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**Selection of Cationic Collector for Reduction of Alumina and Silica in Iron Ore
Slimes of an Operating Plant by Flotation**

T V Vijaya Kumar^{*1}, S J Gopalkrishna²

^{*1}Principal Scientist, Mineral Processing Section, National Metallurgical Laboratory Madras Centre,
CSIR Madras Complex, Taramani, Chennai – 600 113, India

²Associate Professor, Department of Mineral Processing, Vijayanagara Sri Krishnadevaraya University
Post- Graduate Centre, Nandihalli - Sandur – 583 119, Karnataka, India

tvvk65@yahoo.com

Abstract

Ultra fines or Slimes generated as overflow in screw classifiers in iron ore washing plants are generally treated in a single or multi-stage hydrocyclones to recover iron values. The underflow of the hydrocyclones forms the concentrate which is generally used for pellets making due to its attractive granulometry and high iron content. It is found, very often, that the performance of hydrocyclones is sub-optimum due to the frequent choking of their lower diameter spigots (cut-point being 20 μm). This affects the overall performance of the washing plant. Considering the granulometry (d80: 40.5 μm) of slimes, cationic reverse flotation of these slimes is thought to be apt to recover iron values by reducing alumina and silica levels. This is supposed to improve the productivity of the washing plant. As a prelude to detailed flotation studies, four cationic collectors which are generically same but of varying chemical composition are evaluated and tested for their performance in the reverse flotation of iron ore slimes from the screw classifier overflow of an operating iron ore washing plant in Bellary - Hospet sector of Karnataka, India. Basically these collectors are ether amines. A stage wise flotation is conducted by adding the collector in three stages. Starch is used to depress hematite. The performance of the four collectors was evaluated based on Tests of significance, namely, 't-test' and 'F-test' and modified version of Selectivity Index derived by Douglas to select the best one among them for further investigations.

Keywords: Iron ore, washing, ultra fines, reverse flotation, alumina reduction, cationic collector

Introduction

Indian hematite ores are typically rich in iron but contain unusually high alumina (as high as seven percent). It is a well-recognized fact that in order to enhance the competitive edge of Indian iron and steel industry, an efficient alumina removal technology for Indian iron ores is absolutely essential [1]. The adverse effect of alumina on sinter strength productivity and its reduction – degradation characteristics (RDI) are well documented [2 - 4]. The blast furnace productivity is also significantly affected by the presence of alumina in the feed. High alumina slag which is highly viscous, requires larger quantity of flux (10% MgO) and relatively larger slag volumes resulting in an increase of coke consumption and a decrease in blast furnace productivity [4 - 7]. The generation of iron ore slimes in India is estimated to be 10-25% by weight of the total iron ore mined – the iron ore values are lost to the tune of 15-20 million tonnes every year [1]. In addition, these slimes stored in massive water ponds / tailing dams pose enormous environmental hazard. Steel Authority of India Limited (SAIL) alone has more than 50 million tonnes of

slimes accumulated over the years. Considering the fact that iron ore production in India will more than double in the near future, finding suitable means of safe disposal / utilization of slimes is indeed urgent.

The iron ore deposits of Bellary - Hospet sector of Karnataka, India are considered to be one of the richest iron ore deposits next to those in Orissa, Jharkhand and Chattisgarh states. The ore bearing terrain is just south of the Bellary-Hospet railway line and comprises of Ramandurg, Kumaraswamy, Donimalai, Timmappanagudi and Devadarigudda sections along the eastern and western ranges of Sandur hills. The principle ore bearing minerals of normative composition averaged over a number of deposits of this area are hematite 70-75%, goethite / limonite 15-20% and martite 5-15% are highly oxidized. Some of the salient features of these ores are

- relatively soft in nature which generate excess fines during mining, handling and processing, at times, beyond acceptable limits for subsequent processes

- high alumina content
- intrinsic association of alumina with iron bearing minerals at $-25\ \mu\text{m}$ size rendering selective recovery of iron values almost impossible at this size range.

