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Technology for Treatment and Recycling of Wastewater of Automobile Service Stations

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Abstract. A prototype treatment plant was fabricated and tested at varied hydraulic retention times for settling the suspended/settleable matter and skimming out oil and grease at laboratory plants of 40 L and 56 L. The results showed that 99.7% of oil and grease and almost all total suspended solids were removed and sparkling clear water was obtained, reusable for washing vehicles.

Keywords: water treatment technology, water recycling, wastewater treatment, automobile service stations

Introduction

Water resources of Pakistan are not enough to meet the present and the future needs. Greater increase in population during the last two decades is putting strain on meager water resources for the three main consumers i.e. agriculture, industry and human beings. About 47% of the population is without safe drinking water, and nearly 84% of rural population is without sanitation facilities (Afzal, 2003). Like other countries, Pakistan is also facing problems of environmental pollution, threat of depletion of ozone layer, global warming and degradation of natural resources. According to Pakistan Council of Scientific and Industrial Research (PCSIR), only 3% industries treat their wastewater (JICA, 1999), while the rest discharge untreated effluents into rivers, lakes and seas. Dumping of untreated municipal and industrial wastes has contaminated surface and ground water resources and threatened the aquatic life.

On the other hand, rapid urbanization is changing patterns of consumption causing severe misuse of water resources (GOP, 2002). The city of Peshawar has over 350,000 registered vehicles (Mullick, 1987), out of which the share of the main city is 60% (Miller, 1999). Service stations or car wash stations use more than 16,000 L potable water per day. Thus, thousands of service stations in the country can waste billion litres water per day in Pakistan. This water contains oil/grease, suspended solids and even toxic metals. Oil and grease form high oxygen demanding waste which depletes the dissolved oxygen in water bodies and thus contributes to bacterial growth and may also contaminate underground water reservoirs (APHA/AWWA/WEF, 1998). It is estimated that one gallon of used oil can pollute more than one million gallons of drinking water (NEQS, 1993).

The National Water Research Institute of Canada in a study on highway runoff toxicity found that the car wash wastewater contains TSS, salts, particulate matter, oil, grease, organic matter, chlorinated solvents, detergents, lubricants, additives, heavy metals, antifreeze agents and acids/alkalies (Metcalf and Eddy, 1974).

In this background, devising technologies for treatment and recycling of wastewater could save the natural resources of potable water within the country. Studies have been carried out in the recent past on the development of treatment technologies for the wastewater of different industries. Efforts have been made to detoxify the tannery effluents employing physicochemical methods followed by biological methods (Khan *et al.*, 2005). In another study a treatment technology was developed for the treatment of wastewater of sugar industry through which biological oxygen demand (BOD) and chemical oxygen demand (COD) of the wastewater was reduced by 96% and 95%, respectively (Khan *et al.*, 2003). Studies on COD reduction of effluent of cotton textile industry (Babu *et al.*, 2000) showed achievement of an overall COD reduction of 80% using biological treatment technique. Similarly, a physicochemical process was developed for the reduction of excessive fluoride concentration in potable water using indigenous materials (Khan *et al.*,

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2006). Treatment of municipal wastewater in a Korean city was carried out by the city government and the private sector with the establishment of wastewater treatment plants which played significant role in the reduction of BOD and COD (Mullick, 1987). Studies have also been conducted on the treatment of industrial effluents from aminoplast industry for COD reduction (Khan *et al.*, 2008).

The present study is aimed at characterizing and developing an economically feasible and technically viable method for the treatment of wastewater of automobile service stations and reducing the harmful effects on the nearby water bodies.

Materials and Methods

Representative samples of wastewater from different service stations in Peshawar were collected and analyzed for the parameters like pH, total hardness, chloride, sulphate, total suspended solids, total dissolved solids, biological oxygen demand, chemical oxygen demand and oil/grease employing standard methods (APHA/AWWA/WEF, 1998). Heavy metals like lead, copper, cadmium, zinc, iron and nickel were determined by atomic absorption spectrophoto-meter (Z-8000, Hitachi-Japan).

Treatment plant design. Based on trials of different systems and chemical analysis of wastewater, the most economical design amongst all was found to be that of 42 L capacity treatment plant, as shown in Fig. 1, having four compartments. Wastewater was passed through this system continuously for 7-8 h and was then approved to be a better option for recycling of wastewater for skimming out oil/grease and removal of settleable matter.

