Platinum Tailings Review - A comparison of the water quality in the tailings dam to the surrounding groundwater

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Abstract

There are a number of platinum mines in South Africa that exploit platinum group minerals (PGMs) within the Rustenburg Layered Suite of the Bushveld Igneous Complex (BIC). The platinum tailings generated following processing of the ore is disposed of in tailings storage facilities (TSF) and, whilst not acid generating, comprise elevated salts which could leach to the groundwater.

A preliminary comparison of the PGM TSF leachate quality to that of the surrounding groundwater quality was carried out for selected sites. The nitrate concentrations are comparatively higher in the TSFs leachate than in the surrounding groundwater suggesting that nitrates are possibly lost/assimilated within the TSF.

Keywords: Nitrate, Tailings dams, Platinum

Introduction

Platinum group minerals (PGMs) (platinum, palladium, rhodium, iridium, osmium and ruthenium) in South Africa are extracted from the UG2 and/or Merensky Reef (MR) located within the Rustenburg Layered Suite of the Bushveld Igneous Complex (BIC). The BIC covers an area of over 450 km (east to west) and over 200 km (north to south) in the northern part of South Africa extending into Botswana. There are more than twenty mines that exploit PGM's across South Africa, (refer to Figure 1 below).

Although the UG2 and/or MR tailings material is non-acid generating; it comprises elevated salts and nitrogenous compounds derived from the explosives used during blasting and the chemicals utilised for the processing of the ore which can leach to the groundwater, (Bosman, 2009). A simplified flow sheet of a platinum processing plant is provided after Haggard et.al 2015.

Many of the areas in which the platinum mines are located are water stressed and the communities, particularly in the northern limb and eastern limbs, rely on groundwater to satisfy their domestic needs and to support subsistence crops and livestock. Nitrate concentrations of greater than 20 mg/L as N are a common occurrence in groundwater in the Northern and North-West Provinces of South Africa and baseline nitrate levels can typically vary from <0.1 to over 80 mg/L as N, (Tredoux et.al 2009, E Martinelli and Associates 1999, SRK 2001, Barnard, 2000). The leachate of contamination from the TSF can therefore result in further (localised) deterioration of the groundwater quality to concentrations which are significantly higher than the South African National Standard (SANS 241, 2015) for nitrate of 11 mg/L, (SANS 241- 2015).

Methods

The baseline water quality for the general area was referenced from historical records which pre-date the TSFs, information sourced from the National Groundwater Archive and/or from boreholes located up-gradient of the facilities. The nitrate and ammonia concentrations reported in the National Groundwater Archive (accessed May 2018) provide an indication of the variability of the data where:

- Nitrate concentrations are reported as between <1 to over 125 mg/L as N in boreholes located on the eastern limb and <1 to over 140 mg/L as N in boreholes located on the western limb whilst
- Ammonia concentrations are reported as between <0.1 mg/L as N and 6 mg/L as N in boreholes on the eastern limb and 13 mg/L as N for boreholes on the western limb.

