Hydrogeochemical investigations in the vicinity of the former Havelock asbestos mine near Bulembu, eSwatini (formerly Swaziland)

Christian Wolkersdorfer[1], Kagiso S. More[1], Elke Mugova[2], Nokuthula Nchabeleng[3] & Anna Johanna Sotiralis[4]

[1]SARChI Chair for Mine Water Management, Department of Environmental, Water and Earth Sciences, Tshwane University of Technology, Private Bag X680, Pretoria, 0001, South Africa

[2]Technische Universität Bergakademie Freiberg (TUBAF), Department of Hydrogeology and Hydrochemistry, Otto-Meißer-Bau, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany

[3]Sustainable Environment and Water Utilization Processes, Department of Chemical Engineering, University of Pretoria, Private Bag X20, Hatfield, 0028, South Africa

[4]91 7th Street, Menlo Park, 0081, South Africa

Extended Abstract

This study investigated the hydrogeological and hydrochemical conditions of the Tutusi catchment in Bulembu, eSwatini, two decades after the closure of the Havelock asbestos mine. The aim of the study was to evaluate the hydrogeochemical conditions of the waters around the abandoned mine, identify if the surface water in the area reflects the local geological conditions and to recognise potential asbestos pollution downstream the asbestos tailings.

Between 1939 and 2001, Havelock was one of the largest asbestos mines in the world, having produced around 1.8×10^6 t of asbestos. It was initially owned by the British company Turner & Newall (T&N) of Manchester and from 1978 until its closure by several consortia between T&N, the Swazi Government, private investors and at the end by Consolidated Mining Corp of South Africa (McCulloch 2005). In the past years, a mining company tried to get permission for remining the asbestos tailings for magnesium ore. Located about 20 km south-southeast of South African mining town Barberton, the mine consisted of an underground mine and an open pit which was backfilled with waste rock and asbestos tailings as mining progressively moved underground (Fig. 1). No mine cross-sections have ever been published or can be deduced from the available archive material, some of which is damaged. Currently, mine water flows untreated and uncontrolled at an average rate of 3136 L/min through a drainage tunnel located 1.1 km south of the main vertical shaft. From there it flows towards the Mzilanti and Nkomazana rivers and finally into the Komati river. Local drainage is facilitated by the Tutusi and Nkomazana Rivers, with the Tutusi River having been diverted into an easterly direction through a tunnel around the open pit. Approximately 2.5 km east of Bulembu, the Tutusi river flows into the Nkomazana river. Generally, the area is dominated by 50 ha of mostly unremediated asbestos tailings and waste rock piles (Fig. 2). After open pit mining ended, access to the underground workings was through several inclines. These were later replaced by a 504 m deep, four compartment vertical shaft which was constructed between 1961 and 1964 (Barton 1986). It allowed access to five working levels. Rocks in the Bulembu area belong to the Onverwacht Group of the Barberton Supergroup known for its oldest granite-greenstone belt, the Barberton greenstone belt, and range between 3470 to 3550 Ma years in age. Predominant rocks are highly metamorphosed serpentinite, quartzite, granite-gneiss, biotite-mica schists, dunite, banded iron formation, banded cherts, talc and diabase dykes (Hall 1931).

During its 62 years of operation, around 12.6 million m^3 of mine voids were created. Because roughly 80–90% of the mine is flooded, the mine pool comprises 8–11 million m^3

of mining influenced water (MIW), which would result in an average of 9.5 million m^3 of water. Based on the average flow rate of 3136 L/min, the mine could have been flooded within 5–6 years, resulting in a first flush period of 15–30 years (average 22 years). Consequently, the first flush, which according to Younger (2000) lasts 3 to 5 times the time it took to flood the mine, is already in the outgoing tail. This implies that the MIW quality will not further improve in the near future.

