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# Effects of Sodium Iso-butyl Xanthate Dosage on The Froth Flotation of Bead Milled Middle Group 1-3 PGM Ore Blend

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**Abstract -** An investigation was carried out to determine the effects of collector concentration on the grade and recovery in the flotation of middle group 1-3 Platinum Group Metal (PGM) ore mixture. The ore mixture pulp at a relative density of 1.29 was subjected to "bead milling" test, particle size distribution analysis and the 55% passing 75 μm was froth floated at 180, 200 and 220 g/t dosages of sodium isobutyl xanthate (SIBX) and 30 and 80 g/t of Senfroth and Sendep 30D frother and depressant, respectively. The results obtained indicated the predominance of the <38 μm PGM values in the ore and confirmed the need for tertiary milling for better liberation of the PGMs. The grade of the PGM concentrate obtained when dosing at 200 g/t of sodium isobutyl xanthate was highest at 94 g/t and gave the lowest recovery of 53%. The 180 g/t SIBX dosage resulted in highest PGM recovery of 70% and lowest grade of 84 g/t, while dosing at 220 g/t SIBX gave average PGM grades of 90 g/t and recoveries of 60%. The results obtained thus showed that that an SIBX dosage of 180 g/t SIBX would be appropriate when higher recoveries are targeted, while 200 g/t dosage will yield higher grades.

**Keywords**: PGM ores; Milling; Flotation; Collector; Dosage; Grade; Recovery

## Introduction

The Bushveld complex is an enormous eruption of magma from which different minerals solidified and accumulated. It is the largest known deposit of chromite and platinum group metals (PGMs) bearing minerals in the world; accounting for over 80% of the world deposits. The currently exploitable South African reserves of PGMs are concentrated in narrow but extensive strata known as the Merensky Reef, the Plat reef and the UG2 chromite layer. Each of the layers in the Bushveld Complex has its own distinctive associated mineralogy. The Merensky Reef has its PGMs occurring in conjunction with base metal sulphides, the UG2 layer has high chromite content together with relatively low quantities of base metal sulphides, while the Platreef has an even greater quantity of base metal sulphides present. In addition, the tellurides and arsenides of platinum and palladium contribute about 50% of the PGMs present in the Platreef ore and there has been evidence of these minerals reporting to the flotation tailings.The UG2 layer has been described as possibly a hybrid of the sulphide and chromite hosted reefs. It is a platini-ferrous chromatic layer which is found some 20 to 400 metres below the better known Merensky Reef, depending on the geographic location within the Complex. It is of interest as a source of both chromite and PGMs. The downstream energy intensive PGM smelting process has specific sensitivities to the presence of silica rich, ferruginous gangue contaminants and the inherent composition of the chromite spinel ($Cr_2O_3$ content and Cr/Fe ratio). The mineral deposits of the Bushveld complex are classified as upper, middle and lower groups. The upper critical zone hosts the largest concentration of PGMs in the world. The Lower Group 6 and Middle Groups (MG1 and MG2) seams have been described as typical viable seams of the Bushveld complex (Schouwstra *et al.*, 2000;. Cawthorn, 2010; Dawson, 2010; O'Connor , 2013; Cramer *et al.*, 2004).

The PGMs consist of a family of six greyish to silver white metals, that is, platinum, iridium, osmium, palladium, rhodium and ruthenium; with close chemical and physical affinities and belong to the transition metals of the Group 8 in the Periodic Table. The most economically important of the PGMs are platinum, palladium and rhodium with ruthenium, iridium and osmium being less in demand. These metals have similar geochemical behavior and tend to be concentrated together geologically. The base metals nickel, copper, and cobalt commonly occur together with the PGMs and are produced as co-products in the smelters and refineries. The PGMs, along with gold and silver are classified as noble metals because of their high resistance to oxidation and corrosion (Crozier, 1992).

Collectors are organic compounds which render selected minerals water-repellent by adsorption of molecules or ions on to the mineral surface. Therefore reducing the stability of the hydrated layer separating the mineral surface from the air bubble to such a level that attachment of the particle to the bubble can be made on contact. Sodium isobutyl Xanthate (SIBX) is used to collect the PGMs from the pulp. Xanthates and similar compounds tend to oxidize fairly easily, which can lead to complications in flotation (Will and Napier-Munn, 2006). Grind refers to the size distribution of the mill product. Plants operate to a target grind, usually defined as the %-75 µm in the mill circuit product (MCP). Mills are required to produce 60% -75µm (60% passing 75 micron). The smaller the size of the particle the more liberated is the valuables. Best floatation is obtained while operating at 38 µm to 106 µm particle size (Van den Berg, 2004)

