Tertiary Treatment of Secondary Effluent of the Pharmaceutical Company – Design of Aerated Lagoon

Prof. Dr. K. N. Sheth[1] Pritesh[2]
[1]Director [2]PG Student
[1,2]Department of Environmental Engineering
[1]Geetanjali Institute of Technical Studies, Udaipur, India [2]ISTAR, Vidyanagar India

Abstract— A pharmaceutical company in Panoli manufacturing bulk drug needs tertiary treatment to bring the effluent for the desired standards in accordance with the norms given by Gujarat Pollution Control Board. An attempt has been made to design most economical tertiary treatment for secondary effluent of the pharmaceutical company. Subsequent to the detailed analysis of the secondary effluent, it was found that BOD value was high compared to the norms given by the board. Considering the space constraint, aerated lagoon was the option available. An attempt has been made to determine the biological co-efficient in the M/S. Jyoti Om Chemical Research Centre, (lab) Ankleshwar by carrying out characterization and treatability studies. The characterization and treatability studies encompasses of determination of the analysis raw effluent as well as quality of secondary treated effluent continuously for three months. During the monitoring, samples were collected from equalization tank and V-notch chamber for raw effluent and secondary treated effluent respectively. The experiments for treatability studies were carried out in batch reactor and reduction for BOD & COD were recorded. The results were found very encouraging and therefore it was found during the investigation that aeration system without recycling of biomass is sufficient to bring the standards below the prescribed limits by the competent authority. This gives the idea that aerated lagoon system of treatment will be suitable. Many batch type experiments have been carried out to determine the biological co-efficient associated with aerated lagoon in the lab studies. The average BOD removal rate constant, K; maximum rate of substrate utilization, k; the maximum yield co-efficient, Y; endogenous decay co-efficient, kd; the average detention time and half velocity constant in aerated lagoon system were found to be 2.186 d-1, 3.92 L/mg . $d^{-1,}$ 0.60 mg of VSS/mg of BOD5,20 removed, 0.070 d-1; 6.5 d and 269 mg/L respectively. Based on biological constant, aerated lagoon proposed to be total two tanks, each sizing 13 m x7.5 m x 3.5 m (liq. Depth) with 0.6 m free board (F.B.) with a blower (1+1) having capacity of 3 m3/min of air flow.

Key words: Tertiary Treatment, Aerated Lagoon, Kinetic Coefficients, BOD, COD

I. INTRODUCTION

Industrial effluents from Pharmaceutical Company, particularly the liquid wastes, vary widely in quality and quantity. They may contain impurities ranging from simple salt to deadly toxins like compounds of heavy metals, cyanides, phenols, etc. The type and quantity of the impurities, nature of the receiving body of water and its flora and fauna, decide the degree of pollution. The extent of dilution available from the receiving waters and the use to which this mixture of natural water and industrial waste is to be put, to decide the degree of treatment required.[1] Among the different industrial liquid wastes the pharmaceutical waste occupies an important position. Pollution of water resources by the discharge of wastewater is drawing apt attention because freshwater is becoming a rare commodity, day by day. The total water demand commodity, day by day. The total water demand is continuously increasing because of population growth, urbanization, industrialization and high standard of living. Also the effluent discharging norms are very stringent and it has been very difficult to achieve these standards for the industries after giving preliminary, primary and secondary treatments.[2]

A pharmaceutical company located at Gujarat Industrial Development Corporation (GIDC) Estate, Panoli, and Dist. Bharuch is engaged in manufacturing of various bulk drugs. The total (average) effluent generated by the said industry is 85 to 100 m3/day, which contains BOD around 2000 to 2500 mg/L and COD around 5500 mg/L.

The company has presently installed an effluent treatment plant having preliminary, primary and secondary treatment facilities like oil & grease trap, equalization and neutralization, coagulation & flocculation and activated sludge treatment. However, secondary treated effluent does not meet with the requirement of disposal standard of BOD, which is 30 mg/L .The said industry has already spent an amount of Rs 31 lacs for the conventional activated sludge process with diffuser type aeration system. The operation and maintenance cost of the existing plant is Rs 17.11 Lacs. In spite of huge investment the said industry is not in apposition to achieve the desired standards.

