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COD and BOD Reduction of Domestic Wastewater using Activated Sludge, Sand Filters and Activated Carbon in Saudi Arabia

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Abstract: The objective of this study was to determine COD and BOD reduction from domestic wastewater using sedimentation, aeration, activated sludge, sand filter and activated carbon. Mean maximum COD and BOD reduction was 92.17 and 97.66%, respectively. Other water quality parameters such as TSS, TDS, NO_2, TKN and PO_4 showed significant reduction except NO_3 which increased significantly using different materials in the Wastewater Treatment Plant (WTP). The sewage treatment system using different materials showed excellent potential for COD and BOD removal from domestic wastewater. Also, the concentration level of COD and BOD in the treated water was within the permissible limits for industrial cooling and agriculture use especially for landscape development.

Key words: Activated sludge, sand filter, activated carbon, aeration, COD, BOD, TDS, NO_3, wastewater

INTRODUCTION

Recent urban and rural expansion tremendously increased the water consumption in and around major cities of the Kingdom which resulted in many fold increases in wastewater production. The wastewater is a mixture of sewage water, agricultural drainage, industrial waste effluents and hospitals facilities. It is well known that the wastewater from domestic origin contains pathogens, suspended solids, nutrients (nitrogen and phosphorus) and, other organic and inorganic pollutants (Andrew *et al*., 1997). In order to minimize the environmental and health hazards, these pollutants need to be brought down to permissible limits for safe disposal of wastewater (Manju *et al*., 1998; Poots *et al*., 1978). Therefore, removal of the organic contaminants and pathogens from wastewater is of paramount importance for its reuse in different activities (Ali and Deo, 1992; Chen, 1997; Raj *et al*., 1997). The conventional wastewater treatment technologies as adopted in industrialized nations are expensive to build, operate and maintain (Mazumder and Roy, 2000; Piet *et al*., 1994; Mazumder and Kumar, 1999), especially for decentralized communities. Research efforts are underway (Mohammed *et al*., 1998; Wang *et al*., 2005) for the development of treatment technologies suited to these decentralized communities. Fly ash can be used as a promising adsorbent for removal of various types of pollutants from wastewater (Wang and Hongwei, 2006). Low-cost adsorbents of different origin like industrial waste material, bagasse fly ash and jute-processing waste can also be used for removal of organic matter from wastewater (Bhatnagar, 2007; Srivastava *et al*., 2005; Banerje and Dastidar, 2005). The COD and BOD concentrations play an important role in the re-use of these waste effluents. Adsorption-based innovative technology (Devi *et al*., 2002; Devi and Dahiya, 2006) developed with low-cost carbonaceous materials showed good potential, more so for COD removal from the domestic wastewater. Devi and Dahiya (2008) studied COD and BOD reduction of domestic wastewater using discarded material based mixed adsorbents (mixed adsorbent carbon, MAC and commercial activated carbon, CAC) in batch mode. Under optimum conditions, maximum COD and BOD reduction achieved using MAC and CAC was 95.87, 97.45, 99.05 and 99.54%, respectively. The results showed that MAC offered potential benefits for COD and BOD removal from wastewater.

Devi *et al*. (2008) assessed the reduction of chemical oxygen demand (COD) and biological oxygen demand (BOD) of wastewater from coffee processing plant using activated carbon made up of Avacado Peels. The maximum percentage reduction of COD and BOD concentration under optimum operating conditions using APC was 98.20 and 99.18%, respectively and with CAC this reduction was 99.02 and 99.35%, respectively. As the adsorption capacity of APC is comparable with that of CAC for reduction of COD and BOD concentration, it could be a lucrative technique for treatment of domestic wastewater generated in decentralized sectors.

