TREATMENT OF COMBINED WASTE WATER BY ACTIVATED SLUDGE PROCESS

Selvabharathi. G[1], S. Adishkumar[2], G.Ginni[3], S.Devi[4]

[1]Department of Civil Engineering, SSM Institute of Engineering and Technology, Dindigul, Tamilnadu
[2]Department of Civil Engineering, University VOC College of Engineering, Tuticorin, Tamilnadu, India
[3]Department of Civil Engineering, University VOC College of Engineering, Tuticorin, Tamilnadu, India
[4]Department of Civil Engineering, University VOC College of Engineering, Tuticorin, Tamilnadu, India

Abstract

Combined discharge of domestic and tannery waste waters into streams or surface bodies has been witnessed in Vellore district in Tamil Nadu, India where the tannery processes are carried out at small-scale units. In the present study, an attempt has been made to evaluate the treatability of combined domestic and tannery waste waters using lab-scale activated sludge reactor under extended aeration. Studies on the efficiency of the activated sludge reactors were carried out by varying the solids retention time of 8, 12 and 16 days with a various hydraulic retention time of 15, 20, 25 and 30 h with an organic loading rate varying from 1.61 to 3.32 kg COD/ m^3 / day . The results showed that at the end of 30 h HRT at 16 days SRT with a lower F/M ratio of 0.08 kg BOD/kg MLSS, the maximum reduction of COD was observed to be from 2020 to 175 mg/L. From the bio-kinetic parameters estimation studies, the values of kinetic coefficients are obtained such as the half velocity substrate concentration (K_s), maximum specific growth rate (μ_{max}), yield coefficient (Y) , maximum substrate utilization rate (k) and decay coefficient (K_d) as 122 mg/L, 0.224 day^{-1}, 0.539 mg MLSS/mg COD, 0.416 day^{-1} and 0.088 day^{-1}. The study reveals that the combined domestic and tannery waste water is amenable for treatment using ASP, with treatment efficiency as high as 91% and the bio-kinetics arrived at better stability of the system and enhanced microbial activities at longer HRT and SRT. Also the design values suggest that the extended aeration system is the appropriate activated sludge treatment process for combined domestic and tannery waste water treatment.

Keywords: *Advanced Oxidation Process, Activated Sludge Process, Hydraulic Retention Time and Solid Retention Time.*

---***---

1. INTRODUCTION

There are more than 1200 tanning industries in India. Most of the tanneries are located in clusters in river basins. Generally tanneries are classified as "Red - most polluting industries". The dilution of the tannery waste water with domestic sewage, it is proposed to conduct the treatment study using Activated Sludge Process (ASP). The combined waste water treatment makes it possible to meet the effluent standards with minimum effort and cost (KunTog, 2013). The applicability of biologically treating a particular wastewater is a function of the biological degradability of the dissolved organics present in the wastewater (Xu Wang, 2013). The earlier study focused on the general aspects of biological treatment of industrial wastewater and compares the efficiency of treating the wastewater along with the domestic sewage. The activated sludge process was developed around 1913 in England (Saravanakumar, 2007). Combined biological-chemical treatment was introduced in the 1970's, since eutrophication of lakes due to phosphorus and nitrogen from wastewater was discovered.

Leather tannery effluents are a source of severe environmental impacts. Tannery productive cycle includes a series of chemical treatments using a large number of chemicals such as surfactants, acid and metal organic dyes, natural or synthetic tanning agents, sulphonated oils, salts, etc. to transform animal skin into an unalterable and imputrescible product. Apart from organic material, which releases valuable nutrients on decomposition, tannery effluent may contain chromium (Cr), pathogens, mainly of fecal origin, and toxic organic components, all of which pose a serious threat to the environment (Iaconi *et al* 2002). Discharge of tannery effluent is objected by public on aesthetic grounds and river. The constituents generally present in composite tannery wastewater are varied in character and load, and damage a stream when discharged into it untreated. It contains a considerable amount of protein when a hair pulping unhairing system is used (Roche.N,2005). The salt and hydrogen sulphide present in tannery wastewater may adversely affect the stream quality and cause bad taste and odour. Chrome tannery effluent is highly toxic to fish and other aquatic life. The productivity of the soil is found to be decreased when tannery wastes are applied on fields, and some parts of the land become completely infertile (N.N.Rao, 2005). The effluents also contaminate the ground water in cities and towns due to high amounts of chlorides, sulphates and chromium etc. where tannery processing units are indiscriminately discharging their effluents (Daniele, 2013). Discharge of effluent into water bodies can upset the penetration of sunlight and biological activity in the water body. It affects photosynthesis of the phytoplankton, retarding the self-purification capacity of the colored water body (Rajamani, 1995). In the treatment of ayurvedic wastewater, a half velocity concentration of 665 mg of COD/L and decay rate of 0.135day^{-1} has been reported (Santhoshkumar, 1998). For cotton textile wastewater treatment using Activated Sludge Process, the corresponding values reported were 113 mg/L and 0.026 day^{-1} respectively (Pala and Tokat, 2002).