M/s JSW Steel Limited, one of the leading producers of Steel in India outsources iron ore fines ($< 10\ \text{mm}$) from the above mentioned eastern and western ranges of Sandur hills for its beneficiation plant - 1 (BP - 1). It is established that the ore from different sources vary widely in mineralogy, chemical composition, particle size distribution and response to washability for reduction of alumina. Accordingly, they are classified as preferred, tolerable and not amenable for processing. Based on this, necessary caution is exercised while procuring the iron ore fines for their beneficiation plant. A 3.0 Mtpa beneficiation plant is in operation with the primary objective of reducing alumina and silica in iron ore fines. It has two parallel streams, each with a rated capacity of 300 t/h. The unit operations in each stream (Figure 1) comprise of wet screening, classification of undersize product of wet screening by a set of screw classifiers followed by two-stage hydro-cycloning of screw classifiers' overflow at $20\ \mu\text{m}$ cut-point

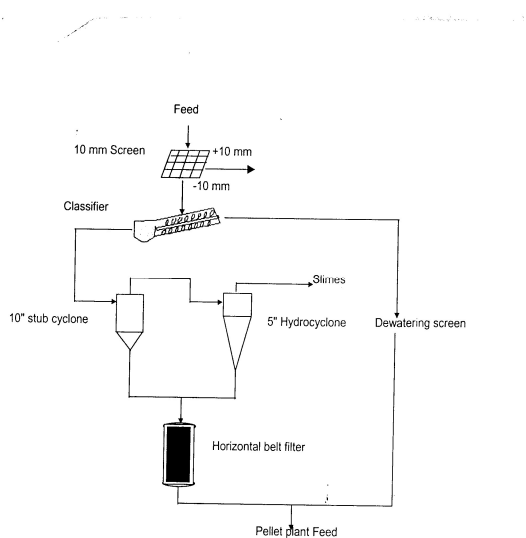


Fig. 1 Flow sheet of one stream of beneficiation plant – 1

The underflow of both the cyclones forms the concentrate after dewatering by horizontal belt filter. This concentrate serves as the feed to the pellet plant. The oversize material from the screen and the fines from the screw classifiers are stock piled in the raw material yard for their usage in the downstream processes. As the cut-point of hydrocyclones is generally at $20\ \mu\text{m}$, relatively lower diameter cyclones in a cluster with

parallel feeding are used. This is found to, often, result in choking of the spigots, at times, by extraneous material reporting along with the slurry. It is observed to lead to sub-optimum performance of the cyclones with loss of iron values into the cyclone overflow and thereafter into the tailings in the form of slimes.

To minimise the loss of iron values into tailings, an attempt is made to beneficiate the screw classifier overflow slimes by reverse flotation and improve the recovery of iron values by reducing alumina and silica levels. This is supposed to improve the process and thereby the overall productivity of the plant.

Flotation is the usual concentration method employed for the ores in the fine size range ($< 150\ \mu\text{m}$) [8]. Different flotation routes are available: (i) reverse cationic flotation of quartz; (ii) direct anionic flotation of iron oxides; (iii) reverse anionic flotation of activated quartz. The reverse cationic route is by far the most widely utilised method and ether amines are by far the mostly utilised class of collectors. Quartz / alumina are floated with ether amines ($\text{R}(\text{OCH}_2)_3\text{-NH}_2$) partially neutralised with acetic acid. Amine also plays the role of frother in iron ore flotation. Starches still represent the most important class of iron oxides depressants. Iron ore flotation system has been widely studied by different researchers on its various aspects [9 - 15]. However, finding the right collector and its suitability to the ore under investigation needs careful selection, experimental planning and evaluation of the results.

