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Conditioning Process of Fresh Activated Sludge

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Abstract**—**The effect of polyelectrolytes; cationic and anionic charges and coagulants have been investigated for fresh activated sludge at different concentrations and pH values in a comparative fashion. The results from the experiments indicate that the cationic polyelectrolytes have a significant effluence on the sludge characteristic, degree of flocculation and water quality such as turbidity and SVI. The results show that the cationic CPAM-80 is the most effective polyelectrolyte used corresponding to turbidity and SVI despite of the variations in feed properties of the fresh activated sludge.

Keywords**—**Coagulant, Polyelectrolyte, Settling volume index, Turbidity.

I. Introduction

SLUDGE is a multi-component mixture with high water (more than 95%), organic content, micro-organism and colloids. It is a very unstable product depending on its origin and because of its characteristics and may present some problems related to engineering such as cost related to its transportation and disposal that are the highest part in the treatment process [1]-[3].

Problems that engineers face during operation due to the microbial contents in the activated sludge are bulking, pin flock and rising sludge [4]. Also, poor settling of waste sludge could be due to the growth of filamentous bacteria and fungi [5]. Although the presence of bacteria is helpful for the removal of organic waste materials, filamentous bacteria have weak floc forming behavior and this leads to low sludge settling.

Chemical coagulation such as polyelctrolytes is a very important phenomenon for the sludge conditioning in waste water treatment. All coagulants are used in order to reduce the electrical charge of the particles breaking the stability of the colloids and thus affecting the flocculated microbial aggregates [3].

II. Activated Sludge

It is well known that the composition of the real activated sludge in waste water plant is continuously unstable; continuously changing characteristics and varying depending on the origin of the feed and time at which is entered the aeration section in the wastewater plant, as well as the differences in the design and operation of the treatment plants [6]. Thus, many researchers have considered the use of synthetic sludge in order to carry out the experiment underideal controlled conditions [7]. However, such sludge does not reflect the reality of the treatment and does not give the true picture of the mechanism of sludge conditioning by using chemical coagulants, especially under unstable characteristic of activated sludge.

Several researchers have applied many polyelectrolytes in simulated waste [8], [9] but, only few discussed its application on real waste as the flocculation optimization practices in the real waste are still based on trial and error, due to the complexity and nature due to variation in the waste water composition and environmental changes [10], these are all affect the flocculation process. Thus, in this project, it has been decided to study the conditioning of a real sample of activated sludge collected from the Nizwa wastewater treatment plant at the Sultanate of Oman in order to observe the effect of coagulant agents on such unstable and complex sludge and then find the optimum dose based on turbidity and settling volume index. As the characteristics of the sludge are time dependent and testing period, testing has to be performed as soon as possible to prevent large variations in the sludge properties which may produce erroneous results.

III. Conditioning Agents

In order to improve the solid-liquid separation of the sludge, conditioning agents shall be used due to the large effect of these agents on the dispersed particles. There are two types of agents, inorganic and organic chemicals. Both are used to change the electrical potential of the suspended particles and reduce the repelling force. These agents form polymeric charged hydroxide and are adsorbed on the dispersed particles and thus modify their surface charge [11].

The overall objective of this study is to investigate the role of coagulants such as aluminum, ferric sulphate, ferric chloride and different types of polyelectrolytes such as poly-aluminum chloride (PAC), Polyacrylamide (PAM), etc, as flocculating and conditioning agents for sewage sludge at the Nizwa waste water treatment plant.

IV. Materials and Methods

The sludge samples used for experimental tests come from the waste water treatment plant at Nizwa city in the Sultanate of Oman. The considered sludge samples were taken from the aeration tank in order to obtain the optimum solid concentration in the digester. However, each test has been performed using a new different fresh sludge solution. Thus, it can be seen that the initial point for all tests differ from each other in reference to all variables under considerations; such as pH, turbidity, conductivity, TSS, etc as shown in Table I.