To date, research has mainly focused on the use of intermittent sand filters for the treatment of domestic strength wastewater (Schudel and Boller, 1990; Gross and Mitchell, 1985; Gold *et al*., 1992; Nichols *et al*., 1997). Generally, these filters are designed and operated in accordance with the US Environmental Protection Agency (1980) guidelines and have provided good organic carbon, TSS and nutrient removal rates. Research on the use of intermittent sand filters in the treatment of high strength wastewater is more limited. Liu *et al*. (1998, 2000, 2003) used sand filter columns to treat high-strength synthetic wastewater containing detergent and milk fat.

Healy *et al*. (2006) studies the performance of a stratified sand filter in removal of chemical oxygen demand, total suspended solids and ammonia nitrogen from high-strength wastewater. Best performance was obtained at a system hydraulic loading rate of 10 $L/m^2/d$, a higher system hydraulic loading rate (of 13.4 $L/m^2/d$) caused surface ponding. The system hydraulic loading rate of 10 $L/m^2/d$ gave a filter chemical oxygen demand (COD), TSS and Total Kjeldahl Nitrogen (TKN) loading rate of 14, 3.7 and 2.1 $g/m^2/d$, respectively and produced consistent COD and TSS removals of greater than 99% and an effluent NO_3-N concentration of 42 mg L^{-1} (accounting for an 86% reduction in total nitrogen (Tot-N)). Tan and Chua (2004) stated that proper control of the activated sludge process is essential in ensuring production of good effluent. The COD adsorption capacity (CAC) of the activated sludge could be used as a control parameter. The CAC is determined by mixing the activated sludge with the settled sewage and measuring the instantaneous COD reduction per unit mass of activated sludge. The CAC measures substrate removal by physical adsorption and reflects the quality of the activated sludge.

The main objective of this study was to develop low cost and effective wastewater treatment technology for the reduction of COD and BOD from wastewater using activated sludge, sand filter, activated carbon and chlorination.

MATERIALS AND METHODS

The experiment was carried at the Technical College Riyadh during 2008-2009. The domestic wastewater was passed through a series of treatment processes for the removal of BOD and COD. The treatment process consists of the following steps:

- Pre-treatment stage includes screening, oil separation and equalization
- Primary treatment stage including two processes:
    - Physical processes which including Sedimentation in clarifiers, flocculation and filtration
    - Chemical processes include precipitation, coagulation and neutralization
- Secondary treatment stage includes two processes:
    - Activated sludge system includes aeration tank and settling tank
    - Bio-filters tank
- Advanced treatment stage or tertiary method includes three processes:
    - Sand filter
    - Activated carbon as an adsorbent (adsorption system)
    - Chlorination (disinfection)

The schematic diagram of Wastewater Treatment Plant (WTP) is presented in Fig. 1.

Analytical procedure: The raw wastewater samples were collected from the main outlet of wastewater from the Technical College. The raw water samples were passed through different steps as indicated in Fig. 1 for the removal of COD and BOD. The treated and untreated wastewater samples were collected on weekly basis and analyzed for COD, BOD, Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN), Total Dissolved Solids (TDS), Nitrate (NO_3), Nitrite (NO_2) and Phosphate (PO_4) in the analytical laboratory according to the methods prescribed by the American Public Health Association