The system was further facilitated with a side valve for the collection of oil/grease from compartment 1. A 0.75 cm diameter hole on the side was made with a stop valve in the first compartment for removal of floating material. A baffle was made between the 2nd and the 3rd compartment with 1″ gap at the base. This all arrangement was made from 4 mm thick plastic sheet. Last compartment had an under-drainage system of 0.5″ diameter and layers of filtration material as mentioned below:

First layer (gravel)	2.5-3.0 cm
Second layer (gravel)	1.5-2.0 cm
Third layer (gravel)	0.5-0.7 cm
Fourth top layer (sand)	0.03-0.05 cm

The under-drainage was placed 5 cm above the base and was given a slope of 1:100 for easy flow of water. Both the materials i.e. sand and gravel used were washed and cleaned before using as filtering media.

Results and Discussion

Critically evaluating the data in Table 1, it becomes apparent that the pH of wastewater was in the range of 7.55-8.25, with an average of 7.161. The total

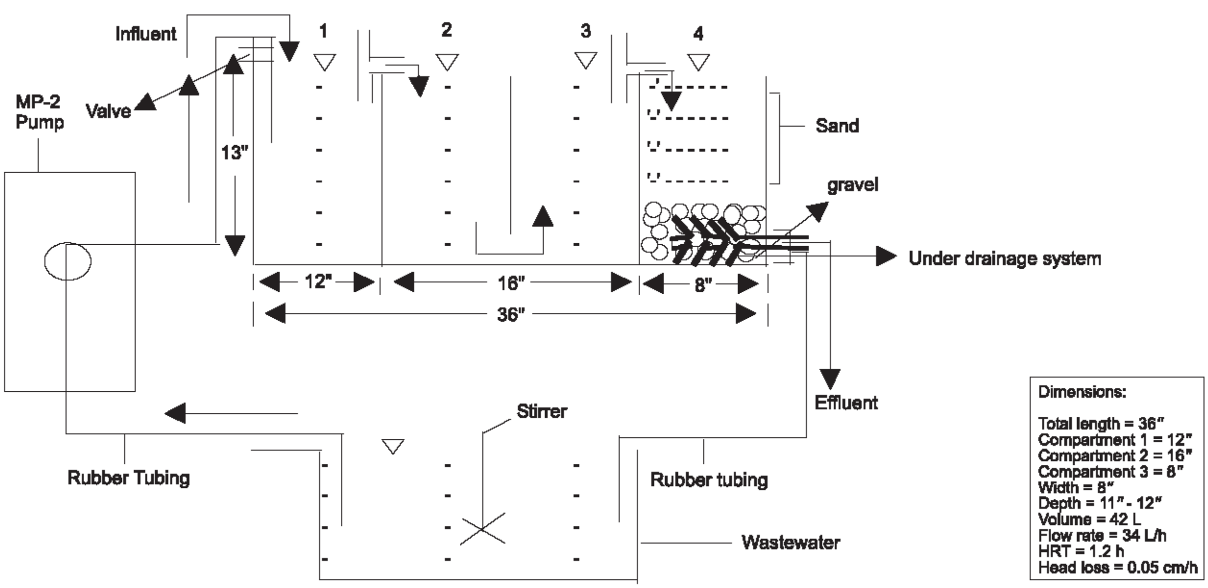

Fig. 1. Schematic diagram of a 42 L capacity treatment plant.

hardness as $CaCO_3$ was in the range of 380-632 mg/L (average 502.4 mg/L), whereas, calcium and magnesium hardness were, respectively, in the range 144-248 mg/L (average 207.2 mg/L) and 164-416 mg/L (average 255.8 mg/L). Chloride was in the range of 56-204 mg/L (average 110.2 mg/L) and sulphate concentration, in the range of 72.9-291.84 mg/L (average value being 165.5 mg/L). Service station wastewater contained soluble as well as dissolved solids. Total suspended solids (TSS) varied widely, in the range of 128-8640 mg/L (average 4397.7 mg/L).

The organic strength of wastewater which was determined in the form of BOD and COD was present in the effluent due to the presence of organics originating from oil/grease in the wastewater. The BOD varied in the range of 52.33-280 mg O_2/L, with average concentration being 158.24 mg O_2/L. COD of wastewater varied from 160.0 mg O_2/L to 470.6 mg O_2/L (average 267.2 mg O_2/L).

