Temporal Evaluation of Effluent Treatment Plant (ETP) and Treatment of Sludge Produced by ETP

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(Received 7th May 2007, revised 11th June 2007)

Summary: An effluent treatment plant (ETP) operating at an ice cream factory was evaluated for percentage removal of various pollution parameters in the wastewater. On the basis of 18 months regular analysis of untreated and treated effluent for various physical and chemical parameters, it was found that the percentage removal of most of the pollutants ranged from 83 - 100 %. ETP was found more efficient during summer than during winter seasons. The treated effluent falls well below the national environmental quality standards (NEQS) set by Pakistan environmental protection agency (EPA). Sludge generated as a result of effluent treatment was analyzed and treated by total fatty material (TFM) extraction, dewatering and drying. 96.62 % reduction in sludge weight was obtained after treatment. Treated sludge can then be safely applied or dumped on land.

Introduction

Wastewater treatment is a process of increasing importance in a world with an ever-growing human population. Today, most wastewater treatment processes make use of the natural self-purification capacity of aquatic environments, which is the result of the presence and action of microbial communities. The performance, at least of large plants, has to be constantly monitored and is subject to strict regulation. Nevertheless, malfunctions resulting in decreased purification efficacy are frequent [1].

With the aim of improving knowledge about the stability and reliability of anaerobic wastewater treatment systems, several researchers have studied the effects of operational or environmental variations on the performance of such reactors. In general, anaerobic reactors are affected by changes in external factors, but the severity of the effect is dependent upon the type, magnitude, duration and frequency of the imposed changes. The typical responses include a decrease in performance, accumulation of volatile fatty acids, drop in pH and alkalinity, change in biogas production and composition, and sludge washout [2]. Colmenarejo et al. (2006) evaluated eight small-scale municipal wastewater treatment plants over a period of 19 months in the suburb of Las Rozas in Madrid (Spain). The best results were obtained from the plants that used conventional technologies and the biodisc. They found that conventional activated sludge and extended aeration had higher removal efficiencies for ammonia, total suspended solids, chemical oxygen denad and 5-day biochemical oxygen demand and produced good quality final effluents for final disposal in accordance with the discharge standard [3]. Mc Garvey et al. (2005) compared the chemical, physical and bacterial composition of circulated and stagnant dairy wastewater. Samples taken from circulated and stagnant wastewater lagoons, over a 1-year period, were analyzed for 10 chemical (total N, NH_3, NO_3, NO_2, Na, Ca, HCO_3, Fe, P and K) and six physical (biological oxygen demand, chemical oxygen demand, dissolved solids, electrical conductivity, pH and sodium absorption ratio) parameters. They found that circulation of dairy wastewater does not affect any of the chemical or physical parameters tested; however, circulation does alter the bacterial community structure [4]. Saber et al. (2006) found that during the warm season, the pilot-scale wastewater treatment system comprising of a 40-l UASB reactor, achieved removal values of 93 %, 96 % and 91 % for COD, BOD and TSS, respectively. The system achieved 99.998 % faecal coliform removal during the warm season with final effluent containing 4×10^3 cfu/ 100 ml. During the winter, the system was efficient in removing COD, BOD and TSS but not nutrients. The system was deficient in the removal of faecal coliforms during the winter, producing effluent with 4.7×10^5 cfu/ 100 ml [5].

Sludge is the solid material remaining after sewage treatment facilities to purify wastewater

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from homes, businesses and industries. Whether the sludge is used or disposed of, it is important to avoid creating additional environmental problems. Sludge quality depends on how clean the incoming wastewater is and which treatment methods are applied. Treatment of municipal wastewater produces different types and volumes of sludge. Raw primary sludge is produced during the first phase of wastewater treatment. Primary treatment removes 40-50 % of the solids in the water. Sludges must be treated or stabilized to make them safe for use or disposal. Since the make-up of sludge affects its suitability for various use or disposal options, a sludge generator must know what is in their sludge.

