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Removal of Lead in High Rate Activated Sludge System

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***Abstract*—**The heavy metals pollution in water, sediments and fish of Lake Manzala affected form the disposal of wastewater, industrial and agricultural drainage water into the lake on the environmental situation. A pilot plant with an industrial discharge flow of 135L/h designed according to the activated sludge plant to simulate between the biological and chemical treatment with the addition of alum to the aeration tank with dosages of 100, 150, 200 and 250 mg/L. The industrial discharge had concentrations of Lead and BOD_5 with an average range 1.22, 145mg/L respectively. That means the average Pb was high up to 25 times than the allowed permissible concentration. The optimization of the chemical-biological process using 200mg/L Alum dosage compared has improvement of Lead and BOD_5 removal efficiency to 61.76% and 56% respectively.

***Keywords*—**Industrial wastewater, Activated sludge, BOD_5, Lead, Alum salt.

I. Introduction

THE industrial activities represent an important pollutant source now a day. This is contributing to a significant increase on the concentrations of heavy metal ions in waters, representing an important source of contamination of the aquatic bodies, especially when it is considered that such ions can be disseminated through the food chain [1].

Heavy metals released by a number of industrial processes in the environment are some of the major pollutants of soil and water resources. The concentration of these pollutants must be reduced to meet ever increasing legislative standards and recovered where feasible [2]. Heavy Metals - Metals, when in significant concentrations in water, which may pose detrimental health effects. Heavy metals include lead, silver, mercury, copper, nickel, chromium, zinc, cadmium and Iron that must be removed to certain levels to meet discharge requirements [3].

Metal precipitation is primarily dependent upon two factors: the concentration of the metal, and the pH of the water. Heavy metals are usually present in wastewaters in dilute quantities (1-100mg/L) and at neutral or acidic pH values (<7.0). Both of these factors are disadvantageous with regard to metals removal. However, when one adds caustic to water which contains dissolved metals, the metals react with hydroxide ions to form metal hydroxide solids as shown in (1) [3].

$$\text{Metal} + \text{Hydroxide}\ (\text{from caustic}) \rightarrow \text{Metal Hydroxide Precipitates} \quad (1)$$

Various physicochemical techniques for removing metal ions from wastewaters include chemical precipitation, adsorption, ion exchange, extraction and membrane processes. Chemical precipitation is the most common utilized conventional technique. Adsorption has been shown to be an economically feasible alternative method for removing heavy metals from wastewater and water supplies [2].

Alum salts are commonly used as coagulant and settling aids in both the water and wastewater industry. They are less corrosive, create less sludge, and are more popular with operators compared to lime. Alum is available in liquid or dry form, can be stored on site in steel or mild concrete, and has a near unlimited shelf life [4]. Samples of water, sediment and fish from Manzala Lake analyzed for the concentration of five major heavy metals Mn, Cd, Zn, Pb, and Cu [5].

Results show that all the water and sediment samples collected from contain different concentration of the five tested heavy metals. Fish samples also had high concentrations of analyzed heavy metals at their flesh. The mean calculated value of Pb was high up to 38 times than the allowed permissible concentration. This confirms that lake fish is highly polluted and dangerous for human health [5].

Many techniques tried out to remove heavy metals from wastewater. Physicochemical methods, such as chemical precipitation, ion exchange, adsorption, electrolysis, and chemical oxidation/reduction and membrane technologies found to be ineffective or rather expensive or generate toxic slurries. Biological treatment is considered a promising technique for bioremediation of metals wastewater, since it can degrade organic pollutant in the wastewater and simultaneously transform heavy metals [6].

Activated sludge is a biological process used to remove organics from wastewater. Like the trickling filter, activated sludge processes used to grow a biomass of aerobic organisms that will breakdown the waste and convert it into more bugs. This accomplished in large aerated tanks instead of the trickling filter's fixed media. These tanks called aeration basins. Activated sludge processes return settled sludge to the aeration basins in order to maintain the right amount of bugs to handle the incoming "food". Activated sludge processes have higher removal efficiencies (95-98%) than trickling filters (80-85%) [7].

