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COMPARATIVE STUDIES OF SOME INDUSTRIAL WASTEWATER TREATMENT TECHNIQUES

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ABSTRACT

Generation of wastewaters in industrial processes is sometimes unavoidable and in most cases, a process to reduce the organic load and other contaminants must be employed before wastewater discharge.

Two industrial effluents from two plants (oil food and a car washing station) at New Damietta industrial Zone were chosen to the pretreatment processes. Among these processes were plain sedimentation, coagulation-flocculation, sedimentation and filtration to minimize the hazardous impacts of contaminated wastewater effluents on the environment. Physicochemical characteristics and heavy metals concentration (Cd, Cu, Fe, Mn, Pb and Zn) were conducted for wastewater samples.

The results showed that a dose of 20 mg/L alum was more effective in reducing several contaminants for car washing station wastewater than that for food oil effluent after gravity settling.

Furthermore, it was found that 5g/L alum (added as solid) is more effective than 100 mg/ L (added as a solution). Therefore, it is recommended to be used for the pretreatment of the food oil effluent. It was also concluded that, the coagulation of the two effluents with dose of 5g/L alum is more effective without addition of lime.

The suggested series of pretreatment techniques for the two effluents is highly effective in reducing several parameters. It is worth to mention that the treated effluents are complying with the regularity standard that regulate the discharge of wastewater into sewerage network (Decree No. 44/2000).

INTRODUCTION

Industrial wastes varied in quantity and polluting strength according to products and the manufacturing processes from which they emerge. Some wastes like cooling waters are large in volume but carry little contamination; others are relatively small in quantity but are highly loaded with organic and inorganic substances [**Mahida (1983)**].

The rapid pace of industrialization even in under-developed countries is intensifying the problem of pollution. It is a healthy sign, however, that industries are now realizing and accepting their responsibilities for the treatment of such wastes before they are discharged into natural waters. Legislative measures to control the discharge of polluting matter and to prescribe the degree of treatment of wastewaters help to prevent pollution. All industrial wastes cannot be treated to the same degree of purification as sewage and a balanced approach to the problem of treatment is necessary [**Gray (1999)**].

Wastewater can be treated by a variety of chemical processes, including acid/base neutralization, precipitation, and oxidation/reduction. In some cases, these treatment steps must precede biological treatment; for example, wastewater exhibiting extremes of pH must be neutralize in order for microorganisms to thrive in it. Cyanide in the wastewater may be oxidized with chlorine and organics with ozone, hydrogen peroxide promoted with ultraviolet radiation, or dissolved oxygen at high temperatures and pressures. Heavy metals may be precipitated with base, carbonate, or sulfide.

Waste water can be treated by several physical processes. In some cases, simple density separation and sedimentation can be used to remove water-immiscible liquids and solids. Filtration is frequently required and flotation by gas bubbles generated on particle surfaces may be useful. Wastewater solute can be concentrated by evaporation, distillation, and membrane processes, including reverse osmosis, hyperfilteration, and ultrafiltration. Organic constituents can be removed by solvent extraction, air stripping, or steam stripping.

Generation of wastewaters in industrial processes is sometimes unavoidable and in most cases, a process to reduce the organic load and other contaminants must be employed before water discharge. To remove part of the organic load, biological processes are usually used, because they are more economic than chemical processes. In some cases, however, due to the high organic load, toxicity or presence of non-biodegradable compounds, biological processes cannot be used, since no chemical oxygen demand (COD) removal is achieved biologically. For these wastewaters, the biochemical oxygen demand (BOD) is orders of magnitude lower than the COD. Thus, a biological treatment is not feasible. In these cases, chemical pre- treatment can adequately reduce the COD prior to biological treatment [**Martinez et al., (2003)**]. Among chemical processes, the coagulation-sedimentation processes have been used to reduce the organic load or toxicity of different waters and wastewaters.

Coagulation with materials such lime, alum, ferric chloride and ferrous sulfate has also been extensively employed in water/wastewater treatment [**Sarika et al., (2005) and Beccari et al., (1999)**].

The purpose of coagulation is to alter the colloids so that they can adhere to each other. Metal salt coagulants react with the alkalinity in the water to produce insoluble metal hydroxide precipitates that enmesh the colloidal particle in water and adsorb other material including dissolved organic matter present. The hydroxide flocs carry a small positive charge that attracts the negative particles in the water. Polyelectrolyte used as coagulant aids are available with either a positive or negative charge and are used to optimize flocculation [**Davis & Cornwell (1991)**].