The discharge of tannery and domestic wastewater into the river depletes the dissolved oxygen present and affects the aquatic life in the river. The aesthetics of the river makes it unsuitable for considering it as a source of drinking water supply. It is understandable that having a treatment system in their premises is beyond their means (Ozlem, 2008). Under this circumstance, mixing of tannery wastewater with the domestic wastewater has created operational problems in the domestic wastewater treatment system. A comprehensive review of the methods for handling tannery effluent showed that the effluents from such plants are generally high in both dissolved organic and inorganic materials, posing particular treatment difficulties (Prakasu.K, 2003). Although a number of treatment procedures are being used or have been proposed, there is no widespread agreement on the most suitable methods (Brdys, 2007). Also the information on the design of treatment plants based on biokinetic parameters for combined domestic and tannery effluent is very limited, the prime objective of the present study is to study the feasibility of combined domestic and tannery wastewater treatment (Michelle, 2013).

The Activated Sludge Process (ASP) was so named because it involved the production of an activated mass of microorganisms capable of aerobically stabilizing a waste (Tchobanoglous *et al* 2003). In biological waste treatment with the ASP the organic waste is introduced into a reactor where an aerobic bacterial culture is maintained in suspension. The reactor contents are referred to as the Mixed Liquor Suspended Solids (MLSS). The aerobic environment in the reactor is achieved by the use of diffused or mechanical aeration, which also serves to maintain the mixed liquor in a completely mixed regime. After a specified period of time (Benhemanu, 1999), the mixed liquor then flows to the clarifier where the microbial suspension is settled. A general process flow diagram of ASP is shown in Figure 1.1. The settled biomass, described as “activated sludge”. A portion of the settled cells is recycled to maintain the desired concentration of organisms in the reactor and a portion is wasted (CPHEEO, 1993).

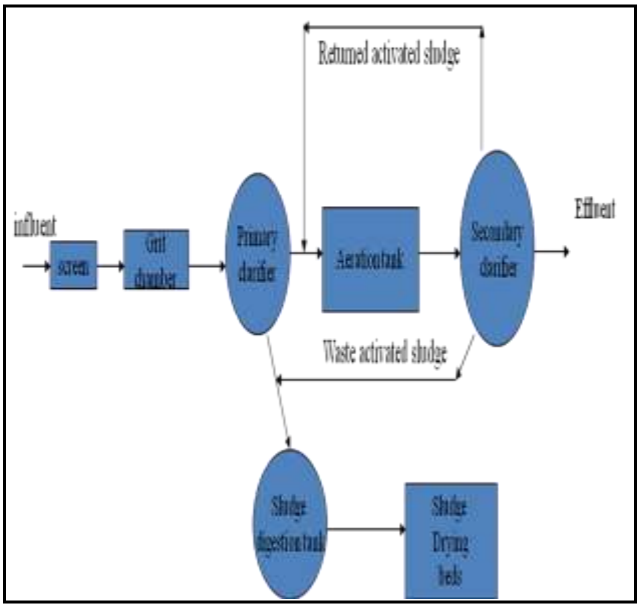
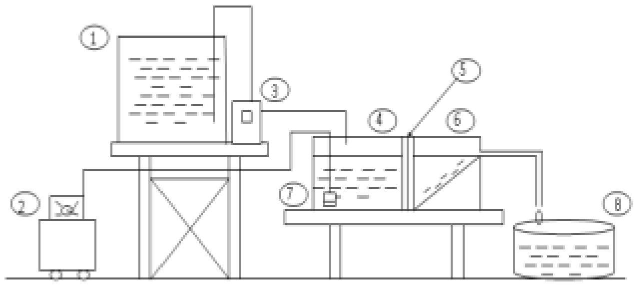


Fig 1.1 Schematic diagram of Activated sludge process

2. MATERIALS AND METHODS

The study was carried out on the combined domestic and tannery wastewaters collected from open drains in Melvisharam located in Vellore district. A significant quantity of tannery wastewater released from tiny units combines with domestic wastewater and flows in open drains. The treatability study on these combined wastewater was being conducted using complete mix Activated Sludge Process with return sludge to evaluate the degradation performance. Samples of combined wastewater were collected from five outfalls of highly contaminated discharging points. The individual and composite samples were analyzed for various parameters such as pH, TSS, TDS, BOD_3, COD, and Chloride (APHA, 1998). The activated sludge laboratory model as shown in Figure 2.1 was made up of plexiglass consisted of two sections namely aeration and sedimentation with a volume of 7.5 L and 2.5 L respectively. A continuous supply of wastewater into the aeration section was maintained with a peristaltic pump.

