Original Article

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Dewatering of Pulp and Paper Mill Sludge by Polymers

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Abstract

Dewatering of sludge of pulp and paper mill is investigated by the use of various organic and inorganic polymers in the present study. During the study it was found that cationic polymers areefficient in dewatering due to the negative nature of sludge. Non-ionic and anionic polymers are relatively less effective. Inorganic polymers are effective in water release only at very high doses which is not cost efficient treatment. The best dewatering rate is achieved when cationic polymer (1kg/T) and Poly Aluminum Chloride (3kg/T) are used in combination whereas amongst cationic polymer, the best is C-7115 followed by C-5115 and C-3115.

Keywords: Sludge; Cationic; Anionic; Dewatering; Polymer.

Introduction

Developmental activities, urban growth and industrialization exert pressure on the infrastructure facilities as well as air, water and land resources. Over the last few decades, concentration of many pollutants has risen dramatically to the point where industrial emissions dominate natural biogeochemical cycles. The paper making industry is one of the largest sources of industrial pollution representing 10% of all industrial pollution (Subrahmanyam, 1981). One of the greatest problems in the wastewater-engineering field is the dewatering of waste sludges (Katsiris & Katsiri,1987). Dewatering is an essential process for any operation that produces, handles and disposes of sludges (Thompson & Paulson,1998). Due to the wide variations in sludge characteristics many processes have been suggested for sludge dewatering and drying (Novak & Langford 1977). Chemical processes include the use of inorganic and organic polymers, whereas the physical processes include "heat treatment" and "freezing and thawing" techniques (Katsiris & Katsiri1987). Polyelectrolyte conditioning has long been utilized to pre-treat the sludge in order to increase its filterability (Chang *et al.,* 1997). The properties, characteristics and the effectiveness of polymers in improving filtration have been discussed by numerous investigators (Parkhurst*et al.* 1974; Shumm*et al.* 1962; Motarnedi 1974). The synthetic organic polyelectrolytes increased the capture of solids in elutriation from 57% to 92% (Dahl *et al.* 1972). Similarly, the most driest and economical cake is obtained when polymers are used in the filtration of raw sludge (Hopkins& Jackson 1971).

The objective of this study was to dewater the pulp and paper mill sludge by polymers. The dewatering efficiency of various polymers and their combinations was studied and the best combination of polymers at minimum dose and minimum cost was selected for the dewatering of the sludge.

Experimental

Sample Collection

The primary and secondary sludge was taken from Ballarpur Industries Limited, Yamuna Nagar,

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Haryana State, India from the return sludge line of primary and secondary clarifier to aeration basin. The samples were kept in icebox and then parameters were analysed as required.

Polymers

Both organic and inorganic polymers were taken. Few inorganic polymers used during the study were PAC (Poly Aluminum Chloride), Alum, Lime, Copperas, Ferric Chloride. All of them were commercially available. Few organic polymers used during the study are P-700, P-3100 (Non-Ionic polymer), 705, 3125 (Anionic polymer) and C-3115, C-7115, C-5115, C-500 (cationic polymer). All the synthetic polymers were supplied from Dai ichi chemicals, Pune, India.

Polymer Preparation

It is ideal to produce 0.1%-0.2% solution preferably in demineralised water. The polymer granules are introduced into water, which is kept under agitation. The best dissolution rate is obtained where individual granules are wetted by water separately with constant stirring at 120 rpm. Warm water at 50°C will facilitate faster dissolution, however, excess temperature should be avoided.

Characterization of Sludge and Organic Polymer

The parameters of sludge which were analysed included pH, consistency, Inorganic and Organic content (APHA,1995), Fibre length (TAPPI, 2001) etc.The various characteristics of organic polymers studied were pH, viscosity, Zeta potential and Bulk density (TAPPI, 2001).

Method used for Checking the Dewatering Rate of Polymers

Different polymers were checked for their tendency towards filterability and effectiveness as per the standard method (APHA,1995). Sludge was taken on weight basis. As secondary sludge has low consistency (Table 1), so it was mixed with primary sludge in the ratio of 20:80 so as to increase the solid content. The dewatering rate was studied using TTF (Time to filter) equipment.