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TABLE I
EXPERIMENTAL DATA

Test No.	Chemical Added	pH	Initial Conductivity (ms/cm)	Final Conductivity (last dose of chemicals add (ms/cm))	Last Dose Of Chemical Added (mg/g solid/l)	TSS g/l	FSS g/l	VSS g/l	% VSS/ TSS
1	CPAM-80	7.6	1.166	1.07	10	10	1.5	8.5	85
2	CPAM-80	9.4	2.294	2.129	13.33	7.5	1.5	6	80
3	CPAM-80	5.6	3.9	3.8	9.6	10.4	2.08	8.32	80
4	CPAM-10	7.2	1.04	1.02	6.8	14.7	3.75	10.95	74.5
5	CPAM-10	9.4	2.46	2.24	6	17	7.55	9.45	55.6
6	CPAM-10	5.6	3.93	3.4	9.6	10.4	2.08	8.32	80
7	APAM-30	7.6	2.236	2	13.8	7.25	2.15	5.1	71.3
8	APAM-30	9.4	2.236	2	13.65	7.32	2.1	5.22	70.3
9	APAM-30	5.6	3.1	3.037	13.33	7.5	1.5	6	80
10	$Al_2(SO_4)_3$	7.6	2.341	2.04	28.1	3.56	1.15	2.41	67.7
11	$Al_2(SO_4)_3$	9.4	2.341	2.04	28.1	3.56	1.15	2.41	67.7
12	$Al_2(SO_4)_3$	5.6	3.8	3.22	13.11	7.6	1.88	5.72	75.2
13	$CaCl_2$	7.6	2.36	2.24	12.5	8	1.7	6.3	78.8
14	$CaCl_2$	9.4	2.468	2.312	13.65	6.64	1.84	4.8	72.3
15	$CaCl_2$	5.6	3.36	3.8	12.5	8	1.7	6.3	78.8
16	Fe_2Cl_3	7.8	2.44	2.207	13.15	6.64	1.84	4.8	72.3
17	Fe_2Cl_3	9.4	2.49	2.43	13.12	8	2.1	5.9	73.8
18	Fe_2Cl_3	5.6	4	3.3	13.12	8	2.1	5.9	73.8

A. Chemical Preparations

Six types of chemicals were used. Three different types of polyacrylamides as flocculants were used, such as CPAM-80, CPAM-10, and APAM-30 provided by Cytec Industries Ltd., UK. Also, three other different types of coagulants, such as Aluminum sulfate, Calcium chloride and Ferric chloride were used. All chemicals were prepared by mixing 1g of each chemical with one liter deionized water and stirring with a magnetic stirrer for at minimum 24 hours. Ten different ranges of concentrations of each chemical used cover from 0.05 to 100mg of chemical per one gram of total suspended solid (TSS) of the activated sludge. The pH for each solution was adjusted by adding sulfuric acid or sodium hydroxide solutions.

B. Turbidity

The turbidity was measured in NTU (Nephelometric Turbidity Unit) using a turbidity meter (CL 52D NEPHELOMETER). Flocculation was carried out on a six multiple stirring unit with a stainless steel paddle (Jar test) using rapid mixing (200rpm) for 2 minutes and then followed by slower mixing (90rpm) for 30 minutes. Short and fast mixing helps in binding the polyelectrolyte molecules and dispersed particles.

C. Settling Property

The measurement of the settling properties was characterized by the sludge volume index (SVI) using Imhoff cone. The position of the interface between the supernatant liquor and sludge zone was observed and recorded. Total suspended solids (TSS) for each fresh sludge sample were analyzed using method 2540D in APHA standard method (1998) [12].

V. RESULTS AND DISCUSSIONS

A. Turbidity

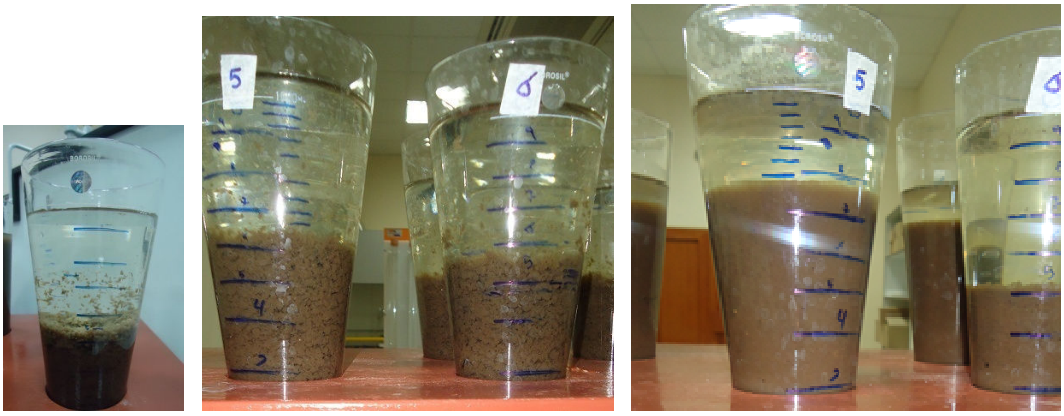
Figs. 1 and 2 show that the turbidity of the supernatant depends on the polyelectrolyte concentration and pH level. The results of their effects of additional different concentrations of coagulants and polyelectrolyte on the turbidity with different pH values are presented in Table II. The results in this table show that the effectiveness of the polyelectrolytes on the turbidity is much higher than that of the coagulants. Also, it can be seen that the APAM and calcium chloride have a negative effect on the turbidity despite the pH value, while there is no improvement with the use of aluminum sulfate and concluded oscillatory results.

