International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

# Role of HRT in Biological Treatment of Combined Industrial and Municipal Wastewater

Muhammad Ahmad[a], Zahir-ud-din Khan[b*], Sher Jamal Khan[b], Muhammad Masoom Pahore[b] and Erum Aamir[b]

[a]GC University, Faisalabad, Pakistan
[b]Institute of Environmental Sciences & Engineering, School of Civil & Environmental Engineering, National University of Sciences & Technology, Islamabad, Pakistan

Accepted 01July 2013, Available online 01 August 2013, **Vol.3, No.3 (August 2013)**

***Abstract***

*A pilot scale wastewater treatment plant was designed, constructed and operated on site to treat wastewater from a combined effluent drain. The activated sludge process (ASP) was used at three different hydraulic retention times (HRT) of 12, 10 and 8 hrs at an average MLSS concentration of 3500 mg/L. Under each HRT, the pilot plant was operated for a period of 10-12 weeks. Chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon (TOC) and total suspended solids (TSS) were the major variables of interest. Average COD removal efficiency at HRT of 12, 10 and 8 hrs was 77, 80, and 87% respectively. Average BOD removal efficiency was 76, 79, and 88 % at HRT of 12, 10 and 8 hrs respectively. For the same HRTs, the average TOC removal efficiency was 64, 65 and 75% respectively. The average TSS removal efficiency was found to be 87, 90 and 96% at the given HRTs. 8 hr HRT was found to be the most appropriate in almost all cases. The average values of BOD reduced from 274.6 to 35.5 (mg/L), COD from 459.7 to 63.9 (mg/L), TSS from 528.2 to 23.4 (mg/L) and TOC from 134.3 to 33.2 (mg/L). This study proved that ASP at HRT of 8 hrs would treat the combined effluent to a level well within National Environmental Quality Standards (NEQS).*

***Keywords****: Activated sludge process; Paharang Drain; textile wastewater; biochemical oxygen demand (BOD); chemical oxygen demand (COD); total suspended solids (TSS)*

## 1. Introduction

Textile effluents are a mixture of complex chemicals that are found in various compositions over time (UNESCO, 1996). The textile industry is characterized as water intensive industry because it uses water for application of dying and finishing agents to the fabric and removing impurities (European Commission, 2002). According to one estimate, there are approximately 6700 registered textile industries in Pakistan, out of which 1228 are located in Faisalabad city (Sial et al., 2006). For each ton of the fabric produced, 200 – 350 $m^3$ of water is consumed (Nosheen et al., 2000). This wide range of water consumption reflects the variety of processes involved. An estimated 7700 $m^3$of wastewater is discharged into the natural waters every day in this city only.

Faisalabad is the 3rd most populated city of Pakistan housing various types of industries. While other industries such as pharmaceuticals, ceramics, petrochemicals, food industries, steel, oil mills, sugar industries, fertilizer factories, and leather tanning units also exist in Faisalabad, the city is famous for its textile industry. Paharang Drain traverses through the largest industrial region of Faisalabad carrying the industrial and municipal wastewater to River Chenab. Paharang Drain has an average flow of $3.7\times10^5$ $m^3$/day. According to Nosheen et al. (2000), a large fraction of wastewater in the Paharang Drain stems from textile industries. Due to the high load of organic and toxic compounds in their effluents, industries have become a key source of water pollution in the Paharang Drain (Nasrullah et al., 2006; Sial et al., 2006). From the environmental point of view, the textile industry is characterized not only by its enormous water consumption but also by the variety and complexity of chemicals employed (Arslan-Alaton and Alaton, 2007). The quality of textile wastewater depends on the dye stuff and chemicals employed (Stephens and Farris; 2004, Neill et al., 2007, Arulazhagan et al. 2009). Hence, such wastewater should be treated before discarding into waterways (Nandy et al., 2007, Qadir et al., 2007). Unfortunately, less than 1 % of the industries are treating their effluents before disposal. Due to low water availability around the country, the inner-city farms are often irrigated with city effluents (Ensink et al., 2004, Iasur-Kruhet al., 2010). The application of untreated sewage and for agriculture, results in the contamination of human and animal food chain (Ahmad, 1993; Mahmood and Maqbool, 2006).

*Corresponding author: Zahir-ud-din Khan

Table 1: Summary of operating parameters, equipment and methods employed

| Parameters | Units | Equipment Used | Method Number Used |
|---|---|---|---|
| Temperature | $^{o}C$ | pH Meter HACH Sension 1 | Laboratory Method |
| pH | | pH Meter HACH Sension 1 | Potentio-meteric Method |
| TDS | mg/L | Conductivity Meter | - |
| TSS | mg/L | TSS Portable Hand held Instrument For turbidity/suspended solids HACH | Modified adsorption measurement Six-channel Multiple-angle measurement |
| DO | mg/L | DO Meter of Model "Oxi 538" | Membrane Electrode Method |
| $BOD_5$ | mg/L | DO Meter of Model "Oxi 538" | 5-Day BOD Test |
| COD | mg/L | Digestion Vessels, HACH COD Reactor | Closed Reflux Titrimetric Method |
| TOC | mg/L | Analytic kjena Multi N/C 3100 | High Temperature Combustion Method |

(APHA, 2005)

Whilst combined wastewater can be treated using physico-chemical methods (Golob, 2005), most efficient and reliable methods are biological and amongst various biological methods, activated sludge process is reported the most effective one. In this process, a consortium of microorganisms is maintained in suspension in the aeration tank by suitable mixing methods (Vesilind, 2003). Air is provided through diffusers or mechanical mixers for maintaining the required level of dissolved oxygen (>2 mg/L) essential for microbial growth and food degradation and for providing enough mixing and keeping the activated sludge in suspension (Metcalf and Eddy, 2003). Major objective of this study was to design and operate a pilot scale wastewater treatment plant and test a conceptual design for treatment of Paharang Drain wastewater. The specific objectives were:

- Hydraulic testing and operation of a pilot scale wastewater treatment plant to treat Paharang Drain wastewater using activated sludge process (ASP)
- Optimization of the pilot plant's hydraulic retention time (HRT) for removing the pollutants of interest.

