDS: *Sustainability, sewage, treatment, disposal, population forecast, waste water generation trends, economics*

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I. INTRODUCTION

Due to the huge population of India, the country is facing food, water and energy shortages in a lot of cities. Sewage generation in the major cities of India account upto approximately 38354 million liters per day but only 11786 MLD is only treated out of the total waste generated. According to the CPHEEO reports, approximately 80% of the total water which is supplied to the households is wastewater. Thus, in a developing nation the reuse of the wastewater after proper treatment is still a challenge and even India is still discovering economic and sustainable method for the treatment of waste water and its substantial use(1).

Kanpur is one of the biggest industrial areas of Uttar Pradesh, India. In Kanpur, the tremendous increase in the population, urbanization and industrialization in past decades have created a lot of pressure on the fulfillment of the basic amenities in the urban areas of an individual such as water supply, resources required and hence enormous amounts of sewage and solid waste generation. The amount of sewage generation is approximately 339MLD in Kanpur city, but the conversion rate is only 50%(2).

Manmohan et al (2013) focused mainly on the methane emission from the wastewater. The untreated waste results in environmental pollution majorly leading to the climatic changes. They took into account the Sewage Treatment Plants in Surat, India and analysed the amount of waste generated from the city and consequently, the methane recovery and power generation from it. It was concluded from the study that 80,000 tonnes of CO2 is emitted every year from four plants in the city. The energy that can be produced per year is in he range of 1.5 to 2. Million kWh. This quantification not only helped in reduction of greenhouse gas emissions but also in reducing water pollution to a large extent (3).

Researchers studied the life-cycle assessment of the 13 treatment plants present in China taking into account the environmental and the economic aspects. The study concluded that anaerobic digestion, incineration and the dewatering techniques are the most suitable eco-friendly methods which can be used for the treatment of sewage and for the energy recovery also. (Changqing et al (2014) (4)

The reduction in the net emissions of the greenhouse gases such as methane reduces the vulnerability of atleast one sector to the environmental pollution and climatic changes. Hence, attempts have been made by the researchers of Jordan to retrospect and propose measures which can be used to mitigate the methane emissions from the sewage treatment plants. Expansion of the treatment plant followed by switching the technology to activated sludge method was proposed. It was accounted that for the As-Samar plant, the largest sewage treatment plant of Jordan adopting both the techniques, the reduction in methane generation will be around 146Gg by the year 2030. (Zaid (2008)).

II. STUDY AREA

Kanpur is one of the biggest cities in Uttar Pradesh and is known as the industrial and commercial hub of the state. The rate of the increase of population in the urban regions of Kanpur is very high like the other major cities in India. The quality of life of the residents is decided by the provision of the basic amenities to the residents. Due to the development at such a higher rate, the amount of waste water being discharged per household has increased significantly and is one of the major concerns.

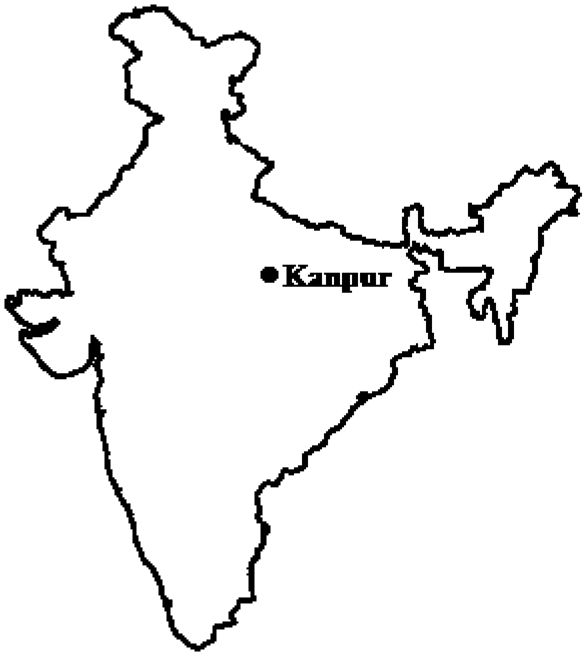

Figure 1:Study Area

III. WASTE WATER TREATMENT METHODS

The waste-water treatment methods can be broadly classified into three categories: Physical, Chemical and Biological methods which are used inorder to remove the impurities and contaminants present in the waste-water. For the rigorous and proper treatment of waste-water a combination of the available techniques and systems have to be considered. The sludge which is produced after the treatment of waste-water is treated using appropriate conventional or modern methods so that disposal or reuse of the sludge is not an issue. The classification physical, chemical and biological methods are described as follows:

- Physical Methods
  - Screening
  - Grit Removal
  - Flow Equalization
  - Primary Sedimentation
  - Flotation
  - Granular-medium Filtration
- Chemical Methods
  - Chemical Precipitation
  - Chemical Coagulation
  - Chemical Oxidation
  - Ion Exchange
  - Adsorption and Chemisorption
  - Precipitation
  - Flocculation
  - Chemical Stabilization
- Biological Methods
  - Aerobic waste- water treatment (Activated Sludge)
  - Anaerobic waste- water treatment

- o Aerated Lagoon
- o Trickling Filters
- o Rotating Biological Contractors
- o Pond Stabilization
- o Biological nutrient removal

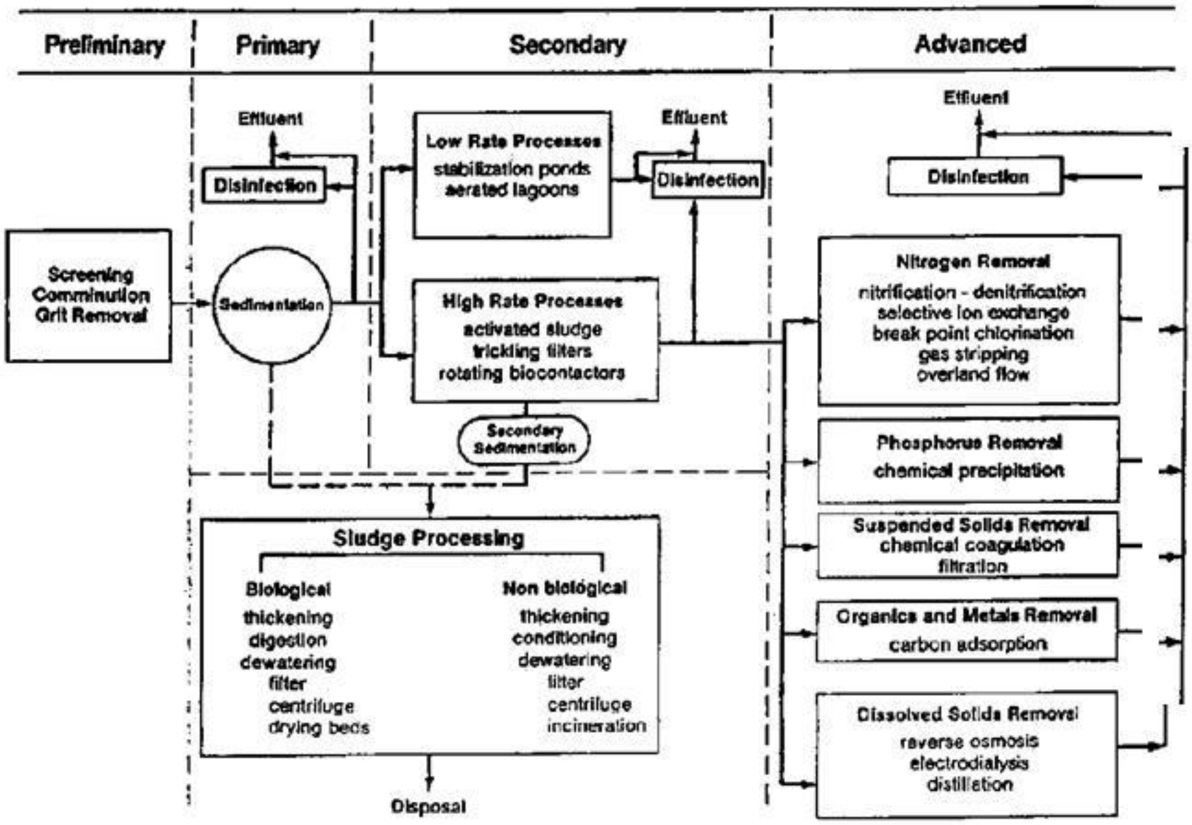

Figure 2: Waste Water Treatment Flow-diagram
[image source: (5)

Out of the various methods listed out, one method of Aerated Lagoon has been briefly explained below:

- **Aerated Lagoon Method:**

This method can be used for treating both the domestic as well as industrial waste. The method involves the biological oxidation of wastewaters in an aerate basin or lagoon. The two types include the Suspension Mixed lagoon and Facultative lagoons.