II. WASTE WATER TREATMENT METHODS

Wastewater treatment methods range from Physico-chemical to biological and in the letter group from aerobic to anaerobic treatment 1. The details of this are shown in fig 1.

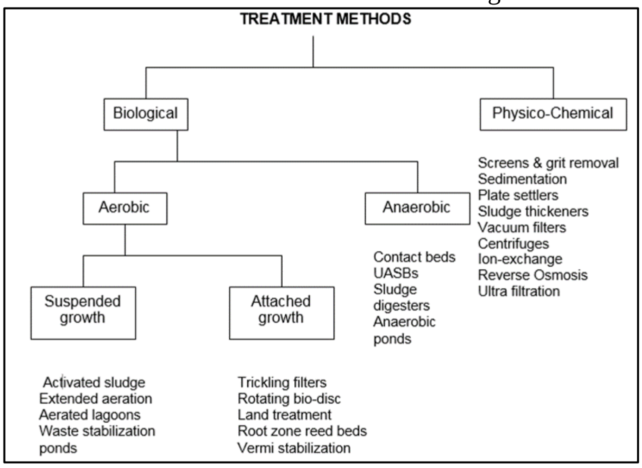

Fig. 1: Some methods of wastewater treatment

Low cost waste treatment methods are a prime need for developing countries. Except waste stabilization ponds, all the wastewater treatment processes like activated sludge process, trickling filters, rotating disc, submerged media beds etc. mentioned above are expensive or require sophisticated equipment or high amount of energy to treat wastewater. Waste stabilization ponds are the simplest of all waste treatment techniques available as lagoon systems use natural and energy-efficient processes to provide low-cost wastewater treatment. Aerated lagoons also have potential for becoming "semi-packed plants". Aerators are or can be manufactured in standard sizes (5, 10, 25 etc.) from which the necessary ones can be ordered and readily installed in a basin of required volume.[3]

Lagoon treatment systems are earthen basins or reservoirs that are engineered and constructed to treat wastewater25. Various examples exist of the successful use of aerated lagoons for the treatment of domestic, municipal and industrial wastewaters. Extensive use of aerated lagoons has been made by the pulp & paper industry, by food processing, petro-chemical and various other industries. There are several instances of overloaded algal ponds having successfully converted into mechanically aerated ponds1. Wastewater treatment lagoons range in depth from shallow to deep, and are often categorized by their aerobic (dissolved oxygen concentration) status and the source of that oxygen for bacterial assimilation of wastewater organics. The four major types of lagoon systems are classified with respect to the presence and source of oxygen in Table 1.

Types of lagoon	Presence of Oxygen
Aerobic	Photosynthesis provides oxygen for aerobic conditions throughout the water column
Facultative	Surface zone is aerobic
Partial mix aerated	Surface aeration produces aerobic zone that ranges from half depth to total depth depending on oxygen input lagoon depth
Anaerobic	Entire depth is anaerobic

Table 1: Classification of lagoon systems based on the presence of oxygen

It has been therefore proposed to make a study of treatment of secondary effluent to bring the present BOD of 400 mg/L to 30 mg/L by low cost treatment and the space available in the industrial plot. It is also proposed to design the tertiary treatment system based on actual bio-kinetics co-efficient based in lab studies.

III. Scope of Work

The prime objective of the present investigation is to determine the kinetic co-efficient in the laboratory for aerated lagoon treatment system as an advance treatment of secondary treated wastewater of a pharmaceutical industry. The present investigation broadly deals with two important aspects of industrial wastewater.

– Characterization studies essentially include sampling and analysis of the effluent.
– Treatability studies, which essentially include determination of amenability of altering the characteristics of secondary treated effluent of a pharmaceutical industry by aerated lagoon treatment system.