In the activated sludge process, the microorganisms kept suspended either by blowing air in the tank or by the use of agitators. The microorganisms to oxidize organic matter use oxygen. To maintain the microbiological population, the

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sludge from the settler is recirculate to the aerated tank, In order to keep the sludge concentration constant despite of the growth of the microorganisms, sludge is withdrawn from the process as excess sludge [8]. The Adsorption/Bio-oxidation technique (AB-system) invented and patented as a two-stage activated sludge plant without primary sedimentation. In this process the excess sludge of the second stage is not transferred to the first stage [9]. The sludge load (F/M) in the high-load stage (A-stage) approximately ranges from 0.6 to 1.5kg BOD_5/kg MLSS.d, and for the low-load stage (B-stage) F/M ranges from 0.1 to 0.2kg BOD_5/kg MLSS.d [10].

All researchers working on the AB-system were concerned only with the biological treatment for the elimination of phosphorous, BOD_5. The BOD_5 elimination efficiencies in the A-stage are variable and easy to control. The degree of efficiency varied between 50-60% for the BOD_5 depending on the sludge load (F/M) and the method of operation. In our case, all elimination efficiency values for the BOD_5 approximately in the normal range of the A-stage [10]. Therefore, the researcher in this work will deal with some points concerning the reaction of Heavy Metals material to the Adsorption/Bio-oxidation technique (AB-system) in order to investigate the following objectives [11].

II. Model Description and Operation

A. Aim of Study

The aim of this research is to increase the elimination efficiency of high concentration BOD_5 and Pb in the influent industrial wastewater came from the industrial area, which is located at the south of Port Said City. By adding chemical precipitant such as $A1_2^+$ salts. The study was carried out in the first biological stage (the A-stage), which is classified as the highly loaded activated sludge stage of the multiple-stage plant (AB-system).

B. Model Description and Operation

The used model system consisted of two rectangular tanks: an aeration tank and sedimentation tank, which designed to act dependently as the A-stage. The two tanks were made of galvanized tin sheets. The total volume of the aeration tank was 135L with a detention time of 30 minutes. The influent flow was 135L/hrs with an average returned sludge of 135L/hrs. The sedimentation tank had a total volume of 270L with a detention time of 1 hour. The water flow was 135L/hr with the temperature ranging from 19ºC to 40ºC, as shown in Fig. 1.

C. Sample Collection Points

There were four sample collection points in the pilot plant. These points were very important in order to examine the characteristics of wastewater and sludge. The four positions to collect the sample were first, the influent of the pilot plant; second, the effluent of the pilot plant downstream from the settling tank; third, the influent of the recycling sludge upstream from the aeration tank; and the fourth point was at the middle of the aeration tank (i.e. the mixed liquor in the aeration tank).