There are large aerated basins which are provided with the mechanical aerators in order to avoid the settlement of the biomass and also, to maintain proper aerobic environment. The plant is setup in such a manner that the net and out let are at two different ends so that the detention time can be retained. The population of microorganism is very less initially in comparison to the Activated Sludge Method and hence, there is a requirement of the longer residence time. This longer time can be advantageous when the degradation of complex chemicals has to be done.

Advantages:

- This is a cost-effective method for the areas where the land is inexpensive.
- Less energy utilization in comparison to other waste water treatment technologies.
- Simple to operate

Disadvantages:

- The land requirement is more in comparison to the other methods.
- Longer detention period in the colder climate and hence less efficient for such places.
- Poor maintenance is required in order to avoid breeding of mosquitoes and odour during algal oxidation.

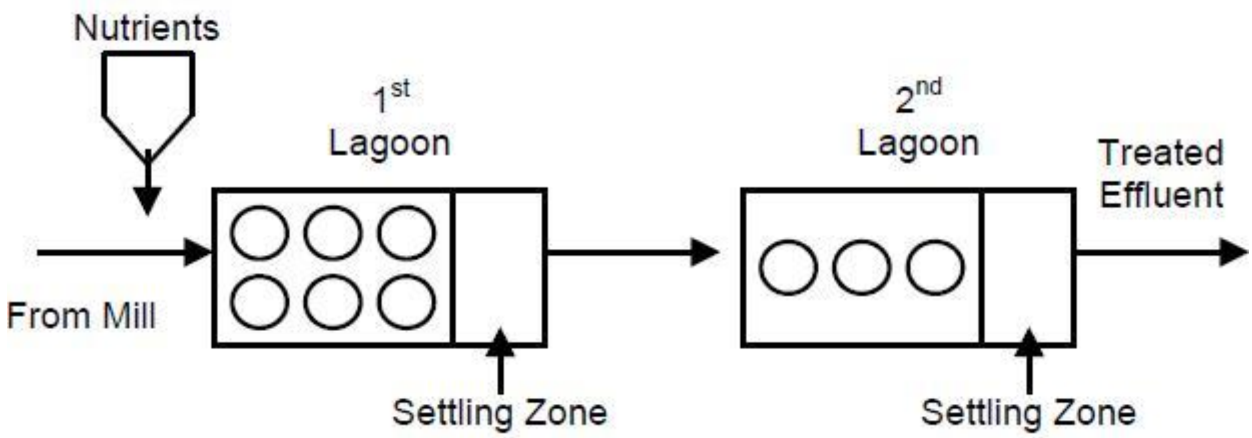

Figure 3: Schematic diagram of the aerated sequential system

1.0 Sustainable sewage management – case study of Kanpur

1.1 Population trends and forecasting:

The population forecasting is an important tool that should be taken into consideration while estimating the sewage production from the population of a place. The population trends from the year 1951 to 2051 are projected in the Table 1 and are reflected in Figure1.

Table 1: Showing population trends and forecasting

Year	Arithmetic Mean	Geometric Mean	Incremental Increase	Average
1951				1,325,778
1961				1,647,150
1971				2,099,164
1981				2,665191
1991				3,253,572
2001				4,167,999
2011				4,581,268
2021	5,123850	5,640,513	5,142,229	5,302,197
2031	5,666,431	6,944,669	5,721,570	6,110,890
2041	6,209,013	8,550,361	6,319,289	7,026,221
2051	6,751,595	10,527,310	6,935,389	8,071,431