Results and Discussion

The secondary sludge has low consistency and less fibre content (Table 1), so it is difficult to dewater secondary sludge on filter belt press as it is not retained on it. Various polymers are added to the mixed sludge in order to increase the water release. The effect of the polymers is to decrease the sludge specific resistance and increase the sludge coefficient of compressibility and hence leads to better dewaterability as observed in earlier studies (Novak & O'Brien, 1975; O'Brien & Novak, 1977; Knocke *et al.*,1987; Tabasaran,1971). From Table 2, it was observed that amongst all the organic polymers, cationic polymers were most efficient in dewatering of sludge as the time taken by them to collect 100 ml of filtrate was less. It may be attributed to the reason that polymers respond to sludge pH variations and cationic polymers work most efficiently at pH values of 7 or below, whereas non-ionic polymers and anionic polymers work more efficiently at a pH range of 6.5-8.5 as also reported in earlier studies (Novak & O'Brien, 1975; O'Brien & Novak,1977). It was observed that sludge has near neutral nature, so this may be the reason for cationic polymers being efficient. We also observe from Zeta potential study that sludge has negative change, therefore in order to neutralize the charge of the sludge, cationic polymers work better and in order to achieve coagulation and water release, sufficient reduction of zeta potential is necessary. Cationic polymers were then selected for further study. It was found that 2kg/T are the optimum dose of cationic polymers as above this dose, the rate of filtration decreases. The reason for the decreased rate of water release may be the reduced particle agglomeration when systems are overdosed with excess polymers (O'Brien & Novak, 1977; O'Melia,1969).

Table 1: Properties of primary and secondary sludge of paper mill

Parameter	Primary sludge	Secondary sludge
Appearance	Yellow to Brown	Brown to black
pH	7.5	7.1
Consistency (%)	8-10	1-2
Fibre content (%)	17	10
Inorganic content (%)	60	55
Organic content (%)	40	45
Zeta potential (mV)	-30.26	-18.94

Table 2: Efficiency of Organic and Inorganic Polymers

	Polymer	Time to collect 100ml Filtrate(min)
Organic	Blank	25
Organic	C-3115	16
Organic	C-5115	15
Organic	C-7115	13
Organic	C-500	19
Organic	P-700	30
Organic	P-3100	32
Organic	P-705	70
Inorganic	C-3125	72
Inorganic	Blank	26
Inorganic	Alum	24
Inorganic	Lime	21
Inorganic	Copperas	23
Inorganic	$FeCl_3$	22
Inorganic	PAC	20

Doseof organic polymer =1Kg/T; Doseof inorganic polymer =3 Kg/T

Table 3: Rate of filtration with different combinations of inorganic polymers

Polymer Combination	Dose taken of each polymer (Kg/T)						
A+B	2+2	5+5	10+10	5+10	10+5	5+2	2+5
	Time taken to collect 100 ml filtrate						
PAC+$FeCl_3$	23.0	15.0	7.0	8.1	8.0	18.0	19.0
PAC+Copperas	21.5	14.0	6.1	8.4	8.1	19.1	19.0
PAC+Lime	21.0	13.9	5.9	7.2	7.0	17.0	17.5
PAC+Alum	22.1	14.8	6.8	9.0	8.3	18.1	18.8
Alum+$FeCl_3$	23.0	15.2	7.1	7.8	7.4	19.2	19.0
Alum+Copperas	21.0	15.0	7.8	8.4	8.1	19.0	19.1
Alum+Lime	20.5	13.4	6.8	9.1	9.0	18.8	18.9
$FeCl_3$+Copperas	22.0	14.0	7.3	8.8	9.0	19.2	19.0
$FeCl_3$+lime	23.0	15.1	6.9	8.1	8.8	18.0	19.8
Lime+Copperas	22.8	14.3	7.2	7.9	8.1	19.0	19.2

Blank= 26 minutes (time to collect 100ml of filtrate)

Table 4: Rate of filtration by combination of one cationic polymer and one inorganic polymer

Cationic polymer +	Time to collect 100ml filtrate (min)		
	C-7115	C-5115	C-3115
Alum	6.416	6.000	7.1
PAC	4.166	5.000	5.6
Lime	6.383	6.200	7.3
Copperas	6.833	6.866	8.0
$FeCl_3$	7.000	7.000	7.5

Table 5: Properties of various Organic flocculants

Polymer	Appearance	Ionic Nature	pH	Bulk Density (g/ml)	Viscosity (cps)
C-500	White granules	Cationic	4 ± 1	0.6-0.8	20
C-3115	White granules	Cationic	4 ± 5.5	0.6-0.8	30
C-5115	White granules	Cationic	4 ± 1	0.6-0.8	50
C-7115	White granules	Cationic	4 ± 1	0.6-0.8	65
P 700	White granules	Non Ionic	8 ± 1	0.6-0.8	65
P 3100	White granules	Non Ionic	8 ± 1	0.6-0.8	40
P 3125	White granules	Anionic	8 ± 1	0.6-0.8	285
P 0710	White granules	Anionic	8 ± 1	0.6-0.8	155

Table 6: Rate of filtration by combination of cationic and two inorganic polymers