Selection of an appropriate cationic collector has a vital role to play in the reverse flotation of iron ore fines for the reduction of alumina and silica in general and alumina in particular. It depends on various factors such as the chemical composition of the reagent, its technical performance, price and availability. However, the dosage and efficiency of the reagent (collector) in terms of its selectivity in separation process are of utmost importance. The process of reagent selection and optimization in flotation systems as practiced today is rather informal and reductionistic on the part of both reagent manufacturers and plant metallurgists. For example, when a plant experiences a recovery problem, an immediate temptation might be to seek an alternative collector. Thus, a testing program either in the laboratory or in the plant, most likely the former, may be initiated to screen several alternative collectors [16]. With the reluctance of reagent manufacturers to part with the information related to chemical composition and properties of the reagents, the alternative route to screen out the best reagent among the available ones for the task at hand is to resort to statistical analysis of the data pertaining to flotation tests conducted under standard and identical test conditions using these reagents. The present paper addresses such an issue during one of its

elaborative test work programme conducted related to reduction of alumina and silica in the screw classifier overflow slimes of the iron ore washing plant mentioned above.

Materials and Methods

Materials

Cationic amine collectors which are generically same but compositionally different from each other are manufactured and supplied by M/s Somu Organo-Chem Pvt. Ltd., Bengaluru, India. These cationic amine collectors are proprietary in nature and their chemical composition is not revealed. Four cationic amine collectors designated as collector 'A' (Sokem 503C), collector 'B' (Sokem 504C), collector 'C' (Sokem 520C) and collector 'D' (Sokem 521C) are used. Their performance is evaluated and the best among them was chosen for lowering alumina and silica content in the iron ore fines and optimizing the flotation process parameters. Causticised maize starch is used as depressant for iron bearing minerals. It was supplied by Riddhi Siddhi Gluco Biols Ltd., Ahmedabad, India. Commercial grade sodium hydroxide is used as pH regulator.

Laboratory flotation tests

Flotation tests are conducted in a laboratory model Denver D12 flotation cell. Conditioning of the ore slurry is done at pH 10.0 and pulp density of 50% solids by adding 1.0 kg/t of causticised starch for a period of 5 minutes. The designated collector is, then, added in three stages of 0.20, 0.10 and 0.10 kg/t respectively. Before introducing the air for flotation to take place, the pulp density is reduced to 40% solids by adding additional water. After each stage-wise addition, conditioning is done for 5 minutes. Flotation is carried out for 10, 10 and 5 minutes respectively corresponding to 1st, 2nd and 3rd stages of addition of amine collector. The iron ore concentrate, remaining in the flotation cell at the end of the test and the tailings collected as froth are analysed for iron, silica and alumina.

Results and Discussion

Characterization

Detailed characterization studies were conducted on the ore samples reporting to the beneficiation plant using microscope, X-ray diffraction, Thermo gravimetric analysis and Electron probe microanalysis (EPMA) [17]. The results indicate that hematite is the major iron oxide mineral with minor amounts of goethite, magnetite, martite and limonite. Quartz and clay occur as major gangue. EPMA studies indicated the presence of gibbsite as the only alumina bearing phase and apatite as phosphorus bearing mineral.

Particle Size Analysis and Heavy Medium Separation (HMS) tests on different size fractions provided the insight into the liberation and separation characteristics of the material (screw classifier overflow slimes) [18]. Eighty percent of the material (d_{80}) is below 40.5 microns. Theoretically, 20.6% by weight of the material could be treated as fairly liberated and obtained as a concentrate assaying 66.29% Fe, 2.15% SiO₂ and 1.17% Al₂O₃ from the feed assaying 60.43% Fe, 6.88% SiO₂ and 3.26% Al₂O₃. This defines the lower bench mark for theoretical recovery and grade of the concentrate. Scope exists for further increase in recovery of iron values from the partially liberated particles without diluting the concentrate grade in terms of allowable limits of alumina (not more than 2.5%) in it for downstream processes like pellets making.