Industrial scale mineral flotation processes consist of several units that are grouped into banks and inter-connected in a pre-defined manner in order to process the feed into concentrate and tailing. The behaviour of these processes depends on the configuration of the circuit and the physical and chemical nature of the slurry treated. Many of the complex circuits used in the mineral processing industry are the results of attempts to find more efficient methods for treating minerals in order to maintain mineral value recovery at a maximum while the contamination of the concentrate with gangue is minimized. The design of the processing circuits is carried out based on the experience of the designer with the aid of laboratory tests and simulations (Yingling, 1993; Williams *et al.*, 2002). The use of inert grinding media has been found to cause great improvement in the kinetics and recovery of values in the subsequent froth flotation (Pease *et al.*, 2013). For the froth flotation of PGM bearing sulphide minerals, silica and chrome are the most common impurities. Most of the gangue materials are not floated to the concentrate zone due to their lack of hydrophobicity (Cramer *et al.*, 2004). The use of Senkol 433 and SIBX have been reported for the froth flotation of of the MG1 ore. The results obtained showed that Senkol 433 yielded higher recovery than SIBX, while SIBX achieved the highest grade for all the dosages as compared to Senkol 433 (Adeleke *et al.*, 2013). In this research, the effects of different dosages of sodium isobutyl xanthate (SIBX) collector on the recovery and grade obtainable from the froth flotation of a blend of bead milled MG1-3 PGM ore was studied.

## Materials and Methods

### Sample Preparation

About 25 kg of MG1, MG2, and MG3 dry samples were collected from the ore dam area of a South African mineral processing plant. The dry samples were blended in the ratio 1:1 and split to 3.6 kg using the rotary riffle splitter. These portions were then packed into plastic bags and stored for further usage.

### Milling curve determination

About 3.6 kg sample of the ore blend was "bead milled" at a specific power input of 10 kWh/t with a laboratory scale SMD bead mill for 15 minutes. The bead milling was repeated at 30 and 45 minutes. The milling curve was plotted from the data obtained and the milled sample was sized at 300, 150, 106, 75, 38 and 25 µm sieve apertures. The milling curve is shown in figure 1.

### Froth Flotation

About 3.6 kg of the ore mixture ground 55% passing 75 µm was weighed into a 8 litre Denver cell and mixed with water to obtain a pulp relative density of 1.29. The pulp was dosed with 180 g/t SIBX collector at 40% strength and conditioned with the pulp for 2 minutes. The Sendep 30D at 80 g/t was added as a depressant and conditioned for 2 minutes. Senfroth 38 was added drop wise to the pulp. The batch float was carried out in three timed increments of concentrate collections at 5, 10, and 15 minutes at 15 seconds intervals. The concentrates and tailings were collected and 4E PGM, 4E Prill and $Cr_2O_3/SiO_2$ analyzed by Fire Assay with Gravimetric finish, Fire Assay, ICP-OES finish and borate fusion X-ray fluorescence, respectively. The procedure described was repeated but at 200 and 220 g/t dosages of the SIBX collector. The experiments were carried out in triplicates.

## Results and Discussion

The milling curve is shown in Figure 1a, while the head grade of the ore mixture, total PGM contents in the size fractions and the particle size distribution are presented in Table 1 and Figures 1b and Figure 1c, respectively. The sizing distribution shows that the major proportions of the PGM value were found within the <38 µm fraction as 25 and 35%, giving a total of 57% of the sample. At the -75 + 53 µm range, the PGM value found was 15% of the total. The higher amount of the PGMs found in the -38 µm would suggest that the bead milling caused a better liberation of the PGMs. At <75 µm, the total PGM fraction was 83% which indicating that most of the PGM could be recovered through flotation (Rule and Anyimadu, 2007).

Figure 2a shows that the different SIBX dosages yield different PGM grades with cumulative time. When the SIBX was dosed at 180, 200, 220 g/t at 5 minutes the grades were 84, 94, and 90 g/t respectively. At 10 minutes the grades were 81, 89 and 86 g/t respectively and at 15 minutes the grades were 79, 84 and 82 g/t respectively. The pattern of the results obtained show that the pulp at 5 min contains a considerably higher PGM grade than at 15 and 30 minutes of floatation and this may be due to the relatively higher content of PGMs in the pulp at the beginning of the flotation. However, as more PGMs are recovered, the PGM content in the pulp also drops and hence the decrease in PGM grade with an increase in time (Will and Napier-Munn, 2006).