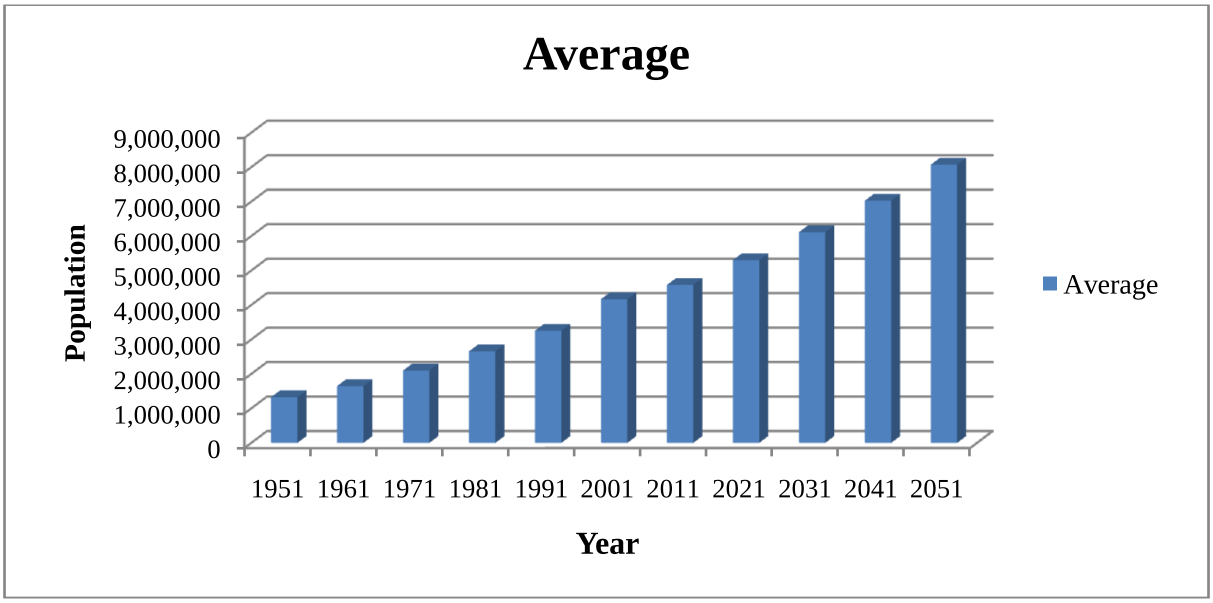

Figure 4: Population Trends and Forecasting

1.2 Sewage generation trends and projections of Kanpur:

The population data from 1951 to 2051 has been taken into consideration. For predicting the sewage production, it has been assumed that for the next decade (2021), the water consumption will be 120 liters/capita/day. Due to increasing urbanization and industrialization in the Kanpur city, the water consumption will increase for the coming decades and hence, it is assumed to increase by 10 liters/capita/day per decade. It is assumed that the 70% of the water that is supplied to household is released as waste water. Table 2 shows the amount of sewage produced in the Kanpur city from 1951 and the projections of the amount of sewage that will increase with the increasing population.

Table 2: Showing sewage generation trends and forecasting

YEAR	POPULATION	ASSUMED PER PERSON WATER CONSUMPTION (in lt/capita/day)	WATER CONSUMPTION	SEWAGE PRODUCED (m^3/capita/day)
1951	13,25,778	50	66,288,900	46,402
1961	16,47,150	60	98,829,000	69,180
1971	20,99,164	70	146,941,480	102,859
1981	26,55,191	80	212,415,280	148,691
1991	32,53,572	90	416,799,900	204,975
2001	41,67,999	100	503,939,480	291,760
2011	45,81,268	110	636,263,640	352,758
2021	53,02,197	120	794,415,700	445,385
2031	61,10,890	130	983,670,940	556,091
2041	70,26,221	140	983,670,940	688,570
2051	80,71,431	150	1,210,714,650	847,500