Evaluation & selection of collector

Cationic collectors are increasingly being used for the flotation of silica away from iron ores and phosphate ores [19, 20]. Many plants in the world are using these reagents in the processing of low grade hematite and magnetite ores [21, 22]. One of the advantages is the rapid flotation with sharp selectivity. DESHPANDE et al [23] made a study on the selection of cationic collector for reduction of silica in reverse flotation of Kudremukh iron ore, India. However, there is little or no evidence in the literature for the development and application of collectors for alumina reduction in the reverse flotation of iron ore fines to improve its grade. In this work, four cationic collectors were developed for this purpose and evaluated for their efficacy in flotation separation process at three dosage levels. For each collector, four repeat tests were carried out. The results are given in Table 1.

Table 1 Evaluation of the performance of collector
(Feed: Fe - 60.43%; SiO₂ - 6.88%; Al₂O₃ - 3.26%)

Collector	Test No.	Stage-wise collector addition, kg/ton			
		0.20	0.10	0.10	
'A' (Sokem 503C)	1	Fe, %	62.25	64.09	64.77
		SiO ₂ , %	5.05	3.73	3.20
		Al ₂ O ₃ , %	2.94	2.19	1.94
	2	Fe rec., %	60.49	44.72	37.81
		Fe, %	62.36	64.18	64.73
		SiO ₂ , %	4.91	3.70	3.14
	3	Al ₂ O ₃ , %	2.90	2.15	1.88
		Fe rec., %	59.08	46.76	39.87
		Fe, %	62.35	64.05	64.76
	4	SiO ₂ , %	5.10	3.65	3.35
		Al ₂ O ₃ , %	2.88	2.19	1.92
		Fe rec., %	59.29	46.06	39.24
Fe, %		62.60	64.12	64.86	
SiO ₂ , %		4.66	3.68	3.15	
Al ₂ O ₃ , %		2.48	1.95	1.86	
	Fe rec., %	54.34	41.30	38.56	

Average for Sokem 503C 1	Fe, %	62.39	64.11	64.78	(Sokem 521C) 4	Al ₂ O ₃ , %	3.07	2.31	2.02	
	SiO ₂ , %	4.93	3.69	3.21		Fe rec., %	75.58	62.25	55.41	
	Al ₂ O ₃ , %	2.80	2.12	1.90		Fe, %	62.28	63.87	64.60	
	Fe rec., %	58.30	44.71	38.87		SiO ₂ , %	5.23	4.07	3.55	
	Fe, %	62.46	64.14	64.89		Al ₂ O ₃ , %	3.09	2.36	2.09	
	SiO ₂ , %	5.03	3.79	3.21		Fe rec., %	71.51	58.87	52.03	
	Al ₂ O ₃ , %	2.90	2.21	1.91		Average for Sokem 521C	Fe, %	62.14	63.69	64.40
	Fe rec., %	66.80	48.90	42.25		SiO ₂ , %	5.17	4.04	3.50	
	Fe, %	62.10	63.97	64.87		Al ₂ O ₃ , %	3.06	2.36	2.08	
	SiO ₂ , %	4.99	3.69	3.06		Fe rec., %	72.97	60.04	53.28	
	Al ₂ O ₃ , %	2.93	2.20	1.89						
	'B' (Sokem 504C) 3	Fe rec., %	63.38	46.32		38.45				
Fe, %		61.92	63.56	64.38						
SiO ₂ , %		5.19	4.03	3.42						
Al ₂ O ₃ , %		3.07	2.34	2.04						
Fe rec., %		68.77	55.58	46.74						
Fe, %		62.10	63.78	64.62						
SiO ₂ , %		5.18	3.92	3.29						
Al ₂ O ₃ , %		2.96	2.24	1.93						
Fe rec., %		63.42	46.43	38.33						
Fe, %		62.15	63.86	64.69						
SiO ₂ , %		5.10	3.86	3.25						
Al ₂ O ₃ , %		2.97	2.25	1.94						
Average for Sokem 504C 1	Fe rec., %	65.59	49.31	41.44						
	Fe, %	62.60	63.91	64.67						
	SiO ₂ , %	5.00	3.75	3.19						
	Al ₂ O ₃ , %	2.91	2.22	1.95						
	Fe rec., %	58.94	43.90	37.49						
	Fe, %	62.25	63.85	64.50						
	SiO ₂ , %	5.07	3.83	3.30						
	Al ₂ O ₃ , %	2.94	2.21	1.95						
	Fe rec., %	57.23	43.54	37.29						
	Fe, %	62.44	64.09	64.69						
	SiO ₂ , %	4.97	3.71	3.23						
	Al ₂ O ₃ , %	2.91	2.17	1.95						
'C' (Sokem 520C) 3	Fe rec., %	61.06	47.17	40.36						
	Fe, %	62.43	64.39	65.09						
	SiO ₂ , %	4.75	3.48	2.92						
	Al ₂ O ₃ , %	2.75	2.06	1.80						
	Fe rec., %	61.17	46.45	39.57						
	Fe, %	62.43	64.06	64.74						
	SiO ₂ , %	4.95	3.69	3.16						
	Al ₂ O ₃ , %	2.88	2.17	1.91						
	Fe rec., %	59.60	45.27	38.68						
	Fe, %	62.17	63.62	64.38						
	SiO ₂ , %	5.18	4.11	3.53						
	Al ₂ O ₃ , %	3.03	2.39	2.09						
Average for Sokem 520C 1	Fe rec., %	72.47	58.98	51.90						
	Fe, %	62.04	63.53	64.15						
	SiO ₂ , %	5.10	4.00	3.49						
	Al ₂ O ₃ , %	3.05	2.38	2.12						
	Fe rec., %	72.33	60.06	53.79						
	Fe, %	62.06	63.72	64.45						
	SiO ₂ , %	5.18	3.98	3.43						

