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A New Development of Wastewater Treatment Unit for Paint Shop in Vehicle Industry

O. H. I. Aly*

Assistant Professor of Sanitary & Environmental Engineering, Higher Institute of Engineering, Sherouk City, Cairo, Egypt.

Email: olfat_hamdy@hotmail.com

Abstract

In vehicle industry, the painting is applied using two types of paints to produce the final color required. The vehicle body is generally pressed and welded and transported to a pre-clean area. Here, high pressure water spray jets are directed at the body with the purpose of cleaning off dirt and debris from previous processes. This study covers the paint workshop inside the vehicle factory and its wastewater. ELPO process use water to ease its application, this waster is wasted containing Zinc (Zn) 2 ppm, Nickel (Ni) 1.5 ppm, copper (Cu) 1.5 ppm, cadmium0.3 ppm and less than 1000 mg/l TSS. This wastewater is mixed with other factory branches in the equalization tank, where, the various combinations of the waste create a unique treatment challenge. At the Equalization Tank the various wastewater streams are blended and homogenized into a predictable and consistent influent. The objective of this research is to submit treatment solution to the existing pollutants mentioned above occupying a small area and with minimum cost. This could be applied by raising the pH of the wastewater to the minimum solubility of the combined metals, Zn, Ni, P and then, adding coagulants and a flocculants to enhance settling of the resulted solids. The separation of the solids from the clean water is accomplished by use of a plate settler unit. Settled solids will be dewatered by filter press unit before its disposal to sanitary land fill. The effluent overflows to a multi-media filter for further polishing. PH is again adjusted to permitted discharge levels, usually less than 9, and the water is discharged to the city sewer.

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* Corresponding author.

E-mail address: olfat_hamdy@hotmail.com.

The effluent wastewater showed high removal efficiency for all parameters in the full scale lab and after applying the system in the factory. The effluent was abiding all the environmental laws for applying to public sewers.

Keywords: Paint shop; ELPO process; TSS; Vehicle Industry; Heavy Metals

1. Introduction

In vehicle industry, the painting is applied using two types of paints to produce the final color required. The vehicle body is generally pressed and welded and transported to a pre-clean area. Here, high pressure water spray jets are directed at the body with the purpose of cleaning off dirt and debris from previous processes. This detritus can take many forms ranging from parts of components used in the production process, to operator refuse or items of clothing such as gloves. The vehicle is then transferred to the alkali dip rinse. The bodies are circulated through a series of dip tanks, which essentially degrease and clean the metal work. Each body is totally submerged in the caustic rinse, ensuring that no section is left untreated. Afterwards, the alkali dip excess fluid is drained from the vehicle body before the rinsing operation. Firstly the vehicle passes in the phosphate unit, which is responsible for the remove of oils and contaminants from the metal surface (substrate), coat the substrate with a crystalline structure to which paint can adhere and improve resistance to corrosion. The phosphate unit has five stages clean, rinse, phosphate, post rinse and DI water rinse [1].

The second process in painting cars is the electrode position process (ELPO) unit, which includes six stages: Ultra filtration (UF) rinse stages, De-ionized water (DI) rinse stages, ELPO oven and Strip accumulator. ELPO is similar to a plating process where positively charged paint particles (anode) are attracted to the vehicle body (cathode) [2].

This study covers the paint workshop inside the vehicle factory and its wastewater. ELPO process use water to ease its application, this waster is wasted containing Zinc (Zn) 2 ppm, Nickel (Ni) 1.5 ppm, copper (Cu) 1.5 ppm, cadmium0.3 ppm and less than 1000 mg/l TSS. This wastewater is mixed with other factory branches in the equalization tank, where, the various combinations of the waste create a unique treatment challenge. At the Equalization Tank the various wastewater streams are blended and homogenized into a predictable and consistent influent [3].

The objective of this research is to submit treatment solution to the existing pollutants mentioned above occupying a small area and with minimum cost. This could be applied by raising the pH of the wastewater to the minimum solubility of the combined metals, Zn, Ni, P and then, adding coagulants and a flocculants to enhance settling of the resulted solids. The separation of the solids from the clean water is accomplished by use of a plate settler unit. Settled solids will be dewatered by filter press unit before its disposal to sanitary land fill. The effluent overflows to a multi-media filter for further polishing. PH is again adjusted to permitted discharge levels, usually less than 9, and the water is discharged to the city sewer.