The aim of this work is to treat industrial wastewater effluents using cheap, available, and simple procedures for application at these industrial companies.

MATERIAL AND METHODS

All chemicals used were of analytical reagent grade quality. Two industrial effluents from two plants at New Damietta industrial Zone were subjected to the pretreatment processes. Samples of different chemical and physical characteristics were obtained from an oil food plant; because it is one of the biggest industrial units in this area; and the other from a car washing station because it is one of the most dispersed activities not only at Damietta Governorate but also all over Egypt. The following physicochemical parameters were analyzed :pH, Total Dissolved Solids (TDS), Total Suspended Solid (TSS), Turbidity, Total Hardness (BOD), COD, TP, TN, Nitrate, Nitrite, Ammonia and Heavy Metals Concentration (Cd, CO, Cu, Fe, Mn, Pb, Zn) before and after pretreatment processes.

Plain sedimentation, coagulation-flocculation, sedimentation and filtration were selected to minimize the hazardous impacts of contaminated wastewater effluents on the environment.

Plain sedimentation (Gravity settling):

A laboratory settling analysis was conducted in a column of type shown in Fig. (1). A minimum diameter of 150 mm is recommended to minimize wall effects. Its height is 67.5 cm sample ports spaced at 22.5 cm depth intervals allow samples to be taken for analysis of different suggested parameters. The wastewater is poured rapidly into the column and mixed to ensure that there is a uniform distribution of particles throughout the column at the beginning of the analysis. Care must also be taken to ensure that uniform temperature is maintained throughout the column to avoid convection currents affecting the settlement rate. The suspension is then allowed to settle quiescently. Samples are withdrawn from the sample ports at selected time intervals up to 15 days and analyzed for total suspended solids (TSS), pH and turbidity. Other parameters are detected at the end of the experiment.

Filtration by Rapid Sand filter

A laboratory Rapid sand filter of 126 cm height and an internal diameter of 4 cm, and an external diameter of 4.8 cm has been designed. The filter is open-top unit operated by gravity. It is made up of a layer of coarse sand of 0.5-1 mm in diameter and 51 cm deep in between of two layers of coarse gravel (> 2mm in diameter). The lower bed of coarse gravel was 28 cm in depth and the upper layer was 34 cm in depth Fig. (2). Sufficient depth above the media was allowed for an adequate depth of water to provide enough hydraulic head for the water to pass rapidly throughout the medium. Filtration rate is 12 L/h giving loading rate of 0.012 m^3m^2/h. Rapid gravity filters need to backwashed every 20 to 60 hrs [**Fadel & El-Morsy (1996)**].

Filtration by Slow sand filter:

Also, a laboratory slow sand filter of 123 cm overall depth, an internal diameter of 5 cm and an external diameter of 6 cm has been designed. The filter is open-top unit operated by gravity. In contrast, slow sand filter, employ a much finer sand of 0.15 – 0.25 mm in diameter. The layer of fine sand up to 50 cm in depth laid on a layer of coarse sand (0.5-1mm) in diameter and 10 cm in depth and a layer of gravel of 20 cm in depth at the bottom of the filter Fig (3). The sand was of silica and thus no to be disintegrated and it is washed as screened to confirm to certain specifications. The depth of the water over the sand bed was 30 cm and the rate of filtration is 1.53 L/h. A slow sand filter is not backwashed, but after a certain amount of dirt has accumulated on the sand bed, the filter shutdown and about 3-5 cm of sand scraped off the top, thereby removing the dirt [**Gray (1999)**].

Coagulation treatment method:

Chemical coagulation experiments were conducted with the jar test method according to [**AWWA (1978); Peavey *et al.*, (1985) and Gray (1999)**]. Each of the sex jars are filled with 1L of wastewater whose physical and chemical characteristics have been predetermined.

Aluminum sulfate (alum) was used as the coagulant, and lime and soda ash as coagulant aid. 10 gm of aluminum sulfate; $Al_2 (SO_4)_3 . 18H_2O$; was dissolved in distilled water. Doses of 5, 20 and 100 mg/L of alum were tested for best results. The supernatant was withdrawn and tested to determine the same physical and chemical characteristics that have been determined before coagulation process (pH, COD, Turbidity, TDS, TSS, Hardness, T.N, TP, Nitrate, Nitrite and Ammonia). The percent removals for the measured parameters were calculated as mentioned above.