The present study therefore encompasses following steps:

– Collection of various grab samples from the pharmaceutical industry.
– Determination of calculation of various parameters present in the secondary treated effluent.
– Preparation of model – a batch type reactor of aerated lagoon system for advance treatment study on collected samples.
– Development of the biological kinetic co-efficient based on the various parameters observed during the study.
– Designing of the actual aerated lagoon system for maximum flow of 100 m3/d.

IV. Materials and Methods

The samples were brought and analysed in the environmental laboratory of M/S. Jyoti Om Chemical Research Centre, Ankleshwar. (JOCRC). The results of analysis for untreated effluent are reported in Table 2 and the results of secondary treated effluent are reported in Table 3. The analysis of all the samples were carried out in accordance Standard Method, 20th Edition APHA 2000. The pH and temperature were measured on the spot itself to avoid any change, which may occur in bringing the samples from sampling port to the environmental laboratory. The other parameters like BOD, COD, TDS, and MLSS etc. have been measured in laboratory.

The treatability study was then carried out in M/S. JOCRC laboratory. The study involves a process of aeration of secondary treated effluent without recycle. The secondary treated effluent was aerated for a period of eight days. The observations were made at the interval of 24 hrs. The interval results have been reported in Table 4. The performance of lab studies for designing aerated lagoon for the treatment of secondary treated effluent was carried out in a batch type reactor. Total 25 L of secondary treated effluent was fed in a reactor employing porous diffuser.

The porous diffuser used for the purpose was aquarium aerator. It is possible that the aquarium aerator may become chocked at high MLSS levels. However, study was carried out on a batch type reactor for a period of eight days at a maximum 200 mg/L of MLSS concentration.

The parameters required for constructing graph for the determination of kinetic co-efficient for the designing aerated lagoon system have been shown in Table 4.

V. Results and Discussions

A. Characterisation Studies

1) The quality of raw effluent

Table 2 describes the quality of raw effluent, which has been collected from equalization tank on 14/02/2004. The initial BOD is 2050 mg/L whereas COD is 5338 mg/L. The ratio of COD and BOD is 2.6. This clearly shows that the effluent requires chemical as well as biological treatment. It is possible during the secondary treatment that some of the chemicals may be oxidized during aeration and BOD & COD both can be brought down below the desired limit.

Sr. No.	Parameters	Untreated effluent
1	pH	4.1

2	Temp in °C	29.5
3	Colors in Hazen	131
4	TSS in mg/L	1574
5	TDS in mg/L	14840
6	BOD in mg/L	2050
7	COD in mg/L	5338
8	Oil & Grease in mg/L	20.9
9	Phenolic Compound in mg/L	Absent
10	Ammonical Nitrogen in mg/L	10.7
11	Chlorides in mg/L	2520
12	Sulphates in mg/L	3780
13	Sulphide in mg/L	Absent

Table 2: The quality of raw effluent

Sr. No.	Parameters	Secondary treated effluent
1	pH	7.12
2	Temp in °C	29.5
3	Colors in Hazen	74
4	TSS in mg/L	72
5	TDS in mg/L	1830
6	BOD in mg/L	434
7	COD in mg/L	893
8	Oil & Grease in mg/L	4.1
9	Phenolic Compound in mg/L	Absent
10	Ammonical Nitrogen in mg/L	8.9
11	Chlorides in mg/L	400
12	Sulphates in mg/L	505
13	Sulphide in mg/L	Absent

Table 3: Analysis of secondary treated effluent collected from V-notch

The results of the analysis of secondary treated effluent are available in Table 3. BOD of the effluent is 434 mg/L and COD is 893 mg/L. It is therefore crystal clear that the desired standards have not been achieved in spite of the fact that biological treatment has been given.

There are various technological options available for the treatment of secondary effluent. After spending for preliminary, primary and secondary treatment it is essential that low cost technological treatment should be adopted. Stabilization (Facultative) pond is the most economical and technologically approved option. However, the required space to accommodate the stabilization pond at the given flow rate is not possible. In the light of these facts aerated lagoon is the suitable alternative.