2. Literature Review

The automobile industry's wastewater not only contains high levels of suspended and total solids such as oil, grease, dyestuff, chromium, phosphate in washing products, and coloring, at various stages of manufacturing but also, a significant amount of dissolved organics, resulting in high BOD or COD loads. The study reveals the performance, evaluation and operational aspects of effluent treatment plant and its treatability, rather than the contamination status of the real property.

Wastewater Treatment is a Complex process and requires site specific design. Most plants cannot discharge the sanitary wastewater to a municipal system without treatment. Thus the treatment of wastewater coming out from different industries is a must. The waste coming out from the paint shop includes different types of wastes. The phosphate unit has phosphate and deionized water rinse, while the ELPO unit waste includes the ultra-filtration water, De-ionized water, Nickel and Zinc. These wastes are mixed together homogenously in an Equalization tank, where they are blended together to get the characteristics of the final waste that will be further treated. From the products of the Paint shop is also the paint sludge, which is a by-product of the vehicle surface treatment and painting process. It contains Paint sludge, which is Paint waste removed from paint both wet eliminators. Phosphate Sludge is the metal salts waste from surface chemical treatment of body vehicle. ELPO waste (Sludge) that is the Scrap ELPO pigment potentially be inherently high-risk wastes by its organic content or if lead is used in the pigment [4].

One of the studies performed on car painting industry was in China by Zhang Linsheng and it showed successful results [5].

The car painting discharge is complex in composition and multi-variable, but it might be classified into two categories specifically the electrophoresis wastewater and the pre-processing wastewater. The electrophoresis wastewater could be treated by two-stage air floatation and hydrolysis acidification in ABR (aerobic buffer reactor) and SBR, the effect of this process has been proved by practical operation. This was studied in China by Zhang Linsheng and it showed successful results [6].

Another study was done in Spain by comparing different types of treatment by measuring the COD of the effluent for these types. The process of car body painting is one of the manufacturing processes that may involve the use of organic solvents for surface treatments. As a result of this process, wastewaters containing raw materials and auxiliary products used during the cleaning step are produced. The main objective of this study is to find an appropriate purification technique to eliminate or reduce the contamination present in this kind of wastewater. Different treatments were investigated: ozonation, ozonation combined with hydrogen peroxide, photo-Fenton treatment, and coagulation- flocculation [7].

3. Materials and Methods

The Experimental work for this study includes two phases. Firstly the work took place in the lab, where a model was performed including different steps of treatment. These steps include an equalization tank, ph. adjustment, Sedimentation and finally multimedia filter. The flow diagram performed in the lab is illustrated in

Figure (1). Different scenarios for the laboratory work were examined to assure the best method for ph. Adjustment with coagulation. We tried first the Ferrous Sulphate for ph. Adjustment and coagulation; samples were collected after the sedimentation tank before filtration. Then we tried the lime for both ph.

Adjustment and coagulation and samples were collected after sedimentation. After that we used all together the Ferrous Sulphate, the lime and polymer, and then samples were collected after the sedimentation, but without filtration. Finally the full line lab was applied and samples were collected after filtration. The second phase of the Experimental work is that the suggested flow diagram was built in Jac vehicle industrial factory in Belbes road for treatment of wastewater coming out from the paint shop. The factory works 24 h/d. The quantity of the effluent wastewater is 500 $m^3$and flow rate 20 m^3/hr. The industry uses clarifier tank where the settling particles land on the inclined cone tank and are directed downward and into the sludge bottom tank. The clarified treated water then exits the top of the clarifier and flows downstream to sewer. The applied treatment in the factory is illustrated in figures 2 and 3. The PH indicator is adjusted by an automatic control. Samples were collected from the vehicle factory to assure the efficiency of the full line lab. The influent water includes the DI rinse (Deionized water), the UF (ultrafiltration) and the filters washing, add on this the wastewater coming from the phosphate unit. There is a PH controller at 3rd stage polymer tank, if the PH is within range Pump1 will run, SV2 will open, while SV1 will close and Pump2 will stop. On the other hand, if the PH is out of range Pump will stop, SV2 will close, while SV2 will open and Pump2 will run.