Lime softening treatment:

- Distilled water used for the preparation of lime suspension boiled for 15 minutes to expel the carbon dioxide and then cooled to room temperature before the lime is added.
- 10 gm of lime and 10 gm of soda ash were weighted and dissolved in 1L of distilled water.
- The suspension was shaken immediately before use.
- The dosages are calculated according to the concentration of total hardness and alum dose [**AWWA (1978)**].
- After addition of the required doses of the lime and soda ash during the slow mixing and the treatment was carried out with the same above-mentioned method.
- A dosage of 0.5 g alum powder for each 100 ml of wastewater was tested also and carried out by using the same procedures for alum suspension according to (**Rajeshkumar & Jayachandran (2004)**] method in a primary treatment of diary wastewater effluents.

Pretreatment process with foam:

Polyurethane foam has been used for the final step in the pretreatment operation. Commercial white sheets of open cell polyether type based polyurethane foams were used. Foam cubes of (10 – 15 mm edge) were cut from the foam sheets, washed with 1 M hydrochloric acid followed distilled water until the washings were free from chloride ions [**Braun *et al.*, (1985) and Mosaad (2004)**]. The foam cubes were then washed with acetone in a soxhlet extraction for 6hrs and finally dried at 80°C in an over for 2hrs. Then, the polyurethane foams were packed separately in a glass column by applying the vacuum method of foam packing as follows: the foam cubes (10 ± 0.01 gm) were homogeneously packed in the column by applying gentle pressure with a glass rod to reduce the foam volume to about one-third of its original volume. The wastewater sample is poured into column and allowed to pass throughout the foam and finally analyzed for different parameters that have been determined at the previous treatment stages.

RESULTS & DISCUSSION

The physico-chemical characteristics of the two-wastewater samples before and after the pretreatment steps are presented in the joined Tables (1-14).

Table (1) summarizes the physico-chemical characteristics of the car washing station effluent before and after plain sedimentation (gravity settling). The pH and turbidity were measured at different time intervals, while the other parameters were analyzed at the end of the experiment period (14 days) only.

It was found that, the turbidity and suspended solids show the highest removal percent (90.4 and 90.6%) and these were directly proportional to the detention period. This may be due to that the suspended solids, which are heavier than water and commonly referred to as the settlable fraction, are removed from suspension by allowing the particles to gravitate to the bottom of the container to form sludge under near quiescent conditions. These processes also remove settlable organic and inorganic materials and thus reducing the organic load [**Ryan (2000) and Gray (1999)**]. Moreover, the discrete particles may be settled out of a dilute suspension as individual entities. Each particle retain its individual characteristics and there is little tendency for such particles to flocculate, and so settlement remains solely a function of fluid properties and particle characteristics. In addition, it may be attributed to that; the subsiding particles coalesce with smaller particles falling at lower velocities to form larger particles that then settle faster than the parent particles. The degree of flocculation is dependent on the opportunity for particle contact [**Eckenfelder (1989) and Davis & Cornwell (1991)**]. The effluent of food oil plant Table (2) did not achieve the same results of TSS and turbidity removal, and that may be due to its emulsifying nature and its small size and negligible settling velocities. However, food oil particles may be hydrophilic colloids, which exhibit a marked affinity for water. The absorbed water retards flocculation and frequently requires special treatment to achieve a good removal [**Eckenfelder *et al.*, (1958) and Gray (1999)**]. Whereas, the nitrogen compounds exhibited good removal percents, this may be attributed to the bacterial activities.

Table (1): Physicochemical characteristics of car washing station effluent before and after Gravity settling (plain sedimentation)

Table (1): Physico-chemical characteristics of car washing station effluent before and after Gravity settling (plain/sedimentation).

Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	TN (mg/L)
			R (%)									
Raw	6.23	164	-	807	620	3225	6.2	0.531	1.541	0.04095	0.032	0.37041
1 h	6.14	116	29									
2 h	6.35	109	33.5									
3 h	6.36	86	47.56									
48 h	6.33	59	64									
7 days	6.35	24	85.4									
14 days	6.34	15.7	90.4	790	160	1220	4.27	0.050	1.394	0.007	0.026	0.2386
Removal percent (R%)				2.11	74.19	62.17	31.13	90.6	9.54	82.9	18.75	35.58

Table (2): Physicochemical characteristics of food oil factory effluent before and after Gravity settling (plain sedimentation).