The results show that the polyelectrolyte CPAM-80 has improved the turbidity more than other two types; CPAM-10 and APAM-30. The best turbidity was obtained for the sample with pH near neutrality as shown in Fig. 3.

Similarly, CPAM-10 shows an improvement in turbidity especially at pH near neutrality. However, the results of using APAM show a positive improvement in turbidity until it reaches the best value. Then the turbidity increased sharply by increasing the dosage.

For the effects of coagulants on turbidity, Table II shows that that effect of aluminum sulfate on turbidity is much larger than that of other two coagulants, but less improvement compare to the effect of the CPAM. The best turbidity results were, also, obtained for samples with pH near neutrality. Also, there was a small improvement in turbidity using ferric chloride but no improvement by using calcium chloride.

Fig. 1 Effect of Polyelectrolyte concentration on turbidity after 2 hours of settling using same pH value



pH=7.6 pH=5.6 pH=9.4

Fig. 2 Effect of pH on the turbidity after 2 hours of settling using same concentration of polyelectrolyte

TABLE II
TURBIDITY MEASUREMENT AT DIFFERENT CONCENTRATIONS OF CHEMICALS ADDED AND DIFFERENT PH VALUE

		Turbidity (NTU)																	
		CPAM-80			CPAM-10			APAM-30			Al2(SO4)3			Fe2Cl3			CaCl2		
No	chem. Ml/l	pH = 7.6	pH= 9.4	pH= 5.6	pH= 7.2	pH = 9.4	pH = 5.6	pH= 7.6	pH= 9.4	pH= 5.6	pH = 7.6	pH = 9.4	pH = 5.6	pH = 7.8	pH = 9.4	pH= 5.6	pH = 7.6	pH = 9.4	pH = 5.6
1	0	0.9	3.3	2.4	5.6	10	2.4	3.6	11	8	4	11	8	13	33	34	2	10	8
2	0.5	0.7	4.4	4.3	0.4	6.9	3.5	2.7	37	21	8	41	6	12	23	12	1	10	11
3	1	0.8	4.1	3.4	0.7	4.5	3.3	2.2	18	19	18	20	5	14	60	15	2	11	14
4	5	0.2	3.6	2.9	0.6	3.3	1.8	1.9	17	11	10	20	5	12	42	11	3	8	10
5	10	0.2	3.3	2.2	0.5	5.1	1.4	3.3	37	8	3	26	4	7	22	11	2	8	10
6	20	0.1	2.4	1.8	0.4	2.2	1.2	11	99	9	1	8	5	7	15	10	4	12	10
7	40	0.2	1.6	1.2	0.6	2	0.8	25	104	14	1	9	9	6	17	11	5	16	9
8	50	0	1.3	2.2	0.4	1.1	1.3	25	229	107	12	40	8	10	45	18	4	16	10
9	60	0.3	2.4	1.7	0.5	0.8	1	26	158	292	16	38	7	11	70	39	5	14	8
10	70	0.1	1.6	2.3	0.1	0.7	0.9	27	109	101	5	16	5	8	43	11	4	13	7
11	80	0	2.6	4.7	0.4	0.6	1	28	373	123	11	8	5	8	26	26	4	10	7
12	90	0.1	2.2	6.2	0.7	0.7	0.9	25	205	201	2	6	5	9	26	19	6	10	11
13	100	0	1.4	2.1	0.3	0.3	0.8	25	268	121	3	7	4	9	21	20	5	11	11

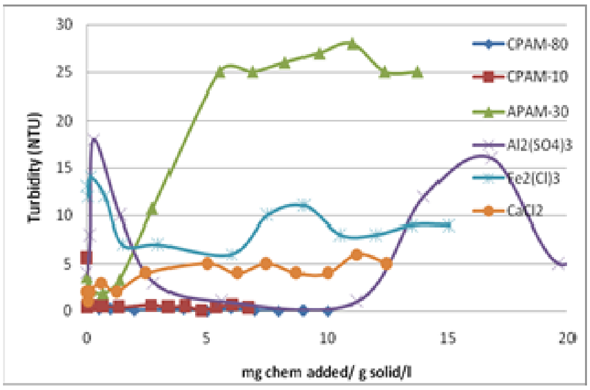


Fig. 3 Turbidity at different dosage of chemicals and at pH near neutrality

B. Settling Behavior

All samples collected within three months from Nizwa waste water treatment plant had a high SVI (eg in thousands). This unhealthy biomass content may be a result of fungi, algae, worms and virus organisms found in the waste water feed as shown in Fig. 4. This behavior may also be due to the high organic contents in the waste water, see Table I which shows that most waste water samples consist significant amounts of Volatile Suspended Solid (VSS).