The extended aeration was carried out with the use of two diffuser stones and an air pump so as to maintain a dissolved oxygen concentration around 2-3 mg/L (Karus, 1958). The aeration was instrumental in terms of bacterial growth as well as maintaining homogeneity of the mixed liquor to confirm the complete mix flow of the reactor. The aeration section was separated from the sedimentation section with an adjustable baffle. The settled sludge was returned to the aeration section by passing it under the adjustable baffle. The experiment was carried out at SRT of 8, 12 and 16 days and HRT of 15, 20, 25 and 30 h. The DO was maintained around 2-3 mg/L. Initially the SRT was maintained at 8 days by removing 1/8th (0.94L) of the reactor content and this procedure was repeated daily until the MLSS in the reactor was stabilized. The MLSS concentration in the aeration tank on the 6th , 7th and 8th day were 4075, 4120, 4285 mg/L indicating a steady state condition in which the concentration of biomass removed was equal to the concentration of biomass produced. In this condition, the HRT was varied from 15–30 h. The influent and effluent wastewater were analyzed for BOD_3 and COD as per standard methods (APHA, 1998). The COD was taken as the parameter for measuring the treatability of the wastewater. The above procedure was repeated for SRT of 12 and 16 days. For a SRT of 12 days $1/12^{th}$ (0.63L) of the reactor content was wasted daily. The MLSS concentration in the reactor was found to be 4900, 5020 and 4985 mg/L on the 10^{th}, 11^{th}, and 12^{th} day respectively. At steady state condition, the HRT was varied from 15-30h.



1.Feeding tank; 2. Portable air pump; 3. Peristaltic pump; 4. Reactor; 5. Adjustment baffle;6. Settling tank; 7. Diffuser stone; 8. Effluent collection

Fig 2.1 Schematic diagram of the experimental setup

2.1 Startup and Bacterial Acclimatization

The Activated Sludge reactor was started using seed collected from local domestic sewage treatment plant. In the reactor sufficient MLSS was developed by adding continuously the fresh sewage, collected from the local treatment plant. The acclimatization of the bacterial culture to the composite wastewater was established by gradual addition of composite wastewater (Ewailwarska.B, 2007) to the reactor starting with a composition of 10% composite wastewater and 90% domestic sewage. The addition of composite wastewater was increased by 10% daily. Gradually the reactor was fed with 100% composite wastewater and acclimatization was achieved. The design considerations for the treatability study of combined wastewater are given in Table 2.1

Table 2.1 Design considerations for Activated Sludge Process

Sl.No.	Parameter	Range proposed
1.	Solids Retention Time	10-30 days
2.	F/M Ratio	0.1-0.2kgBOD/ kg MLSS/ day
3.	MLSS	3000-6000 mg/L
4.	Hydraulic Retention Time	15-30 h
5.	Oxygen supply	2-4 mg/L
6.	pH	7-8.5 mg/L

Source: IS 8413 (part II)-1982

3. RESULT AND DISCUSSION

The pH ranged from neutral to slightly alkaline. During the period of study, the raw wastewater was sent into the reactor without neutralization as the pH of the raw wastewater was within the range of 7.5 – 8.5 which is conducive for the treatment process. Activated Sludge system performs better reaction in the pH range of 7-8 (Tchobanaglous *et al* 2003). TDS Showed was higher than the permissible limit and other parameters such as BOD_3 and COD showed requirement of treatment for safe disposal.

Table 3.1 Physiochemical Characteristics of wastewater samples

Parameter	Domestic sewage	Tannery wastewater
pH	7.3-7.9	7.5-8.6
TS	710	19300
TSS	210	3600
TDS	500	15200
BOD_3	204	1480
COD	460	3525
Chloride	50	4980

Except pH all the values are in mg/L

The start-up of the ASP was carried out in a three-phased manner consisting of seeding phase, acclimatization phase and a biomass build up phase. The acclimatization of the bacterial culture to the composite wastewater is being established gradually by increasing 10 to 100%. The variation of MLSS during the start-up of the reactor is shown in Figure 3.1. After the seeding phase of activated biomass, the acclimatization of the activated sludge to the tannery waste was carried out by means of gradual introduction (Ajejandro, 2008). During the acclimatizing phase, the MLSS showed a steady rise and reached the value of 3200 mg/L, which was below the desired biomass concentration for operating the ASP. Hence the biomass build-up phase was carried out in order to determine a consistent MLSS concentration of about 4490 mg/L.

MLSS concentration was also monitored daily during the start-up phase to understand the aerobic biomass growth in the reactor. The initial MLSS was found to be 1360 mg/L and it is gradually (Ganesn.R, 2006) increased up to3200 mg/L on 10^{th} day and attained equilibrium around a concentration of 4490 mg/L. The reactor was monitored for outlet BOD, COD, pH and MLSS daily to understand the activity of the reactor.