Table (2): Physico-chemical characteristics of food oil factory effluent before and after Gravity settling (plain sedimentation).

Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	TN (mg/L)
			R (%)									
Raw	6.38	288	-	112	930	5913	17.4	3.3	4.15	0.4653	0.2482	1.74459
1 h	6.65	284	1.4									
2 h	6.51	276	4.16									
3 h	6.51	252	12.5									
48 h	6.51	248	13.8									
7 days	6.51	240	16.6									
14 days	6.51	238	17.36	90	300	2313	13.74	2.70	3.62	0.0246	0.0281	0.4981
Removal percent (R%)				19.63	67.74	60.88	21.03	18.8	12.77	94.61	88.67	71.45

The ratio of BOD/COD in wastewater is normally used to express the biodegradability of the wastewater. When the ratio of BOD/COD is greater than 0.3, the wastewater has a better biodegradability, whereas the BOD/COD is less than 0.3 indicates that the wastewater generated from these activities inhibit the metabolic activity of bacterial seed due to their toxicity or refractory properties and it is difficult to be biodegraded [**Chun & Wang (1999)**]. The obtained results in Table (3) showed that the ratio of BOD/COD for car washing station effluent is less than 0.3. Therefore, this wastewater required chemical pretreatment before being discharged into the sewer system.

Table (3): Physicochemical characteristics of gravity settling of car washing station effluent before and after coagulation with alum (5mg/l alum.)

Simple	Time	pH	Turbidity (NTU)		T.H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	TN (mg/L)
			Value	R (%)									
Gravity settling of car washing before treatment		6.34	60	-	790	160	1220	4.27	0.050	1.394	0.007	0.026	0.2386
Raw car washing after treatment	1 h	6.6	54	10									
	24 h	6.5	35	41.6									
	48 h	6.3	20	66.6									
	72 h	5.6	11	81.6	86	38	970	3.58	0.01	1.292	0.0017	0.015	0.139
	96 h	5.5	10	83.3									
	120 h	5.5	9	85									
Removal percent (R%)					16.1	76.25	20.5	16.16	80	7.32	75.71	42.3	41.71
Threshold limit decree no. 44/2000		6-9.5			-	600	1100	25	800 (mg/L)	-	-	-	100

After plain sedimentation of the car washing station effluent, it undergoes coagulation and sedimentation process and the initial and final physico-chemical characteristics of the influent and effluent were represented in Tables (3,4). Two doses of alum were used for coagulation of car washing effluent (5 and 20 mg/L). The pH of the initial influent was slightly acidic (6.34) and the values of pH and turbidity were selected to be observed at different time intervals, while the other investigated parameters were analyzed after 72h of the sedimentation process. The results indicated that, there was a direct relation between alum dose and the removal percent for all the investigated parameters. There is a pH decrease (5.5) after coagulation process of the effluent using a coagulation dose of 5mg/L, so it was necessarily to neutralize this effluent by using a base such as soda ash (sodium carbonate). Applying a dose of 20 mg/L of alum, the pH became 7.81 and this value complies with the acceptable pH value of 6-9.5 (Decree No. 44/2000). The other parameters were removed by a percent that improves the effluent to comply with the threshold limit (Decree NO. 44/2000). Therefore, the dose of 20mg/L alum was more effective in reducing several parameters in the effluent of car washing station.

Table (4): Physicochemical characteristics of gravity settling of car washing station effluent before and after coagulation with alum (20mg/l alum.)

Simple	Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	TN (mg/L)
			Value	R (%)									
Gravity settling of car washing before treatment		6.34	60	-	790	160	1220	4.27	0.05	1.394	0.007	0.026	0.2386
Raw car washing after treatment	1 h	6.72	14	76.6									
	24 h	7.63	10	83.3									
	48 h	8.03	5	91.6									
	72 h	8.03	5	91.6	320	17.14	470.56	1.36	0.005	0.369	0.0014	0.0066	0.076
	96 h	7.84	5	91.6									
	120 h	7.81	5	91.6									
Removal percent (R%)					59.49	89.29	61.43	68.15	90	73.53	80	74.6	68.15
Threshold limit decree no. 44/2000		6-9.5			-	600	1100	25	800 (mg/L)	-	-	-	100

After applying the same two doses of alum (5 and 20 mg/L) to coagulate a raw car washing effluent without plain sedimentation (tables 5, 6), the removal percent increased with increasing the dose to 20 mg/L. The reduction percent was more effective and improved the characteristics of the effluents to comply with the threshold limit (Decree No. 44/2000).