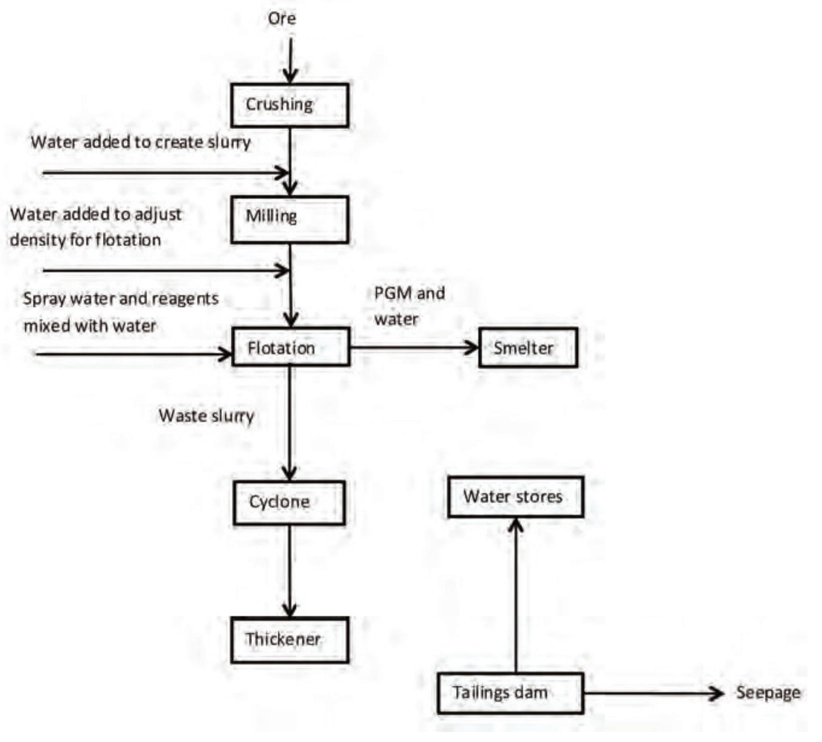


Figure 1 *Simplified water flow sheet for a platinum processing plant, after Haggard, 2015*

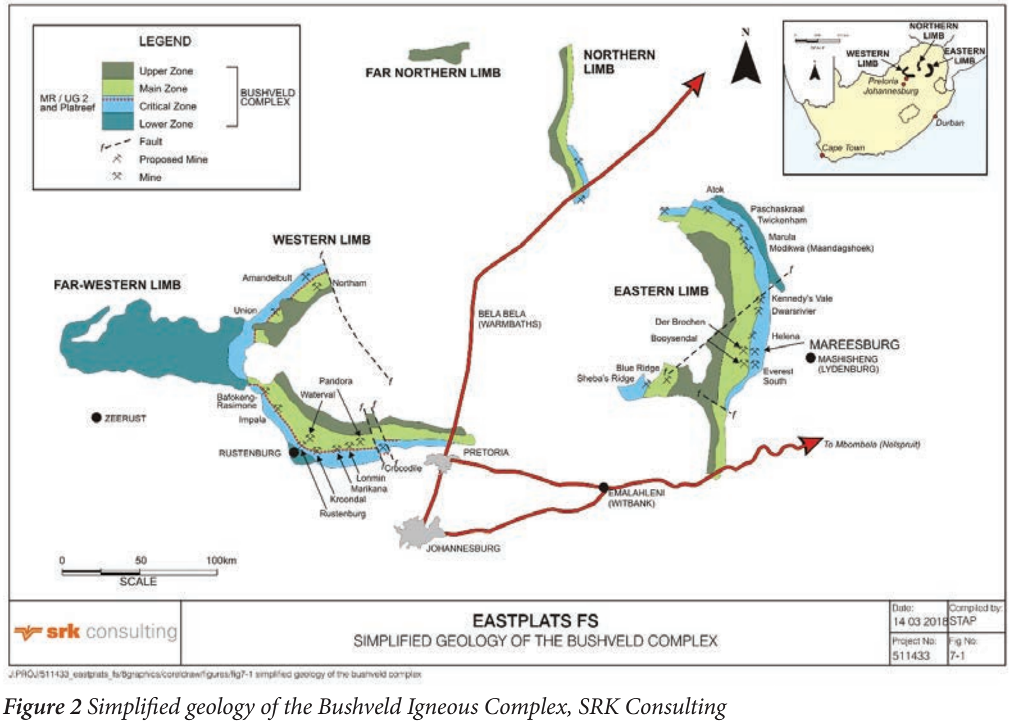


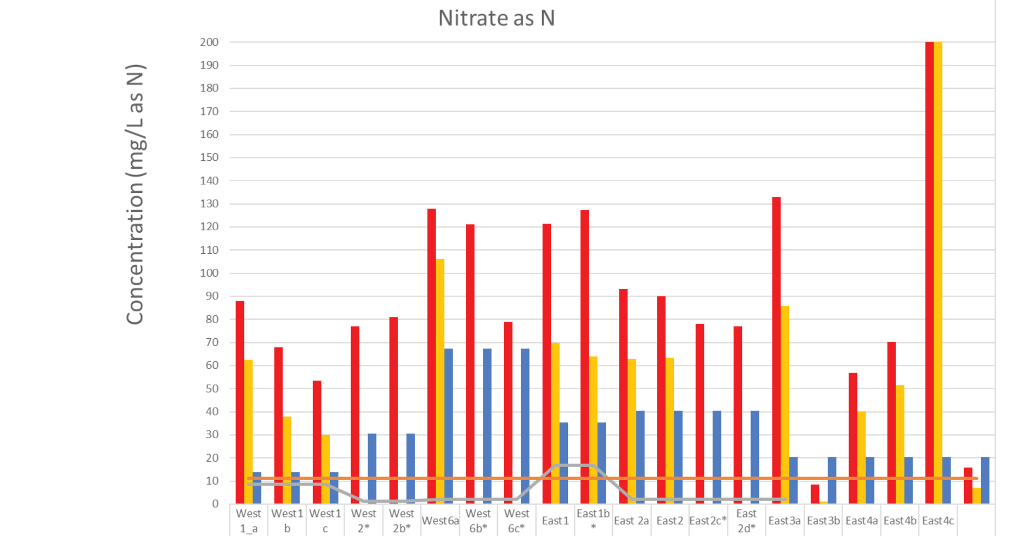
Figure 2 *Simplified geology of the Bushveld Igneous Complex, SRK Consulting*