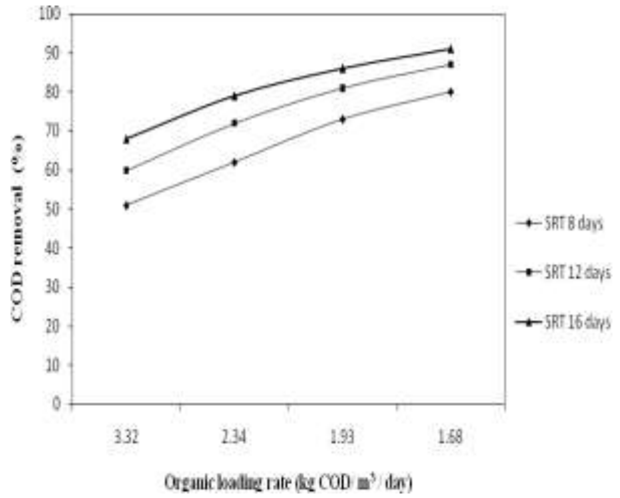


Fig 3.2 Relationship between Organic loading rate and percent COD removal

3.2 Treatability Studies

The treatability studies on the composite wastewater were carried out by ASP. A start-up period of about one month was required for biomass acclimatization and stable unit performance. This is in total agreement with findings of Vaiopoulou *et al* (2007). The reactor took 30 days to develop the sufficient MLSS concentration after acclimatization and when the reactor reached the steady state condition (Gujer.W, 1999), the treatability studies were conducted by feeding the reactor regularly with composite wastewater at different SRT. SRT of 8, 12 and 16 days were maintained during which the reactor was continuously fed with composite wastewater at a flow rate of 8.33, 6.25, 5.00 and 4.17 mL/min. The DO content in the reactor was monitored using a DO meter and aeration was adjusted to keep the DO content around 2-3 mg/L. After the stabilization of the reactor at a particular SRT, which was ascertained by measuring the MLSS in the reactor(Falas,2013), the parameters like initial and final BOD, COD of the wastewater were analyzed under different HRT of 15, 20, 25 and 30 h. Similarly, the performance of the reactor with respect to BOD and COD removal was assessed for different SRT.

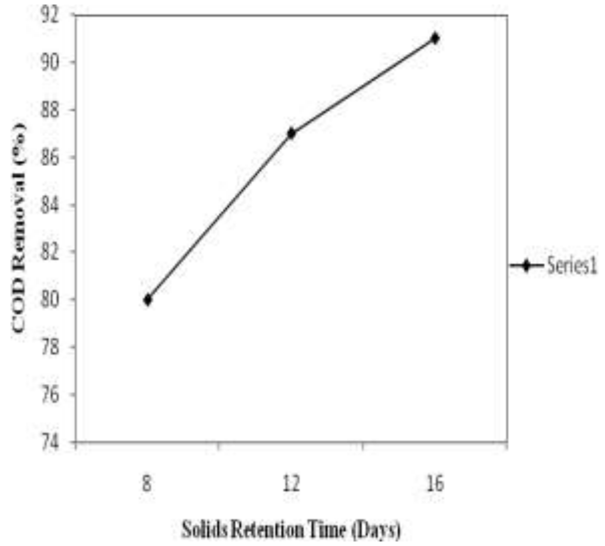


Fig. 3.3. Relationship between percent COD removal and Solids Retention Time

The effect of SRT on COD removal was also observed. The maximum percentage of COD reduction obtained at SRT of 8, 12 and 16 days was 80, 87 and 91 respectively. The corresponding organic loading rate was 1.68, 1.64 and 1.61 kg COD/m^3/day. The relationship between percentage COD removal and SRT is shown in Figure 3.3. The percentage of COD reduction was minimum at lower SRT but increased as SRT was increased. A maximum COD removal of 91% was observed at a SRT of 16 days. As the increase was marginal when compared to the COD reduction at 12 days SRT, further increase in SRT was not considered for the study.

In the present study on combined domestic and tannery wastewaters, a maximum COD removal of 91% was observed at SRT of 16 days and HRT of 30 h (Vaiopolou, 2007). In the treatment of cotton textile wastewater using ASP, a treatment efficiency of 94% in terms of COD removal was reported at an optimum SRT and HRT of 30 days and 38 h (1.6 days) respectively (Pala and Tokat 2002). In the treatment of combined dairy and domestic wastewater, overall removal efficiency of 98.9% for COD and 99.6% for BOD was achieved for the treatment of combined dairy and domestic wastewater at a HRT of 26 h and a SRT of 20 days (Tawfik *et al* 2008).

3.3 Effect of F/M ratio on COD removal

The effect of Food to Microorganism ratio on COD removal was also studied. The F/M ratio maintained in the reactor for each organic loading rate was arrived at using the equation 4.1.

$$\frac{F}{M} = \frac{S_o}{X\Theta} \qquad (4.1)$$

The F/M ratio obtained for an influent BOD concentration of 350 mg/L, HRT of 30 h and MLSS concentration of 3500 mg/L was as below:

$$F/M = \frac{615 \times 24}{30 \times 4200} = 0.12 \text{ kg of BOD/ kg of MLSS}$$

The graph drawn between the calculated F/M values and percentage COD reduction is shown in Figure 3.4. The maximum COD reduction obtained for the F/M ratio of 0.08 was 91%. It could be observed from the graph that maximum COD reduction was observed for lower F/M ratio. In substrate/biomass limited conditions, the ubstrate would be essentially consumed in order to ensure the cell maintenance requirements instead of growth functions (Jorge *et al.*, 2008).

