Dewatering Characteristics of Sludges From Effluent Treatment Plant of Indian Paper Mills & Effects of Chemical Conditioning

Dhingra H.K. * Ray A. K. ** and Mohindru V.K. ***

ABSTRACT:-- Sludge handling and its disposal from waste water treatment plant is one of the major constraints in any chemical industry, pulp and paper industry in particular. This major problem relating to sludge handling can be overcome by applying efficient sludge dewatering techniques. Dried sludge will be having lesser moisture and volume and thus will be easy to handle. Moreover it may be used to produce value added byproducts. Chemical conditioning of sludge is a commonly applied practice to improve the dewatering characteristics of sludge to result in dried sludge. While doing Chemical Conditioning of sludge, the understanding of sludge and flocculant characteristics is very much needed for better economical dewatering.

An attempt has been made in this present investigation to study in depth by laboratory scale experiments, the dewatering characteristics of both primary and secondary sludges of two different Indian mills using different kind of raw materials. The influence of various flocculants, both organic and inorganic in nature on dewatering have also been studied at room temperature.

INTRODUCTION

Environment cleanliness is one of the major challenges for any industry today. Pulp and Paper Industry, in particular, discharges huge amount of solid/liquid and gaseous pollutants to environment. Sludge from effluent treatment plant is one of the major streams affecting environment to a considerable extent and is also difficult to handle. Sludge from an effluent treatment plant can be mainly classified as primary sludge and secondary sludge.

With the increasing awareness about the environment cleanliness, it is very much important to look into the every aspects of disposal or profitable use of sludge. To achieve the above goal, several process steps are to be followed. The first stage is obviously dewatering. Basically dewatering helps to reduce transportation volume, to make it suitable for landfill, or to prepare the sludge for incineration or other value added byproducts.

Dewatering is usually accompalished by mechanical means using vacuum filter, belt filter press, screw presses, centrifuge, pressure filter or double wire belt washer. Table-1 shows the achievable cake dryness of primary sludge by various mechanical

* CPPRI (Central Pulp & Paper Research Instt.) Saharanpur

** Institute of Paper Technology, Saharanpur

*** CPPRI, Saharanpur

dewatering equipments mostly being used (1).

Table-1.

Achievable Cake Dryness by Mechanical Dewatering

	Achievable Cake Mean (% T.S.)	Dryness Range (% T.S.)
Vacuum Filter	20	15 - 22
Vacuum Filter and V-press	35	30 - 40
Belt Filter press	35	30 - 40
Screw presses	45	40 - 50

Of late various paper mills have installed secondary treatment plant which has led to significant increase in generation of secondary sludge. Dewatering of mixed secondary (biological) and primary sludges have received attention because biological sludge is generally considered more difficult to dewater than primary sludge. There is a growing tendency of the Industry to dewater in the existing devices more efficiently by increasing cake dryness as much as possible for its efficient utilization using various means.

One way for improving dewatering efficiency is by chemical conditioning of sludges by using flocculants in order to flocculate the sludge and enhance the ease with which water may be removed. Hence, chemical conditioning or flocculation prior to dewatering will improve not only throughput capacity but also cake dryness for all dewatering devices. The chemicals most widely used for conditioning are inorganic chemical like ferric chloride, ferric sulfate, alum and lime or some organic polymers.

The performance of a particular flocculant and its optimum dose is dependent on sludge characteristics and vary from sludge to sludge and also from mill to mill. Other operating variables like speed and time of mixing, pH, concentration and type of ions present in sludge, temperature, and duration of storage of sludge also greatly influences the performance of chemicals to flocculate the sludge and hence dewatering efficiency. It is therefore, important from both cost and performance considerations, to optimize the addition of flocculant for sludge conditioning. To handle such a situation with innumerous variables for optimal results Laboratory scale experiments are generally preferred before taking plant scale trials. Even during the routine operation, occasionally laboratory scale tests are performed to get the best results.

Therefore in this present investigation laboratory scale experiments have been performed to compare the dewatering characteristics of sludges and the effect of different flocculants by measuring specific resistance to filteration. The specific resistance to filtration measurement is generally preferred among the various available tests due to its sound theoretical basis (2-4). More detailed work, for example, the mathematical analysis, effect of operating variables and a non detailed economical feasibility is available elsewhere (5).

MATERIALS AND METHODS

Primary and secondary sludge samples were collected from waste water treatment plant of two Indian paper mills, Mill A and Mill B. Mill A is a large integrated kraft paper mill based on wood and bamboo producing bleached grade paper. Mill B is a small paper mill which uses nonwoody raw material for producing unbleached grade paper. The pulping process being followed by Mill B is chemical soda process and chemi-mechanical process. The secondary treatment being used is activated sludge process in both the paper mills.

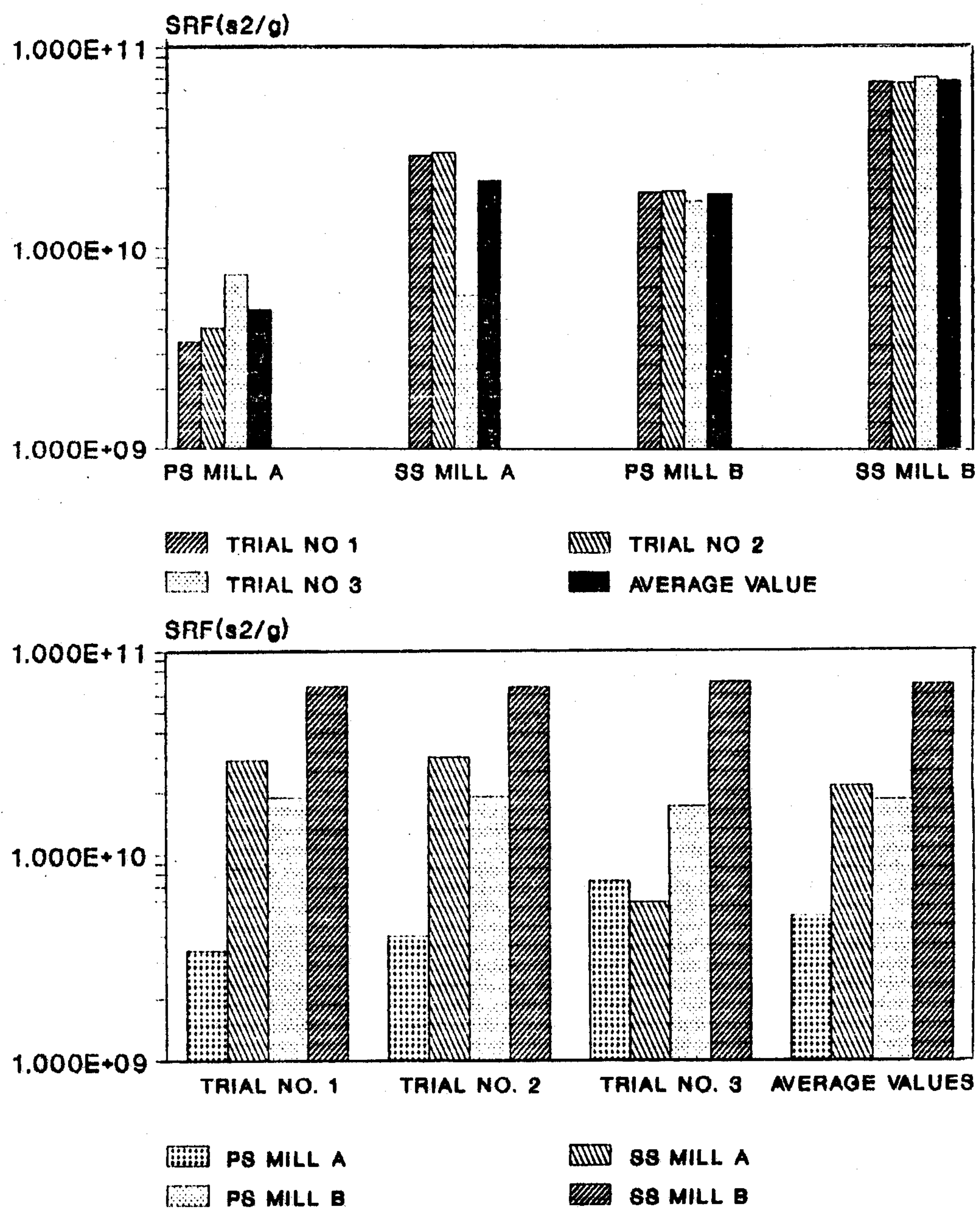
The secondary sludge samples were thickened after collection and primary sludges were used as such.