## 2. Materials and Methods

Sample analysis of the drain wastewater was carried out on-site as well as in the laboratory. The parameters of interest, equipment used and methods employed for optimization of HRT are given in Table 1. The pilot plant was operated continuously at steady state conditions for almost 08 months including acclimatization period. Seed, sludge was collected from a fully functional STP. An average of eight readings of TDS, DO, pH, TSS and temperature taken on-site on daily basis were used as the daily reading. $BOD_5$, COD and TOC were measured twice a week at the Institute of Environmental Sciences and Engineering (IESE) laboratory.

### *2.1 Experimental Design*

Saqib (2010) conducted lab scale physico-chemical and biological treatability studies for the same water and recommended that activated sludge process (ASP) would be the most feasible systems for treating Paharang Drain wastewater. A pilot scale set-up for ASP was thus constructed for evaluating its performance in a continuous flow mode. The pilot set-up was installed at the West bank of the Paharang Drain at a point beyond which drain does not receive any major input. The wastewater from Paharang Drain was first passed through a preliminary treatment system of manually cleaned bar screen of 10 mm spacing. Using a submersible pump having a capacity of approximately 30 L /min and head of 5m placed in a bank-side sump. Then, two plastic tanks with working volume of 1000L each were used as an integrated primary sedimentation tank. A continuous flow of 5.25 (12 hr HRT), 6.3 (10 hr HRT) and 10.6 (8 hr HRT) L/min was maintained into an aeration tank.

The aeration tank had a working volume of 3000 L. Aeration was provided with a diffuser disc that had main body made of PVC and high density polyethylene porous disc with flow rate range from 1.5 to 5$m^3$/hr. The disc diffuser was connected to an air compressor (blower) having name plate capacity of approximately 20 $m^3$/hr and rated at 700 m-bar. Air pressure was monitored by pressure gauge installed air compressor. Aeration helped in maintaining a required DO level and at the keeping the sludge in suspension as suggested by Bosnic et al., (2000) and Metcalf & Eddy (2003). Air flow was monitored by an air flow meter in $m^3$/hr having measuring capacity up to 18 $m^3$/hr - air, maximum pressure of 70 psi and maximum temperature of 130°F (54°C). Solid particles in the aerated flow from aeration tank settled in the secondary clarifier while the treated effluent was discharged into the drain. pH of the wastewater in the reactor varied between 7 and 8.5, which was a suitable range for biological treatment. A sludge return line was used to return the sludge into the aeration tank for maintaining the required MLSS concentration at 3500 mg/L in aeration tank. Excess sludge was removed as soon as the MLSS concentration