Although most of the oil/grease was removed during oil change, a small quantity found its way into the wastewater, which ultimately became a cause of oxygen depletion upon its discharge into the water bodies. Hence, oil/grease is not welcomed in water bodies, due to the hazardous effects and long-term consequences. The concentration of oil/grease in the service station wastewater was higher than the threshold limit of 10 mg/L (NEQS, 1993), the actual range being 13.6-20.3 mg/L, averaging 16.32 mg/L.

Oil/grease is regarded as one of the most unacceptable substance in potable water. It has been reported that one gallon of oil can spoil one million gallons of fresh water. Similarly 1.5 hectares of water surface can have a film of oil 0.3 micron thick due to just 10 litres of oil (Khan *et al.*, 2005). In the present study, the oxygen demanding waste (BOD and COD) was mostly higher than the threshold limit of NEQS (1993). BOD values in some of the samples were although less than the limits set by NEQS, yet their corresponding COD values made them unfit for discharge into water bodies.

As indicated in Table 1, sample No 2 and 4 had BOD less than 80 mg/L of NEQS; the corresponding COD values of these samples were 235.3 and 470.6 mg O_2/L. Similarly the COD of sample No. 9 and 10 was less than the threshold limit of NEQS (150 mg O_2/L). Despite higher concentration of TSS in the most wastewater samples, the materials of high oxygen demanding wastes were sufficient to make service station wastewater unfit for its safe disposal.

The service station wastewater samples also contained heavy metals (Pb^{++}, Cu^{++}, Zn^{++}, Fe^{++} and Ni^{++}) in less than 0.5 mg/L limit of NEQS (Table 1). As such, service station wastewater with regards to heavy metals was safe as the concentration of the latter lied below the

Table 1. Chemical analysis of wastewater of automobiles service station

Parameters*	Wastewater sample number										Average value	NEQS
	1	2	3	4	5	6	7	8	9	10		
pH 7.87	7.55	7.62	7.89	7.83	8.21	8.15	8.24	8.24	8.25	7.161	6-10	
Total hardness as $CaCO_3$	*380	632	348	468	464	500	420	408	484	436	502.4	-
Calcium as $CaCO_3$	204	216	184	144	220	240	208	200	208	248	207.2	-
Magnesium as $CaCO_3$	176	416	164	324	244	260	212	298	276	188	255.8	-
Chloride as Cl′	88	204	56	200	70	73	56	90	155	110	110.2	1000
Sulphate as SO_4''	291.8	245.7	161.3	238.1	176.6	96	80.6	72.9	134.0	157.5	165.5	600
TSS	128	2047	585	6241	3975	6104	5420	5642	8640	5195	4397.7	200
TDS	457	251	286	435	307	1478	697	708	958	836	641.3	3500
BOD	101.79	73.9	216.73	52.33	157.63	270	280	150	120	100	158.2	80
COD	164.71	235.3	288.3	470.6	188.6	160.0	323.5	270.5	260.3	310.5	267.2	150
Oil/grease	18.0	19.1	14.1	15.1	15.6	13.5	14.1	13.6	19.9	20.3	16.3	10
Heavy metals												
Lead as Pb^{++}	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL		0.5
Copper as Cu^{++}	0.06	BDL	0.02	BDL	0.03	BDL	BDL	BDL	BDL	BDL		1.0
Cadmium as Cd^{++}	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL		0.1
Zinc as Zn^{++}	BDL	0.01	0.04	0.03	0.01	BDL	BDL	BDL	BDL	0.02		5.0
Iron as Fe^{++}	BDL	0.15	0.11	BDL	BDL	BDL	0.09	BDL	0.18	0.05		2.0
Nickel as Ni^{++}	0.06	0.01	0.01	0.02	0.05	0.02	BDL	0.03	0.04	BDL		1.0

BDL = below limit of detection; * = except pH, all values are in mg/L.

detection limit of the instrument. (i.e. 0.001 mg), being unlikely to pose a serious threat to water bodies.

The data in Table 2 are related to the average discharge of total dissolved solids (TDS), total suspended solids (TSS), BOD, COD and oil/grease in service station wastewater. TSS discharge was estimated to be 8.79 tons/day. This tonnage is quite significant being able to choke water channels during the course of water flow. TDS was only 1.28 tons/day. BOD and COD discharge were 0.355 and 0.498 ton/day, respectively, whereas oil and grease discharge was 0.034 ton/day.