The flocculants selected for use on study were inorganic chemicals viz. Ferric chloride, ferric sulfate, alum and lime and also polyelectrolytes (one cationic and two anionic). Fresh 10% w/w stock solutions of inorganic flocculants and 0.1% w/w stock solution of polyelectrolytes were prepared whenever experiments were conducted.

A mechanical stirrer was used to mix sludge samples. After adding the required flocculant dose to the samples, these were mixed for 1 min. at 150 and 250 rpm to generate homogeneous samples and for 2min. at 40 and 70 rpm (lower value for secondary sludge of low T.S. concentration and higher value for primary sludge of higher T.S. concentration) to promote the floc formation. Parameters for rpm and time combination have been selected based on preliminary laboratory scale trials and literature information.

Specific resistance to filtration (SRF) is calculated using Buchner Funnel test data as the Buchner Funnel has been used mostly to determine the dewatering characteristics of sludge samples (6-7). All the experiments have been performed at constant vacuum (375 mm Hg) and using same Buchner funnel i.e. the area has remained constant.

FIG. 1: SPECIFIC RESISTANCE TO FILTERATION (SRF) OF PRIMARY AND SECONDARY SLUDGES OF MILL A AND MILL B



PS: PRIMARY SLUDGE; SS: SECONDARY SLUDGE

SRF: SPECIFIC RESISTANCE TO FILTERATION

RESULTS AND DISCUSSION

Based on experiments conducted in the laboratory, data on Specific Resistance to Filtration (SRF) as a function of various parameters have been estimated using mathematical models (5). The data have been interpreted in various figures. These are described in the following paragraphs :

Specific Resistance of Cake to Filtration for Various Sludges Without Addition of Flocculants:

The values of specific resistance of cake to filtration for primary and secondary sludges of Mill A and Mill B without any addition of flocculants are shown in Figure-l. These values are for the sludges as such i.e. sludges without any addition of flocculants.

On comparing the SRF values of primary sludges for Mill A and B, it is evident that the SRF values of Mill B is found to be relatively large compared to that of Mill A (by almost 4.0 times.). It may be attributed to the more fines content (material passing through 100 mesh screen) in the sludge of Mill B which is clear from Table-2.

Table-2.

Fiber Classification and Ash Content of Primary Sludge of Mill A and Mill B

Mesh Specification	%Fraction (Weight/Weight) Mill A	Mill B
+30	11.09	4.28
+50	16.81	3.95
+100	13.20	6.95
+200	2.80	3.80
-200	56.10	81.02
Ash %	21.25	20.56

Similarly, the secondary sludge of Mill B is also found to have larger SRF values compared to those of secondary sludge of Mill A (about 3 times). The reason for higher SRF of secondary sludge of Mill B may be the same as explained earlier i.e. more fines are carried into the secondary treatment system resulting in more difficult dewatered sludge.

On comparing the primary and secondary sludges from the same mill, it is clearly reflected that secondary sludges are having larger SRF values compared to primary sludges, and thus are found more difficult to dewater. The reason for larger SRF of secondary sludges may be due to presence of very fine biological matter which are also more hydrous in nature.

Effect of Various Flocculants on SRF :

The effect of various flocculants (both inorganic and polymers) on the SRF values have been obtained for different dosage of flocculants. The experiments have been conducted for both primary and secondary sludge for both the mills. The data on SRF at different dosage of various flocculants have been shown on semi-log plot from Figs.2a to 9c for comparison.

By comparing the data, the effect of inorganic flocculants on primary and secondary sludge of both mills, it has been observed that all the flocculants used improved the sludge dewatering characteristics as indicated by substantial decrease in SRF values from those of unconditioned sludge. However, the best results in terms of maximum dosage required to achieve minimum SRF have been obtained with ferric chloride and the poorest performance has been with lime. The performance with Alum and Ferric Alum sulfate was found to be in-between those due to ferric chloride and lime. For example at 8% dose, SRF value of secondary sludge is of the order 6.71×10^{10} s^2/g. Initial SRF values have been found to be 8.31×10^7, 1.50×10^8, 2.00×10^8 and 5.01×10^8 s^2/g with ferric chloride, ferric sulfate, alum and lime respectively. **It is important to note that alum gives better results than ferric sulfate in case of mill A. However results are reverse in case of mill B.**

On comparing the effect of organic polymer in conditioned sludges for dewatering i.e., on SRF values, it has been found that only cationic polymer has improved the dewatering rate by significant lowering of SRF values. The power of SRF reduction of sludge by anionic polymer has been observed identical (at a dose of 0.2 to 0.4%) with cationic polymer initially. But, at higher doses of anionic polymer it is found that there has been no decrease in SRF value. It is important to note that the minimum SRF value obtained has not been significant to appreciably improve the filtration rate as

EFFECT OF DIFFERENT DOSAGE OF VARIOUS INORGANIC FLOCCULANTS ON SPECIFIC RESISTANCE TO FILTERATION (SRF)