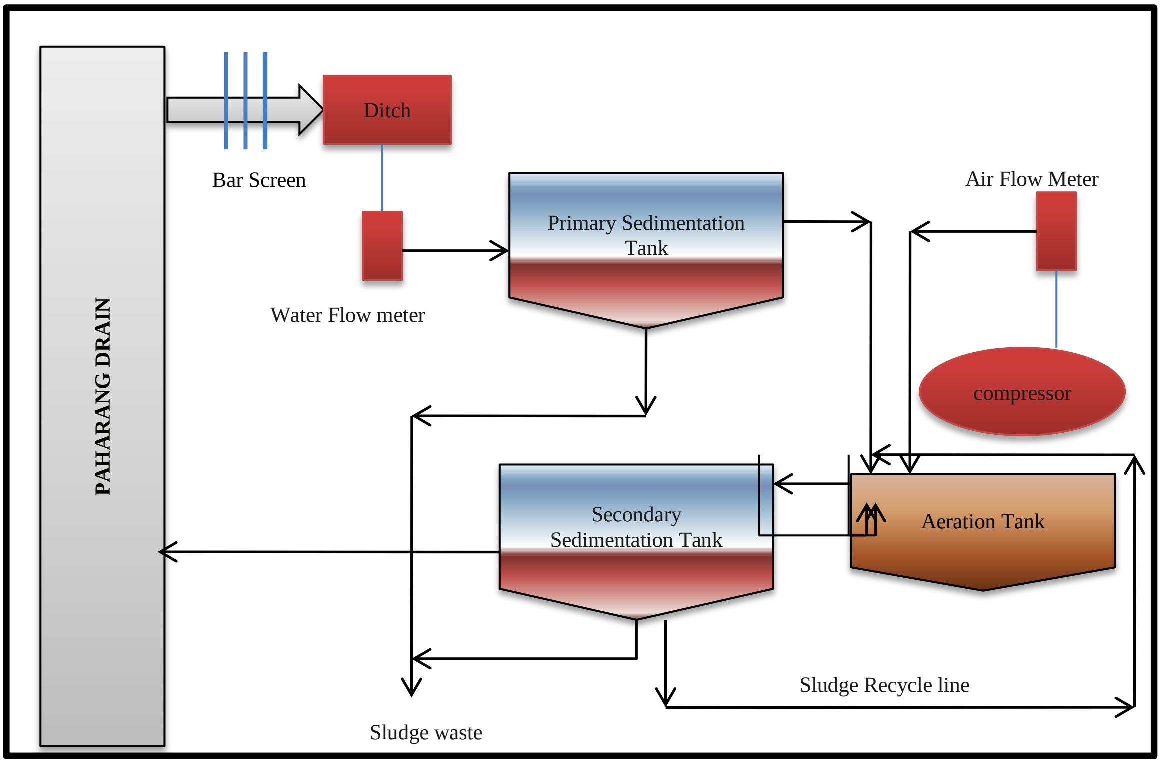



Fig. 1: Process Flow diagram of pilot scale biological treatment plant

touched 3800 mg/L. Table 1 explains the methods and equipment used for determination of various parameters in the study. The experimental set-up of the pilot scale plant is illustrated in Fig. 1.

## 3. Results and Discussion

As mentioned earlier, HRT was the major independent and BODs, COD, TSS and TOC were the major dependent variables of interest. The same have been discussed in the subsequent sections.

### *3.1 $BOD_5$ Removal*

In this study HRT was gradually decreased from 12 to 8 hrs. Fig. 2 (a, b, c) shows variations in the influent and effluent $BOD_5$ and removal efficiencies at HRTs of 12, 10 and 8 hrs respectively. The influent $BOD_5$ varied in the range of 267 - 300 mg/L whereas the effluent $BOD_5$ concentrations were in a range of 22-67mg/L. Average $BOD_5$ removal efficiencies were 77, 78.4 and 87.1%, at HRTs of 12, 10 and 8 hrs. Maximum $BOD_5$ removal efficiency for the same HRTs was 82, 82 and 91% respectively.

$BOD_5$ removal efficiency at all the tested HRTs was not very different, yet at 8 hrs HRT it was consistently high i.e., 91 % when compared with HRT of 12 and 10 hrs. This could be attributed to the on-going acclimatization of the sludge which, by the end of 10 hrs HRT experiments would have been more uniform and consistent in concentration as shown in Fig. 2 (a). These results were in line with the findings of Diez et al., (2002). Diez and co-workers (2002) noted that BOD removal efficiency was 90% at HRT of 6 hrs. BODs removal efficiency increased when HRT was decreased from 16 to 6 hr but decreased when HRT was less than 6 hr.

### *3.2 COD Removal*

Fig. 3 (a, b, c) shows variation in COD removal at different HRTs. The influent COD concentrations varied in the ranges of 394 - 506 mg/L whereas effluent COD concentrations were found to be in the ranges of 93-118 mg/L, 85-112 mg/L and 38 - 72 mg/L at HRTs of 12, 10 and 8 hrs respectively. The average COD removal efficiencies were 77, 80 and 87% for the same HRTs respectively. Whereas the maximum COD removal efficiency for the same HRTs was 81, 83 and 92% respectively.

The COD removal pattern was quite similar at all the three HRT conditions and plant consistently showed more than 76% removal. The maximum COD removal efficiency achieved was 92.3% at 8 hr HRT. It can be inferred from the results that with increase in sludge maturity, the COD removal efficiency increased. Better COD removal efficiency can also be attributed to the increase in MLSS concentration at low HRT when compared with high HRT. The results revealed in this study are also supported by other case studies such as (Pala and Tokat (2003); Ren et al., (2005); Kapdan and Oztekin, (2006) and Ranganathan et al., (2007).