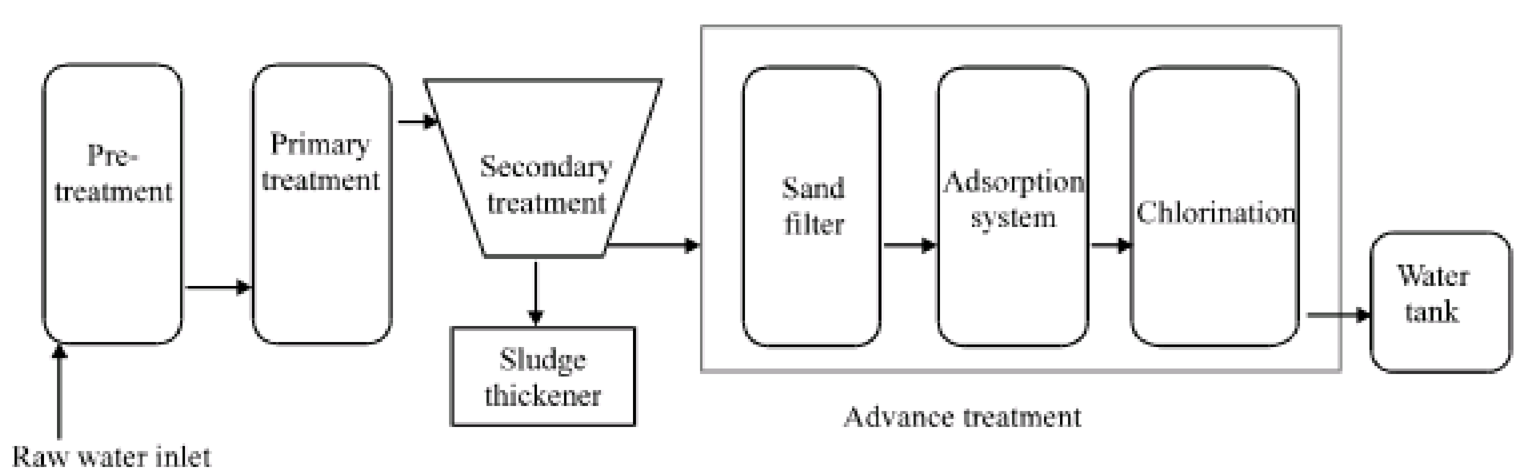

Fig. 1: Domestic wastewater treatment plant

(1989). The experimental duration was 5-weeks and each treatment replicated three times. Overall percent efficiency for each parameters was also calculated relative to the control treatment by considering the control values equal to 100%.

The data were analyzed by ANOVA for treatment evaluation according to Snedecor and Cochran (1973).

RESULTS AND DISCUSSION

Biological Oxygen Demand (BOD): The BOD decreased significantly in the treated water as compared to the untreated wastewater ($LSD_{0.05}$ = 9.677) (Table 1). The results showed that the activated sludge, sand filter and the activated carbon were very effective for the removal of BOD from the wastewater. The reduction in BOD was 128.57 mg L^{-1} (raw water) to 3.03 mg L^{-1} (treated water) with a mean removal efficiency of 97.66%. Similar results were reported by Devi *et al*. (2008) who assessed the reduction of BOD of wastewater from coffee processing plant using activated carbon made up of Avacado Peels.

Chemical Oxygen Demand (COD): The COD concentration decreased significantly in the treated water as compared to the untreated wastewater ($LSD_{0.05}$ = 18.145) (Table 1). The results showed that the activated sludge, sand filter and the activated carbon were effective for removal of COD from the wastewater. The reduction in COD was from 130.33 mg L^{-1} (raw water) to 10.2 mg L^{-1} (treated water) with a mean removal efficiency of 92.17%. The study results agree with those of Healy *et al*. (2006) who studied the performance of a stratified sand filter in removal of chemical oxygen demand, total suspended solids and ammonia nitrogen from high-strength wastewater. They also stated that the system hydraulic loading rate of 10 L/m^2/d gave a filter COD, TSS and total TKN loading rate of 14, 3.7 and 2.1 g/m^2/d, respectively and produced consistent COD and TSS removals of greater than 99% and an effluent NO_3-N concentration of 42 mg L^{-1} (accounting for an 86% reduction in total nitrogen (Tot-N)). Similarly, Tan and Chua (2004) reported that proper control of the activated sludge process is essential in ensuring production of good effluent. COD adsorption capacity (CAC) of the activated sludge could be used as a control parameter. CAC is determined by mixing the activated sludge with the settled sewage and measuring the instantaneous COD reduction per unit mass of activated sludge.