Compiling records of seasonal variations in sludge quantity and quality helps a community determine which treatment and disposal options are most appropriate. The high content of organic matter and the presence of nutrients make sludges a potentially valuable addition to soils [6]. The ultimate disposal of sludge to the environment usually requires satisfactory sludge handling operations such as thickening, stabilization, dewatering and disposal. Sludge dewatering is a process whereby water is removed from sludge so as to reduce its volume and alters its physical state from semisolid to damp solid. There are many methods of dewatering and the cheapest method is the use of drying beds or lagoons depending upon the availability of land [7]. Centrifuges or filter presses removed about 89 percent of the initial water from digested sludges, whereas open beds and filter press from self sustaining incineration removed 84, 85 percent and 91, 94 percent, respectively [8]. It is also reported that wastewater and sludge treatments can change the dewaterability of the digested sludges [9]. Sludge dewatering characteristics can be improved by various sludge conditioning methods, which include use of inert filter aids, thermal conditioning, freezing and thawing, elutriation and the addition of chemical conditioners [7]. Freezing and thawing is an efficient, no-odour dewatering operation for plants operating in cold climates [10]. Recycling is the most desirable environmental option for handling the oily sludge. Recycling oil and sludge can minimize the disposal of pollutants outside the industrial zone, prevent the extent of contamination, and decrease the use of natural nonrenewable resources [11]. Agricultural use of sludge is often regarded as the best alternative if the pollutants in the sludge is below limiting and guidance values. However, lack of acceptance from food industry and the public may make it difficult to use sludge for agriculture. Many attempts have been done to find agreements for agricultural use of sludge. Landfill of sludges will probably be restricted considerably in the future. Land deposit of sludges can contribute to diffusive spread of materials as phosphorus and metals due to leakage and emission of materials such as methane gas (a green house gas), methylated metal compounds (such as methylated mercury) and odours [12]. During the last years an increased interest has been devoted to extraction of products from sludge [13]. Sludge product recovery, therefore, aims at separating sludge components into different fractions that can be used as products and fractions with pollutants that can be destructed or separated from the sludge [13-14].

The present study focuses on the chemical evaluation of effluent treatment plant of an ice cream factory, analyzing the percentage removal of various pollutants from the effluent and finally analyzing the sludge being generated after the treatment of effluent. On the basis of analysis of sludge, its treatment has also been suggested prior to disposal on land.

Results and Discussion

Samples of untreated and treated effluent from effluent treatment plant (ETP) of an ice cream factory were taken regularly for about 18 months and were analyzed for turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total fatty material (TFM), ammonia and anionic detergents. Table- 1 represents percentage removal of various parameters by ETP. The results in Table- 1 are on average basis.

The major parameters of concern with reference to NEQS were turbidity, TSS, BOD, COD and TFM, since these values are much greater than the NEQS. The treated effluent parameters concentrations are well below the NEQS. Fig.1 shows the comparison of various treated effluent parameters concentrations with NEQS. By legislation of the country's environmental law, the treated effluent can be safely discharged into any inland drainage system. More than 90 % removal

Table- 1. Percentage removal of various parameters by effluent treatment plant (ETP).

Parameters	Wastewater	Treated Effluent	*NEQS	Removal %
Turbidity (FTU)	939.6	6.07	5	99.35
TSS (mg/ L)	212.4	6.5	150	96.94
TDS (mg/ L)	1521.0	789.6	3500	48.09
BOD (mg/ L)	562.79	13.53	80	97.60
COD (mg/ L)	1022.3	33.26	150	96.75
TFM (mg/ L)	25.79	4.4	10	82.86
Ammonia (mg/ L)	13.6	0.9	40	93.09
Anionic Detergents (mg/ L)	10.0	0.0	--	100.00

*National Environmental Quality Standards set by EPA – Pakistan.

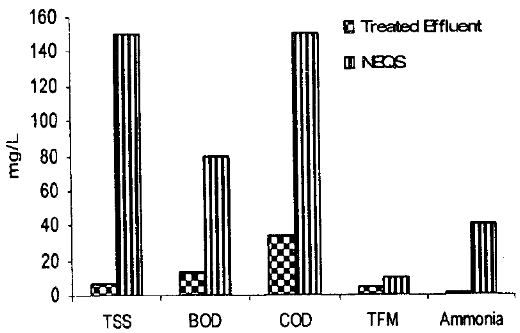

Fig 1. Comparison of treated effluent parameters with NEQS.

has been achieved for turbidity, TSS, BOD, COD, ammonia and anionic detergents. TFM removal is about 83 %. However relatively less percentage removal (48 %) for TDS has been obtained, which can be ignored as the concentration falls within the permissible limit of NEQS.

Seasonal effects on the characteristics of untreated and on the treated effluent had also been analyzed. Fig. 2 shows the seasonal effects on the

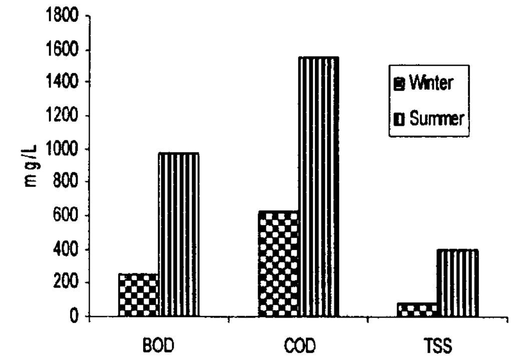

Fig. 2. Seasonal effect on various parameters of untreated effluent.