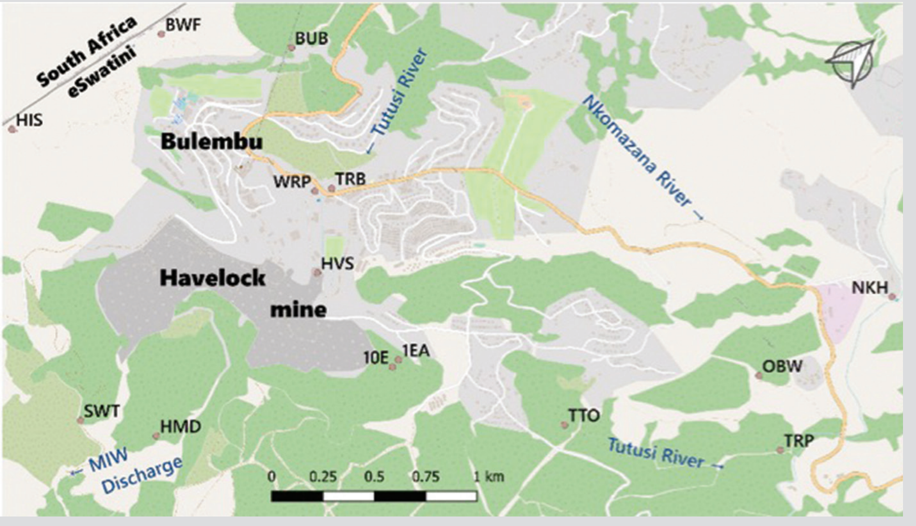

Figure 1 Location of Bulembu, the abandoned Havelock asbestos mine and the sampling locations in eSwatini (map source: OpenStreetMap contributors).

The investigation included on-site assessments at 12 surface and underground sites and the collection of 14 water samples for chemical and stable isotope analysis. An additional sample from the Bulembu drinking water works was included in the investigation. Flow measurements at seven sites and underground mine water tracer tests using NaCl and uranine were carried out. Using multivariate statistical analysis (PCA, cluster analysis) and PHREEQC modelling, three distinct water types were identified, with TDS being the most relevant parameter: 1) surface water with low mineralisation (approximately 40 mg/L TDS), 2) mining-influenced water from the Havelock mine pond with TDS of 230 mg/L and 3) waste rock pile leachate with a TDS of 400 mg/L (Fig. 3). The Appelo diagram, which plots electrical conductivity against the Mg and Ca concentration difference, and which allows water chemistry to be correlated with different rock types in a serpentinite environment, shows that schist and serpentinite dominate the water quality at Bulembu. All water types had an alkaline earthy, predominantly hydrogen carbonate composition with a predominance of Mg and hydrogen carbonate. It was not possible to establish a statistically significant correlation between the water chemistry and the Onverwacht or Moodies Group rocks. All surface water samples meet WHO standards for inorganic parameters, while the mine pool water shows elevated As concentrations and the tailings leachate elevated Cr concentrations compared to WHO limits. The mine pool seems to be well mixed as the water chemistry at the outflow and the 2 km apart 10E incline is similar. In addition, the low mean residence time of eight days between the injection point and the outflow, shown by the results of the uranine tracer test, indicates a fast mixing of the MIW in the mine pool (Fig. 4). The Tutusi River catchment, the upper Nkomazana catchment and downstream areas exhibited exceptionally pristine water quality 22 years after mining ceased. Despite the absence of chemical contamination in the water samples, individual

samples downstream the tailings contained detectable asbestos fibres, which will not cause health effects to the Bulembu population due to their distant location. Further tracer investigations are recommended to test the hydraulic connection within the flooded mine for understanding the mixing behaviour in the mine pool. In addition, continuous down-the hole on-site parameter measurements in the main vertical shaft should be measured to identify potential density stratification. Because the vertical shaft is blocked by a wire mesh at a depth of 100 metres this was not possible so far.

Based on the results of the investigation, the authors propose that this area be included in a trans-boundary national park alongside the Barberton Makhonjwa Mountains UNESCO World Heritage Site. To reduce environmental risks and protect the local population from asbestos exposure, the authors recommend that the tailings be remediated rather than remined for magnesium.

Figure 2 *Largely unremediated asbestos tailings and waste rock at the former Havelock asbestos mine, eSwatini*

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Remarks

This extended abstract is based on a manuscript that has been submitted for publication in an international peer-reviewed journal and has been modified accordingly.