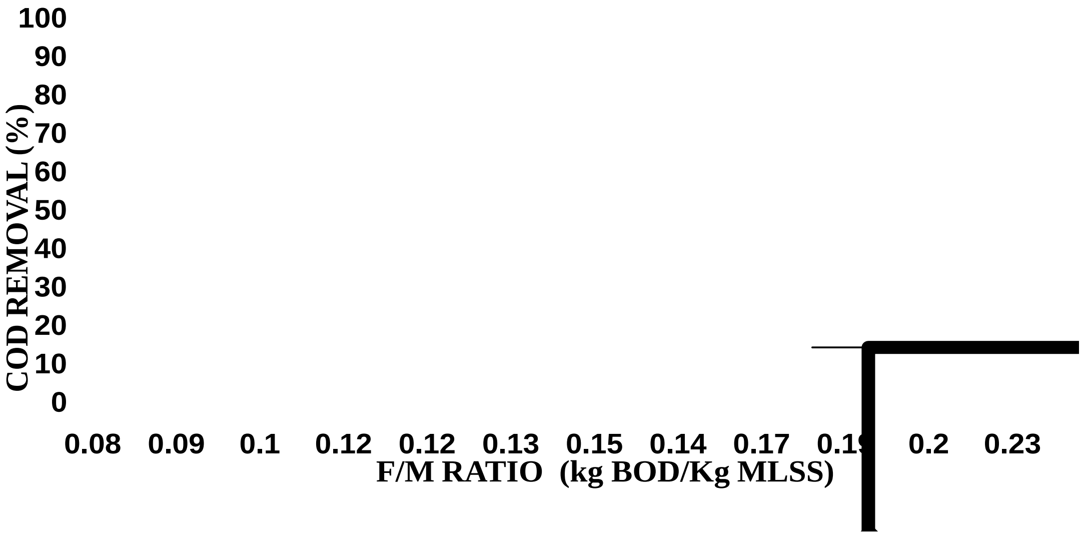


Fig 4.4 Effect of F/M Ratio on percent COD removal

3.4 Determination of Kinetic Coefficients

From the data observed during the treatability study, the values required for the determination of bio-kinetic coefficients are tabulated in Table 4.6. The graphs drawn for the determination of kinetic coefficients are shown in Figure 3.5 and 3.6. From the graph, the maximum rate of substrate utilization rate 'k' and half-velocity substrate concentration 'K_s' were found as 0.416 day^{-1} and 122 mg/L respectively. The maximum yield coefficient 'Y' and the endogenous decay coefficient 'k_d' were obtained as 0.539 mg of MLSS/mg of COD removed and 0.088 day^{-1} respectively. The maximum specific growth rate (μ_m) was also calculated and found to be 0.224 day^{-1}. In the present study, the half velocity concentration and decay rate were 122 mg of COD/L and 0.088 day^{-1} respectively. The half velocity constant and decay rate recorded for the domestic wastewater were 10-60 mg of COD/L and 0.06-0.15 day^{-1} respectively (Tchobanoglous *et al* 2003). In the treatment of combined dairy and domestic sewage reported a growth yield of 0.29 mg MLSS/mg COD and a decay rate of 0.023–0.075 day^{-1} for glucose-fed aerobic granules (Liu *et al* 2005). This model reported by Gujer *et al* (1999) explained that the decay rate for heterotrophic bacteria was in the range of 0.1 and 0.2 day^{-1}.