Figure 2b shows the kinetics at different SIBX dosages. As a rule of thumb the recovery at 5 minutes is used as a first pass prediction of minimum recovery which would be expected on a commercial plant operation. From these results, it can be observed that at 180, 200 and 220 g/t the predicted plant recovery stands at 28, 18, and 24 % respectively. At 15 min, recoveries were 49, 34, and 41% respectively. At 30 minutes, the PGM recoveries were 70, 53, and 60%, respectively. The results obtained show that higher recoveries were obtained with increased froth scraping time and that the highest recoveries were obtained at the lowest dosage of 180 g/t. The results obtained suggest that the feed has a low recovery kinetics as the recovery only increased substantially after a considerable amount of time.

In Table 2 are presented the grades and corresponding recoveries at varying scraping times. The results obtained showed that cumulative grade generally decreased with increasing scraping time, while the cumulative recovery increased. The cumulative grade increased from 180 g/t dosage to 200 g/t and then decreased at 220 g/t for all corresponding froths. The grade and recovery are inversely proportional with the highest recoveries obtained at the 180 g/t dosage that gave the lowest grade and the lowest at the 200 g/t that yielded the highest grades (Will and Napier-Munn, 2006). The results obtained suggest that an increase in collector concentration will result in the increasing hydrophobicity of the valuables, but overdosing the collector may not result in further improvement in recovery. Guler and Akdemir (2012) observed from statistical evaluation that at very high collector dosage, the flotation of an artificial ore yields almost no further improvement in grade and recovery.