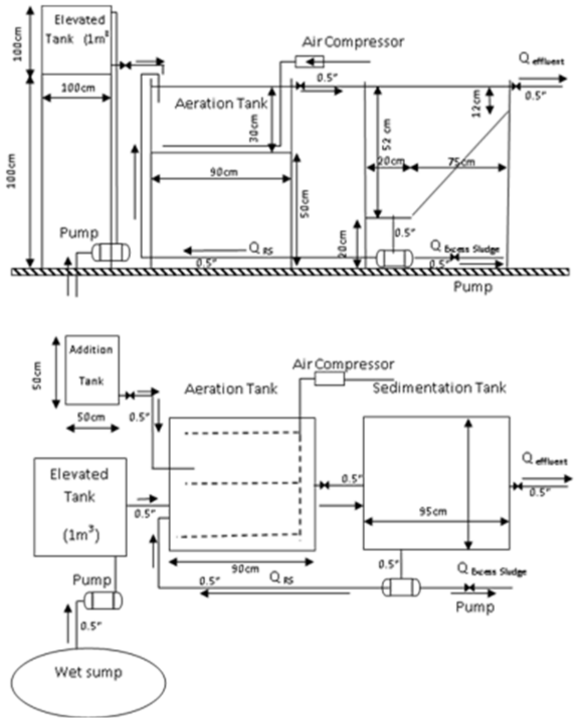

Fig. 1 A-stage process

D. Chemicals Used for Precipitation (Alum Salt)

Alum is acidic in nature while sodium aluminate is alkaline, which may be an important factor in choosing between them. Alum was more effective than sodium aluminate based on the molecule ratio. The commercial product for alum (aluminum sulfate), $Al_2(SO_4)_3.18H_2O$ [10]. In this study, the alum dosages used ranged from 100 to 250mg/L.

E. Wastewater and Sludge Analysis Method

Biochemical oxygen demand (BOD_5) and Lead (Pb) were the parameters determined for the influent wastewater to the aeration tank and the effluent from the settling tank. The influent and effluent samples mixed samples, collected during the 24 hours of the day in a refrigerator. The samples are taken at regular intervals 3 times a day.

Samples of the returned sludge and mixed liquor are taken once a day in the morning. PH-value, mixed liquor suspended solids (MLSS), suspended solids in the returned sludge (SSRS) and sludge load rate (F/M) were the parameters determined for the returned sludge (RS) to the aeration tank and the mixed liquor in the aeration tank (A-tank). The sludge as well as the mixed liquor samples are taken 3 times per day at 9.00 a.m., 11.00 a.m. and 1.00 p.m. All the parameters were determined in accordance with the American standards methods for the examination of water and wastewater [12].

Lead Determined by using differential pulse stripping voltammetry technique. All electrochemical experiments carried out using VSP Potentiostat/galvanostat (BioLogic).

III. Results and Discussions

The experimental work for this study subdivided into two groups. The first group (with zero additive) was carried out in one run without salt addition with 12 days as a retention time, to describe the natural performance of the pilot plant for the high-loaded activated sludge stage (A-stage). The working properties for the pilot plant, BOD_5 and Pb were determined with a mixed sludge recirculation ratio of 89%.

A. BOD_5, MLSS and F/M Parameters

Table I illustrates influent BOD_5, aeration tank MLSS and F/M for all of trials. As shown in Table I the average F/M ratios which were ranged between 2.55 and 4.18kgBOD_5/ kg MLSS.d (F/M ratio must be equal or larger than 1.5kg BOD_5/kg MLSS.d [10]. This means that the pilot plant was working as highly loaded activated sludge at all trials.

TABLE I
VALUES OF INFLUENT BOD_5, AERATION TANK MLSS AND F/M

Alum Salt	0 mg/l Alum Salt			100 mg/l Alum Salt			150 mg/l Alum Salt			200 mg/l Alum Salt			250 mg/l Alum Salt		
day	BOD_5 mg/L	MLSS mg/L	F/M mg/L	BOD_5 mg/L	MLSS mg/L	F/M mg/L	BOD_5 mg/L	MLSS mg/L	F/M mg/L	BOD_5 mg/L	MLSS mg/L	F/M mg/L	BOD_5 mg/L	MLSS mg/L	F/M mg/L
1	88.25	440	4.99	153.5	1760	2.36	153	610	5.93	142.5	1306	2.83	180.5	835	5.57
2	97	811	3.06	159.25	1963	2.16	142.5	829	4.28	185	1214	3.85	187.5	1015	4.60
3	95.75	457	4.73	150.25	1896	2.06	124.5	965	3.30	177.25	1072	4.00	185.25	750	6.41
4	99.75	534	4.68	127	1574	2.07	120	1360	2.40	194	1634	3.12	147.75	1118	3.45
5	98.5	726	3.64	135.75	1311	2.80	105.25	1374	2.04	198.25	1462	3.50	187.25	1490	3.13
6	94	872	2.76	120	844	3.69	136.5	938	3.83	200	1251	4.09	176	1215	3.71
7	95	739	3.18	101.75	1024	2.74	139.5	1385	2.83	182.75	1188	4.13	192.75	2010	2.42
Av.	95.46	650	3.86	135.36	1480	2.55	131.61	1070	3.52	182.82	1300	3.65	179.57	1200	4.18