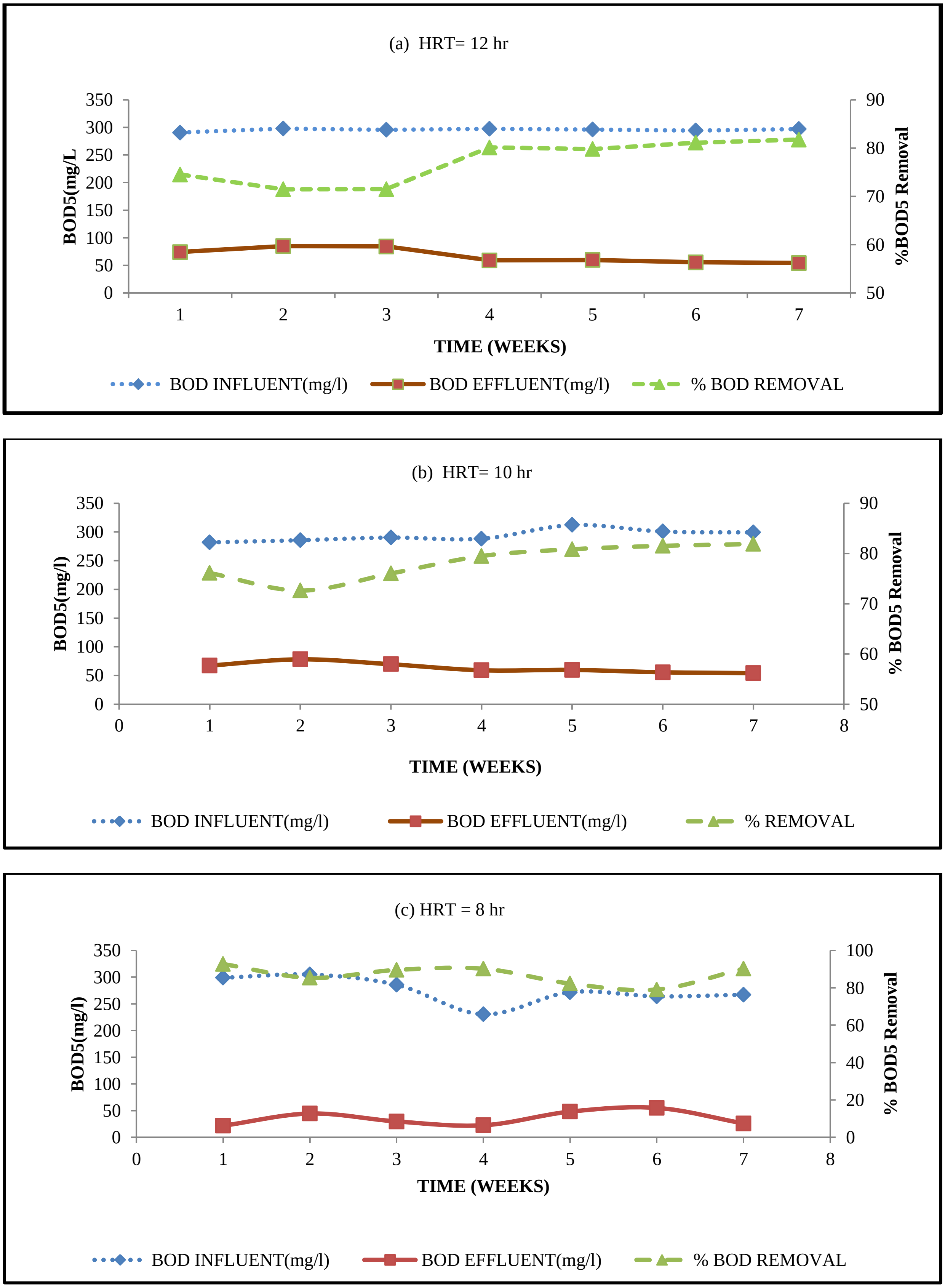



Fig. 2: BOD5 variations: (a) HRT=12 hr (b) HRT=10 hr (c) HRT=08 hr

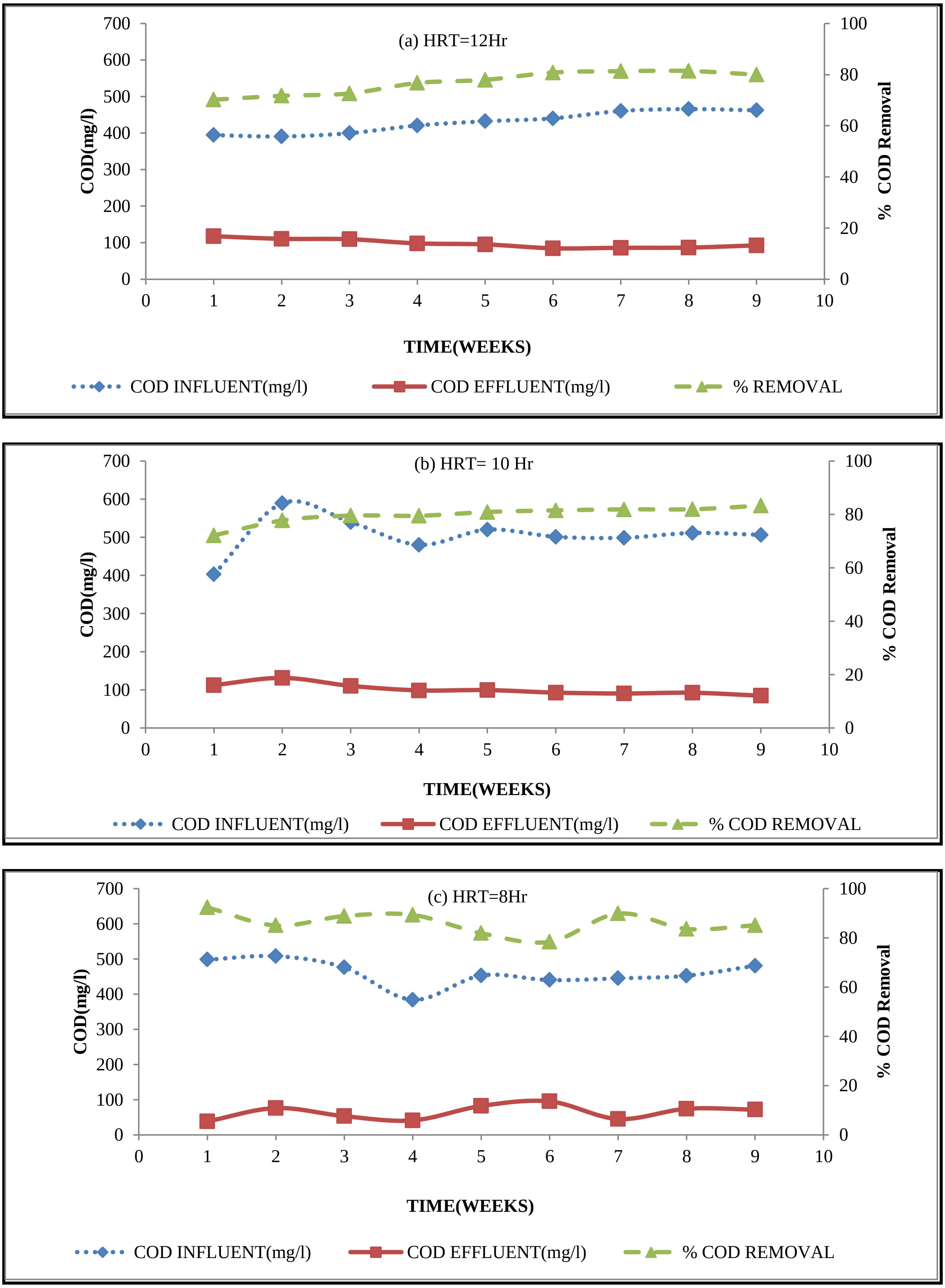



Fig. 3: COD variations: (a) HRT=12 hr (b) HRT=10 hr (c) HRT=8 hr

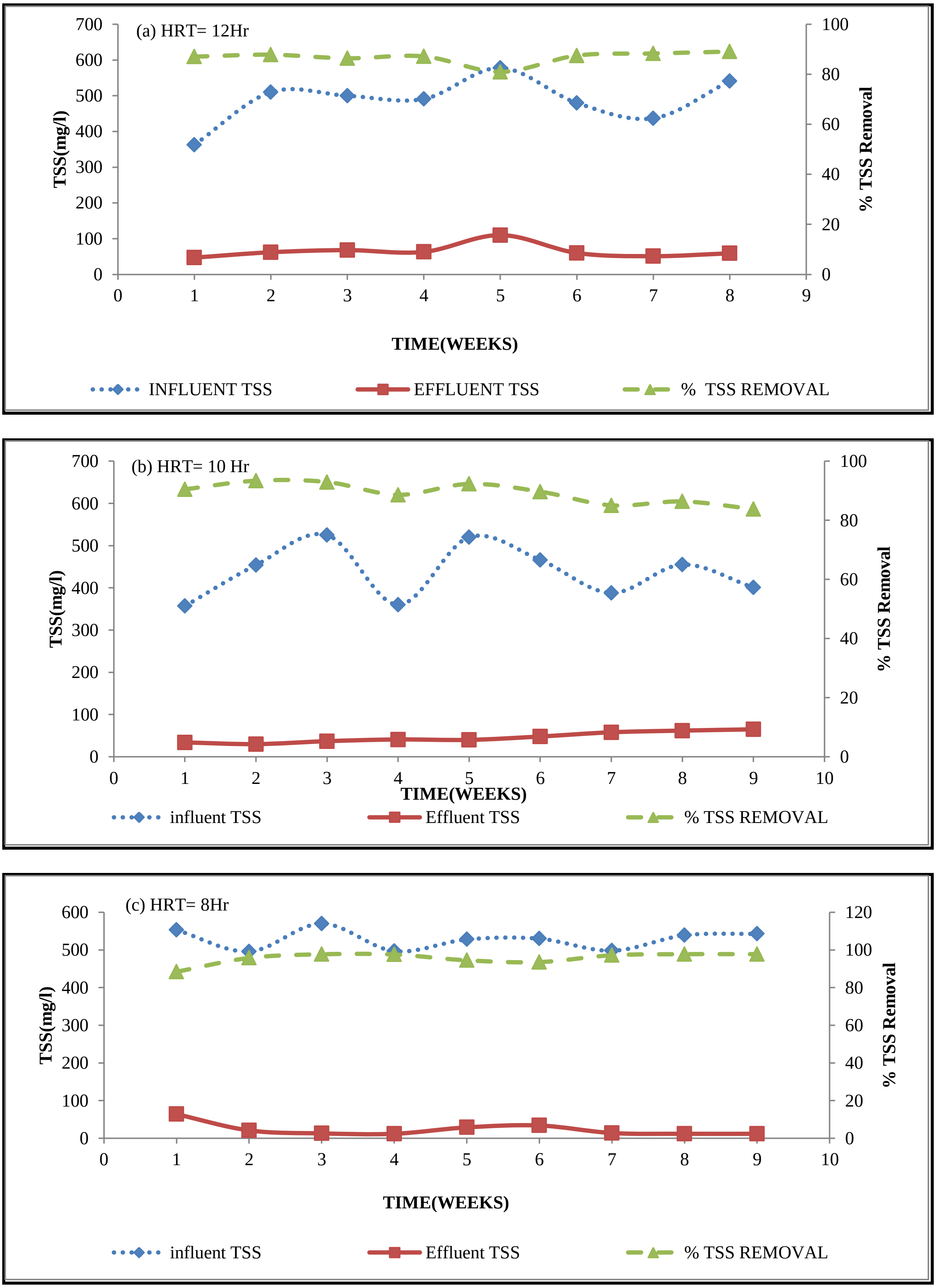



Fig. 4: TSS variations: (a) HRT=12 hr (b) HRT=10 hr (c) HRT=8 hr