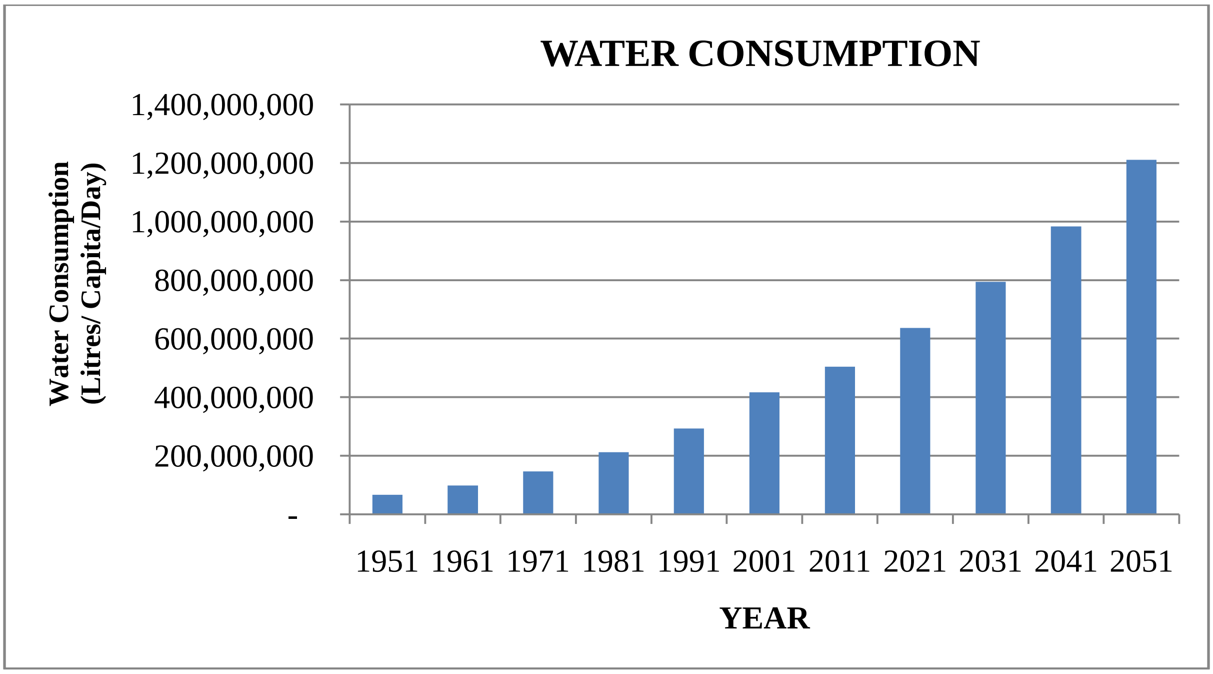

Figure 5: Water Consumption Trends and Forecasting

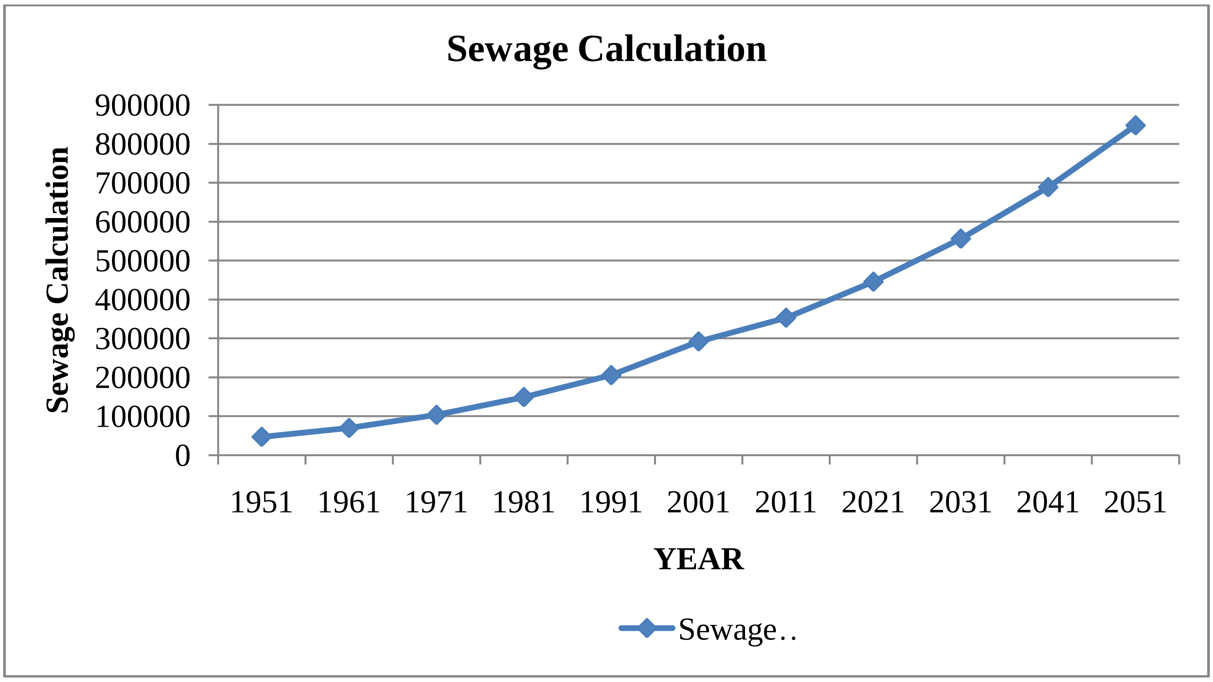

Figure 6: Sewage generation trends and forecasting

IV. DESIGN OF AERATED LAGOON

Table 3: Sewage Wastewater Water Characteristics

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

Design of screen chamber:
According to the calculations,
The volume of sewage production the year 2021 = 445,385 m^3/capita/day
Assuming, the design rate flow to be 1.5 times the average flow
Hence,
Designed volume to be handled is=1.5*445,385=66,807 m^3/day =0.77m^3/sec
Ideal velocity flow through velocity is assumed as 0.6m/s
Area required to accommodate flow= 0.77/0.6 =1.28 m^2
Assuming width of screen chamber=0.55meter =550 mm
Depth of flow= 1.28/2 = 0.64 meters
Using 12mm rectangular bars at 50mm centre to centre distance
Clear opening= 40mm
End clearance=40mm
Let there be n bars
Total width of opening= (n+1)*40
550 = (n+1)*40
n= 12.75 = 13 nos
Total width of the screen chamber= 55+13*1.2=70.6 cms

Design of primary clarifier:
While designing primary clarifier, following assumptions are taken
High performance flow rate=20 m^3/m^2/day
Clear water depth= 3 meters
Design calculations:
Assume the number of clarifier to be 20
Sewage Production= 66807/10