Fig. 2a: Primary Sludge Mill A,Trial No. 1

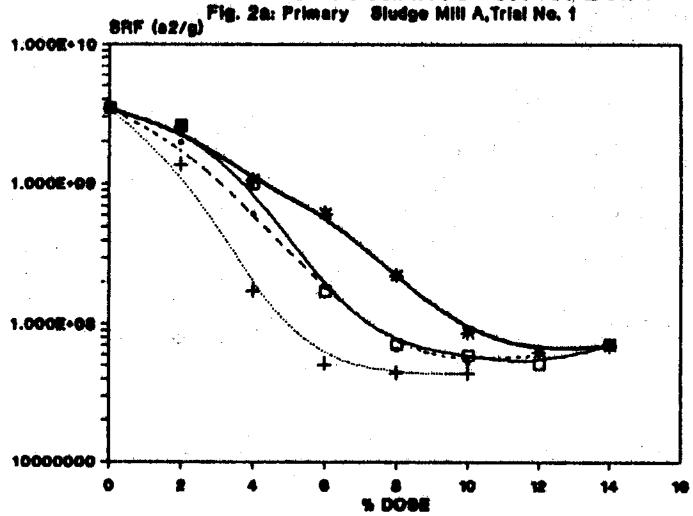


Fig. 3a:Secondary Sludge Mill A, Trial No.1

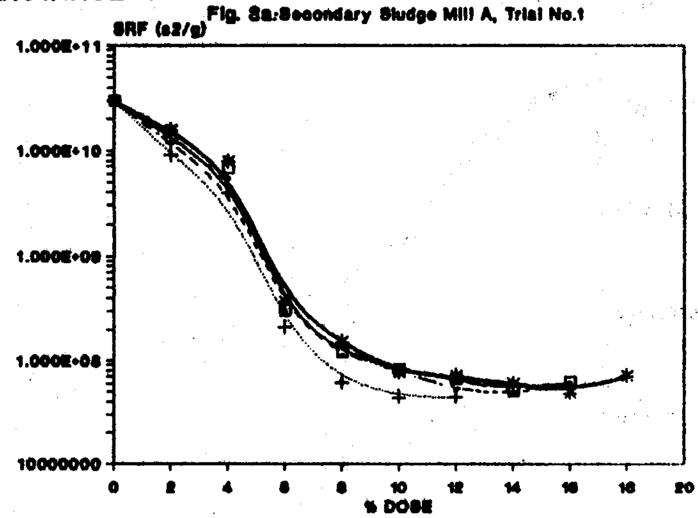


Fig. 2b: Primary Sludge Mill A,Trial No. 2

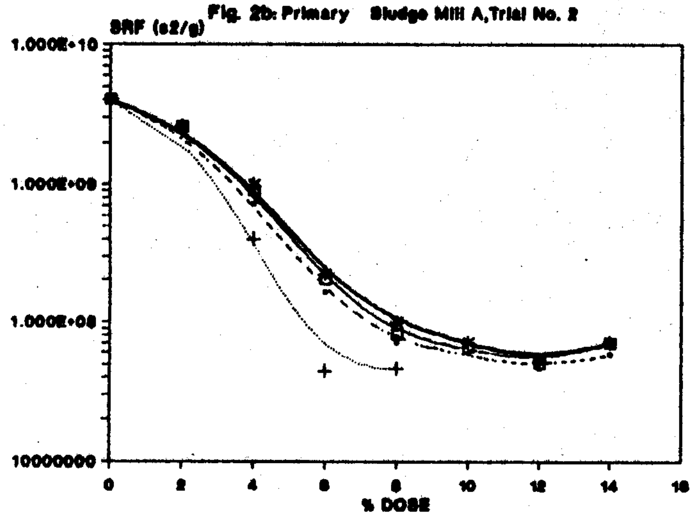


Fig. 3b: Secondary Sludge Mill A, Trial No.2

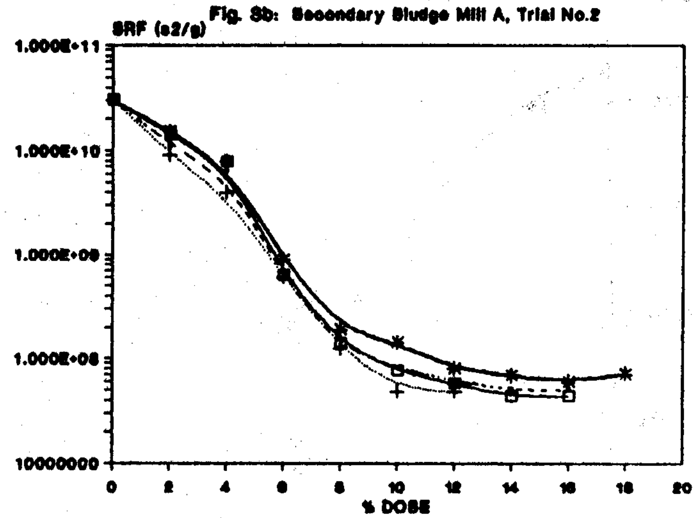


Fig. 2c: Primary Sludge Mill A,Trial No. 3

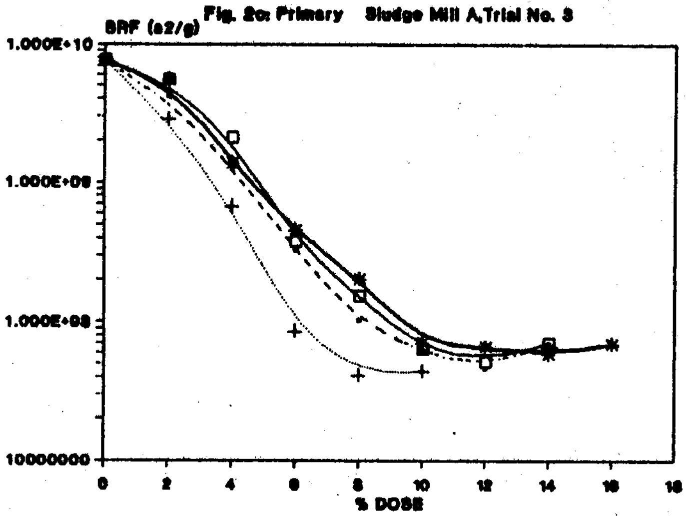
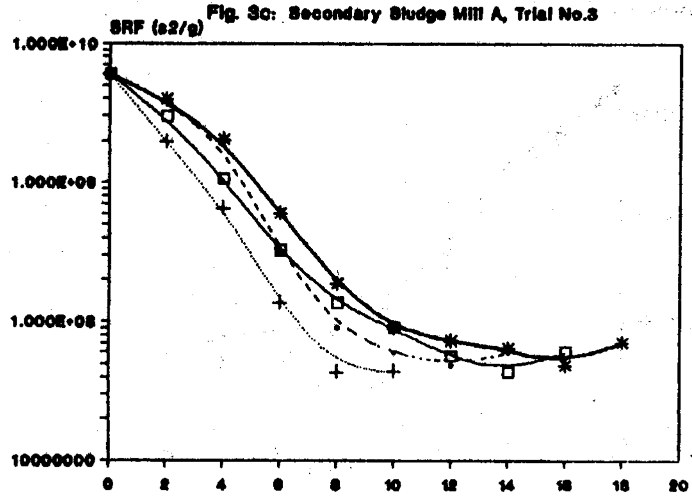