Table (5): Physicochemical characteristics of car washing station effluent before and after coagulation with alum (dose: 5 mg alum/L)

Simple	Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	TN (mg/L)
				R (%)									
Raw car washing before treatment		6.22	186	-	885	703	3628.8	6.9	0.602	1.630	0.0419	0.034	0.432
Raw car washing after treatment	1 h	6.34	114	38.7									
	24 h	6.32	70	62.36									
	48 h	6.31	60	67.7									
	72 h	6.22	39	79	758	503	2804	2.98	0.1204	1.514	0.036	0.028	0.42
	96 h	6.21	38	79.5									
	120 h	6.2	36	80.6									
Removal percent (R%)					14.35	28.4	22.75	56.8	80	7.12	14.08	17.6	2.7
Threshold limit decree no. 44/2000		6-9.5			-	600	1100	25	800 (mg/L)	-	-	-	100

Table (6): Physicochemical characteristics of raw car washing station effluent before and after coagulation with alum. (dose: 20mg/l alum.)

Simple	**pH**	**Turbidity (NTU)**		**T. H (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**	**TP (g/L)**	**TSS (g/L)**	**TDS (g/L)**	**NO_3^- (mg/L)**	**NO_2^- (mg/L)**	**TN (mg/L)**
		Value	**R (%)**									
Raw car washing before treatment	6.22	186	-	885	703	3628.8	6.9	0.602	1.630	0.0419	0.034	0.432
Raw car washing after treatment	6.95	34	81.7									
	6.94	25	86.56									
	7.93	13	93									
	7.9	7	96.2	370	30	201.6	1.15	0.022	1236	0.004	0.0301	0.385
	7.62	6	96.7									
	7.62	6	96.7									
Removal percent (R%)				58.2	95.7	94.4	83.3	96.3	24.17	90.45	11.47	10.88
Threshold limit decree no. 44/2000	6-9.5				600	1100	25	800 (mg/L)	-	-	-	100

From the above-obtained results, a dose of 20 mg/L is more effective than that of 5 mg/L. Thus, it is used directly to coagulate the food oil effluent after plain sedimentation and it achieved nearly the same reduction percent of the different characteristics of that effluent **Table (7)**.

Table (7): Physicochemical characteristics of gravity settling of food oil plant effluent before and after coagulation with alum. (20mg/l alum.)

Simple	Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	TN (mg/L)
			Value	R (%)									
Gravity settling of oil food before treatment		6.86	242	-	90	603	593	13.74	2.7	3.62	0.0246	0.0281	0.498
Raw oil food after treatment	1 h	6.18	38	84.29									
	24 h	6.9	25	89.67									
	48 h	7.67	11	95.45									
	72 h	7.7	8.3	96.57	41	72.5	65.32	7.64	0.08	3.58	0	0.02	0.296
	96 h	7.56	6.1	97.48									
	120 h	7.55	4.5	98.14									
Removal percent (%)					54.9	87.97	88.98	44.39	97	1.1	100	28.8	40.56
Threshold limit decree no. 44/2000		6-9.5				600	1100	25	800 (mg/L)				100

After applying a dose of 100 mg/ L in the coagulation of heavy polluted affluent from food oil plant, it achieved good removal percent. Data in Table (8) showed that the ratio of BOD/COD for the effluent was 0.115, which is less than 0.3, therefore it required chemical pretreatment before being discharged into the sewer system. After coagulation process the pH value of the resulting liquid was lowered to reach 4.64 and thus need to be neutralized before discharging into the sewer system. However, the COD removal percent was found to be 99.6% and BOD (96.13%),which indicate that the value of COD (26.88mg/L) after the treatment of the effluent with 100 mg/L alum dose was lower than that of BOD (36mg/L), thus implying that the resulting liquid phase was biodegradable aerobically than the original sample. This may be an important consideration if the resulting liquid phase is to be post-treated biologically. Moreover, complete nitrate removal was recorded at this dose of alum, but the pH value was lowered to 4.64 **[Davis & Cornwell (1991)]**. Therefore, this effluent needs to be neutralized using a base such as soda ash.

Table (8): Physicochemical characteristics of food oil plant effluent before and after coagulation with alum. (Dose: 100mg/l alum.)