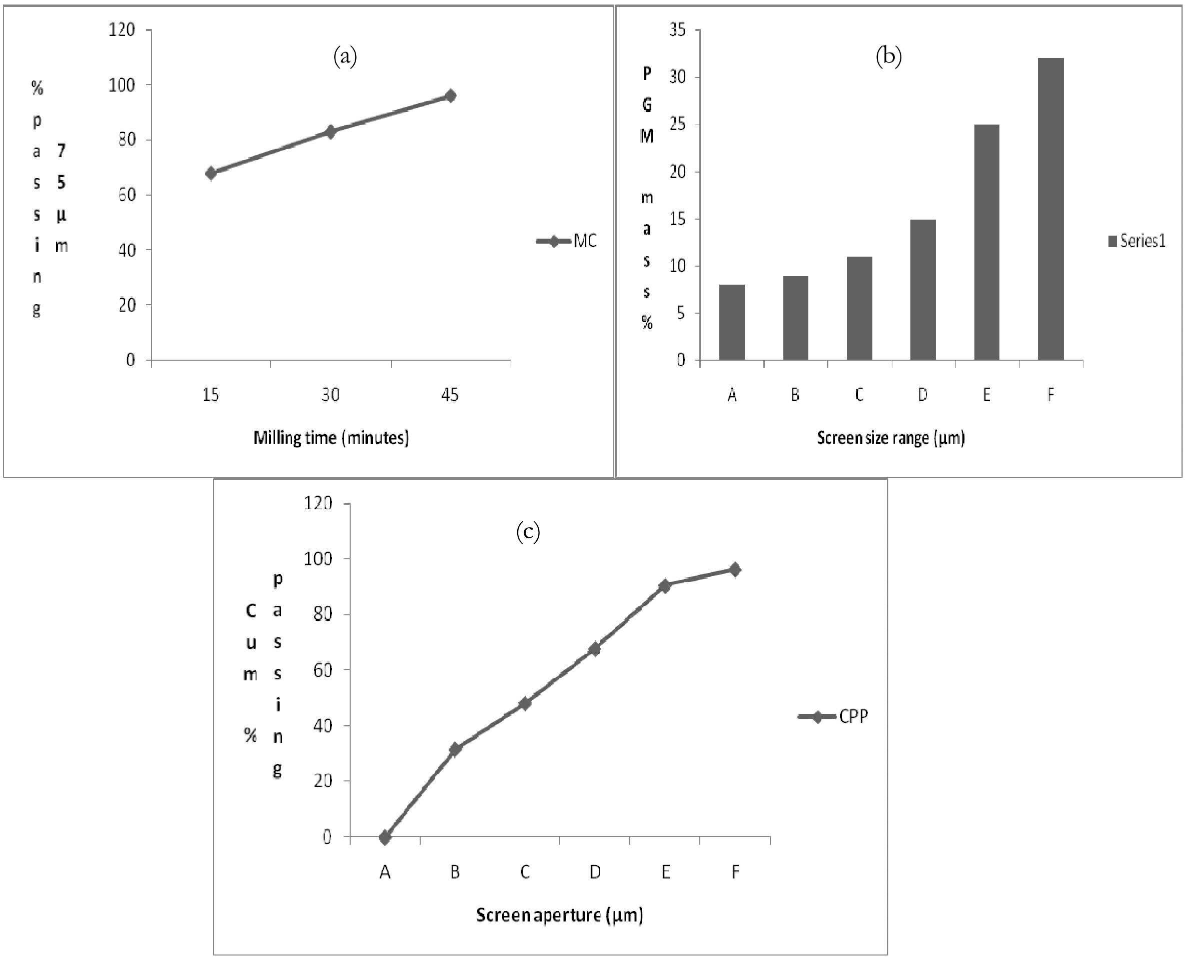


Figure 1. (a) Milling Curve (%<75 µm, (b) PGM distribution at size ranges A(>150 µm), B(-150+106 µm), C(-106+75 µm), D(-75+53 µm), E(-53+38 µm) and F(<38 µm), (c) Particle size distribution.

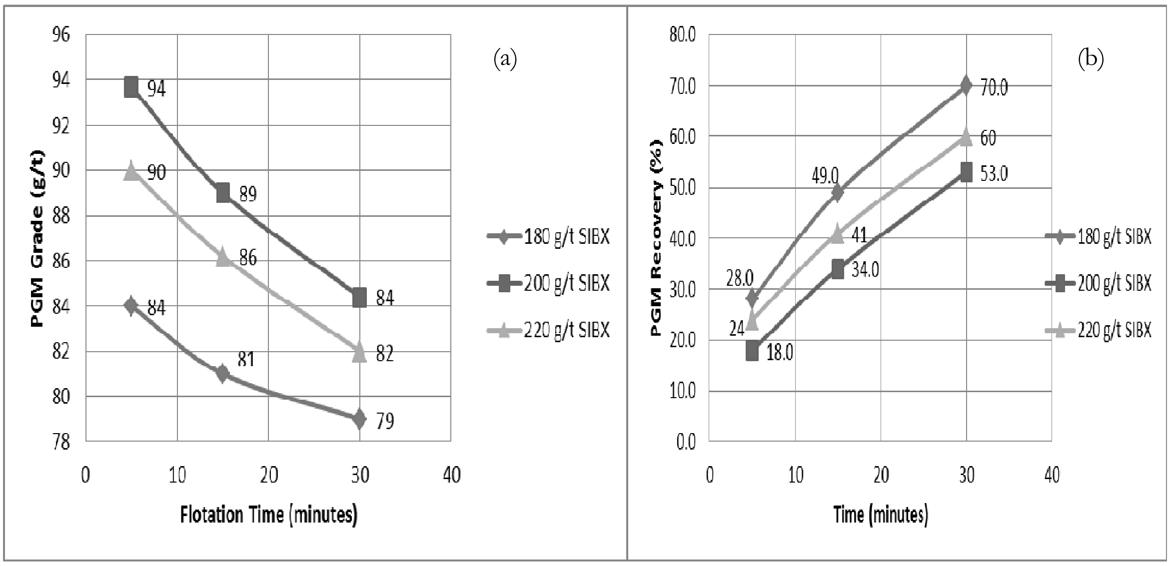


Figure 2. (a) Rougher PGM grade kinetics curve, (b) Rougher recovery kinetics curve

Table 1. Summary of head grades

| | | | Grade | | | |
|---|---|---|---|---|---|---|
| Pt (g/t) | Pd (g/t) | Rh (g/t) | Au (g/t) | 4E g/t | Cr2O3 % | SiO2 % |
| 1.55 | 1 | 0 | 0.02 | 2.88 | 23.51 | 26 |

Table 2. Grades and recoveries at varying scraping time

| Time (mins) | SIBX Dosages (g/t) | | | | | |
|---|---|---|---|---|---|---|
| | 180 g/t | | 200 g/t | | 220 g/t | |
| | Grade | Recovery | Grade | Recovery | Grade | Recovery |
| 5 | 84 | 28 | 94 | 18 | 90 | 24 |
| 15 | 81 | 49 | 89 | 34 | 86 | 41 |
| 30 | 79 | 70 | 86 | 53 | 82 | 60 |

## Conclusions

The screening analysis shows that the majority of the PGM values were found within the <38 μm fraction. The higher amount of the PGMs found in the <38 μm would suggest that there should be better liberation of the PGMs if further milling is done below -75 μm. The PGM grade obtained while dosing at 200 g/t was also the highest and stood at 94 g/t, but gave the lowest recovery of 53%. Dosing at 180 g/t resulted in higher PGM recoveries of 70% and lower grade of 84 g/t, while dosing at 220 gave average PGM grades of 90 g/t and recoveries of 60%.

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