Before designing the aerated lagoon, the laboratory studies were carried out to determine various biological kinetic co-efficient.

B. Treatability Studies

1) Treatment of secondary effluent

The experiments were carried out for nine days as a batch reactor and reduction in BOD and COD along with MLSS obtained daily have been recorded in Table 5.13. It is crystal clear from the table that the percentage reduction in BOD on 9th day is 93.77 % i.e. BOD from 434 mg/L reduced to 27 mg/L. Similarly, COD from 893 mg/L reduced to 85 mg/L i.e. overall reduction achieved in COD is 90.48%. The results are quite encouraging and it clearly indicates that the aerated lagoon i.e. aeration system without recycling - the bio-mass is sufficient to bring the standards below the described limit. The day wise percentage reduction of BOD & COD is shown in Fig. 2.

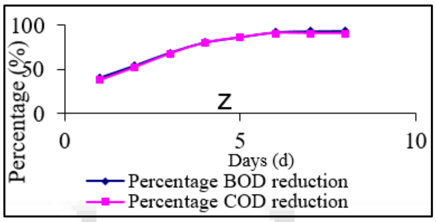

Fig. 2: Relationship between days vs BOD & COD reduction

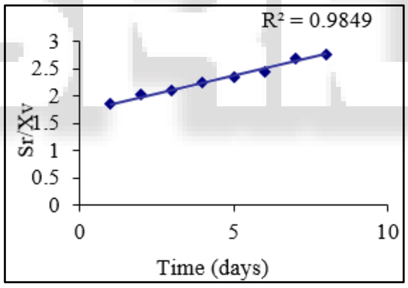

Fig. 3: Sr/Xv vs time

	pH	BOD (mg/L)	COD (mg/L)	MLSS (mg/L)	TDS (mg/L)	Reduction of BOD (%)	Reduction of COD (%)
Day 1	7.12	434	893	72	4480	-	-
Day 2	7.11	258	554	206	4415	40.55	37.96
Day 3	7.08	198	425	228	4350	54.37	52.40
Day 4	7.15	134	288	235	4260	69.12	67.75
Day 5	7.14	84	180	247	4216	80.64	79.84
Day 6	7.12	58	125	159	4175	86.63	86.00
Day 7	7.09	34	83	164	4025	92.16	90.70
Day 8	7.10	29	85	150	3980	93.32	90.48
Day 9	7.13	27	85	147	3975	93.77	90.48

Table 4: Result of treatment of aeration without recycle

The corresponding is presented in fig 3. From this graph BOD removal rate constant, K (d-1); Maximum rate of substrate utilization, k (d. L/mg); Maximum yield co-efficient, Y (mg of VSS/mg of BOD removed); Endogenous decay co-efficient kd (d-1) and half velocity constant, substrate concentration at half the maximum growth rate (mass/Unit Volume) have been worked out in accordance with the sample calculation shown in calculation sheet below Table 5 is the result of the computation for the construction of graphs for determination of biological kinetic co-efficient.

Day	t	So	Se	X	Sr = So - Se	Sr/X	1/t	Xt/So-Se	1/Se
1	0	434	-	72	-	-	-	-	-
2	1	-	258	95	176	1.85	1	0.534	0.004

3	2	-	198	117	236	2.03	0.5	0.99	0.005
4	3	-	134	142	300	2.11	0.33	1.42	0.0074
5	4	-	84	155	350	2.26	0.25	1.77	0.01
6	5	-	58	159	376	2.36	0.20	2.12	0.017
7	6	-	34	164	400	2.44	0.16	2.45	0.029
8	7	-	29	150	405	2.70	0.14	2.60	0.034
8	8	-	27	147	407	2.77	0.125	2.88	0.037

Table 5: Construction of graph for determination of kinetic constants

1) Sr/Xv vs. Time to determine Y & kd using Equation 1.