Total Suspended Solids (TSS): The TSS concentration decreased significantly in the treated water as compared to the un-treated water with $LSD_{0.05}$ value of 9.620 (Table 1). The mean TSS concentration decreased from 111.33 to 2.7 mg L^{-1} in the raw water and treated water, respectively with a mean removal efficiency of 97.58%. This suggests that the treatments applied to the wastewater were significantly effective for the removal of TSS from wastewater. The results agree with the findings of Healy *et al*. (2006) who observed TSS removal up to 99% using sand filters.

Total Dissolved Solids (TDS): The TDS decreased significantly in the treated water as compared to the un-treated water with $LSD_{0.05}$ value of 5.449 (Table 1). Although, the TDS showed decreases ranging from 593.5 mg L^{-1} (raw water) to 401.33 mg L^{-1} (treated water), but the removal efficiency was very low (32.38%). The results indicated that there was not appreciably reduction in the total water salinity.

Total Kjeldahl Nitrogen (TKN): Mean TKN concentration decreased significantly in the treated effluent as compared to the raw wastewater (Table 1). Mean TKN concentration was 26.25 and 4.17 mg L^{-1} in the raw and treated wastewater, respectively, but the different between the two was significant ($LSD_{0.05}$ = 2.93). The reduction in TKN in the treated effluent could be due to the decomposition of organic nitrogen from wastewater to other forms of nitrogen such as NH_4, NO_2 and NO_3 in the treated water using different materials in the system.

Table 1: Effect of treatments on different parameters (mg L^{-1}) of wastewater

	Different water quality parameters							
Water type	BOD	COD	TSS	TDS	TKN	NO_3	NO_2	PO_4
Raw	128.57a	130.33a	111.33a	593.50a	26.25a	1.88a	0.327a	1.92a
Treated	3.03b	10.20b	2.70b	401.33b	4.17b	6.66b	0.028b	0.60b
$LSD_{0.05}$	9.677	18.145	9.620	5.449	2.930	1.225	0.049	0.313
R^2	0.995	0.983	0.994	0.999	0.986	0.955	0.979	0.960
CV (%)	9.915	17.404	11.372	0.738	13.009	19.240	18.534	16.763
RMSE	6.521	12.226	9.484	3.672	1.978	0.822	0.334	0.211
TE (%)	97.660	92.170	97.580	32.380	83.990	-258.990	89.760	67.850

Figures in the column followed by the same letters are not significantly different at 5% level of significance ($LSD_{0.05}$). BOD: Biochemical Oxygen Demand, COD: Chemical Oxygen Demand, TSS: Total Suspended Solids, TDS: Total Dissolved Solids, TKN: Total Kjeldahl Nitrogen, NO_3: Nitrate, NO_2: Nitrite, PO_4: Phosphate, R^2: Coefficient of determination, CV: Coefficient of variation, RMSE: Root of Mean Standard Error, TE: Treatment Efficiency

Table 2: Comparison of some chemical parameters

Parameters	Concentration treated water	*Maximum permissible limits
Biochemical oxygen demand (mg L^{-1})	3.03	3-4
Chemical oxygen demand (mg L^{-1})	10.20	30-45
Total suspended solids (mg L^{-1})	2.70	1050
Total dissolved solids, TDS (mg L^{-1})	401.33	450

Source: Meteorology Environmental Protection Administration (MEPA) (1981)

Nitrate (NO_3) and nitrite (NO_2) concentration: The NO_3 concentration increased significantly in the treated effluent than the raw wastewater (Table 1). Mean NO_3 concentration was 1.88 and 6.66 mg L^{-1} in the raw and treated wastewater, respectively. The significant increase in the NO_3 concentration could be attributed to the conversion of organic form of nitrogen to nitrate form due to oxidation reaction during the wastewater treatment process. Because, organic nitrogen is mostly in NH_4 form which might have oxidized to NO_2 and finally to a more stable form of nitrogen (NO_3). On the other hand, the NO_2 concentration was low than NO_3 as the NO_2 form of nitrogen is highly unstable and is immediately converted either to NH_3 (volatile form of nitrogen) or to NO_3, highly stable form of nitrogen into the wastewater treatment system.