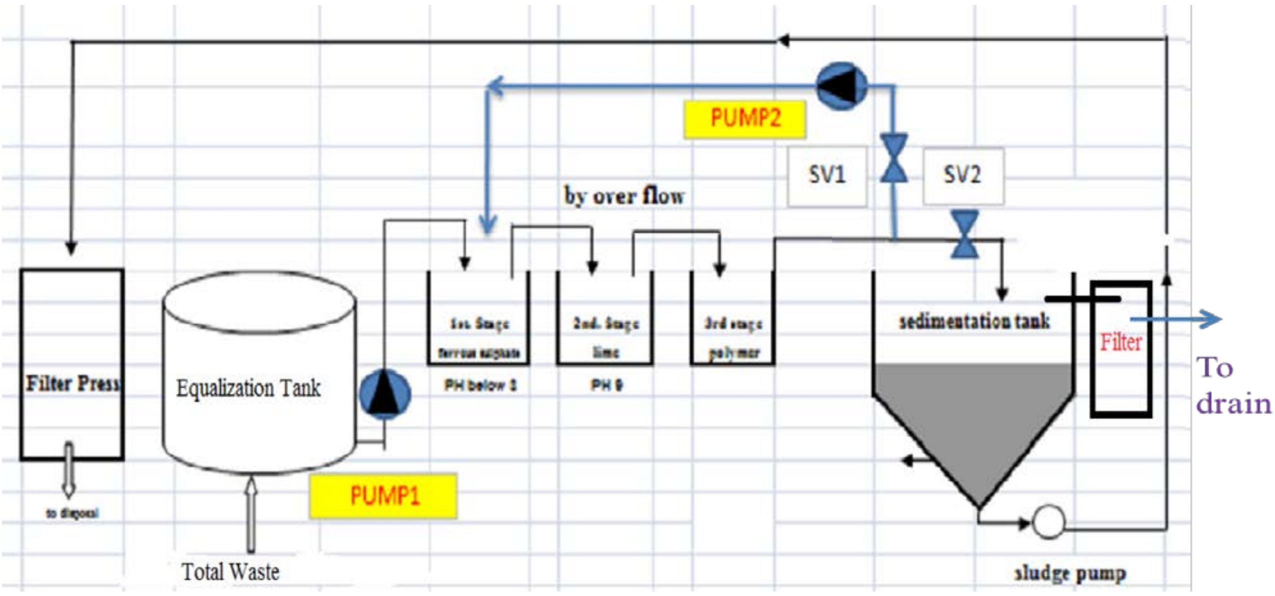

Figure (1): The Lab Pilot Unit.

The resulted clarifier waste sludge is periodically removed from the clarifier at a slow rate and sent to the sludge holding tank where it further thickens and accumulates a batch for disposal or processing in a filter press. The sludge is mixed and conditioned with a filter aid to improve porosity and filterability which will improve cake dryness and prevent premature blinding of the filter cloths. The thickened clarifier sludge is allowed to accumulate sufficiently to provide a full batch for the Filter Press. The sludge is pumped until the filter press is full. The filter press is then emptied of the “cake” which is a semi solid of approximately 20-60 % solids. Sludge cake is high in paint solids and should be disposed of according to environmental regulations.

Figure (2): Photos for real Plant Clarifier, Inclined Plate.

4. Results and Discussion

The samples were taken and examined from the influent and effluent of the treatment unit. Table 1 shows the results of the Influent samples, which were collected in months December and January and Table 2 shows the results of the treated samples after the use of Ferrous Sulphate. Table 3 shows the results after the use of Lime. Table 4 shows the results after the use of Polymer for the ph. adjustment and coagulation. Table 5 shows the results of Full Scale unit lab as per figure 1. Finally table 6 shows results of the treated samples, after applying in the factory.

Figures driven to clarify the removal efficiency for each case studied as mentioned above.