If we compare the results, after first stage of addition of collector (i.e., after adding 0.20 kg/t of collector), there was substantial improvement in the quality of the concentrate produced in all cases. But better results were obtained in case of collector 'D'. In its case, iron percentage increased from 60.43% (feed) to 62.14% while its recovery was 72.97%. After second stage of addition of the collector, there was again marked improvement in the grade of the concentrate up to 63.69%, while the alumina content was reduced to around 2% in all cases. In the case of collector 'D', at this stage, iron recovery was 60.04%, higher than that of the rest of the collectors. It is important to note here that, after the third addition of 0.10 kg/t of collector, there was marginal improvement in the grade of the concentrate in all the cases. However, in case of collectors 'A', 'B' and 'C', more of the material was observed to float resulting in loss of selectivity and recovery. But in case of collector 'D', the final concentrate analysed 64.40% Fe, 3.50% SiO₂ and 2.08% Al₂O₃ from the feed assaying 60.43% Fe, 6.88% SiO₂ and 3.26% Al₂O₃. The iron recovery, in this case, was 53.28% whereas it varied from 38.68% to 41.44% for collectors 'A', 'B' and 'C'.

The analysis of flotation test results was done by two methods. In the first method, two important tests of significance namely the 't-test' and 'F-test' [24, 25] were performed on the test results obtained. The results are also evaluated in terms of 'Selectivity Index' (SI) for the efficacy of the collector in the separation process.

Null Hypothesis

There are several instances when we have to make decisions about the choice of the particular reagent or of a different practice altogether in a flotation process [26]. For example, suppose a flotation plant was using a reagent 'R' to obtain a grade of 68% Fe with the standard error of 0.5% Fe, and after changing to reagent 'S' the corresponding grade and standard error were 67.5% and 0.6% Fe respectively. In order to assess as to whether the change in grade and variability of grade are due to the change in the reagent exclusively, one should perform a 'test of significance'. There is an equal probability that the indicated change may simply be due

to chance. In such cases one should first assume that there is no real difference in the samples under question and that the samples are in fact drawn from the same parent population. This is called 'Null Hypothesis'. To test the hypothesis, we should calculate the probability that certain statistics will have values that fall outside given limits. The level of significance to test the hypothesis depends on the importance of the test. In general, if an observed value could only occur about five times out of hundred (P=5%) we conclude that the null hypothesis is false and that the observed value is significant. The two important tests of significance of use in flotation research are the 't-test' and the 'F-test'. The former one uses the t-table and the latter involves the determination as to whether differences between two variances are simply due to chance or is real.