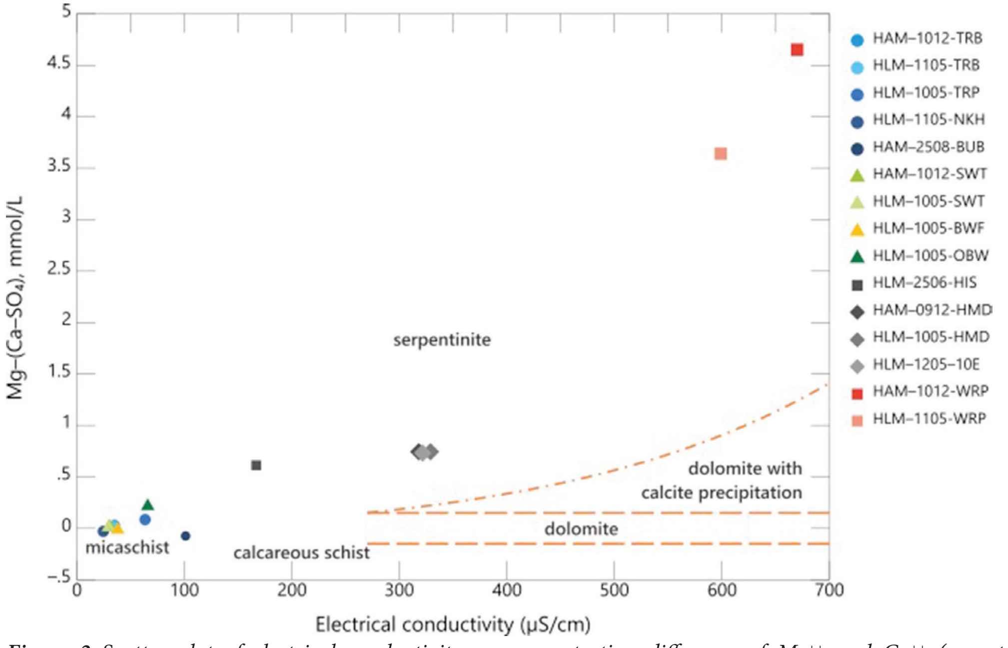

Figure 3 *Scatter plot of electrical conductivity vs. concentration difference of* Mg^{++} *and* Ca^{++} *(except gypsum* Ca^{++}*) of the water samples taken around Bulembu. Diagram type based on Appelo* et al. *(1983) for serpentinite rock based environments. The high pH values at Bulembu do not result from carbonate rocks*

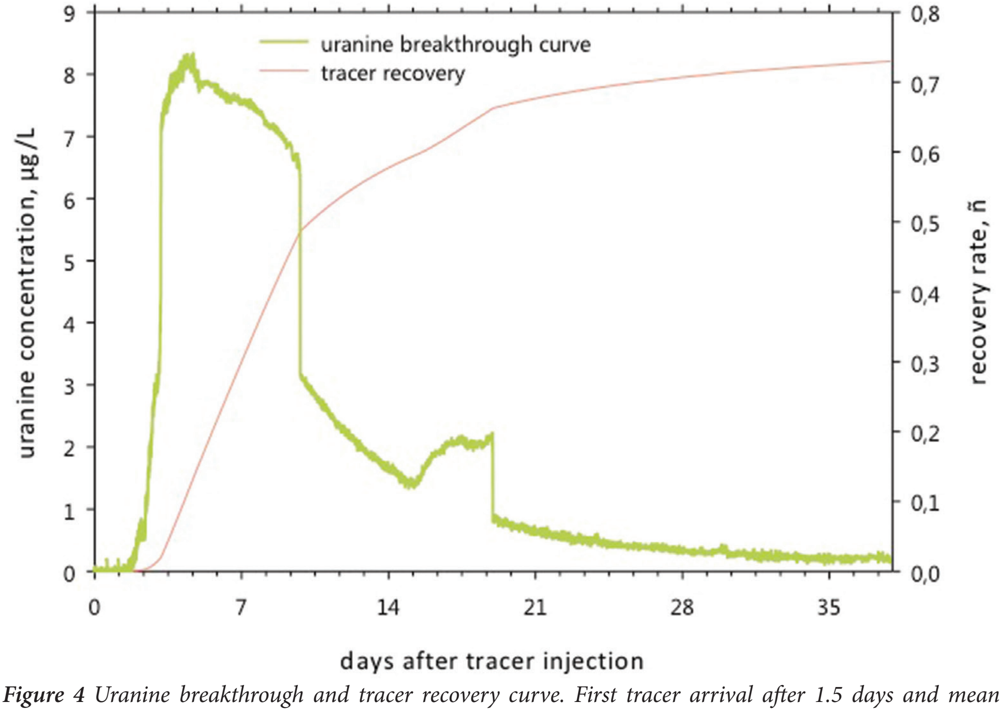

Figure 4 *Uranine breakthrough and tracer recovery curve. First tracer arrival after 1.5 days and mean residence time 8 days*

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