Fig. 3c: Secondary Sludge Mill A, Trial No.3



Alum — Ferric chloride — Lime — Ferric Sulfate

EFFECT OF DIFFERENT DOSAGE OF VARIOUS INORGANIC FLOCCULANTS ON SPECIFIC RESISTANCE TO FILTERATION (SRF)

Fig. 4a: Primary Sludge Mill B,Trial No.1

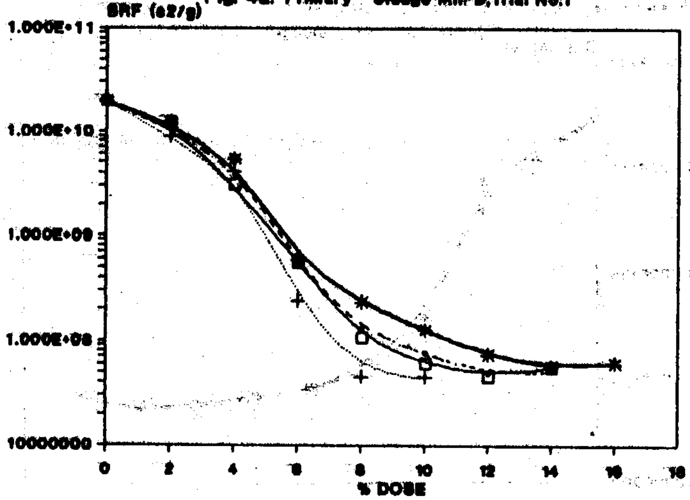


Fig. 5a: Secondary Sludge Mill B, Trial No.1

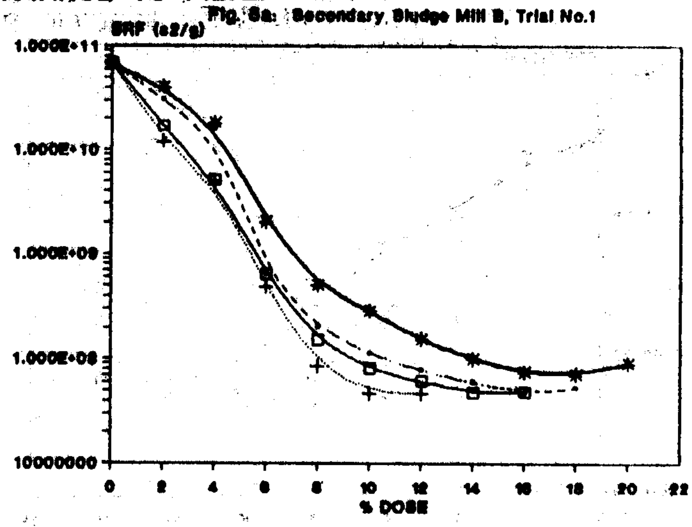


Fig. 4b: Primary Sludge Mill B,Trial No.2

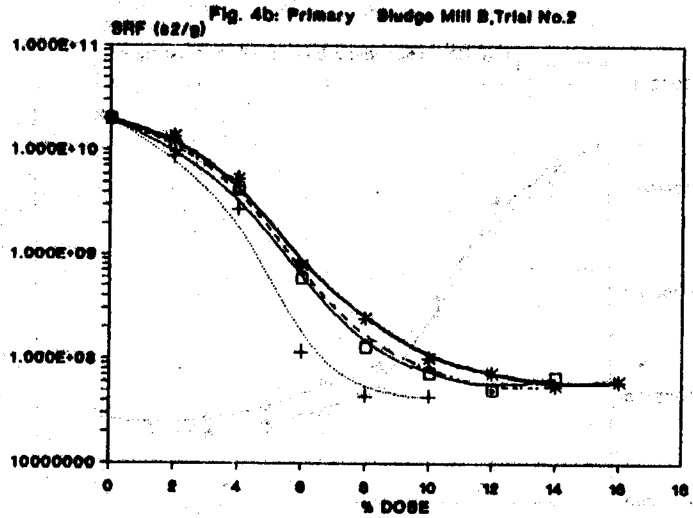


Fig. 5b: Secondary Sludge Mill B, Trial No.2

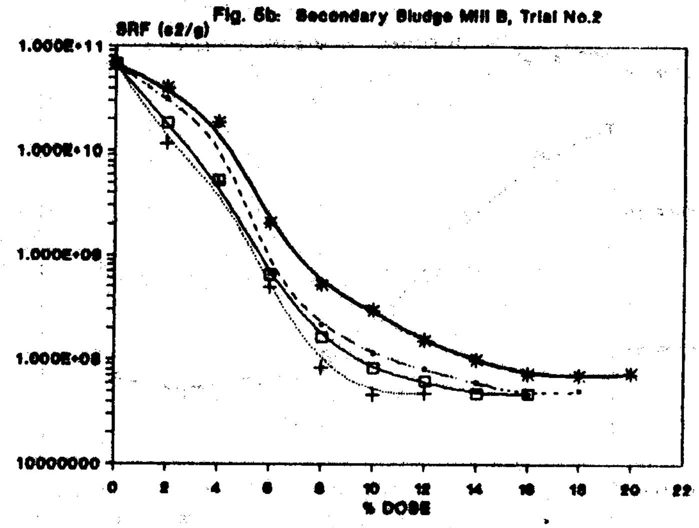


Fig. 4c: Primary Sludge Mill B, Trial No. 3

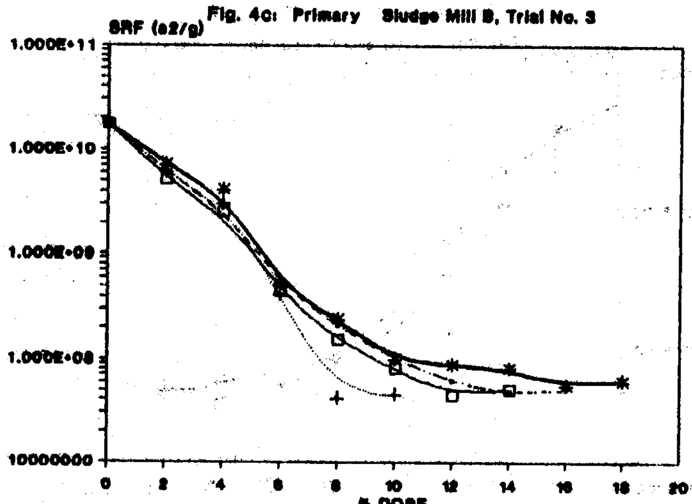
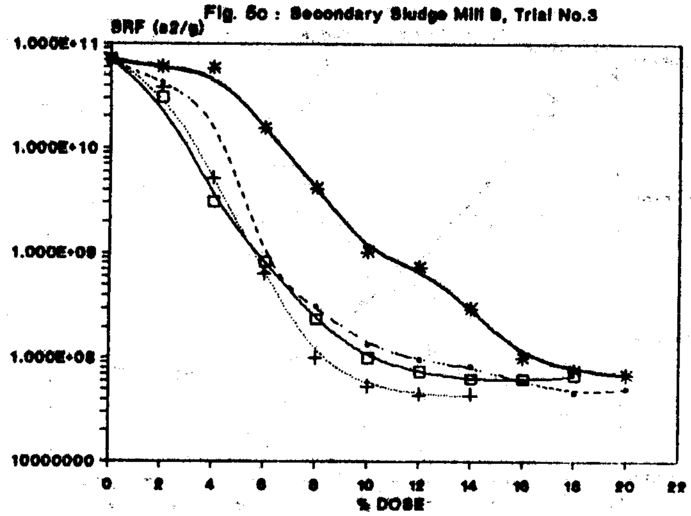