$F = \frac{\text{(Greater variance)}}{\text{(Smaller variance)}}$

F-distribution tables are available for data analysis.

Tests of significance for alumina reduction

Let us consider a null hypothesis in which both the collectors 'A' and 'D' are the same.

Table 2 Tests of significance for alumina reduction (using collectors 'D' & 'A')

Test no.	Collector 'D' : % Al ₂ O ₃ in the final concentrate	Collector 'A': % Al ₂ O ₃ in the final concentrate
1	2.09	
2	2.12	
3	2.02	
4	2.09	
5		1.94
6		1.88
7		1.92
8		1.86
	Total = 8.32	Total = 7.6
	Average, X _D = 2.08	Average, X _A = 1.9

Table 3 Analysis of variance for alumina reduction (using collectors 'D' & 'A')

	Collector 'D'	Degrees of freedom, °F	Collector 'A'	Degrees of freedom, °F
Crude sum of squares	17.311	4	14.444	4
Correction factor	17.3056	1	14.440	1

Total sum of squares	0.0054	3	0.004	3
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Variance for collector 'D', $V_D = \sigma_D^2 = 0.0054/3 = 0.0018$ & variance for collector 'A', $V_A = \sigma_A^2 = 0.004/3 = 0.00133$

Variance of experimental error = $(0.0054 + 0.004) / (3+3) = 0.001567$

Thus, standard deviation for 'A' & 'D', $\sigma_A = \sigma_D = \sqrt{0.001567} = 0.0396$

Let $Z = X_D - X_A = 2.08 - 1.90 = 0.18$

That is, the difference in the % alumina in the flotation concentrate appears to be 0.18 Al₂O₃ units.

The 95% confidence interval of Z is calculated as

$X_D - X_A = 0.18 \pm 2.45 * (0.0396/2) * \sqrt{2}$

$X_D - X_A = 0.18 \pm 0.0686$

Clearly, this confidence interval does not include zero. So we conclude that the collectors are not the same.

Table 4 F-test for alumina reduction (using collectors 'D' & 'A')

	Collector 'A'	Collector 'D'
Number of tests	4	4
Average % Al ₂ O ₃ in the final concentrate, X	1.9	2.08
Variance, V=S ²	0.00133	0.0018

The apparent variance of 'D' is greater than that of 'A'. To test whether this variance is significant or not, an F-test was performed.

$F = \frac{\text{(Greater variance)}}{\text{(Smaller variance)}} = \frac{0.0018}{0.00133} = 1.3533$

Degrees of freedom, $\Phi_1 = 4-1 = 3$, $\Phi_2 = 4-1 = 3$.

From the F-tables, we get

$F_{10} = 5.39$, $F_5 = 9.28$, $F_1 = 29.5$.

We can see that we cannot obtain a value nearer to 9.28 five times out of hundred. Thus, the F-test suggests we reject the null hypothesis and conclude that the observed value or the change from collector 'A' to collector 'D' is really significant at 95% confidence level.

Tests of significance for silica

Let us consider a null hypothesis in which both the collectors 'A' and 'D' are the same.

Table 5 Tests of significance for silica reduction (using collectors 'D' & 'A')

Test no.	Collector 'D': % SiO ₂ in the final concentrate	Collector 'A': % SiO ₂ in the final concentrate
1	3.53	
2	3.49	
3	3.43	
4	3.55	
5		3.20
6		3.14
7		3.35
8		3.13
	TOTAL=14	TOTAL = 12.82
	Average, X _D = 3.50	Average, X _A = 3.205

Table 6 Analysis of variance for silica reduction
(using collectors 'D' & 'A')