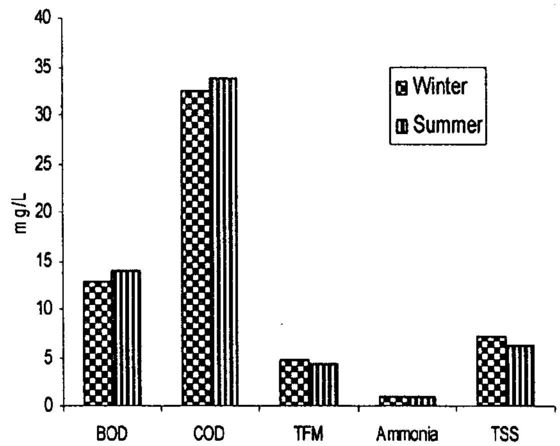

Fig. 3. Seasonal effect on various parameters of treated effluent.

wastewater characteristics of the factory. During the summer season, BOD, COD and TSS of the wastewater were higher than during the winter season. This might be due to the greater production rate of ice cream in the summer and hence more polluted effluent. Fig. 3 shows the seasonal effects

Table- 2. Percentage removal of various parameters during summer and winter by ETP.

Parameters	Summer			Winter		
	Wastewater	Treated Effluent	Removal %	Wastewater	Treated Effluent	% Removal
TSS (mg/ L)	391.67	6.2	98.42	78	7.1	90.90
TDS (mg/ L)	2341.7	768.0	67.2	905.5	822.8	9.13
BOD (mg/ L)	978.4	13.98	98.57	251.08	12.84	94.89
COD (mg/ L)	1550.7	33.84	97.82	626.01	32.36	94.83
TFM (mg/ L)	24.17	4.28	82.29	27	4.63	82.85
Ammonia (mg/ L)	13.9	0.94	93.24	13.21	0.94	92.88
Anionic Detergents (mg/ L)	5.33	0	100.00	14.67	0	100.00

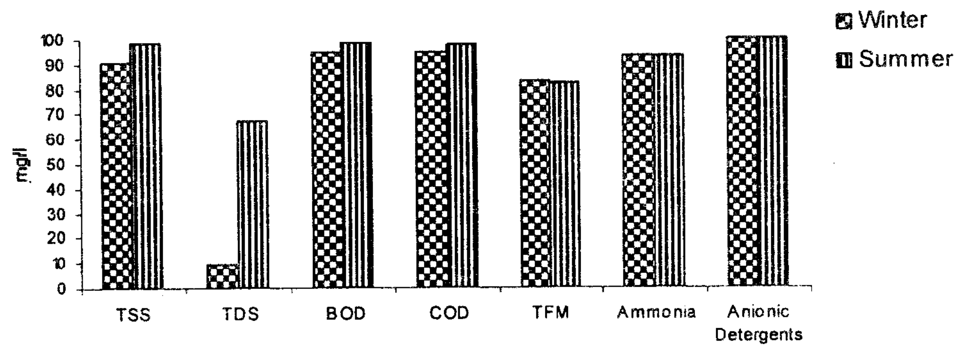

Fig. 4. Percentage removal of various parameters in summer and winter.

on the treated effluent of the treatment plant for various parameters. During summer relatively greater concentrations of BOD and COD were analyzed in the treated effluent than in the winter. This increase is directly related to the greater concentrations of BOD and COD in the untreated effluent during summer.

Table-2 represents percentage removal of various parameters during summer and winter seasons by ETP, while fig. 4 shows the comparison of percentage removal of various parameters of the treated effluent in summer and winter. The analysis results in Table-2 are on average basis for 18 months. From the data analysis, it was found achieving percentage removal of various parameters by ETP is more in summer than in winter.

The effluent treatment plant at the ice cream factory is working quite efficiently and the treated effluent meets the national environmental quality standards (NEQS) set by the environmental protection agency (EPA) of Pakistan. Hence, the treated effluent by ETP of the ice cream factory is being safely discharged into the municipal drain system.

However, as a result of the good efficiency of the treatment plant, a large amount of sludge is being generated. Sludge was analyzed for dry solids, moisture contents, COD, TFM, total organic carbon (TOC), nitrogen and phosphorous. Table-3 represents the analysis of sludge for various parameters.