Fig. 5c : Secondary Sludge Mill B, Trial No.3



Alum — Ferric chloride — Lime — Ferric Sulfate

EFFECT OF DIFFERENT DOSAGE OF VARIOUS ORGANIC FLOCCULANS (POLYMERS) ON SPECIFIC RESISTANCE TO FILTERATION (SRF)

Fig. 6a: Primary Sludge Mill A, Trial No. 1

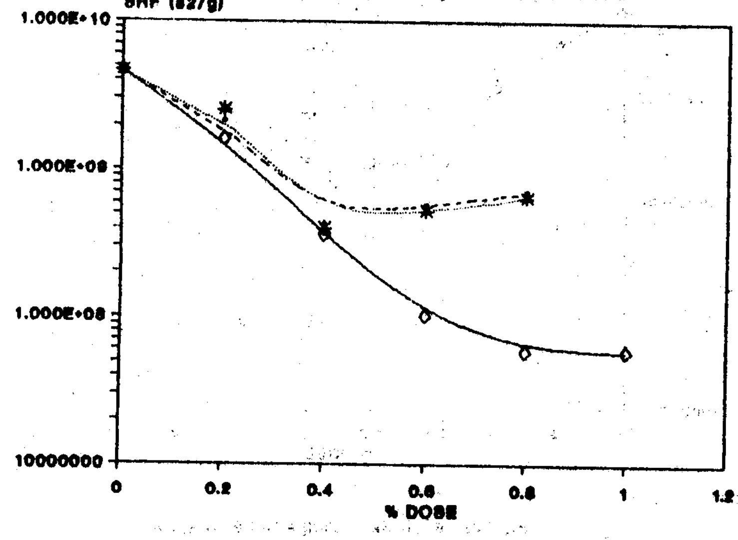


Fig. 7a: Secondary Sludge Mill A, Trial NO.1

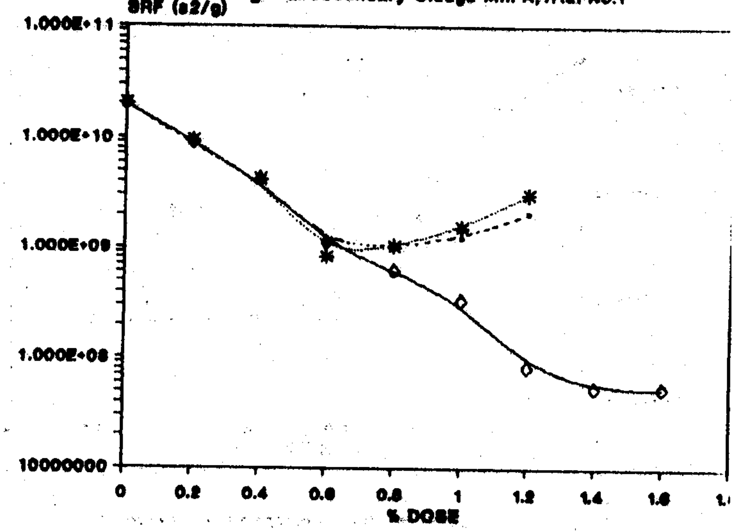


Fig. 6b: Primary Sludge Mill A, Trial No.2

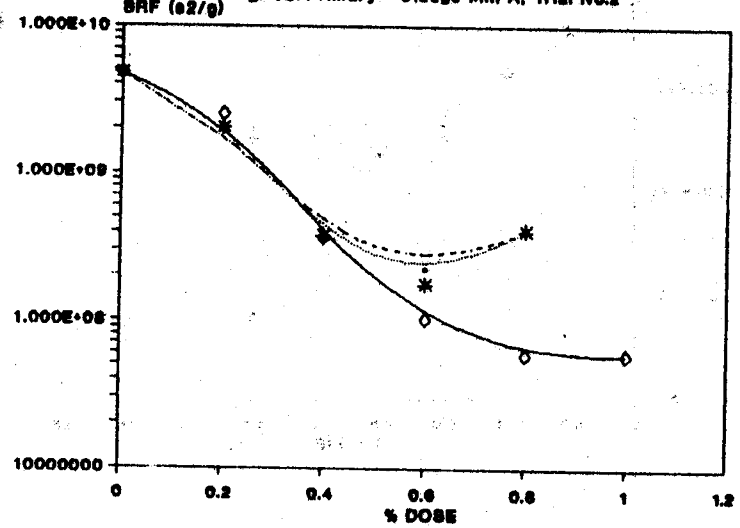


Fig. 7b: Secondary Sludge Mill A,Trial No.2

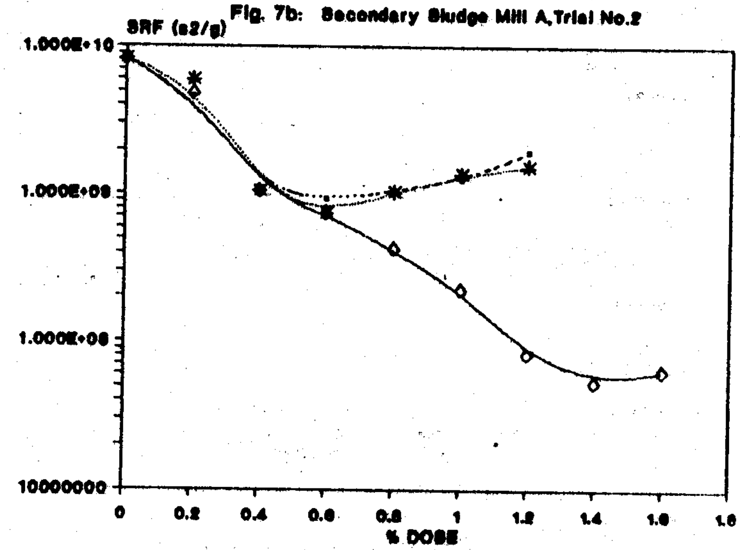


Fig. 6c: Primary Sludge Mill A, Trial No.3

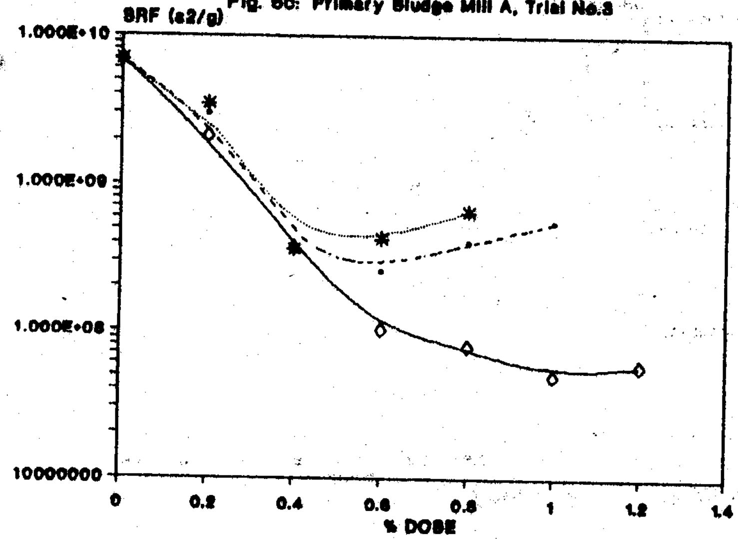
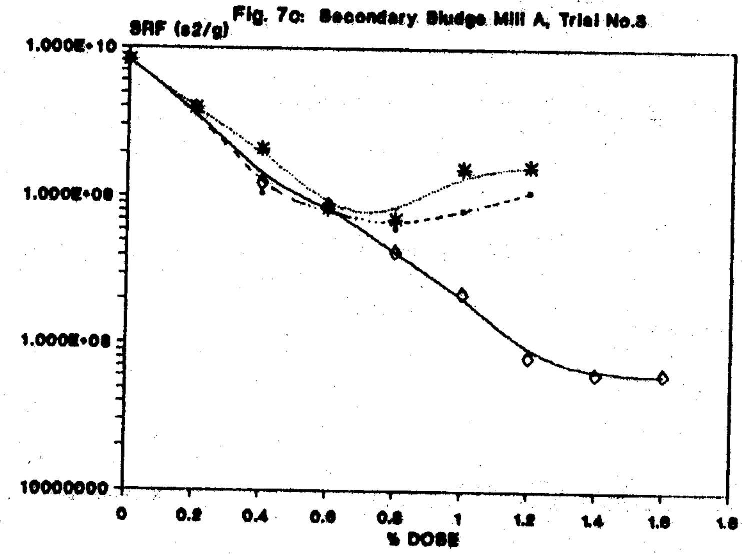


Fig. 7c: Secondary Sludge Mill A, Trial No.3



-·- ANIONIC A —◇— CATIONIC —✳— ANIONIC B

EFFECT OF DIFFERENT DOSAGE OF VARIOUS ORGANIC FLOCCULANS (POLYMERS) ON SPECIFIC RESISTANCE TO FILTERATION (SRF)