mg = milligram, L = Liter

Biological Oxygen Demand BOD_5

Experimental results indicated that, the high rate activated sludge system were effective in removing BOD_5 from the samples. Figs. 2-4 illustrate the influent and the effluent BOD_5 average concentration values when adding 0,100, 150, 200, 250mg/L Alum salt. The average BOD_5 concentrations at influent were 95.46, 135.4, 131.6, 182.8, 179.57mg/L, and the average BOD_5 concentrations at effluent were 41.9, 41.7, 36, 36.46 and 35.9mg/L respectively.

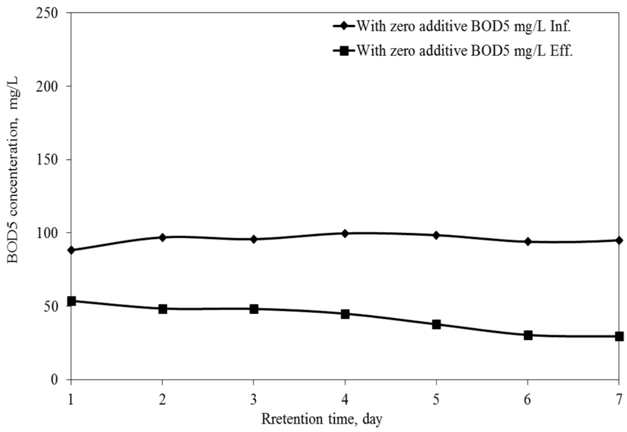

Fig. 2 Influent and Effluent BOD_5 during the first group (zero additives)

The BOD_5 elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts represented at Figs. 5, 6. The BOD_5 elimination efficiency was 56%, 69.21%, 72.67%, 80.05% and 80.01% respectively. This means that increased by using more dosage of Alum Salts. All effluent BOD_5 gave less than the allowable values range (60mg/L)[13].

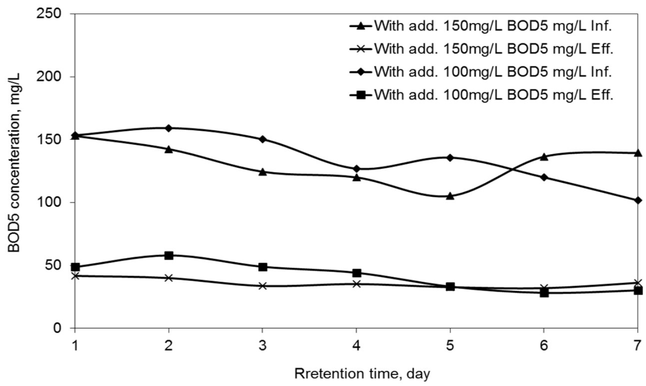

Fig. 3 Influent and Effluent BOD_5 during the second group (with 100 and 150mg/L Alum. salts addition)

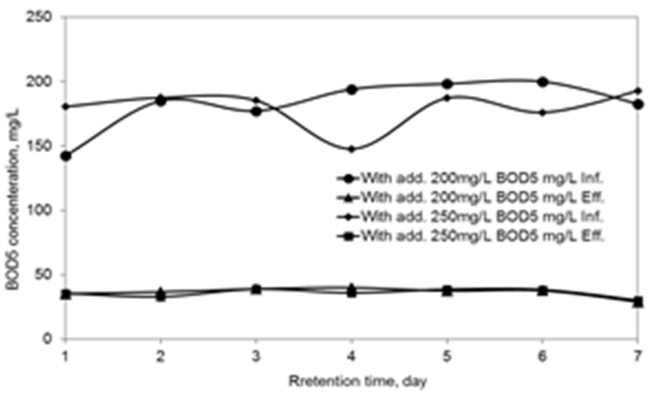

Fig. 4 Influent and Effluent BOD_5 during the second group (with 200 and 250mg/L Alum. salts addition)