Simple	Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO$_3^-$ (mg/L)	NO$_2^-$ (mg/L)	TN (mg/L)
			Value	R (%)									
Raw oil food before treatment		6.61	680	-	980	930	8064	40.5	7.8	13.95	0.2743	0.2483	1.4128
Raw oil food after treatment	1 h	5.11	150	77.9									
	24 h	4.95	110	83.8									
	48 h	4.82	73	89.2									
	72 h	4.64	13	98.1	140	36	26.88	2.6	0.08	5.18	0	0.007	0.37
	96 h	4.64	12	98.2									
	120 h	4.64	10	98.5									
Percent removal (R%)					85.7	96.13	99.6	93.58	98.97	62.86	100	97.18	73.8
Threshold limit decree no. 44/2000		6-9.5			-	600	1100	25	800 (mg/L)	-	-	-	100

The same wastewater effluent obtained from food oil plant was treated by an alum dose of 0.5 gm/L (the alum was added as solid material not as a solution, **[Rajeshkumar & Jayachandran (2004)]**, it was found that, this dose was more effective in treating this effluent and so, it the best dose for the pretreatment of the raw food oil effluent Table (9). The results obtained may be attributed to that, the coagulant reacts with the alkalinity in the water to produce insoluble metal hydroxide precipitates that enmesh the colloidal particles in waters and adsorbs other materials including dissolved organic matter present. The hydroxide flocs carry a small positive charge that attracts the negative particles in the water **[Davis & Cornwell (1991)]**.

Table (9): Physicochemical characteristics of food oil plant effluent before and after coagulation with alum. (Dose: 5gm/l alum.)

Simple	Time	pH	Turbidity (NTU)		T. H (mg/L)	BOD (mg/L)	COD (mg/L)	TP (mg/L)	TSS (g/L)	TDS (g/L)	NO$_3^-$ (mg/L)	NO$_2$ (mg/L)	TN (mg/L)
			Value	R (%)									
Raw oil food before treatment		6.61	680	-	980	930	8064	40.5	7.80	13.95	0.2743	0.2483	1.4128
Raw oil food after treatment	1 h	6.61	76	88.8									
	2 h	4.06	58	91.5									
	3 h	4.06	57	91.6									
	24 h	4.06	55	91.9									
	48 h	4.05	19	97.2									
	72 h	4.04	13	98.1	20	18.4	107.52	11.161	0.04	3.34	0	0.0098	0.184
Removal percent (R%)					97.95	98.02	98.66	72.4	99.5	76.05	100	96.05	86.97
Threshold limit decree no. 44/2000		6-9.5			-	600	1100	25	800 (mg/L)	-	-	-	100

Nishide (1977) stated that in coagulation operation, a chemical substance is added to an organic colloidal suspension to cause its destabilization by the reduction of forces that keep them apart. It involves the reduction of surface charges responsible for particle repulsion and causes agglomeration. Particles of larger size are then settled and clarified effluent is obtained.

Whereas, [**Meyssami & Kasaeian (2005)**] reported that the major coagulation mechanism was chemical bridging rather than charge neutralization. Thus, wastes containing emulsifying oil can be clarified by coagulation. An emulsion can consist of droplets of oil in water; the oil droplets are of approximately 10^{-5} cm and are stabilized by adsorbed ions. Emulsifying agents include soaps and anion active stabilized by adsorbed ions. The emulsion can be broken by "salting out" with the addition of salts, such as $CaCl_2$ Flocculation will then charge neutralization and entrainment, resulting in clarification. An emulsion can also frequently be broken by lowering the pH of the waste solution [**Eckenfelder (1989)**].

Table (10) represents the turbidity as a function of time for the two effluents (the car washing station and the food oil plant) which have the same initial turbidity of 655 NTU. A dose of 5g/L was added to each of them and then they left to settle. It was found that, after half an hour, the turbidity removed by 82.14% for the food oil effluent, while the car washing effluent recorded a removal percent of 74.8. However, after 96 hr, the turbidity of food oil plant effluent was reduced by 95.87%, whereas, the car washing station effluent turbidity was removed by 98.5%. Consequently, the car washing station effluent responded to coagulation-flocculation and sedimentation effectively but need more time to show good final reduction of turbidity. After the step of coagulation and sedimentation, the two effluents pass through a foam packed column and the turbidity of the food oil plant effluent was reduced by 99.54%, while the turbidity of the car washing station effluent removed by 99.39%.

Table (10): Turbidity as a function of time for the two effluents before and after treatment with alum (0.5 gm / 100 ml) and foam adsorption.