Fig. 4 Sample of fresh sludge consisting many organisms such us warms, fungi, bacteria, etc.

The effect of high organic content decreases the efficiency of the conditioning by polyelectrolytes causing amorphous appearance, non-compact and non-dense flocs. The non-compact and non-dense flocs and irregular particle formation are photographically illustrated in Figs. 5 and 6.

The Settling Volume Index (SVI) was considered as the indicator for the settling properties. The results of these tests are shown in Fig. 7. The results show that an improvement of 50% was achieved by using CPAM-80 and CPAM-10 for samples with pH near neutrality. The optimum SVI =1100 was achieved at dosage 2.8 mg/g solid/l of CPAM-80 and at dosage 3.3 mg/g solid/l of CPAM-10. However, there was no improvement observed for samples using APAM.

The use of coagulants has a negative effect on SVI which was increased by increasing the concentration of coagulants.

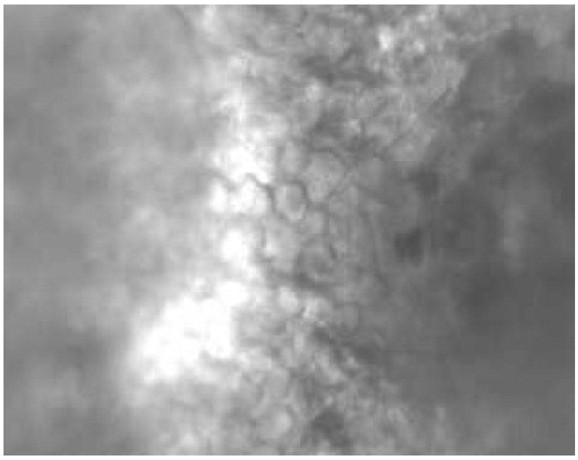


Fig. 5 Non-regular shapes flocs of sludge particles after conditioning

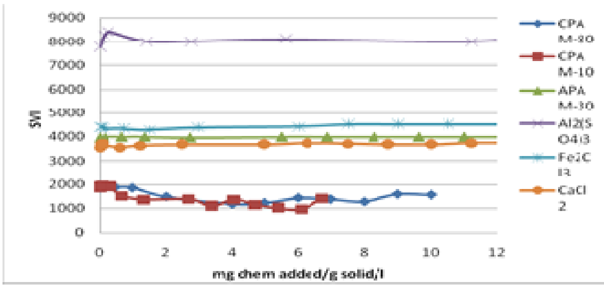


Fig. 6 SVI at different dosage of chemicals and at pH near neutrality

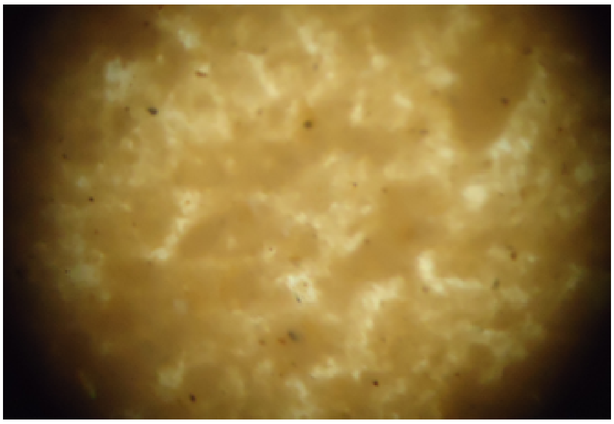


Fig. 7 Non-dense flocs of sludge particles after conditioning

VI. Conclusions

The high molecular weight polyelectrolyte PAM shows significant effect on improving turbidity and reducing sediment thickness. The following conclusion can be drawn:

1. The fresh activated sludge collected from Nizwa waste water treatment plant has a high SVI and unhealthy biomass content which caused slow settling.
2. The pH effect on the sludge characteristics, results with pH value higher or lower than neutrality display a negative profile in the case of using polyelectrolyte and display non-notable effect using coagulants.

3. The results show that the polyelectrolyte CPAM-80 improved the turbidity more than the other two types; CPAM-10 and APAM-30. The best turbidity was obtained for a sample with pH near neutrality.
4. The effect of aluminum sulfate on turbidity is much larger than that of other coagulants; but less improvement compared to that of the CPAM-80.

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