=6680.7 =6681
Loading rate = 20 = 6681 / $(\pi/4)*D^2$
D=20.62 meters = 21meters
Detention time= Volume of clarifier/ wastewater quantity
Volume of clarifier= 20*($(\pi/4)*D^2$
= 6924 m^3
Waste water quantity= 66,807 m^3/day
So,
Detention time= Volume in m^3/ Waste water quantity
=6924/66807=0.1036 days = 2.5 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 .1mg/l=200 mg/l

Design of Aerated Lagoon:
BOD influent= Li= 200mg/l
System rate constant= K=0.12/day
Oxygen requirement for 90 percent removal of BOD = 1.4kg/kg
Oxygen capacity of surface aerators=1.36 kgO_2/H.P/hr
Liquid depth = 3 meters
Free board = 0.3 meters
Shape = Rectangular
Length: Breadth = 2 : 1
Side slope = 1 vertical: 1 horizontal
Effluent BOD after lagoon treatment= 83 mg/l

Design calculations:
Lagoon Size-
Detention time, t= log(Li/Le)/K
= 3.18 days= 4 days approximately
Hence,
Volume of the lagoon, V= Q*t = 66807*4
=2, 67,228 m^3
Providing 8 lagoons of equal size

Size of each lagoon, V= 2,67,228 / 8 =33,403 m3
V = 33,403 = [(2a*a) +(2a-6)(a-6)*3] / (8)
a= 186 meters
Hence, size of lagoon=
Assuming 90 percent BOD reduction
Oxygen requirement = 1.4 kg/kg of BOD applied
Total kg of BOD applied = 66807 * 283* 200 / 10^6 =3781.28 kg/ day
Oxygen required = 1.4*3781 kg O2/ day = 220.55 kg/hr = 221 kg/hr