Phosphate (PO_4) concentration: The PO_4 concentration decreased significantly in the treated wastewater under various treatments processes than the raw wastewater (Table 1). The decrease in the PO_4 concentration could be due to the decomposition of some organic phosphorus compound from the wastewater by the activated sludge and the activated carbon.

Comparison of some chemical parameters: A comparison of some chemical parameters with the established standards showed that the concentration of BOD, COD, TSS and TDS was within permissible limits for agricultural and industrial uses (Table 2).

CONCLUSIONS

The study showed that by using sedimentation, aeration, activated sludge, sand filter and activated carbon COD and BOD reduction was 92.17 and 97.66%, respectively in the domestic sewage water. Other water quality parameters such as TSS, TDS, NO_2, TKN and PO_4 showed significant reduction except NO_3 which increased significantly using different materials in the Wastewater Treatment Plant (WTP). The sewage treatment system using different materials showed excellent potential for COD and BOD removal from domestic wastewater. Besides, the final COD and BOD concentration in the treated was within the permissible limits for industrial cooling and agriculture use especially for landscape development.

REFERENCES

Ali, M. and N. Deo, 1992. Effect of pH on adsorption process of chromium(VI) with a new low cost adsorbent. Indian J. Environ. Prot., 12: 202-209.

American Public Health Association (APHA), 1989. Standard Methods for the Analysis. 7th Edn., University Press, Washington DC, New York, USA.

Andrew, B., S. Xiaodong and G.J. Edyvean, 1997. Removal of coloured organic matter by adsorption onto low cost-waste material. Water Res., 31: 2084-2092.

Banerje, S. and M.G. Dastidar, 2005. Use of jute processing wastes for treatment of wastewater contaminated with dye and other organics. Bioresour. Technol., 96: 1919-1928.

Bhatnagar, A., 2007. Removal of bromophenols from water using industrial wastes as low cost adsorbents. J. Hazardous Mater., 139: 93-102.

Chen, P.H., 1997. Adsorption of organic compounds in water using asynthetic adsorbent. Environ. Inter., 23: 63-73.

Devi, R., R.P. Dahiya and K. Gadgil, 2002. Investigation of coconut coir carbon and sawdust based adsorbents for combined removal of COD and BOD from domestic wastewater. Water and Environmental Management Series, International Water Association.

Devi, R. and R.P. Dahiya, 2006. Chemical oxygen demand (COD) reduction in domestic wastewater by fly ash and brick kiln ash. Int. J. Water Air Soil Pollut., 174: 33-46.

Devi, R. and R.P. Dahiya, 2008. COD and BOD removal from domestic wastewater generated in decentralized sectors. Bioresour. Technol., 99: 344-349.

Devi, R., V. Singh and A. Kumar, 2008. COD and BOD reduction from coffee processing wastewater using Avacado peel carbon. Bioresour. Technol., 99: 1853-1860.

Gold, A.J., B.E. Lamb, G.W. Loomis, J.R. Boyd, V.J. Cabelli and C.G. McKiel, 1992. Wastewater renovation in buried and recirculating sand filters. J. Environ. Qual., 21: 720-725.

Gross, M. and D. Mitchell, 1985. Biological virus removal from house hold septic tank. Proceedings of the 4th National Symposium on Individual and Small Community Sewage Systems, Dec. 10-11, 1984, New Orleans, LA., pp: 295-304.

Healy, M.G., M. Rodgers and J. Mulqueen, 2006. Performance of a stratified sand filter in removal of chemical oxygen demand, total suspended solids and ammonia nitrogen from high-strength wastewater. J. Environ. Manage., 83: 409-415.