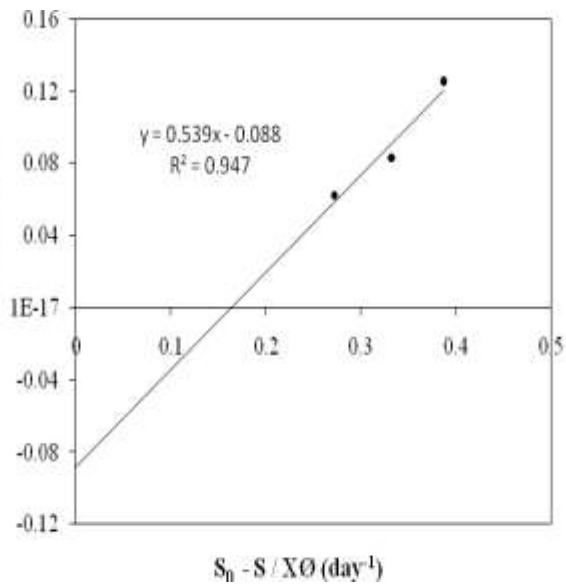


Fig 3.5 Evaluation of Biokinetic constants

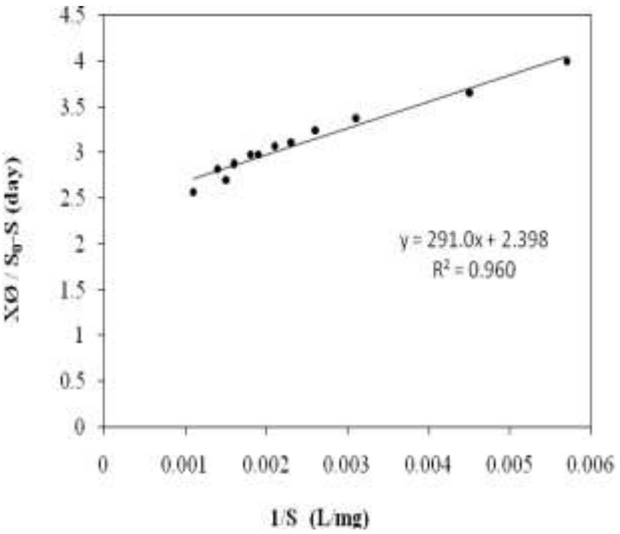


Fig 3.6 Evaluation of Kinetic coefficients

In the treatment of tannery wastewater, a half velocity concentration of 133 mg of COD/L and decay rate of 0.186 day^{-1} has been reported (Ramanujam 2004). For domestic and textile wastewater using ASP, the corresponding values reported were 423 mg/L and 0.086 day^{-1} (Saravanakumar 2007). Above data indicates that wastewater of purely organic nature has a high half velocity concentration and decay rate. Wastewater which is of less organic nature has less half velocity concentration and decay rate. It could be observed that in the present treatability study on combined domestic and tannery wastewater, the corresponding values are in the intermediate range. Orhon and Artan (1994) stated that highest organic removal efficiency in Activated Sludge Process is achieved when the reactor is maintained at stationary phase of microbial growth rather than the log phase of microbial growth and this is possible at relatively low organic loading rate. In the present study, a maximum treatment efficiency of 91% was achieved at an organic loading rate of 1.61 kg COD/m^3/day at a SRT of 16 days. This is in total agreement with findings of Orhon and Artan (1994).

In the Monod's equation [$\mu = \mu_m S/(K_s + S)$], the value of two constants, maximum specific growth rate (μ_m) and half velocity concentration (K_s) determine the relationship between the substrate concentration (S) and specific growth rate (μ). In the present study, μ_m value was very low (0.224 day^{-1}) and the half velocity concentration was relatively high (122 mg/L). This combination of high 'K_s' and low 'μ_m' value provided the best operational stability as it minimizes the sensitivity of specific growth rate to the variations of substrate concentration as illustrated by Monod's equation (Orhon and Artan 1994). The yield coefficient 'Y' obtained as 0.539 mg MLSS/mg COD in the study is less than the average value of 0.64 mg MLSS/mg COD (Ramanujam *et al* 2004) obtained for tannery wastewaters and slightly greater than 0.3-0.6 mg MLSS/mg COD (Tchobanoglous *et al* 2003) for domestic wastewater. The endogenous decay coefficient 'k_d' value of 0.088 day^{-1} is less than the corresponding average value of 0.186 day^{-1} for treatment of tannery wastewater (Ramanujam *et al* 2004), 0.16 day^{-1} for treatment of textile wastewater (Orhon *et al* 1999) and 0.15 day^{-1} for domestic wastewater. The higher yield coefficient and lower death rate obtained can be due to the long HRT and SRT having a positive effect on microbial growth.

The present study clearly indicates that the combined domestic and tannery wastewater is amenable for biological treatment using Activated Sludge Process. Further, the bio-kinetics obtained from the study indicates a stable functioning of the ASP and enhanced microbial activities at longer HRT and SRT.

5. SUMAARY AND CONCULSION

- The combined domestic and tannery wastewater is amenable for treatment by Activated Sludge Process and a maximum treatment efficiency of 91% in terms of COD removal was achieved.
- The optimum operating conditions for the treatment of composite wastewater were obtained as 16 days Solids Retention Time and 30 h Hydraulic Retention Time.
- The organic loading rate at optimum operating condition was 1.61 kg COD/m^3/day.
- The bio-kinetics obtained for the treatment of combined domestic and tannery wastewaters are as given below:

  Maximum substrate utilization rate (k) - 0.416 day^{-1}.
  Half saturation constant (K_s) - 122 mg/L.
  Yield coefficient (Y) -0.539 mg of MLSS/mg of COD
  Endogenous decay coefficient (k_d) - 0.088 day^{-1}.
  Maximum specific growth rate (μ_m) - 0.224day^{-1}.

A maximum treatment efficiency of 91% was obtained for a lower F/M ratio of 0.08 kg BOD/kg MLSS.A relatively higher half velocity substrate concentration and lower 'μ_m' value obtained provides better stability for the Activated Sludge Process. The maximum rate of substrate utilization and half velocity- substrate concentration obtained in the present study are around the same than those obtained for combined tannery waste with cow dung because of higher initial substrate concentration. The yield coefficient obtained in the present study was higher and decay coefficient was lower than the corresponding typical values for domestic wastewater due to longer SRT and HRT. The present study will be a promising solution for the treatment of combined tannery and domestic wastewater in areas, inclusive of Melvisharam Municipality, where their disposal without treatment causes environmental degradation. Pilot plant studies could be conducted to establish the treatment of combined wastewater using the Activated Sludge Process under field conditions and to obtain necessary data for full scale design.

REFERENCES

[1] Alejandro H.C, Leda G., and Noem E.Z. (2008) 'Reduction of hexavalent chromium by *Sphaerotilus natans* a filamentous micro-organism present in activated sludges', Journal of Hazardous Materials, Article in press.