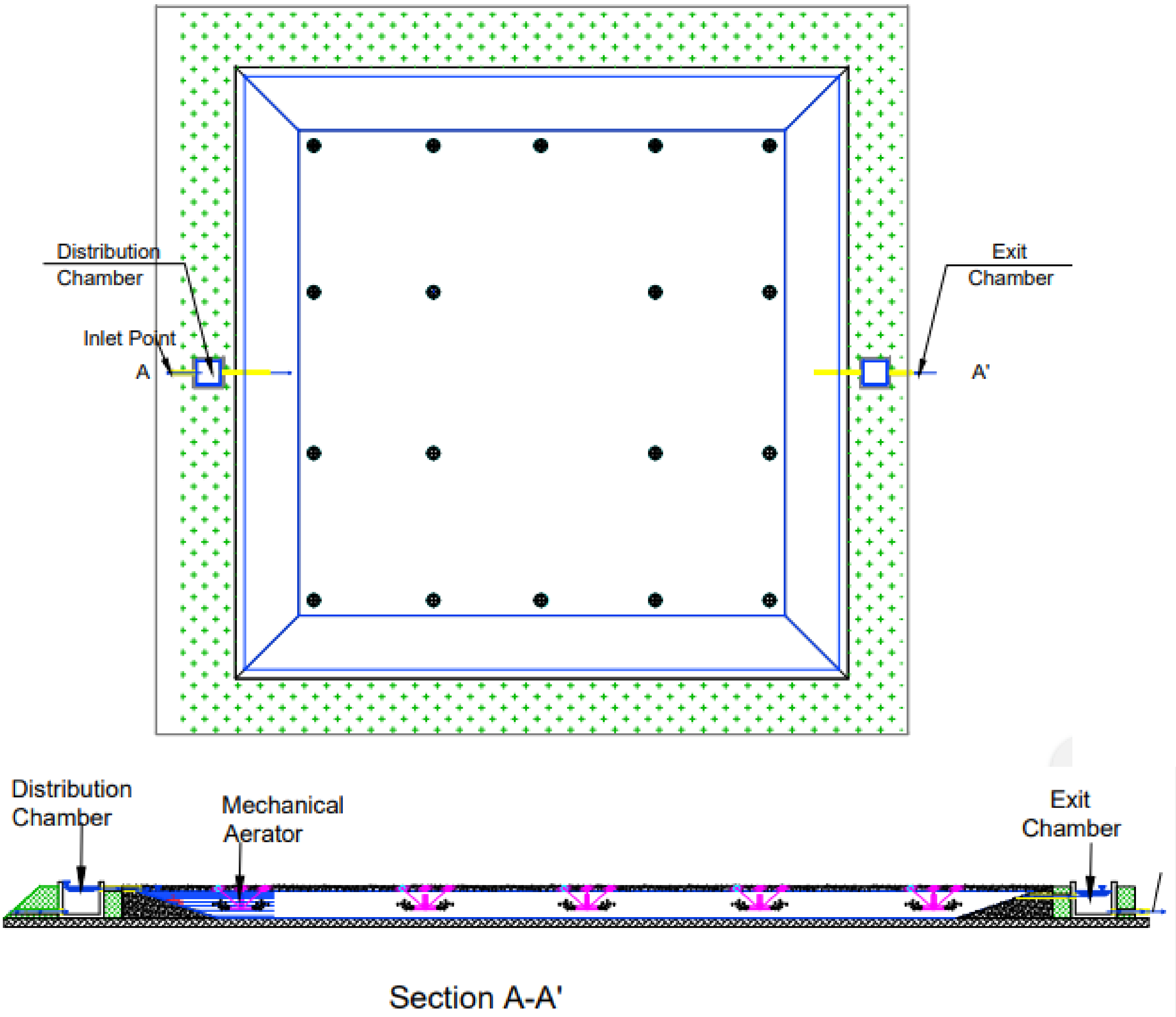

Figure 7: Plan and Section of the Aerated Lagoon

Horse power requirement:
Assuming surface aerators capable of transferring 1.36 kg of O2/ H.P/ Hour at lagoon condition

Total H.P required = 221/1.36 = 163 H.P
Providing 8 aerators of 20.38 H.P capacity each, each lagoon compartment to have 4 aerators.

Design of Quiescent settling zone:
This zone may be a diked-off portion of the aerated basin
Assuming detention time for quiescent settling = 2 days
Volume of settling basin = 8*63807 = 510,456 m3
Providing one settling basin for each lagoon
Volume of each basin = 510,456/8 = 63807 m3
Assuming that the width of the basin is equal to lagoon, that is, 186 meters and depth 3 meters

Length of settling basin = 63807/186*3= 114meters

Design of sludge disposal:
Average suspended solids = 633 mg/l
Assuming 80 percent removal of suspended solids
Suspended solids removed = 633*0.8 = 506 mg/l
Quantity of settled solids = 506*63807*1000/ 106
= 32,286 kg/day
Assuming, primary sludge contains 4% solids by dry weight
Hence, the volume of settled sludge=32286*100/4= 8,07,150 liters/day
= 807.150m^3/day

V. 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 odor 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.

Figure 8: Green Belt around the Waste Water Treatment

VI. CONCLUSION:

With rapid increase in urban population, the municipal sewage in 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 pollute 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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