Table 1: Influent samples results

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	500	2500	10	88.6	52.8	42.8
Sample 2	600	2600	10.5	89.2	52.7	43.5
Sample 3	630	2700	10.2	88.7	53.5	43.1
Sample 4	650	2900	9.8	89	53.2	42.75
Sample 5	700	2950	10	89.5	53	42.88
Sample 6	700	3000	9.7	90	54	43.2

Table 2: The treated effluent after the first scenario.

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	300	1300	10.7	45	27.3	22.5
Sample 2	350	1350	10.3	50	26.4	24.8
Sample 3	310	1400	10.4	44	22.7	21.75
Sample 4	320	1500	10	45	23.5	23.4
Sample 5	400	1550	10.5	52	24.8	24.6
Sample 6	390	1600	9.9	53	26.8	25.45

Table 3: The treated effluent after the second scenario.

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	270	1150	10	25	12.5	21.2
Sample 2	310	1250	10.5	28	13.2	22.6
Sample 3	290	1200	10.2	19	9.8	20.65
Sample 4	300	1300	9.8	15	10	21.1
Sample 5	380	1350	10	17	10.8	21.45
Sample 6	370	1400	9.7	22	11.4	23.25

Table 4: The treated effluent after the third scenario.

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	100	300	9	8	7.6	11.2
Sample 2	180	390	9.7	9.5	8.3	9.6
Sample 3	175	410	8.9	15	6.6	10.65
Sample 4	210	450	9.2	11	5	11.1
Sample 5	237	420	7.9	11.3	5.7	13.45
Sample 6	250	550	9.66	16	6.2	12.25

Table 5: the treated full scale pilot lab

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	80	244	9	0.07	1	10.2
Sample 2	160	366	9.7	0.05	0.055	8.6
Sample 3	168	381	8.9	0.04	0.01	9.65
Sample 4	200	431	9.2	0.044	0.02	10.1
Sample 5	228	400	7.9	0.076	0.06	12.45
Sample 6	232	534	9.66	0.067	0.07	11.25

Table 6: the treated samples in the factory

Parameter	TSS	COD	pH	Zinc	Nickel	Phosphate
Sample 1	67	223	9	0.066	0.089	9.87
Sample 2	145	340	9.7	0.042	0.04	8.2
Sample 3	153	348	8.9	0.029	0.01	9.15
Sample 4	178	409	9.2	0.033	0.015	9.09
Sample 5	189	378	7.9	0.068	0.042	11.78
Sample 6	210	512	9.66	0.055	0.056	10.65

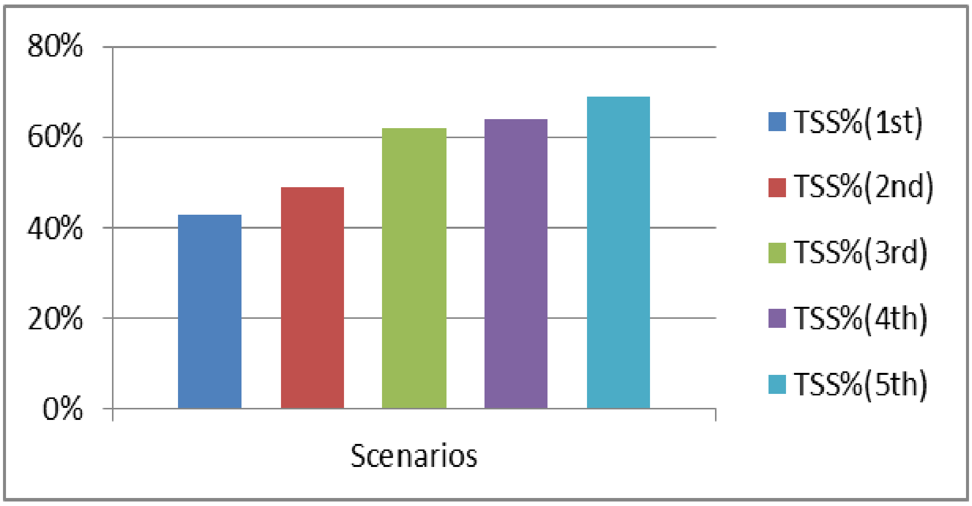

Figure (2): The removal efficiency for TSS for all scenarios.