Fig. 8a: Primary Sludge Mill B, Trial No.1

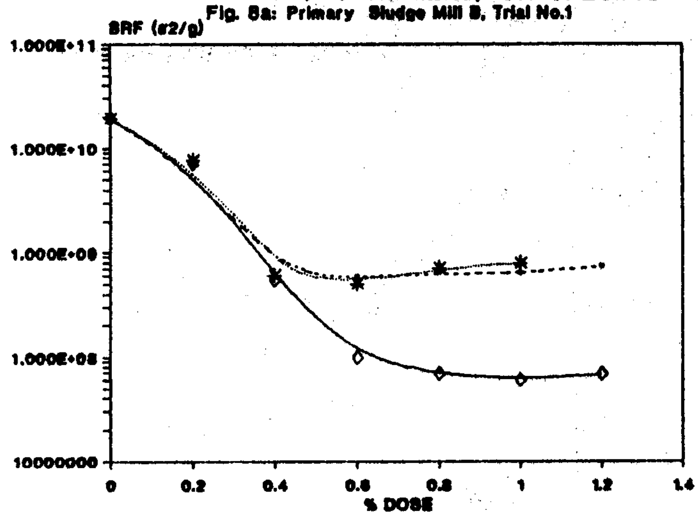


Fig. 9a: Secondary Sludge Mill B, Trial No. 1

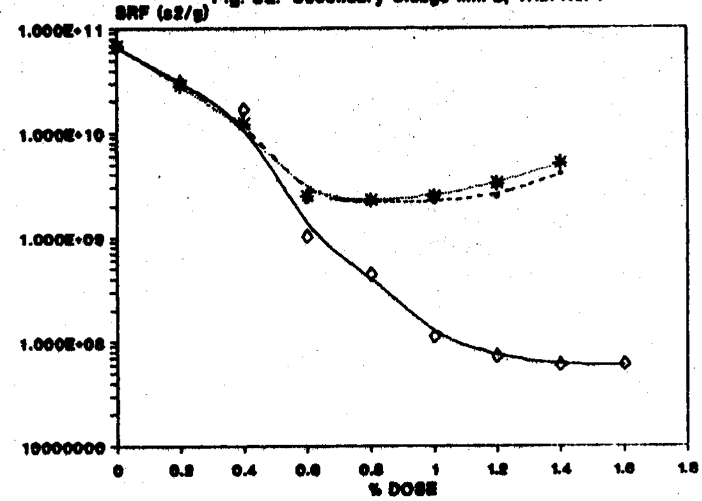


Fig. 8b: Primary Sludge Mill B, Trial No. 2

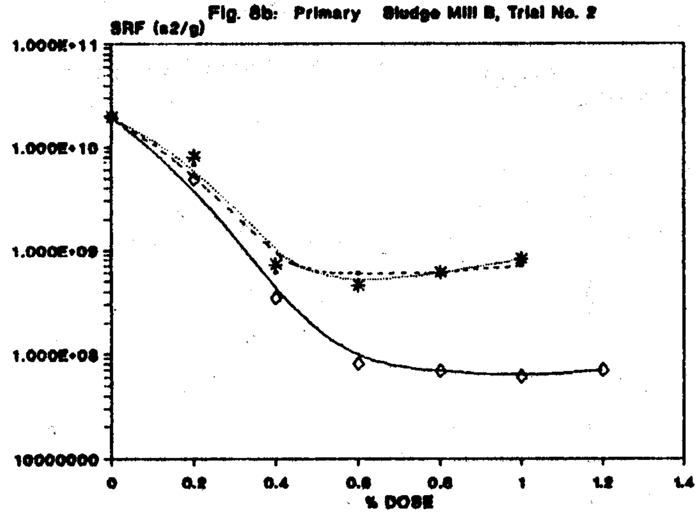


Fig. 9b: Secondary Sludge Mill B, Trial No.2

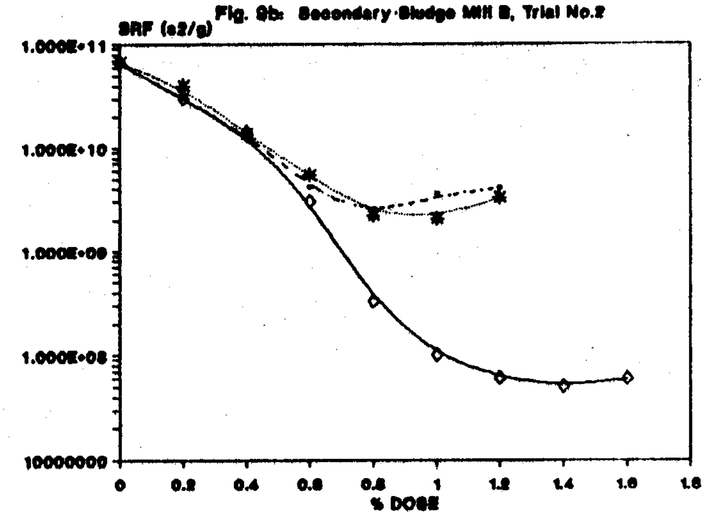


Fig. 8c: Primary Sludge Mill B, Trial No.3

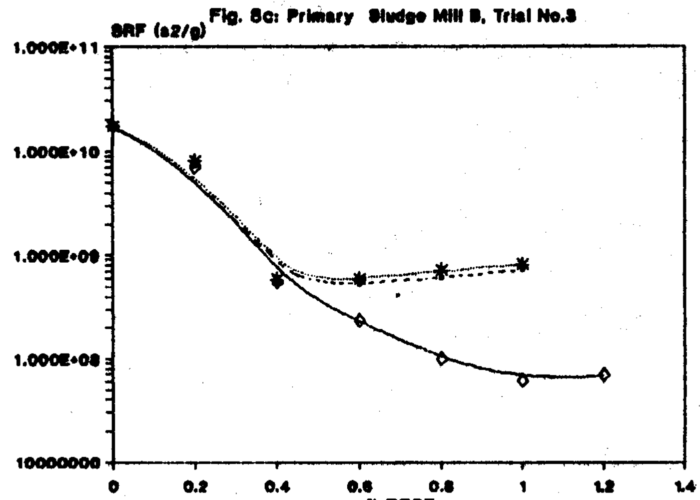
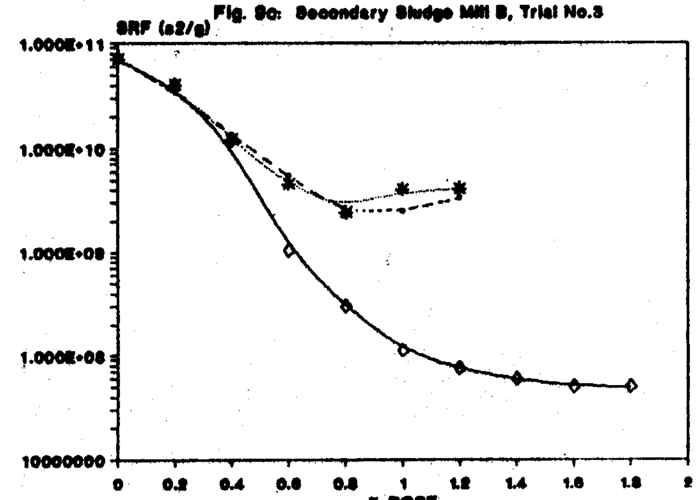