Form pollution viewpoint, the only parameter of concern is the TFM (total fatty material), due to which the COD is also very high. Total organic carbon (TOC), nitrogen and phosphorous contents of the sludge are suitable for the dumping of sludge on land. However, due to higher contents of TFM (53.2 %) and COD (170.4 %), the sludge should not be disposed off on land.

Table- 3. Sludge analysis results.

Parameters	Results (%)
Dry solids	16.18
Moisture contents	83.82
COD	170.38*
TOC	12.80*
TFM	53.21*
Nitrogen	6.92*
Phosphorous	0.96*

*Dried basis

Sludge water extract (1: 2) was obtained by vacuum filtration. Table-4 represents the chemical analysis of this sludge water extract. COD, TFM and TDS of the sludge liquor (sludge water extract) are much greater than the NEQS.

Table- 4. Analysis of sludge water extract.

Parameters	Results	NEQS
pH	7.93	6-10
COD (mg/ L)	1905	150
TFM (mg/ L)	1884	10
TDS (mg/ L)	4990	3500

From the analysis of sludge and the sludge liquor, it was found that TFM is the major pollutant in the sludge. Therefore, there must be removal of TFM from the sludge prior to its disposal. TFM from sludge was extracted with solvent n-hexane. Table-5 represents the treatment results for the sludge.

Table-5. Sludge treatment results.

Parameters	Results
Original weight of sludge	100g
TFM extracted	83.27% (dried basis) 13.48% (wet basis)
Final weight of sludge	3.378 g
% reduction in sludge weight / volume	96.62

After extraction of TFM from sludge, dewatering of sludge was done by filtration and finally the sludge was sun dried. As a result it was found that the sludge mainly consists of TFM, since the removal of TFM from sludge and dewatering has reduced the original weight of the sludge up to 96.6 %.

After treatment, the sludge can be safely applied on land as it is rich in organic carbon and nitrogen. The plans for the application of treatment of sludge on large scale are in progress.

Experimental

A well-known ice cream factory situated at Multan Road, Lahore was selected for the study. The factory is manufacturing mainly non-dairy ice cream products. There is a well-operated effluent treatment plant (ETP), which is based on primary treatment. Wastewater of the factory is being collected in a large lagoon where primary sedimentation of the coarse particles takes place. Wastewater is then passed through a large tank in which air flotation takes place. Scum formed on the surface is collected and the treated effluent after sedimentation is then discharged into the drain.

Both untreated and treated effluent was analyzed for physical (temperature, pH, turbidity, total suspended solids - TSS and total dissolved solids - TDS) and chemical (biochemical oxygen demand - BOD, chemical oxygen demand - COD, total fatty material - TFM, ammonia and anionic detergents) parameters. Methods 2550 B, 4500 B, 2130 B, 2540 D, 2540 B, 5210 B, 5220 B and 5520 B [15] were applied for the analysis of temperature, pH, turbidity, TSS, TDS, BOD, COD and TFM respectively. Seasonal effects on wastewater characteristics and on the efficiency of plant were also analyzed. Regular analyses were performed for 18 months.

The ETP is generating a huge amount of sludge causing threat to the environment. Currently, there are no safety measures for the proper management and disposal of the sludge. Sludge was also analyzed for different parameters (dry solids, moisture contents, COD, TFM, total organic carbon, nitrogen and phosphorous). Sludge water extract in the ratio of 1: 2 was obtained by filtering through a vacuum filter. Both the residual sludge and the sludge extracts were analyzed. Treatment of sludge was done by extracting the total fatty material (TFM) with solvent n-hexane and dewatering by vacuum filtration. Weighed amount of sludge was extracted with n-hexane in a screw caped glass jar of length 30 inches and diameter 5.5 inches. Sludge was extracted thrice with equal volumes (500ml) of n-hexane. The liquid layer was separated in a separating funnel. Finally, the sludge was sun dried.

Conclusions

The effluent treatment plant (ETP) operating at an ice cream factory was evaluated for its removal efficiency of various wastewater pollutants. Seasonal effects on the effluent characteristics and on the percentage removal of various parameters were also analyzed. Finally, the treatment of sludge was recommended for the safe disposal on land. It was found that the percentage removal of most of the parameters ranged from 83 – 100 % and that the ETP is more efficient during summer than during winter. The sludge being generated as a result of effluent treatment was analyzed to be highly contaminated with total fatty material (TFM). Sludge treatment was done by extraction of TFM, dewatering and drying. The treatment was quite sufficient for the safe disposal of sludge on land.

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