This variability is also observed on a local scale, where groundwater quality varies significantly across the mine areas. This is probably due to the heterogeneity of the aquifers where the transmissivity of the aquifer is governed by the fracturing (orientation, spacing, connectivity etc.) present in the underlying lithologies.

Despite the data variance, it is possible to obtain an indication of the correlation between the tailings leachate concentrations (as in the penstock and/or return water dams) and the surrounding groundwater. The graphs below (Figures 3, 4 and 5) present a summary of the information collated as part of this study:

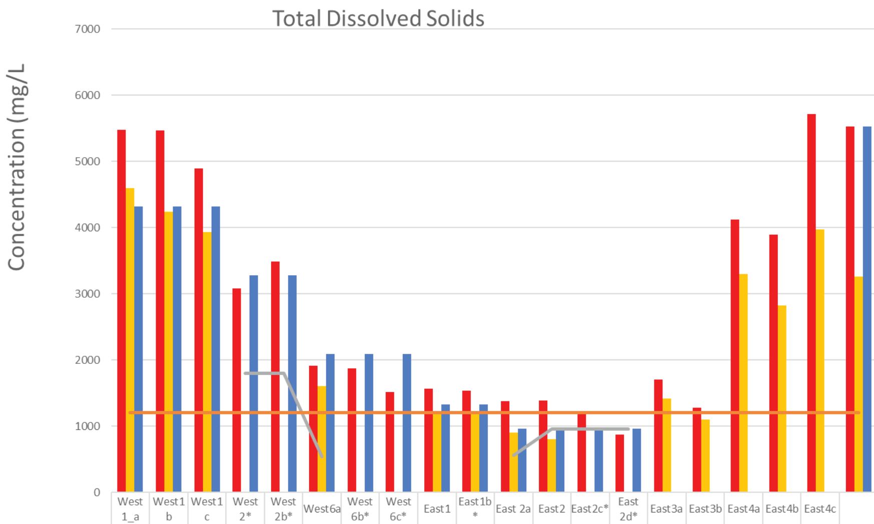
- Ambient groundwater quality for boreholes (as discussed above) where the median data is provided,
- Median and 95th percentile of time series data (where available) for the tailings leachate concentration. If only one data set was available, this was included as the 95th percentile and indicated as such on the sample ID
- The groundwater quality for boreholes within the vicinity of the TSF (indicated as affected boreholes) is represented by the 95th percentile.

The SANS 241-2015 drinking water quality standard is provided for comparison to the nitrate (11 mg/L as N) and TDS (1200 mg/L). If TDS was not reported, it was estimated from the result for electrical conductivity (EC).