	Time (h)	Turbidity (NTU)			
		Food oil plant effluent		Car washing station effluent	
		Turbidity	Removal Percent	Turbidity	Removal Percent
Raw	-	655	-	655	-
After dose (5 gm / L)	1/2	117	82.14	165	74.8
	24	84	87.17	74	88.7
	48	71	89.16	21	96.79
	72	56	91.45	20	96.95
	96	27	95.87	10	98.5
After foam	-	3	99.54	4	99.39

A series of pretreatment techniques was applied for the two effluents with the same sequence and the physico-chemical characteristics of the two effluents were recorded before and after each technique. Consequently, the removal efficiencies for them were calculated as shown in Tables (11-14). The first pretreatment technique was filtration through rapid filter (RF) followed by the slow sand filter (SSF), then the coagulation-flocculation and sedimentation and finally filtration through foam. At the coagulation process, lime dose of 1.25 g/L was added to neutralize the alum dose [**AWWA (1990)**].

Chemical precipitation is used to remove the organic forms of phosphate by the addition of lime and alum. The lime addition removes calcium ions as well as phosphorus from wastewater, along with any suspended solids. The lime reacts first with the natural alkalinity in the wastewater to produce calcium carbonate, which is primarily responsible for enhancing suspended solids removal according to the following equation:

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O$$

After the alkalinity is removed, calcium ions combine with the orthophosphate presents under alkaline conditions (pH 10.5) to from insoluble and gelatinous calcium hydroxyapatite [$Ca_5(OH)(PO_4)_3$] as followes:

$$5Ca^{+2} + 4OH^- + 3HPO_4^{-2} \rightarrow Ca_5(OH)(PO_4)_3 \downarrow + 3H_2O$$

The lime dose required can be approximated at 1.5 times the alkalinity as $CaCO_3$. A disadvantage is that large quantities of lime sludge are produced possibly doubling the normal volume of sludge requiring disposal.

The removal of some heavy metals from the car washing station wastewater exhibited a different removal behavior than their reduction behavior from the food-oil plant. This may be attributed to the nature of the wastewater itself, the lime dose, the solution pH and interfering substances present in the effluent such as ammonia and cyanide, which form complexes with many metals that limit their removal by lime precipitation. Heavy metals may also be precipitated as the sulfide and in some cases as the carbonate, as in the case of lead. For many metals such as arsenic and cadmium, coprecipitation with iron or aluminum is highly effective for removal to low residual levels [**Sayer *et al.*, (1994)**].

Lead is effectively precipitated as the carbonate by the addition of soda ash, resulting in effluent-dissolved lead concentration of 0.01 to 0.03 mg/L at a pH of 9 to 9.5. Precipitation with lime at a pH 11.5 resulted in effluent concentrations of 0.019 to 0.2 mg/L [**Eckenfelder (1989)**].

Zinc can be removed by precipitation as zinc hydroxide with either lime or caustic. The disadvantage of lime addition is the concurrent precipitation of calcium sulfate in the presence of high sulfate levels in the wastewater. An effluent soluble zinc of less than 0.1mg/L has been achieved at pH 11 [**Eckenfelder (1989)**].

The filtration through the rapid filter may be attributed to a physical removal of particles with an order of magnitude smaller than the interstices in the sand being retained [**Metcalf & Eddy (1991) and AWWA (1971 & 1977)**] conducted experiments at the Chicago water treatment plant and have demonstrated that satisfactory water quality can be obtained by rapid sand filters of rates as high as $235m^3$ /d.m^2 **[Montgomery (1985)]**.

Whereas, the filtration through slow sand filter showed more effective removal percent than those of the rapid filter, this may be due to that, on the surface of the sand a gelatinous layer developed which is rich in microorganisms (*e.g.*, bacteria, protozoa, algae) called the schmutzdecke . This layer is largely responsible for the treatment of the water by both physical removal of particles and by the biological treatment of dissolved organic matter and nutrients. The top 2 mm is an autotrophic layer, a mixture of algae and nitrifying bacteria, remove nitrogen and phosphorous and releasing oxygen. Below this, heterotrophic bacteria dominate where residual organic matter is removed. The heterotrophs extend up to 300mm within the sand layer **[Gray (1999) and Ryan (2000)]**.

CONCLUSION AND RECOMMENDATIONS

Conclusion:

From the forgoing discussion, it can be concluded that, the plain sedimentation is effective method of pretreatment for car washing effluent rather than that of food oil wastewater and this is due to the emulsifying nature of food oil effluent.