Table 2. Analysis of actual service station wastewater (average of 10 service stations)

Parameters	Concentration	Quantity
TDS*	641.0 mg/L	1.28 tons/day
TSS*	4397.7 mg/L	8.794 tons/day
BOD*	158.24 mg O_2/L	0.355 tons O_2/day
COD*	249.46 mg O_2/day	0.498 tons O_2/day
Oil and grease*	16.79 mg/L	0.034 tons/day

* = on the basis of 5 million vehicles in Pakistan @ 600 liter/month (if washed once a month) for one year.

Treatment of wastewater. Several options of laboratory scale treatment plants were tried. Variation was made in the number of compartments, size, flow rate, hydraulic retention time etc. Studies were also conducted in the presence and absence of sand and gravel bed and each time chemical analysis was performed and efficiency of the plant was examined. It was found that none of the options were effective in reducing the concentration of oil/grease and settleable matter and above all, the effluent was not sparkling clear especially in the absence of sand/gravel bed. Finally an option with sand/gravel bed was adopted since filtration is an important process for solid-liquid separation in many industries, and especially for final removal of suspended particles in water and wastewater treatment (Babu *et al.*, 2000). Four compartments system with 56 L capacity as shown in Fig. 2 was selected owing to the efficiency and the quality of effluent; the results are presented in Table 3. The Fig. 3 represents the settling characteristics of different waste water samples collected from various service stations with respect to time.

The data of Fig. 3 clearly suggest that most of the matter settled within 10 min. After 30 min, very small percentage of settleable matter was left in the liquid portion.

The data in Table 3 suggest serial reduction of different pollutants from the service station wastewater. Compartment 1 contains service station wastewater (influent) supplemented with additional 15-20 times higher oil and grease to assess the capability of the treatment plant at a higher concentration of these pollutants. Generally oil/grease in service station wastewater lied in the range of 13.60 -20.27 mg/L

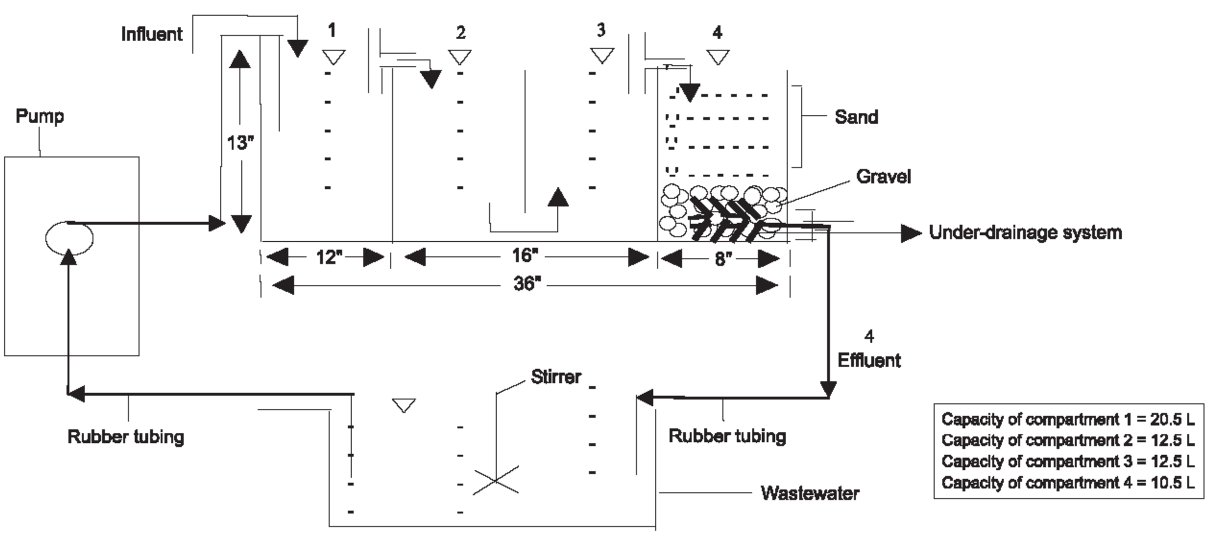

Fig. 2. Schematic diagram of a 56 L capacity laboratory scale treatment plant.