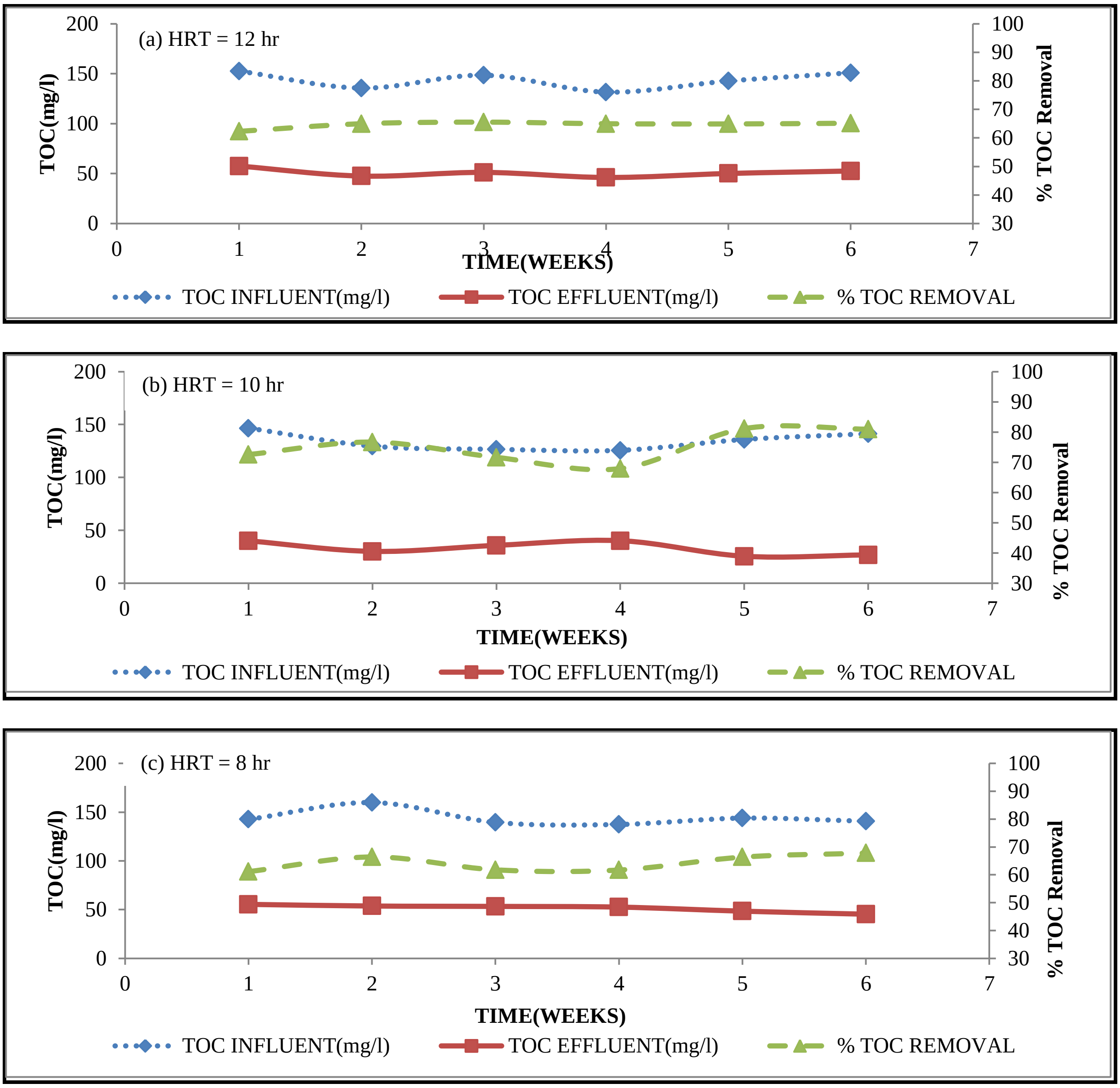



Fig. 5: TOC variations: (a) HRT=12 hr (b) HRT=10 hr (c) HRT=8 hr

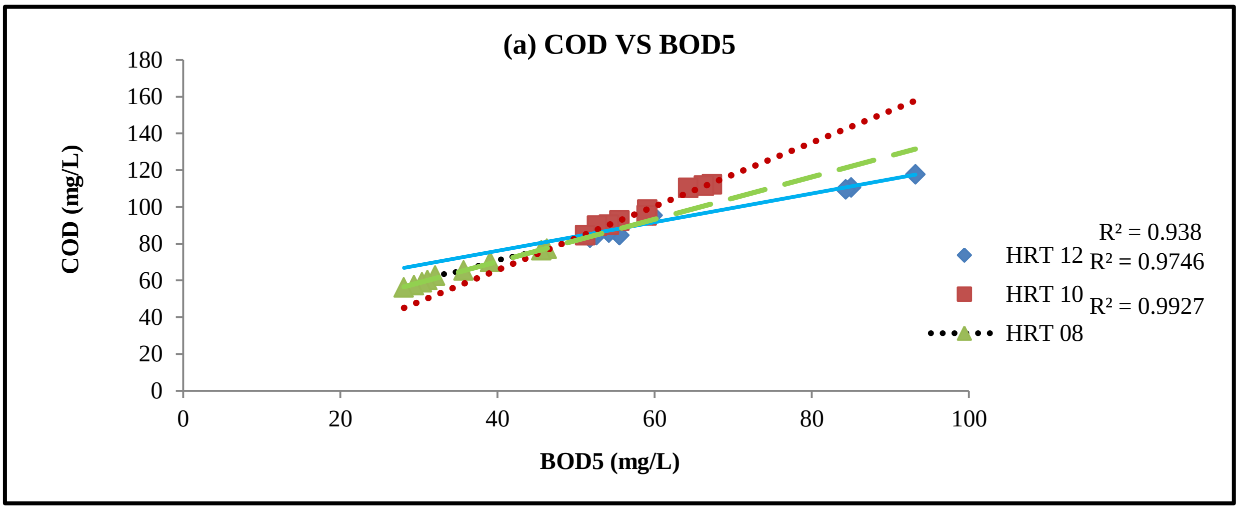
### 3.3 *TSS Removal*

Results of TSS removal at various HRTs are shown in Fig. 4 (a, b, c). The influent TSS concentrations varied in the ranges of 363 - 541 mg/L, 357 - 401 mg/L and 553 - 543 mg/L at 12, 10 and 8 hrs HRTs respectively. For the same HRTs, the effluent TSS concentrations were in the ranges of 47 - 59 mg/L, 34 - 65 mg/L and 12-64 mg/L respectively. The average TSS removal efficiency at HRT=12 hr was 87%, HRT=10 hr was 89% and HRT=8 hr was 96%. The maximum TSS removal efficiencies for the same HRTs were found to be 89, 93 and 98% respectively.