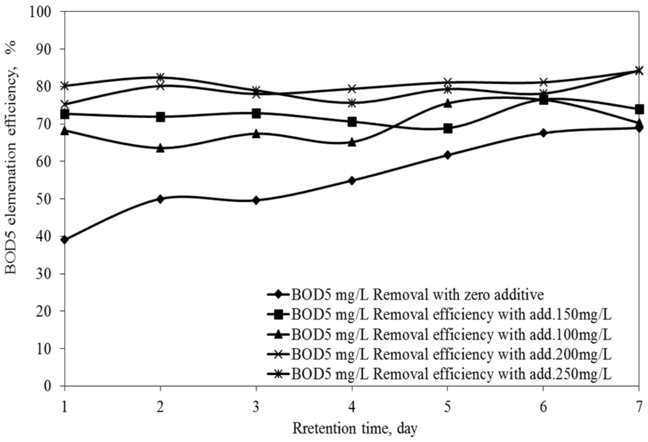

Fig. 5 BOD_5 Elimination values during Alum. Salts addition for dosages from 0 to 250mg/L

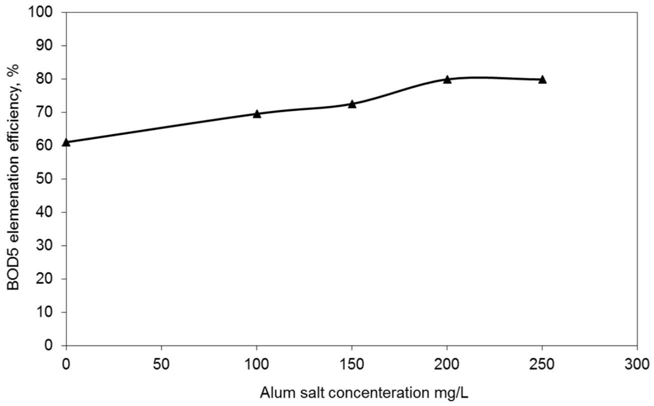

Fig. 6 Average BOD_5 Elimination Efficiency values during Alum. Salts addition for dosages from 0 to 250mg/L

The BOD_5 elimination efficiencies in the A-stage are variable and easy to control. The degree of efficiency is varied between 50-60% for the BOD_5 depending on the sludge load (F/M) and the method of operation [10].

B. Lead Results (Pb)

Experimental results indicated that, the high rate activated sludge system were effective in removing Pb from the samples. Figs. 2-4 illustrate the influent and the effluent Pb average concentration values when adding 0,100, 150, 200, 250mg/L Alum salt. The average Pb concentrations at influent were 0.57, 2.08, 1.06, 1.1 and 1.3mg/L and the average Pb concentrations at effluent were 0.29, 0.57, 0.47, 0.41 and 0.39mg/L respectively.

The Pb elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts represented at Figs. 5, 6, the Pb elimination efficiency were 47.11%, 55.21%, and 60.25%, 61.76% and 61.26% respectively. This means that increased by using more dosage of Alum Salts until reach to 200mg/L after that the efficiency were constant. However, all effluent Pb gave higher than the allowable values range (0.05mg/L) [13].