Inorganic polymer 2Kg/T	2Kg/T	Cationic polymer (1Kg/T)	Time to collect 100ml filtrate(min)
PAC	Alum	C-3115	8.1
		C-5115	7.5
		C-7115	8.0
PAC	Lime	C-3115	7.3
		C-5115	7.0
		C-7115	6.3
PAC	Copperas	C-3115	8.3
		C-5115	8.0
		C-7115	8.0
PAC	$FeCl_3$	C-3115	7.7
		C-5115	8.0
		C-7115	7.8
Lime	Alum	C-3115	7.8
		C-5115	7.3
		C-7115	7.0
Lime	Copperas	C-3115	8.0
		C-5115	7.2
		C-7115	7.2
Lime	$FeCl_3$	C-3115	8.5
		C-5115	8.0
		C-7115	7.9
Alum	Copperas	C-3115	7.9
		C-5115	7.1
		C-7115	8.0
Alum	$FeCl_3$	C-3115	7.8
		C-5115	7.3
		C-7115	7.2
Copperas	$FeCl_3$	C-3115	8.0
		C-5115	8.0
		C-7115	8.0

Blank = 26 min (Time to collect 100ml filtrate)

During the study of filtration by inorganic polymers (Table 2) it was observed that all the inorganic polymers show approximately same rate of water release. PAC is showing the best results and the reason behind it is that these species are larger and less hydrated, they have coordinated hydroxide groups, the replacement of the aquo group by a hydroxide group may render the complex more hydrophobic, in turn, enhance the specific chemical adsorptionon the surface and more than one hydroxide group can become attached at the interface (Hong-Xias & Stumm 1987). "Free" metal ions can interact specifically to form a coordinative bond with suitable donor group of an organic surface (Stummet al.; 1976, Stumm & O' Melia1968; Garg & Garg1998).

$A1^{3+}$ + org-OH '! org-OAl^{2+} +H^+

PAC was followed by lime which acts as an effective conditioner as it has dense and porous crystals that are incorporated into sludges, providing a matrix that allows rapid removal of water (Thompson & Paulson 1998). Salts of Fe are more effective as compared to Alum, the reason is that iron is denser, and it is easy to dewater. The other reason is that alum works best at higher pH (Garg & Garg1998) and as the sludge is neutral in nature so alum is not very effective in dewatering (Katsiri & Katsiri 1987). Among iron polymers it was observed that $FeCl_3$ was more effective than $FeSO_4$ and similar results were observed by (Katsiris & Katsiri 1987). They explained that the trivalent salts are more effective than salts of divalent metal, this may be the reason that why $FeSO_4$ is less effective as compared to $FeC1_3$.

During the study of the rate of filtration by the use of two inorganic polymer (Table 3), it is found that at lower dosages, the rate of water release is very less and the time taken to collect 100 ml filtrate is high whereas at higher dosages, though the time to collect 100m1 filtrate is decreasing but not to an appreciate level and also it is not economical to use such high doses. The sludge volume will increase to a considerable level, which will further cause the problem of handling of sludge. Further when the rate of filtration of one cationic polymer and one inorganic polymer was studied (Table 4), it was observed that when cationic polymer at the rate of 1 kg/T and inorganic polymer at the rate of 3kg/T were taken, the phase separation is very fast and floc formation is good. The rate of filtration in this combination was better than the cationic polymers at the rate of 2kg/T.

All the combinations (Table 4) are showing good results but best combination is of cationic polymer and PAC. Using this combination for dewatering of sludge will be very effective as the time to collect 100m1 of filtrate is very less and it is economical too. Though other combination can be used but dewatering rate is less comparatively and treatment will be costly. Amongst all the cationic polymers, the best is C-7115 followed by C-5115 and then C-3115, when used in combination with PAC as the viscosity of C-7115 is more followed by C-5115 and then C-3115 (Table 5). The viscosity is directly related to degree of polymerisation and hence molecular weight and further higher the molecularweight, better will be the floc formation, so this may be the reason of best floc formation and phase separation by C-7115 followed by C-5115 and then C-3115. When rate of filtration by combination of one cationic polymer and two inorganic polymers was studied, it was found that the rate of filtration was good and flocs were strong (Table 6) but when compared to the dewatering rate when one cationic polymer and one inorganic polymer were used in combination, it was observed that former combination had less dewatering rate and the dose of the inorganic polymer is more i.e. 4 kg/T in combination whereas, in the later case, the dose of the inorganic polymer is 3kg/T (Table 4), so later is a cost effective combination too. So observing all the aspects, it was concluded that combination of one cationic polymer and one inorganic polymer (3kg/T) is better than the combination of one cationic polymer and two inorganic polymers.

Conclusion

Organic and Inorganic polymers are used for the dewatering of sludge. The effectiveness of the polymer is checked by noting the time to collect 100 ml. Lesser the time taken, better is the dewaterability. The most suitable organic polymer for dewatering of sludge are cationic polymers as the sludge having negative charge will be neutralized by it. Inorganic polymers are effective in dewatering only at very high doses, which will not be cost effective. During the study of combinations of polymers it was observed that Cationic polymers (1 kg/T) and PAC (3kg/T) shows the best dewatering rate when compared to other combinations. The best out of the three chosen cationic polymers is C-7115 followed by C-5115 and the C-3115. By using this combination, there will be no change in the quality of sludge, problem of thickening will be solved and it will be a cost effective method.

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