[2] APHA (1998), 'Standard methods for the examination of water and wastewater', 20th edition, American Public Health Association, Washington.
[3] Beline F., Boursier H., Daumer M.L., Guiziou F. and Paul E. (2007) 'Modeling of biological processes during aerobic treatment of piggery wastewater aiming at process optimization', Bioresource Technology, Vol. 98, No.17, pp.3298-3308.
[4] Brdys M.A., Piotrowskia R., Konarczaka K., Duzinkiewicza K. and Chotkowski W. (2007) 'Hierarchical dissolved oxygen control for activated sludge processes', Control Engineering Practice, Article in press.
[5] Ewaliwarska B. and Marcin B. (2007) 'The influence of the selected nonionic surfactants on the activated sludge morphology and kinetics of the organic matter removal in the flow system', Enzyme and Microbial Technology, Vol. 41, No.1-2, pp.26-34.
[6] Farabegoli G., Carucci A., Majone M., and Rolle E. (2004) 'Biological treatment of tannery wastewater inthe presence of chromium', Journal of environmental management, Vol. 71, pp.345-349.
[7] Ganesh R., Balaji G. and Ramanujam R.A. (2006) 'Biodegradation of tannery wastewater using sequencing batch reactor' Bioresource Technology, Vol. 97, pp.1815-1821.
[8] Han-Qing Y. and Bing-Jie N. (2008) 'An approach for modeling two-step denitrification in activated sludge systems', Chemical Engineering Science, Vol. 63, pp.1449-1459.
[9] Hong-Duck R., Sang-Ill L. and Keun-Yook C. (2007) 'Chemical Oxygen Demand removal efficiency of biological treatment process treating tannery wastewater following seawater flocculation', Environmental Engineering Science, Vol. 24, pp.394-399.
[10] Iaconi D.C., Lopez A., Ramadorai R., Pinto A.C.D. and Passin R. (2002) 'Combined chemical and biological degradation of tannery wastewater by a periodic submerged filter (SBBR)', Water Research, Vol. 36, pp.2205-2214.
[11] Jan F.V.I., Ilse Y.S., Ephraim N.B., Jeroen D., Nele R. and Rika J. (2006) 'Dynamic modeling of filamentous bulking in lab-scale activated sludge processes', Journal of Process Control, Vol. 16, No.3, pp.313-319.
[12] Jorge L., Christelle W., Marc H. and Alain G. (2008) 'Sequencing versus continuous membrane bioreactors: Effect of substrate to biomass ratio (F/M) on process performance', Journal of membrane science, Vol. 317, pp.71-77.
[13] Kornaros M., Drillia P., Dokianakis S.N., Fountoulakis M.S., Stamatelatou K. and Lyberatos G. (2005) 'On the occasional biodegradation of pharmaceuticals in the activated sludge process: The example of the antibiotic sulfamethoxazole', Journal of Hazardous Materials, Vol. 122, No.3, pp.259-265.
[14] Lee T.T, F.Y. Wang, and R.B. Newell (2006) 'Advances in distributed parameter approach to the dynamics and control of activated sludge processes for wastewater treatment', Water Research, Vol.40, No.5, pp.853-869.
[15] Liu L.L., Wang Z.P., Yao J., Sun X.J. and Cai W.M. (2005) 'Investigation on the formation and kinetics of glucose-fed aerobic granular sludge', Enzyme Microbiology Technology, Vol. 36, pp.712–716.
[16] Ozlem K., Emine U.C. and Orhon D. (2008) 'The effect of mixing pharmaceutical and tannery wastewaters on the biodegradation characteristics of the effluents', Journal of Hazardous Materials, Article in press.
[17] Padoley K.V., Rajvaidya A.S., Subbarao T.V. and Pandey R.A. (2006) 'Biodegradation of pyridine in a completely mixed activated sludge process', Bioresource Technology, Vol. 97, No.10, pp.1225-1236.
[18] Pala A. and Tokat E. (2002) 'Color removal from cotton textile industry wastewater in an Activated sludge system with various additives', Water Research, Vol. 36, pp.2920-2925.
[19] Prakask N.B. (2003) 'Treatment of composite tan liquor' Journal of American leather chemists association', Vol.98, pp.49-55.
[20] Ramanujam R.A. (2004) 'Biokinetics and Toxicity assessment of tannery wastewater using batch reactor system', Journal of American leather chemists association, Vol. 99, pp.468-473.
[21] Ramanujam R.A. (2004) 'Treatment of Tannery wastewater by Activated sludge process- A kinetic approach', Indian Journal of Environmental protection, Vol. 24, No.7, pp.490-498.
[22] Roche N., Latifi M.A. and Chachuat B. (2005) 'Optimal aeration control of industrial alternating activated sludge plants', Biochemical Engineering Journal, Vol. 23, No.3, pp.277-289.
[23] Samuel S. and Anjaneyalu Y. (2005) 'Evaluation of biokinetic parameters for pharmaceutical wastewaters using aerobic oxidation integrated with chemical treatment', Process Biochemistry, Vol.40, pp.165-175.
[24] Saravanakumar V. (2007) 'Treatability studies on combined domestic and tannery wastewaters using activated sludge process', M.E Thesis, Anna University.
[25] Simon B., Alan W., Magnus C. and Thomas W. (2008) 'Production of polyhydroxyalkanoates by activated sludge treating a paper mill wastewater', Bioresource Technology, Vol. 99 pp.509-516.
[26] Suvilampi J., Lehtomaki A. and Rintala J. (2005) 'Comparative study of laboratory-scale thermophilic and mesophilic activated sludge processes', Water Research, Vol. 39, No.5, pp.741-750.
[27] Tawfik A., Sobhey M. and Badawy M. (2008) 'Treatment of a combined dairy and domestic wastewater in an up-flow anaerobic sludge blanket (UASB) reactor followed by activated sludge (AS system)', Desalination, Vol. 227, pp.167-177.
[28] Tchobanoglous G., Burton F.L. and Stensel H.D. (2003) 'Wastewater Engineering –Treatment and

Reuse', Metcalf and Eddy, Tata McGraw-Hill fourth edition, pp.547-644.