Liu, Q., K. Mancl and O.H. Tuovinen, 1998. Effect of inoculation on the biodegradation of butterfat–detergent mixtures in fixed-film sand columns. Bioresour. Technol., 64: 27-32.

Liu, Q., K. Mancl and O. H. Tuovinen, 2000. High fat wastewater remediation using layered sand filter biofilm systems. Proceedings of the International Symposium on Animal, Agricultural and Food Processing Wastes, (AAFPW'00), ASAE, St. Joseph, MI, pp: 242-248.

Liu, Q., K. Mancl and O.H. Tuovinen, 2003. Biomass accumulation and carbon utilization in layered sand filter biofilm systems receiving milk fat and detergent mixtures. Bioresour. Technol., 89: 275-279.

Manju, G.N., C. Raji and T.S. Anirudhan, 1998. Evaluation of coconut husk carbon for the removal of arsenic from water. Water Res., 32: 3062-3070.

Mazumder, S.C.B. and K. Kumar, 1999. Removal/recovery of acetic acid from wastewater by adsorption on bagasse and coconut jute carbon. Indian J. Environ. Health, 41: 170-175.

Mazumder, D. and B. Roy, 2000. Low cost options for treatment and reuse of municipal wastewater. Indian J. Environ. Prot., 20: 529-532.

Mohammed, A., H.K. Akhtar, A. Ahmad and A. Ahmad, 1998. Role of sawdust in the removal of copper(II) from industrial wastes. Water Res., 32: 3085-3091.

Meteorology and Environmental Protection Administration (MEPA), 1981. Environmental protection standards document. 1401-01 Ministry of Defense and Aviation, Kingdon of Saudi Arabia.

Nichols, D.J., D.C. Wolf, M.A. Gross and E.M. Rutledge, 1997. Renovation of septic Effluent in a Stratified Sand Filter. In: Site Characterization and Design of On-site Septic Systems, Bedinger, M.S., J.S. Fleming and A.I. Johnson (Eds.). American Society for Testing and Materials, America, pp: 235-247.

Piet, N.L., M.V. Piet, S. Lode and H.V. Willy, 1994. Direct treatment of domestic wastewater by percolation over peat, bark and wood chips. Water Res., 28: 17-26.

Poots, V.J.P., G. Mackay and J.J. Healy, 1978. Removal of basic dye from effluent using wood as an adsorbent. J. Water Pollut. Control Federation, 50: 926-935.

Raj, C.P., T.S. Subha and T.S. Anirudhan, 1997. Use of chemically modified sawdust in the removal of Pb(II) ions from aqueous media. Indian J. Environ Health, 39: 230-238.

Schudel, P. and M. Boller, 1990. Onsite wastewater treatment with intermittent buried filters. Water Sci. Technol., 22: 93-100.

Snedecor, G.W. and W.G. Cochran, 1973. Statistical Methods. 6th Edn., Iowa State University Press, Ames, USA.

Srivastava, V.C., I.M. Deo and I.M. Mishra, 2005. Treatment of pulp and paper mill wastewater with poly aluminium chloride and bagasse fly ash. Colloids Surfaces Physicochem. Eng. Aspects, 260: 17-28.

Tan, K.N. and H. Chua, 2004. COD adsorption capacity of the activated sludge-Its determination and application in the activated sludge process. Environ. Monitor. Assess., 44: 211-217.

US Environmental Protection Agency, 1980. Design manual: Onsite wastewater treatment and disposal systems. EPA Report No. 625/1-80-012, Cincinnati.

Wang, S., L. Lin, W. Hongwei and Z.H. Zhu, 2005. Unburned carbon as a low-cost adsorbent for treatment of methylene blue containing wastewater. J. Colloid Interface Sci., 292: 336-343.

Wang, S. and W. Hongwei, 2006. Environmental-benign utilization of fly ash as low-cost adsorbents. J. Hazardous Mater., 136: 482-501.