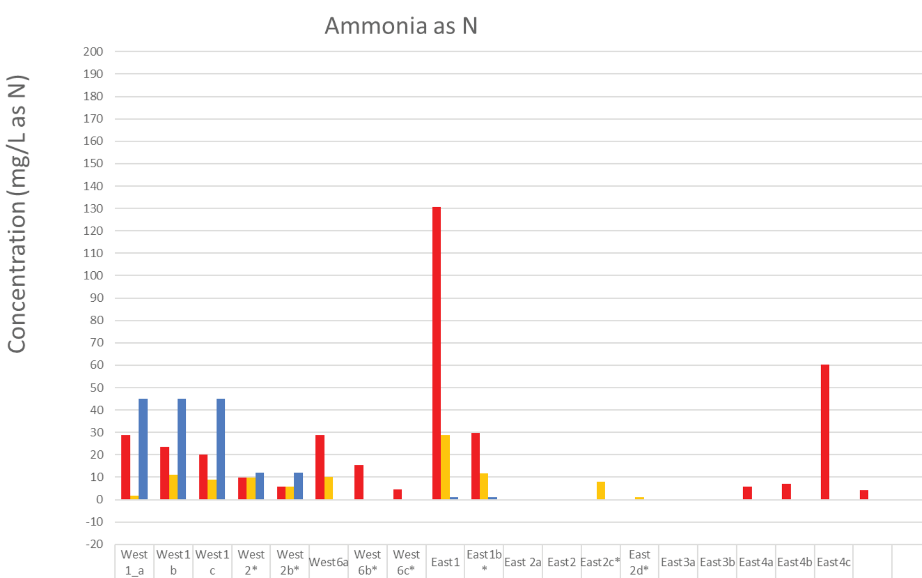
	West 1_a	West1 b	West1 c	West 2*	West 2b*	West6a	West 6b*	West 6c*	East1	East1b *	East 2a	East2	East2c*	East 2d*	East3a	East3b	East4a	East4b	East4c	
TSF leachate (95th percentile)	88	68	53	77	81	128	121	79	121	127	93	90	78	77	133	9	57	70	577	16
TSF Leachate (Median)	62	38	30			106			70	64	63	63			86	1	40	52	377	7
Affected Boreholes	14	14	14	31	31	67	67	67	35	35	40	40	40	40	20	20	20	20	20	20
Ambient (Median for Groundwater)	9	9	9	1	1	2	2	2	17	17	2	2	2	2	2					
SANS 241:2015	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

***Figure 3** Nitrate concentrations in the TSF leachate as compared to groundwater quality for selected mines in the Western and Eastern Limb of the BIC.*



	West 1_a	West1 b	West1 c	West 2*	West 2b*	West6a	West 6b*	West 6c*	East1	East1b *	East 2a	East2	East2c*	East 2d*	East3a	East3b	East4a	East4b	East4c	
TSF leachate (95th percentile)	5482	5471	4895	3080	3486	1917	1870	1520	1570	1539	1375	1387	1196	871	1709	1281	4125	3897	5721	5528
TSF Leachate (Median)	4600	4240	3935			1607			1214	1185	904	807			1412	1104	3302	2819	3974	3264
Affected Boreholes	4320	4320	4320	3279	3279	2090	2090	2090	1323	1323	958	958	958	958						5528
Ambient (Median for Groundwater)	673			1802	1802	541			1014		560	960	960	960						
SANS 241:2015	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200

***Figure 4** Total Dissolved Solids (TDS) concentrations in the TSF leachate as compared to groundwater quality for selected mines in the Western and Eastern Limb of the BIC.*



	West 1_a	West1 b	West1 c	West 2*	West 2b*	West6a	West 6b*	West 6c*	East1	East1b *	East 2a	East2	East2c*	East 2d*	East3a	East3b	East4a	East4b	East4c		
TSF leachate (95th percentile)	29	24	20	10	6	29	16	5	131	30							6	7	60	4	0
TSF Leachate (Median)	2	11	9	10	6	10			29	12			8	1			0	0	0	0	
Affected Boreholes	45	45	45	12	12				1	1	0	0	0	0							

Figure 5

Conclusion

Ammonia is often excluded from the monitoring analyses. As observed in Figure 4 above, ammonia should be included in the assessment. Higher concentrations were observed in the groundwater quality within the Western limb boreholes but this should be confirmed by expanding the study area and including ammonia in the monitoring program.

Nitrate concentrations in the datasets reported are generally lower in the groundwater samples than the tailings leachate. Conversely, the TDS reported in the boreholes is generally within a similar range to that reported in the groundwater.

Since nitrate is highly soluble and mobile in groundwater; the concentrations could be expected to be higher than are observed in this investigation. This preliminary comparison of the PGM TSF leachate quality to surrounding groundwater quality could imply that nitrogen is possibly being lost/assimilated within either the TSF, the soil matrix or within the aquifer itself.

This data suggests that further investigation is merited into whether there are naturally occurring processes within or underlying the TSF which could mitigate the potential for leaching/contamination of the groundwater. This information can then be used in the design and/or management of the TSF to reduce the impact of the TSF's to groundwater. It is noted, however, that this assessment doesn't include other leachables that could leach from the TSF.

Further interrogation would be necessary to confirm these findings and should include for example, an analysis of the sodium and chloride variance, whether aerobic or anaerobic conditions exist in or under the TSF, the age, design and operation of each TSF, rain events, chemicals used in the TSF slurry, type of tailings (UG2 versus Merensky or a mixture with slag or brine), vegetation on the TSF soil characteristics below the TSF, flow drivers, hydrogeology and hydrochemistry.

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