	Collector 'D'	F	Collector 'A'	F
Crude sum of squares	49.0084	4	41.119	4
Correction factor	49.00	1	41.0881	1
Total sum of squares	0.0084	3	0.0309	3

$$V_D = \sigma_D^2 = 0.0084/3 = 0.0028 \quad V_A = \sigma_A^2 = 0.0309/3 = 0.0103$$

Variance of experimental error = 0.00655

$$\text{Thus } \sigma_A = \sigma_D = \sqrt{0.00655} = 0.0809$$

$$\text{Let } Z = X_D - X_A = 0.295$$

The 95% confidence interval of Z is calculated as

$$X_D - X_A = 0.295 \pm 2.45 * (0.0809/2) * \sqrt{2}$$

$$X_D - X_A = 0.295 \pm 0.1402.$$

Clearly, this confidence interval does not include zero. So, we conclude that the collectors are not the same.

Table 7 F-test for silica reduction
(using collectors 'D' & 'A')

	Collector 'D'	Collector 'A'
Number of tests	4	4
X	3.5	3.205
V=S ²	0.0028	0.0103

The apparent variance of 'A' is greater than that of 'D'. To test whether this variance is significant or not, an F-test was performed.

$$F = (\text{Greater variance}) / (\text{Smaller variance}) = 3.6786.$$

$$\Phi_1 = 4-1 = 3, \Phi_2 = 4-1 = 3.$$

From the F-tables, we get,

$$F_{10} = 5.39, F_5 = 9.28, F_1 = 29.5.$$

We can see that we cannot obtain a value nearer to 9.28 five times out of hundred. Thus, the F-test suggests we reject the null hypothesis and conclude that the observed value or the change from collector 'A' to collector 'D' is really 'significant'.

Selectivity Index

Selectivity index gives an accurate scientific measure of the effectiveness of the separation. It seems, in fact, to be the most accurate measure that could be devised. The performance of the collectors' was evaluated based on modified version of Selectivity Index (SI) derived by E. Douglas [27]. According to his definition, an index of 100 is indicative of a perfect separation between the valuable minerals and the gangue; an index of zero indicates no separation. The numerical value of this selectivity index, as defined, is adjusted for the variations in head assay. As such, therefore, it served as a useful measure of the efficacy of the separation process on a number of different samples as well. It is given by

$$SI = [(R-C)*(c-f)*100] / [(100-C)*(c_{max}-f)]$$

Where C is % weight of the concentrate; R is % recovery of iron in the concentrate; c is % iron of the concentrate; c_{max} is the maximum (theoretical) iron in the concentrate and f is % iron of the feed.

Using this formula, the SI for the four collectors 'A', 'B', 'C' and 'D' are found out to be

$$\text{SI for collector 'A' (Sokem 503C) = 1.58}$$

$$\text{SI for collector 'B' (Sokem 504C) = 2.10}$$

$$\text{SI for collector 'C' (Sokem 520C) = 1.80}$$

$$\text{SI for collector 'D' (Sokem 521C) = 2.81}$$

From this also, it can be concluded that collector 'D' is better than all the other collectors used.

Conclusions

The selection of an appropriate collector for reverse flotation of iron ore slimes was made based on statistical methods and also by 'Selectivity Index'. Flotation separation was found to be sensitive to the amount of collector added. As the collector dosage is increased in stages, more of the material was observed to float resulting in loss of selectivity and recovery in case of collectors 'A', 'B' and 'C'. The change from collector 'A' to 'D' is really significant at 95% confidence level. In case of collector 'D', the final concentrate analysed 64.40% Fe, 3.50% SiO₂ and 2.08% Al₂O₃ from the feed assaying 60.43% Fe, 6.88% SiO₂ and 3.26% Al₂O₃. The iron recovery, in this case, was 53.28% whereas it varied from 38.68% to 41.44% for collectors 'A', 'B' and 'C'. Selectivity Index for collector 'D' was also found to be

superior as compared to that for rest of the collectors tested. Thus, out of four cationic collectors tested, collector 'D' (Sokem 521C) was selected for further detailed investigations and optimization of flotation process parameters.

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