The average TSS removal efficiency fluctuates between 87 and 89% at HRTs of 12 and 10 hrs. There was no significant difference in TSS removal efficiency at these HRTs, however, significant (96%) TSS removal efficiency was observed at 8 hr HRT because, by the time, experiments were conducted at 8 hr HRT optimum sludge growth rate was achieved, hence removal efficiency increased by decreasing HRTs. These results were consistent with findings reported by Fang (1999). He reported that with increase in MLSS concentration from 1000 to 3000 mg/L the COD removal efficiency increased from 92 to 95% and $BOD_5$ removal efficiency increased from 97 to 98% as observed in this study as well.

### *3.4 TOC Removal*

Fig. 5 (a, b, c) illustrates the TOC removal rates at the selected HRTs. The influent TOC concentrations varied in the ranges of 141-143 mg/L, 151-153 mg/L and 141 – 147 mg/L at HRTs of 12, 10 and 8 hrs respectively. The effluent TOC concentrations were found in the ranges of



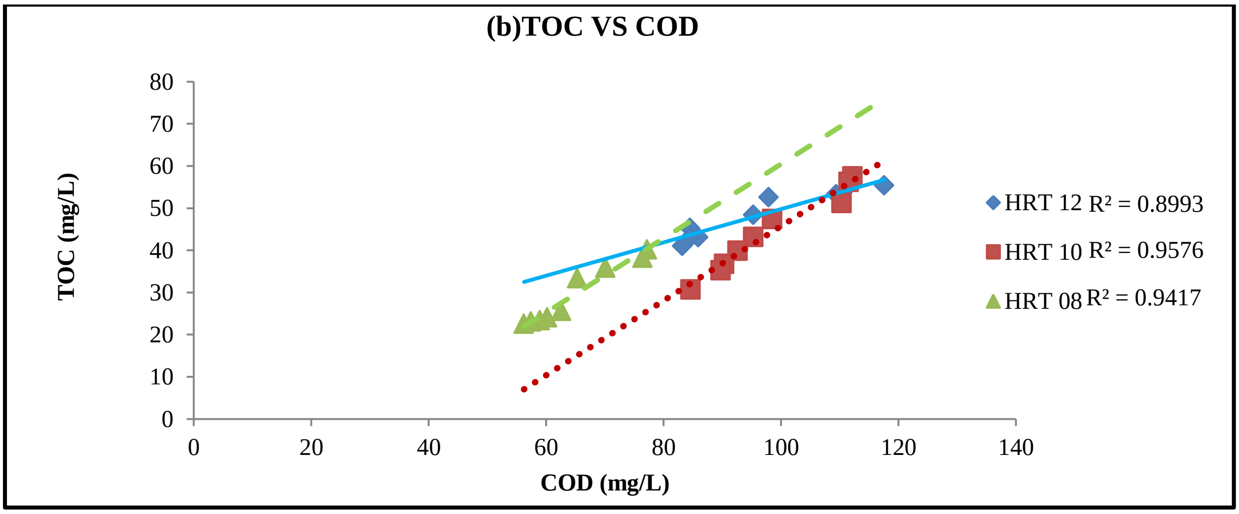




Fig. 6: Correlation between (a) BOD and COD, and (b) COD and TOC

45-55 mg/L, 53-58 mg/L and 27-40 mg/L at the same HRTs. The average TOC removal efficiency at HRT=12 hr was 64%, HRT=10 hr was 65% and HRT=8 hr was 75% and the maximum TOC removal efficiency for the same HRTs was found to be 70, 66 and 81% respectively.

Again the TOC removal at 8 hr HRT was the highest having an average value of 75%. The maximum TOC removal of 81% was also achieved at 8 hr HRT. Keeping in view the correlation between COD and TOC removal efficiencies (Fig. 6), the TOC removal efficiency compliments the COD removal efficiency. Strong correlation between BOD & COD and a relatively weaker correlation between TOC and COD indicates that concentration of non-biodegradable carbon was high in the Paharang Drain wastewater confirming that major fraction of this wastewater stemmed from textile industry. This was also indicated by high amount of mineral salts in the Paharang Drain water, as confirmed by consistently high TDS and pH. These results were also in conformity with those reported by Fang (1990) that the TOC removal efficiency varies between 60 to 96% at different HRTs ranging between 10 to 8 hrs.

## Conclusions

Activated sludge pilot plant was successfully operated for a total period of eight months. A reliable, technical and meaningful data were collected from the on-site pilot plant studies of Paharang Drain wastewater. Some important findings of this study are summarized as under:

- Wastewater of Paharang Drain can be treated successfully by activated sludge process as validated from this pilot scale study.
- The optimum HRT for the activated sludge process was found to be 8 hr, as the average removal efficiency of 87, 87, 96 and 75% was achieved for COD, BOD, TSS and TOC respectively using 8 hr HRT.
- The study showed that as the HRT decreased, the

removal efficiency of all the variables of interest increased.

**Acknowledgement**

Authors gratefully acknowledge the financial support by Higher Education Commission (HEC) Pakistan.