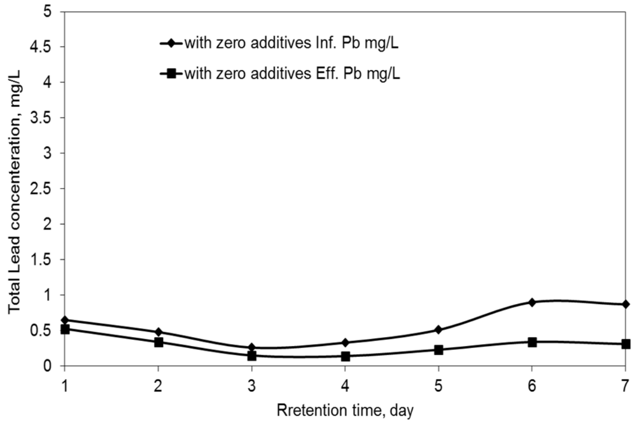

Fig. 7 Influent and Effluent Pb during the first group (zero additives)

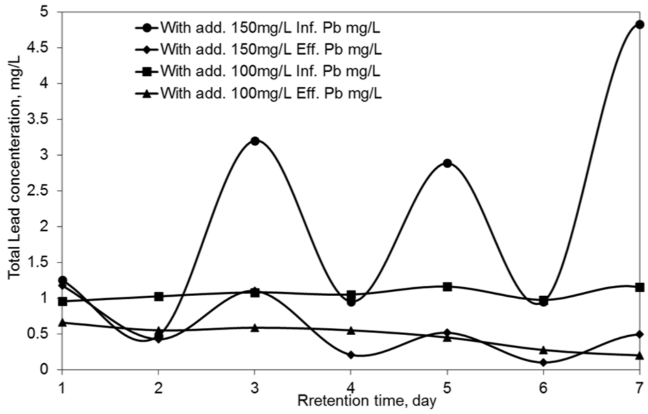

Fig. 8 Influent and Effluent Pb during the second group (with 100 and 150mg/L Alum. salts addition)

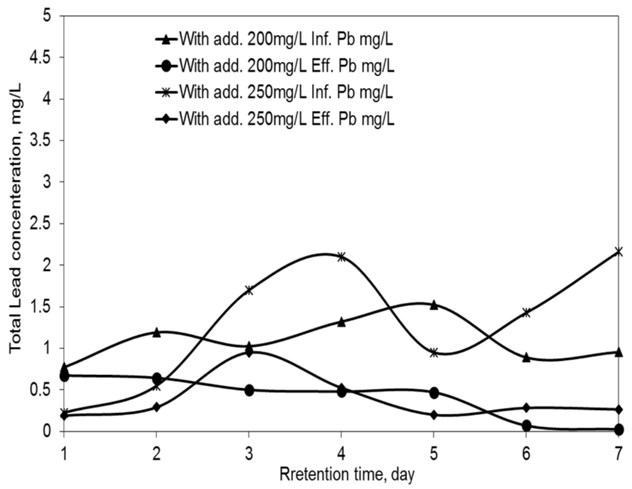

Fig. 9 Influent and Effluent Pb during the second group (with 200 and 250mg/L Alum. salts addition)

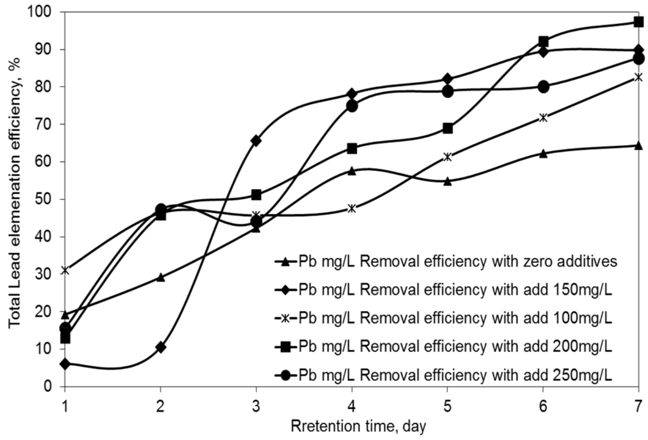

Fig. 10 Pb Elimination values during Alum. Salts addition for dosages from 0 to 250mg/L