The removal efficiency for TSS was found to be around 40 % for the 1st scenario, while for the 2nd one it was found around 50%, for the 3rd scenario it raised to be 62%, while for the full scale lab it reached 64% and finally after applying in the factory it was 69%.

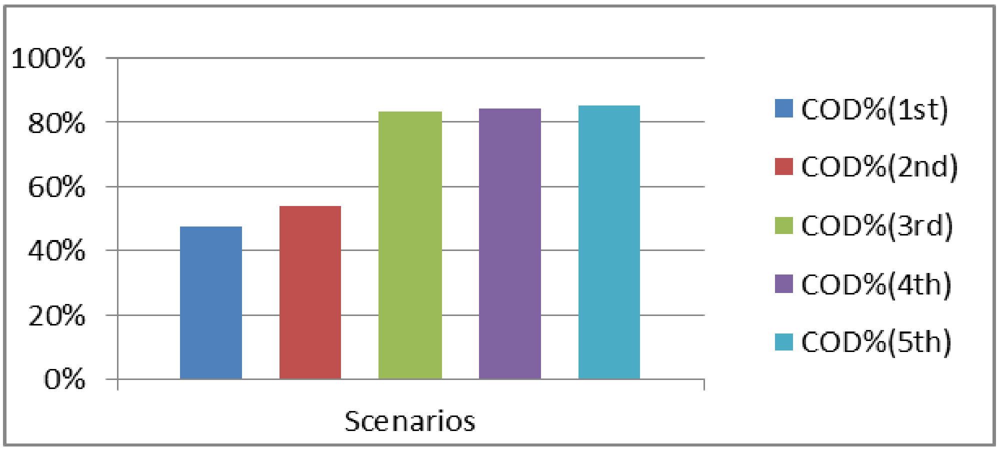

Figure (3): The removal efficiency for COD for all scenarios.

The removal efficiency for COD was found to be around 48 % for the 1st scenario, while for the 2nd one it was found around 54%, for the 3rd scenario it raised to be 83%, while for the full scale lab it reached 84% and finally after applying in the factory it was 85%.

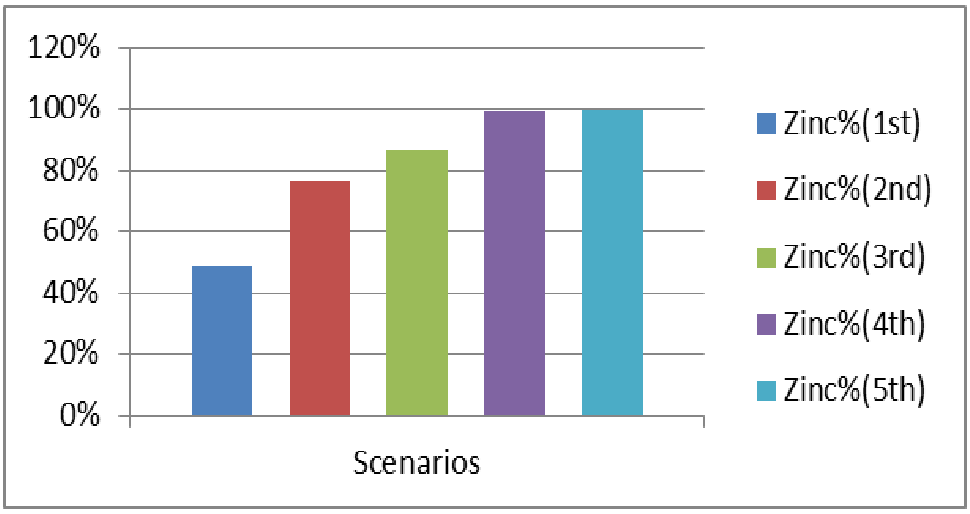

Figure (4): The removal efficiency for Zinc for all scenarios.

The removal efficiency for Zinc was found to be around 49 % for the 1st scenario, while for the 2nd one it was found around 76%, for the 3rd scenario it raised to be 87%, while for the full scale lab it reached 99% and finally after applying in the factory it was 100%.