Fig. 9c: Secondary Sludge Mill B, Trial No.3



ANIONIC A — CATIONIC — ANIONIC B

compared to initial rate without flocculant. The reason may be due to the fact that the particles in the sludge are also anionic in nature. Hence, better flocculation is achieved with cationic polymer.

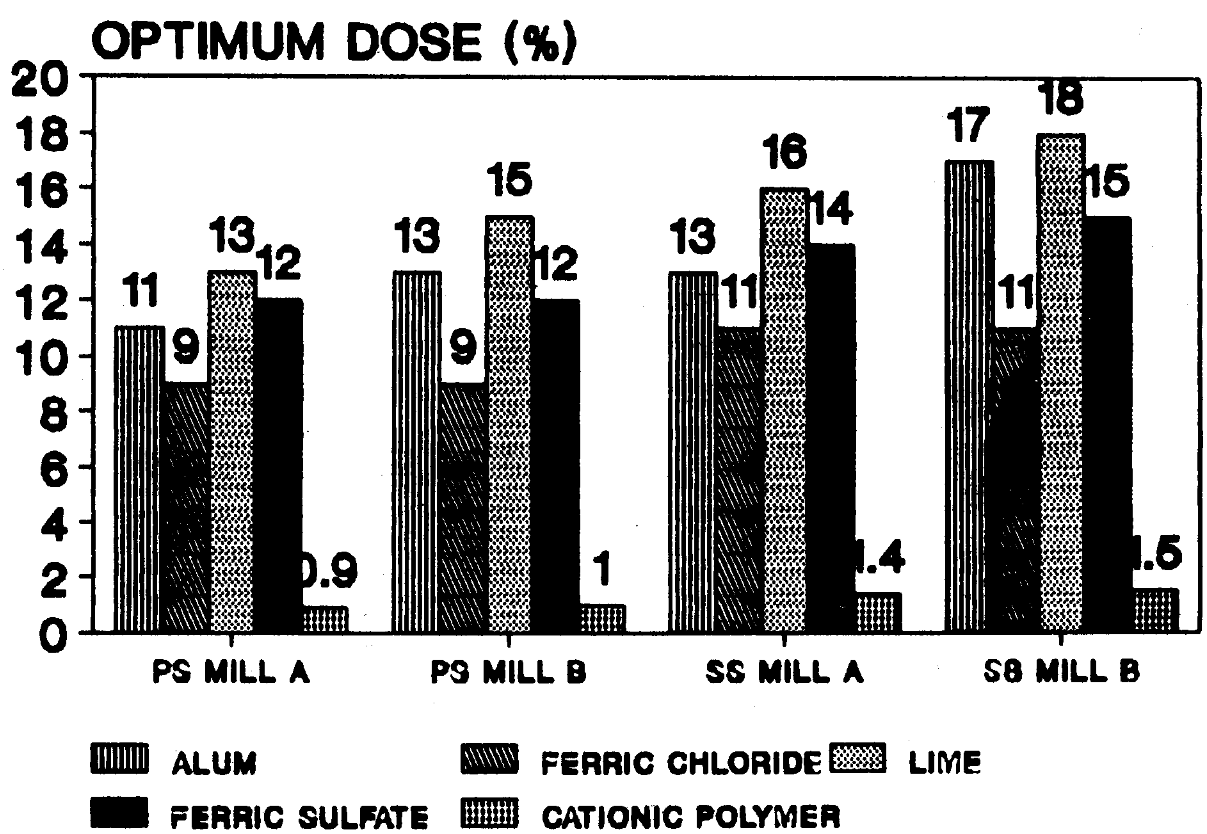
It is also clear that in comparison to inorganic polymers, the dose required for cationic polymer is found to be much lower for the same degree of SRF reduction.