$$\frac{Sr}{X_v} = \frac{k_d}{Y}t + \frac{1}{Y} \quad (1)$$

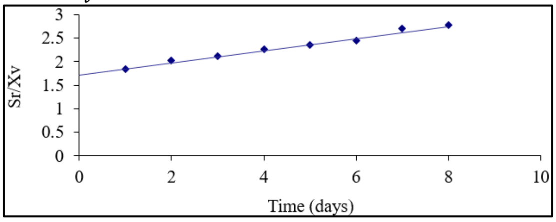

Fig. 3: A Sr/Xv vs time

From equation (1), the y intercept equals (1/Y)

1/Y = 1.706,

So, Y = 0.586 (mg of VSS/mg of BOD5 removed)

From equation (1), the slope of curve in fig 3 is

$$\frac{K_d}{Y} = 0.142$$

So, $K_d = 0.142 \times 1.706 = 0.083\ d^{-1}$

2) Xt/Sr vs. 1/Se. to determine Ks & k from equation:

$$\frac{Xt}{Sr} = \frac{Ks}{k}\frac{1}{S} + \frac{1}{k} \quad \text{.........Eqn - 2}$$

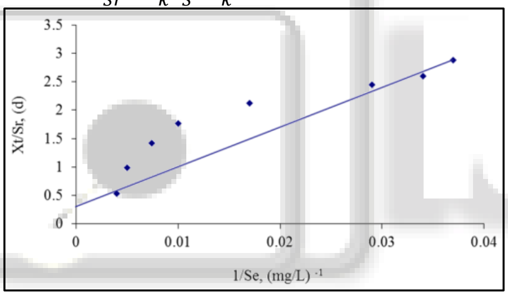

Fig. 4: Xt/Sr vs 1/Se

VI. Design of Aerated Lagoon

A. Step 1: Determination of Lagoon size

Volume of the lagoon required, $V = Q \times \theta_C = 100 \times 6.5 = 650\ m^3$

For two tanks, Volume of each tank = $325 m^3$

Considering 3.5m depth of the tank, the Surface area = $93 m^2$

Let us provide the length of the tank = 13 m

Width of the tank = 93/13 = 7.15m = Say, 7.5m

Final size of each tank: 13m×7.5m×3.5m (liq. Depth) + 0.6 m (F.B.)

Provide two tanks of 13m×7.5m×3.5m (liq. Depth) + 0.6 m (F.B.) size.

B. Step 2: Estimation of summer and winter liquid temperature

1) Summer

$$T_W = \frac{A \times f \times T_a + Q \times T_O}{A \times f + Q}$$

$$= \frac{217\ m^2 \times 0.5 \times 40^O C + 100\ m^3/d \times 34^O C}{217\ m^2 \times 0.5 + 100\ m^3/d} = 37.12^0 C$$

2) Winter

$$T_W = \frac{A \times f \times T_a + Q \times T_O}{A \times f + Q} = \frac{217\ m^2 \times 0.5 \times 20^O C + 100\ m^3/d \times 34^O C}{217\ m^2 \times 0.5 + 100\ m^3/d}$$

$$= 26.17^o C$$

C. Step: 3 Estimation of soluble BOD5 measured at lagoon outlet

$$S = \frac{K_S(1 + \theta \times k_d)}{\theta(Y \times k - k_d) - 1} = \frac{269\ mg/L \times (1 + 6.5 \times 0.07)}{6.5 \times (0.6 \times 3.92 - 0.07) - 1}$$