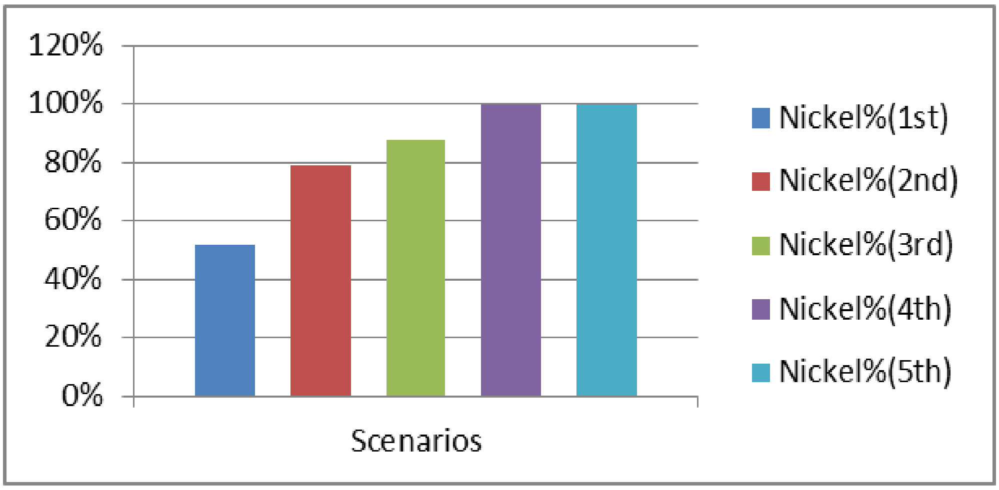

Figure (5): The removal efficiency for Nickel for all scenarios.

The removal efficiency for Nickel was found to be around 51 % for the 1st scenario, while for the 2nd one it was found around 79%, for the 3rd scenario it raised to be 88%, while for the full scale lab and the factory it reached 100%.

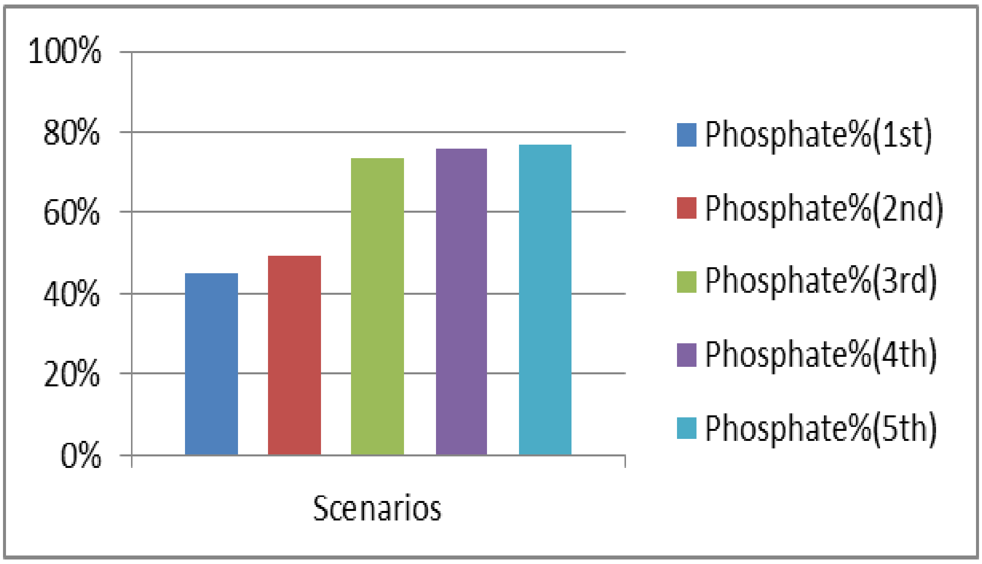

Figure (6): The removal efficiency for Phosphate for all scenarios.

The removal efficiency for Phosphate was found to be around 45 % for the 1st scenario, while for the 2nd one it was found around 50%, for the 3rd scenario it raised to be 73%, while for the full scale lab and the factory it was 77%.