Optimum Dose of Various Flocculants:

The values of optimum dose of different flocculants for primary and secondary sludges for both the mills have been shown in Figure-10 for better clarity. The optimum dose has been found to vary with the type of sludge. Surpsisingly slight variation has been noticed for even the same sludge collected at different times from the same mill.

The percent optimum dose of various flocculants for primary sludge of Mill A were 9%, 11%, 12%, 13%, and 0.9% for ferric chloride, alum, ferric sulfate, lime and cationic polymer respectively. Similarly, in case of primary sludge of Mill B, the optimum dose has been found to be 9%, 13%, 12%, 15% and 1.0% respectively of ferric chloride, alum, ferric sulfate, lime and cationic polymer. It is clear that the optimum dose requirement for primary sludge of Mill B is higher compared to primary sludge of Mill A in the case of all the flocculants used except in the case of ferric chloride. Also, the optimum dose requirement is minimum for cationic polymer followed by ferric chloride, alum/ferric sulfate and lime for primary sludges of both the mills. The similar trend has been observed for secondary sludges of both the mills. However, the optimum dose requirement of secondary sludge is higher than primary sludge of the same mill. For example, the optimum dose of cationic polymer, ferric chloride, alum, ferric sulfate and lime are 1.4%, 11%, 13%, 14%, 16% and 1.5%, 11%, 17%, 15%, 18% respectively for secondary sludges of Mill A and B.

FIG. 10 : OPTIMUM DOSAGE OF VARIOUS FLOCCULANTS



PRELIMINARY ECONOMIC EVALUATION OF THE PROCESS

A preliminary economic comparison for a 50 TPD paper plant based on certain assumptions is given in Appendix-I for the cases i.e. with or without flocculants.

Land requirement has been assumed equal and cost of only vacuum filters, man power, chemical consumption and additional equipment required for conditioning has been considered. Power consumption is found to be almost the same in both the cases except power consumption in vacuum filter operation.

The minimum SRF obtained in case of each flocculant at its respective optimum dose is almost the same and the optimum dose of alum, ferric chloride, lime, ferric sulfate and cationic polymer is approximately 15%, 10%,18%, 14% and 1.4% (based

APPENDIX-I

Economic analysis considering major items of cost and savings and using A non detail estimate for capital investment

Parameter Evaluated	RESULT	
	Unconditioned Sludge	Conditioned Sludge
Vacuum filters required	5 (each of 50 m^2)	1 (20 m^2)*1
Fixed Cost (Interest, Insurance, Depreciation etc.) **Per Day**	7636/-	1060/-*2
Operating Cost Per Day		
(a) Power, Persons, Maint.	3263/-	689/-*3
(b) Chemical Cost *4		
Alum	--	840/-
Ferric Chloride	--	5600/-
Lime	--	1008/-
Ferric Sulfate	--	1176/-
Cationic Polymer	--	7840/-
Savings Per Annum (Rs in Lakhs)		
Alum	--	27.42
Ferric Chloride	--	11.72
Lime	--	26.87
Ferric Sulfate	--	26.31
Cationic Polymer	--	04.32

*1 : Cost of each filter of size 15' x 12' (50 m^2) and 10' x 7' (20 m^2) has been taken approximately 18 lakhs and 12 lakhs respectively.

*2 : Assuming plant life of 10 years & rate of interest 18% per annum. Cost of accessories required for conditioning has been considered to be approximately Rs. 50,000.

*3 : Assuming motor of 5 KW is required for each vacuum filter and total 3 number of persons per shift are required for operation of 5 filters & 1 for 1 filter. Maintenance cost is 5% of capital cost. Cost of electricity and manpower has been assumed Rs. 2/- per KWH and Rs. 100/- per man.

*4 : Cost of Alum, Ferric chloride, lime, ferric sulfate and cationic polymer is approximately Rs. 2000/-, Rs. 20,000/-, Rs. 2000/-, Rs. 3000/- and Rs. 2.0 lakhs per ton respectively based on 1994 cost data.

on experiments) respectively.

It has been observed that in the present case utilisation of inorganic flocculants provids promising profit. The highest saving has been obtained with Alum followed by lime/ ferric sulfate and ferric chloride. Thus although ferric chloride amongst inorganic flocculants has shown the best operational benefits by decreasing SRF values, its use is least profitable as its market cost is prohibitatively high and thus at present is not economically viable. Similarly, in the present case, at a cost of Rs. 2 lakhs per tonne and a optimum dose of 1.4%, utilisation of cationic polymer has not been found economical at par with inorganic flocculants.

It is also important to note that in case of conditioning of sludge, advantage of more dry sludge, less land requirement (due to less Vaccum filters required) has not been considered in the present economical evaluation. Moreover, at higher dryness of sludge, it can be better utilised to get suitable end products. Thus, overall it can be said that it is economical to have chemical conditioning of sludge.

CONCLUSIONS

Based on the results obtained experimentally and theoretically calculated, the following conclusions can be drawn :

1. Primary sludges give lower SRF, hence, are easy to dewater than secondary activated sludges. The dose of flocculant required for minimum SRF is also lower for primary sludge in comparison to secondary sludge from same treatment plant for the same degree of dryness. It is true for any wood or non-wood based mills.

2. The high fines content in the sludge result in high SRF value and poor dewaterability. Also, the optimum dose requirement of the flocculant to achieve the minimum SRF value may be high in case of sludge of high fines content.

3. Flocculants have definite beneficial effect on sludge dewatering. However, the dose must be optimised in each case.

4. The performance of Ferric Chloride has been found to be the best among the inorganic flocculants used while lime gives the poorest values in terms of operational benefits by decreasing SRF. However, in case of Alum and ferric sulfate, the performance has been found to be sludge dependent. Similarly, amount of dose required for the best results (optimum conditioning) has been found to vary with the type of sludge (primary or secondary), and the source, the nature or type of mill. Surprisingly, this can also be varying even with the same sludge collected at different times from the same mill.

   Therefore, it can be concluded that the performance of a particular flocculant for conditioning and its dose required may vary from sludge to sludge and even with the same sludge with different characteristics, frequently varying with the mill operational conditions.

5. Between cationic and anionic polymers, the cationic polymers give better results. With anionic polymers, the effect on conditioning and hence on improvement in dewatering is found to be negligible in all the trials and with all the sludges used.

   However, the study is not made with non-ionic polymer which might give acceptable values than anionic.

6. Preliminary economic evaluation based on the optimized data on optimum flocculant dose and relative benefits indicates an promise in future. Detailed study will throw more light on the economic indicators of the process.

   Finally, it can be concluded that conditioning of flocculation of ETP sludge can result in excellent dewatering performance provided proper flocculant is employed, the flocculant dosage is adequate, and also the other process variables like pH, mixing, speed/time are in optimum range.

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