**References**

Ahmad, N. (1993) Water resources of Pakistan. 61-B/2 Gulberg III, Lahore, Pakistan.

APHA (2005) Standard methods for the examination of water and wastewater. (Washington: *American Public Health Association*).

Arslan - Alaton, I. and Alaton, I. (2007) Degradation of xenobiotics originating from the textile preparation, *Dyeing and finishing industry using ozonation and advanced oxidation Ecotoxicology and Environmental safety.* 68: 98-107.

Arulazhagan, P. and Vasudevan, N. (2009) Role of a moderately halophilic bacterial consortium in biodegradation of polyaromatic hydrocarbons. *Marine Pollution Bulletin* 58: 256–262.

Bosnic, M., Buljan J. and DanielsR. P. (2000) Pollutants in tannery wastewater, United Nations Industrial Development Organization (UNIDO), *Regional Programme for Pollution Control in the Tanning Industry in South-East Asia*, report US/RAS/92/120.

Diez Castillo, M.C., Aguilara, L., Vidal, G. and Mora, M.L. (2002) Operational factors and nutrients effects on activated sludge treatment of pinus radiate kraft mill wastewater. *Bio res. Technol*.83:131-138.

Ensink, J. H. J., Simmons, R. W. and vander Hoek, W. (2004) Wastewater re-use in Pakistan: The cases of Haroonabad and Faisalabad. In Scott, C. A., Faruqui, N. I. and Raschid, L. (eds.) Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities. *CAB International, Wallingford.* 91–99.

European Commission DG JRC. (2002) Integrated pollution prevention and control (IPPC), reference document on best available techniques for the textile industry.http://europa.eu.int/comm/environment/ippc/brefs/ txt_bref_0703.pdf.

Fang, H. H. P. (1990) Treatment of wastewater from a whey processing plant using activated sludge and anaerobic processes.*Dairy Sciences*. 74: 2015-2019.

Golob, V., Vinder, A. and Simony, M. (2005) Efficiency of the coagulation/flocculation method for the treatment of dye-bath effluents, *Dyes Pigments* 67: 93–97.

Iasur-Kruh, L., Yitzhak, H., Milstein, D., Gasith, A. and Minz, D. (2010) Microbial population and activity in wetland microcosms constructed for improving treated municipal wastewater. Environmental Microbiology 59: 700-709.

Kapdan, I. K. and Oztekin, R. (2006) The effect of hydraulic residence time and initial COD concentration on color and COD removal performance of the activated sludge system. *Journal of Hazadous materials*. 136: 896-901.

Mahmood.S. and Maqbool.A. (2006) Impacts of wastewater irrigation on water quality and on the health of local community in Faisalabad. *Pakistan Journal of Water Resources*. 10(2): 19-22.

Metcalf and Eddy (2003) Wastewater engineering treatment, disposal and reuse. *Tata Mc Graw-Hill Publication Co*., New Delhi.

Nandy, T., Pravin, M., Rita, D., Girish, P. and Sukumar, D. (2007) Water conservation through Implementation of ultra filtration and reverse osmosis system with recourse to recycling of effluent in textile industries case study.Resource, *Conservation and Recycling*. 51: 64-77.

Nasrullah, Naz, R. Bibi, H. Iqbal, M. and Durrani, M.I. (2006) Pollution load in industrial effluent and ground water of GaDOon Amazai Induatrial Estate (GAIE) Swabi, NWFP. *Agri Bio. Sci* .1:18–24.

Neill, Hawkes, F.R., Hawkes, D.L., Lourenzo, N.D., Pinheiro, H.M. and Delee, W. (1999) Colour on textile effluents sources, measurement, discharge consents and simulation: a review. Chem. *Technol. Biotechnol*. 74: 1009–1018.

Nosheen, S., Nawaz, H. and Rehman. U. K. (2000) Physico-chemical characterizations of effluents of local textile industries of Faisalabad, *Pakistan. International Journal of Agricultural and Biology*.2(3): 232-233.

Pala, A. and Tokat, E. (2003) Activated carbon addition to an activated sludge model reactor forcolor removal from a cotton textile processing wastewater. *Environ. Eng-ASCE*

Qadir, Malik. N. R. and Husain. Z. S. (2007) Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, *Pakistan. Environmental Monitoring Assessment.*140: 43-59.

Ranganathan, K., Karunagaran, K. and Sharma, D.C. (2007) Recycling of wastewaters of textile dyeing industries using advanced treatment technology and cost analysis, case studies. Resource, *Conservation and Recycling.* 50:306-318.

Ren, N., Chen, Z., Wang. D. and Hu. A. (2005) Removal of organic pollutants and analysis of MLSS-COD removal relationship at different HRTs in a activated sludge", *International Biodeterioration & Biodegradation* ;( 55): 279-284.

Saqib Nawaz Rao (2010) ,Treatability studies for treatment of Paharang Drain wastewater, MS Thesis, *Institute of Environmental Sciences and Engineering, NUST*, Pakistan

Sial, R.A., Chaudhary, M.F., Abbas, S.T., Latif, M.I. and Khan, AG. (2006) Quality of *effluents from Hattar Industrial Estate. J* Zhejiang Univ Sci B 7:974–80.

Stephens, W.W. and Farris, J.L.(2004) In stream community assessment of aquaculture effluents.*Aquaculture*.231: 149–162.

UNESCO/WHO/UNEP.(1996) Water quality assessments. *University Press*, Nancy. 651

Vesilind, P.A. (Ed.), (2003).Wastewater treatment plant design. *IWA Publishing*, London.