[29] Tsun-teng L. and Shin-shou L. (2004) 'Return sludge employed in enhancement of color removal in the integrally industrial wastewater treatment plant', Water Research, Vol. 38, No.1, pp.103-110.

[30] Tulay A.O., Onder H.O. and Pınar A. (2007) 'Effect of acclimatization of microorganisms to heavy metals on the performance of activated sludge process', Journal of Hazardous Materials, Vol. 142, No.1-2, pp.332-339.

[31] Uma M.R.S. (2000) 'Treatability of combined effluent- A case study of Kottedan industrial estate', Pollution Research, Enviro media, Vol. 19, No.4, pp.565-569.

[32] Vaiopoulou E., Melidis P. and Aivasidis A. (2007) 'An activated sludge treatment plant for integrated removal of carbon, nitrogen and phosphorus', Desalination, Vol. 211, pp.192-199.

[33] Vaidyanathan R., Meenambai T., Senthilvelavan K. and Vijayakumar T. (1995) 'Treatability of predigested Distillery wastewater Diluted with Domestic Sewage', Indian Journal of Environmental protection, Vol. 15, No.4, pp.241-243.

[34] Vidal G., Nieto J., Cooman K., Gajardo M. and Bornhard C. (2004) 'Unhairing effluents treated by an activated sludge system', Journal of hazardous materials, Vol. B112, pp.143-149.

[35] Vijayaraghavan K., Desa A., and Mohd Ezami B.A.A. (2007) 'Aerobic treatment of palm oil mill effluent', Journal of Environmental Management, Vol. 82, pp.24-31.

[36] Vinay k., Shankar S., Absar A.K. and Chopra A.K. (2007) 'Microbial community in conventional and extended aeration activated sludge plants in India', Ecological Indicators, Article in press.

[37] Yongmei Li., Junming Z., Chaojie Z., Qingling Z. and Zhou Q. (2008)' Sorption and degradation of bisphenol A by aerobic activated sludge 'Journal of Hazardous Materials, Article in press.

[38] Yong Li., Liu Y. and Hailou X. (2008) 'Is sludge retention time a decisive factor for aerobic granulation in SBR' Bioresource Technology, Article in press.

[39] Kun Tong, Yihe Zhang, Guohua Liu, Zhengfang Ye, Paul K. Chu(2013) 'Treatment of heavy oil wastewater by a conventional activated sludge process coupled with an immobilized biological filter', International Biodeterioration & Biodegradation,Vol.84, pp.65-71.

[40] Peng Yan,Fangying Ji, Jing Wang, Jianping Fan, Wei Guan, Qingkong Chen (2013) 'Pilot-scale test of an advanced, integrated wastewater treatment process with sludge reduction, inorganic solids separation, phosphorus recovery, and enhanced nutrient removal (SIPER)',Bioresource Technology, Vol.142, pp.483-489.

[41] Daniele Di Trapani, Magnus Christensson, Michele Torregrossa, Gaspare Viviani, Hallvard Ødegaard(2013) 'Performance of a hybrid activated sludge/biofilm process for wastewater treatment in a cold climate region: Influence of operating conditions', Biochemical Engineering Journal,Vol. 77,PP.214-219.

[42] Michelle N. Young , Andrew K. Marcus , Bruce E. Rittmann (2013)' A Combined Activated Sludge Anaerobic Digestion Model (CASADM) to understand the role of anaerobic sludge recycling in wastewater treatment plant performance',Bioresource Technology,Vol.136, pp.196-204.

[43] Falås P., Longrée.P, la Cour Jansen.J, Siegrist.H, Hollender.J, Joss.A(2013) 'Micropollutant removal by attached and suspended growth in a hybrid biofilm-activated sludge process',Water Research,Vol. 47, Iss. 13, PP. 4498–4506.

[44] Xu Wang, Junxin Liu, Bo Qu,Nan-Qi Ren, Jiuhui Qu (2013) 'Role of carbon substrates in facilitating nergy reduction and resource recovery in a traditional activated sludge process: Investigation from a biokinetics modeling perspective',Bioresource Technology,Vol.140,pp.312-318.

[45] Stefan Diehl, Sebastian Farås (2013) 'Control of an ideal activated sludge process in wastewater treatment via an ODE–PDE model',Journal of Process Control,Vol. 23, Iss 3,PP. 359–381.

[46] Kerry McPhedran, Rajesh Seth, Min Song, Shaogang Chu and Robert J. Letcher (2103),' Fate and mass balances of triclosan (TCS), tetrabromobisphenol A (TBBPA) and tribromobisphenol A (tri-BBPA) during the municipal wastewater treatment process',Water Quality Research Journal of Canada, Vol. 48, No 3 pp 255–265.