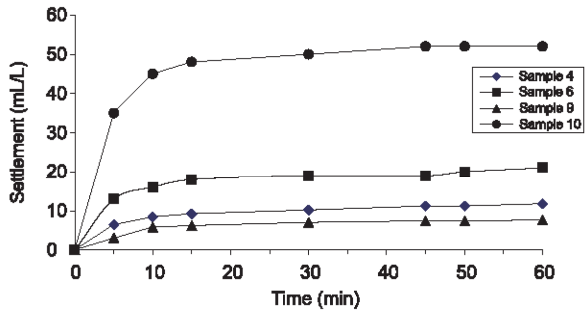

Fig. 3. Settling characteristics of service station wastewater.

Table 3. Chemical analysis of wastewater in 56 L laboratory scale treatment plant

Parameters	Concentration (mg/L) in compartment no.				NEQS (mg/L)
	1 Influent	2	3	4 Effluent	
pH	7.38	7.33	7.50	7.20	6-10
Total alkalinity (mg/L)	250	224	160	140	-
Total hardness as $CaCO_3$ (mg/L)	290	260	180	140	250
Calcium as $CaCO_3$ (mg/L)	94	84	80	78	-
Magnesium as $CaCO_3$ (mg/L)	196	176	100	62	-
Chloride (mg/L)	13.7	12.8	8	3.6	1000
Sulphate (mg/L)	290.72	240.56	220.18	176.78	600
TSS (mg/L)	5503	4323	585	5	150
Settlable matter (mL/L)	17.5	5.5	5.5	0	-
BOD (mg O_2/L)	250.00	140.35	60.28	3.00	80
Oil and grease (mg/L)	323.6	15.6	10.7	2.8	10

averaging 16.79 mg/L (Table 1). The oil/grease concentration in influent, in this case, was nearly 323.6 mg/L.

Table 3 also indicates that the quality of wastewater improved in compartment 2 with slight reduction in almost all parameters. Significant decrease is apparent in oil/grease, BOD, settleable matter and TSS. Oil/grease quantity decreased from 323.6 mg/L to 15.6 mg/L in compartment 2, the reduction being 95.18%. Settleable matter markedly decreased from 17.5 to 5.5 ml/L, the decrease being 68.57%. BOD decreased by 43.86% from 250.0 mg O_2/L to 140.35 mg O_2/L. TSS lowered from 5503 to 4323 mg/L in compartment 2; the reduction was 21.44%.

There was no marked decrease in the concentrations of different parameters in compartments 2 and 3 except BOD, oil/grease and TSS. The concentration of the settleable matter remained unchanged in the compartment 3 compared to that in compartment 2, whereas BOD decreased by 57.05% due to removal of oil/grease. BOD decreased from 140.35 mg O_2/L (compartment 2) to 60.28 mg O_2/L (compartment 3), and oil/grease, from 15.6 mg/L (compartment 2) to 10.70 mg/L (compartment 3), the decrease in oil and grease being 31.41%.

The effluent sample (from sand and gravel bed) of compartment 4 was markedly improved and the concentrations of almost all parameters decreased. The effluent was sparkling clear with very low concentration of TSS (5 mg/L), oil/grease, (2.8 mg/L) and BOD (3 mg O_2/L). Settelable matter of the effluent was nil in compartment 4 as compared to the influent in compartment 1, indicating almost 100% removal. The suspended solids decreased to as low as 5 mg/L, i.e. by 99.91%. Likewise, the BOD decreased from 250 mg O_2/L in the influent to as low as 3 mg O_2/L with a total removal of 98.8%. The quality of the effluent as mentioned in Table 3 is fit enough to be successively used for washing purposes.

Conclusion

Chemical analysis of wastewater of service stations of Peshawar city indicated that the pollutants like suspended solids, oil/grease and BOD exceeded the NEQS (1993) limit set by the Government of Pakistan. A huge quantity of potable water of Peshawar i.e. 1.75 to 2 million litres/day is wasted in just washing of automobiles. The system devised for treatment of wastewater of automobile service stations successfully removed almost 100% turbidity, 99.18% BOD, 99.74% oil/grease and 99.95% suspended solids. Filter media i.e. sand and gravel of the plant must be cleaned/washed before using, requiring back washing after a week or ten days and complete cleaning after 2-2½ months. The accumulated oil/grease may be removed manually on daily/weekly basis as deemed necessary. The accumulated sludge may also be removed after 2-2½ months or at the time of cleaning of plant. These items should then be disposed off properly. The treated wastewater (effluent) may be used for other purposes like washing floors, irrigation, gardening and sprinkling except drinking. Employing the developed technology, huge volumes of potable water could be saved for human consumption.

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