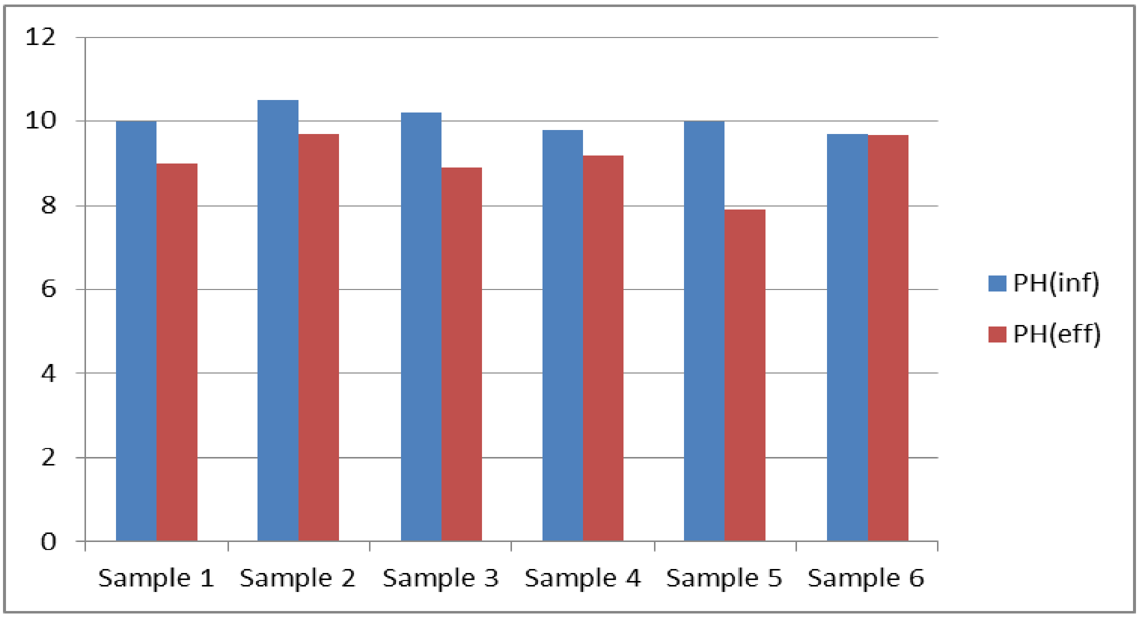

Figure (7): The influent and effluent pH for the factory.

The PH for the influent wastewater was from 9.7 to 10.5 and for the effluent was from 7.9 to 9.7.

5. Conclusion and Recommendations

During the period of study the influent wastewater had an influent concentration of TSS between500 to 700 mg/l and for the COD was between 2500 to 3000 mg/l.

By comparing between the samples for the five scenarios for the examined parameters, we can conclude that

1. The removal ratio for the first scenario using the Ferrous Sulphate was ranging from 40% to 50 % for all the parameters.
2. The removal ratio for the second scenario using the Lime was around 50% for TSS, COD & Phosphate, however for Zn & Ni was around 75%.
3. The removal ratio for the third scenario using polymer was for TSS was 62%, while for COD, Zn, Ni was around 85% and for Phosphate was 79%.
4. The removal for the full scale lab was for TSS was 64%, for COD was 84%, while for Zn & Ni was around 100% and for phosphate was 77%.
5. After applying the system in the factory, the system showed great success for the removal ratio for all parameters. They results were very close to those in the lab

Therefore, it is recommended to use the Electrode Deposition unit along with coagulation in the treatment of wastewater from paint industry. Also the effluent wastewater results abide the rules of the wastes according to the Environmental laws. The Total Suspended solids should not exceed 800 mg/l, the COD should not exceed 1100 ppm, the pH should not be more than9, the Zinc and the Nickel should not exceed 1 mg/l and the Phosphate should not exceed 25 ppm. For the cost of the pilot scale unit and the applied system in the factory it does not differ much accordingly for the previous scenarios. These limits are according to law 93/ 1962 and its decree number 44/2000 concerning the discharge of final effluent to the public sewer system.

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