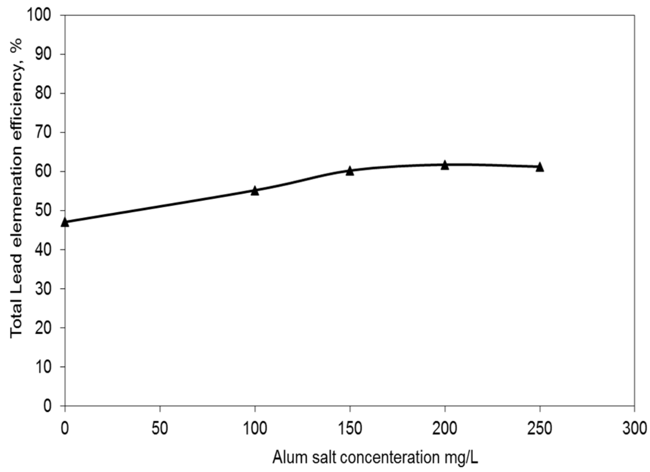

Fig. 11 Average Pb Elimination Efficiency values during Alum. Salts addition for dosages from 0 to 250mg/L

IV. Summary of Results

The principal target of this research is not to develop the entire treatment system, but to develop the highly loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system). The aim of this research is to examine, if by adding the chemical precipitants such as $A1_3^+$ salts in the influent of the activated sludge system, the elimination efficiency of BOD_5 and the Lead (Pb) in the treatment system improved.

The results clearly indicate that the highly loaded activated sludge (A-stage) has a high elimination efficiency of inorganic matters compared with the mechanical stage of the conventional treatment plants. Without adding alum salt, the removal efficiency of BOD_5 and Lead (Pb) were approximately 56% and 47.11% respectively. Adding alum salt improved the elimination efficiency of BOD_5 and Lead (Pb) in the first treatment stage.

A pilot plant with an influent discharge flow of 135L/hrs designed according to the highly loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system) to simulate between the biological and chemical treatment with the addition of alum sulfate to the aeration tank with dosages in of 100, 150, 200 and 250mg/L. The average F/M ratios increased incrementally as the dosage of the aluminum salt increased. In addition, the ratios were higher than the values of the conventional activated sludge unit. The average F/M ratio with 100, 150, 200 and 250mg/L aluminum salt added found to be 2.553, 3.516, 3.645 and 4.18 $KgBOD_5$/KgMLSS.d, respectively. Aerated mixed liquor classified as highly-loaded activated sludge because all over (F/M) ratios was larger than 1.5 kg BOD_5/kg MLSS*d [10].

The BOD_5 Effluent elimination efficiencies increased and then became constant as possible. In addition, the BOD_5 elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts were 56%, 69.21%, 72.67%, 80.05% and 80.01% respectively which means that the BOD_5 elimination efficiency increased by using more dosage of Alum Salts until the efficiency reaches to 200mg/L and after that, the efficiency had low increment.

The Influent and Effluent Pb elimination efficiencies increased with time. The Pb elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum salt were 47.11%, 55.21%, 60.25%, 61.76% and 61.26% respectively. The lead elimination efficiency increased by using more dosage of Alum Salts until the efficiency reaches to 200mg/L and after that, the efficiency had low increment. Also, all the effluent values were approximately had Pb more than the allowable value (0.05mg/L) [13].

V. Conclusion

Referring to the observations and the results obtained, the following points concluded:

1) It is stated that the detention time of 30 minutes in the A-tank was sufficient for mixing and flocculation of the mineral salt.
2) Adding alum salt in the influent of the highly loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system) improved the elimination efficiency of BOD_5 as well as Lead.
3) The optimization of the chemical-biological process using 200mg/L Alum dosage compared with the biological process in the A-stage has a number of advantages :
   - Improvement of BOD_5 removal efficiency from 56% without additives to 80.05% with 200mg/L Alum Salt.
   - Improvement of Lead removal efficiency from 47.11% without additives to 61.76% with 200mg/L Alum Salt addition.

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