$$= \frac{391.39}{13.833} = 28.30\ mg/L$$

1) Estimate the effluent BOD

a) Correct the removal rate constant for temperature effect

$$\frac{k_T}{k_{20}} = \theta^{T-20}$$

– Summer: T = 37.12°C

$$k_{37.12} = 2.2 \times 1.06^{37.12-20} = 5.96$$

– Winter: T = 26.12°C

$$k_{26.12} = 2.5 \times 1.06^{26.12-20} = 3.57$$

b) Determine the effluent BOD_5

$$\frac{S_e}{S_o} = \frac{1}{1 + K \times t}$$

– Summer

$$\frac{S_e}{450} = \frac{1}{1 + 5.96(6.5)}$$

S_e = 11.32 mg / L

– Winter

$$\frac{S_e}{450} = \frac{1}{1 + 3.57(6.5)}$$

S_e = 18.59 mg / L

– Ratio of

$$\frac{S_{W\ inter}}{S_{Summer}} = \frac{18.59}{11.32} = 1.64$$

D. Step 4: Estimation of concentration of biological solids produced

$$X = \frac{Y(S_o - S_e)}{1 + k_d\theta} = \frac{0.6(450 - 30)}{1 + 0.07 \times 6.5} = 173\ mg/L$$

1) Estimation of T.S.S in the lagoon

$$T.S.S. = \frac{173\ mg/L}{0.8} = 216\ mg/L$$

E. Step: 5 Oxygen required

1) Oxygen required per day =

$$\frac{Q(S_o - S_e)}{f} - 1.42\,P_X = 61.76 - 24.57 = 37.20\ kg/d$$

2) Compute the ratio of O_2 require to BOD_5 removed

$$\frac{O_2 require}{BOD_5 removed} = \frac{37.20\ kg/d \times 1000\ g/kg}{(450 - 28.3) \times 100\ m^3/d} = 0.88$$

3) Theoretical air requirement

Assume that air weighs 1.202 kg/m^3 and contains 23.2 % oxygen by weight.

The oxygen transfer efficiency for the aeration equipment is 8% and a safety factor of 2 is used to determine the actual volume for sizing the blowers.

$$\text{Air required} = \frac{37.20\,kg/d}{1.202\,kg/m^3 \times 0.232\,gO_2/gair} = 133.34\,m^3/d$$

The actual air required at an 8 % oxygen transfer efficiency;

Actual air required = 133.34 $m^3/d \div 0.08$ = 1666.75 m^3/d = 1.16 m^3/min

The design air required (with safety factor 2) is = 2 × 1.16 = 2.62 m^3/min.

Provide 2 nos. of blowers (1+1) of 3 m^3/min

VII. Conclusions

From the results and discussion, the kinetic constants for biological system in aerated lagoon for each of the experiment set up have been computed. The average value of kinetic co-efficient from these values can be summarised as under:

- BOD removal rate constant, K is 2.186 d-1.
- Maximum rate of substrate utilization, k is 3.92 L/mg. d^{-1}.
- Maximum yield co-efficient, Y is 0.60 mg of VSS/mg of BOD5, 20 removed.
- Endogenous decay co-efficient, kd is 0.070 d^{-1}.
- Average detention time in aerated lagoon system is 6.5 d.
- Half velocity constant; substrate concentration at half the maximum growth rate, Ks is 269 mg/L.

Concluding from the above kinetic co-efficient aerated lagoon has been designed. We need two tanks, each having size of 13m^3 7.5m^3 3.5 m^3 (liq. Depth) + 0.6 m (F.B.). The oxygen required is 37.2 kg per day. The blower (1+1) of 3 m^3/min should be provided for aeration. The detail calculation is already shown in Calculation sheet no. 6.1.

References

[1] Prof.K.N.Sheth, S.A Puranik, Cleaner Production via Critical Analysis of Technologies Pollution Control, Journal of Engineering & Technology, 02,Apr-09,ISSN: 0970-3543, pp 1-7
[2] Nelson Leonard Nemerrow, Avijit Dasgupta, “Industial & Hazardous waste treatment”, Van Nostrand Reinhold – NY, pp 431-435
[3] Chaturvedi Malay, “Virus Removal In Wate Stabilization Ponds”,Indian Journal of Environmental Health, Vol 16, No. 1 pp 15 – 22 (1976)
[4] Prof. Jorgenson S. E. and Dr. Grommice M. J.;ELSEVIER “Mathematical Models in biological Wastewater Treatment”, National Research Council, Washington D. C., pp 169 –177