A dose of 20 mg/L alum was more effective in reducing several contaminants for car washing station wastewater than that for food oil effluent after gravity settling. It is found that 5g/L alum dose is highly effective than that of 100 mg/L and thus it is recommended to be used for the pretreatment of the food oil effluent to control or minimize pollution of this effluent before discharging into the sewer.

The suggested series of pretreatment techniques for the two effluents is highly effective in reducing several parameters. It is proved that, the coagulation of the two effluents with the alum dose of 5g/L (added as solid) is more effective without addition of lime. Moreover, the investigated pollutants of the two effluents were removed by a percent enables them to comply with the threshold limit (Decree No. 44/2000).

From all the above results, it is indicated that, any treatment techniques depends on the nature of the wastewater, its composition, the temperature of both effluent and environment, initial concentration of the different physical and chemical parameters of the effluent, the presence or absence of toxic components in the effluent and the dose in the coagulation process.

Further investigation is required regarding the characterization and the quantity of solids including the coagulation by both alum and alum with lime.

Recommendations:

It can be concluded that the appropriate ways of controlling the pollution are to:

1. A dose of 5 g/L of alum (added as solid) to coagulate the effluents of food oil factory and car washing station can produce effluents comply with Egyptian standard.

2. Minimize pollution from industrial sources through technological modernization.
3. Provide incentives to industries to encourage them to invest in new pollution abatement equipment.
4. Conduct regular inspections to ensure that industrial and hazardous waste is segregated at source.
5. Establish waste transfer stations to control and manage industrial and hazardous waste streams.
6. Raise awareness of industrial and hazardous waste segregation.

Ensure that large industries introduce necessary pollution abatement equipment to comply with Egyptian law and standard on levels of pollution.

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الملخص العربى

دراسات مقارنة لبعض طرق معالجة المخلفات الصناعية السائلة

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اهتمت الحكومة المصرية اهتماما كبيرا بإقامة مناطق صناعية بالمدن الجديدة دون الأخذ في الاعتبار كيفية التخلص الآمن من للملوثات الخطرة الناتجة عن العمليات الصناعية المختلفة بهذه المناطق.

لذا تهدف هذه الدراسة إلى محاولة التوصل الى طريقة لمعالجة المخلفات السائلة الناتجة عن بعض الصناعات و التي قد تلعب دورا هاما فى إحداث التلوث بهذه المنظومة البيئية. و من ثم تم اختيار صرف محطة غسيل سيارات و صرف مصنع لزيت الطعام بالمنطقة الصناعية بدمياط الجديدة لتخضع لعمليات تجريب المعالجة الأولية المقترحة و هي الترسيب بالجاذبية الأرضية، التخثر الكيميائى، الترشيح بالمرشحات الرملية السريعة و البطيئة، و الادمصاص على سطح الاسفنج.

و اوضحت النتائج أن الترسيب بالجاذبية و كذلك التخثر الكيميائى (باستخدام جرعة شبة ٢٠ ملليجرام/لتر) كان أكثر فاعلية فى معالجة صرف محطة غسيل السيارات عنه فى معالجة صرف مصنع زيت الطعام. وباستخدام جرعة الشبة (١٠٠ ملليجرام/لتر) و جرعة من الشبة ٥ جرام /لتر أضيفت كمادة صلبة لكى تحدث عملية ترسيب كيميائى لنفس الصرف الناتج من مصنع زيت الطعام فقد وجد أن استخدام جرعة ٥ جرام/لتر حققت نتائج عالية عنها فى استخدام جرعة ١٠٠ ملليجرام/لتر. و قد تم تطبيق سلسلة متعاقبة من طرق المعالجة المختلفة على الصرفين و اتضح أنها أزالت الكثير من المكونات الموجودة بالصرفين بكفاءة عالية لتصرف بأمان على شبكة الصرف الصحى حسب المعايير المذكورة فى القرار رقم ٤٤ لسنة ٢٠٠٠. كما اتضح أن كفاءة عمليات المعالجة المختلفة تعتمد على تركيز و طبيعة هذا الصرف و مكوناته و درجة حرارته ودرجة حرارة الوسط التى تجرى فيه عملية المعالجة ووجود أو عدم وجود مواد سامة فى الصرف و فى عملية الترسيب الكيميائى يختلف باختلاف الجرعة المناسبة و المادة المستخدمة فى عملية التخثر.