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Water quality in a mining and water-stressed region

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ABSTRACT

The aim of this study was to evaluate trends in water quality and mineral footprint along the catchment of a dam located in a coal mining area and water-stressed region. The study was conducted along the upper Olifants River, which is the catchment of Witbank Dam, in the jurisdiction of Emalahleni Local Municipality in South Africa. The study analysed water quality data over an eight-year period, obtained from the water authorities, and two-year data from the municipality. The analysis focused on water quality determinants such as pH, turbidity, total dissolved solids, sulphates and manganese. The analysis was conducted in line with South African National Standard 241:2015 on drinking water. By using allowable mineral concentration limits and thresholds, a statistical process capability index was calculated to determine the efficiency of controls on the potential of water being contaminated by land use and mining activities. It was found that the coal mining region was associated with adverse effects on the raw water quality. The paper presents a generic method in terms of a concentration-independent process capability index for monitoring deterioration of water across many water quality determinants. The results provide a warning signal to stakeholders. There is a time-critical and growing deterioration of water quality, which may pose health risks to consumers if there is no reduction in contamination sources or improved efficacy of water purification systems.

1. Introduction

An increase in population, urbanisation, industrial growth and agricultural activities has a significant impact on the demand of scarce water resources. Furthermore, sources of contamination within the water catchment area and the pipe water supply system present challenges to the supply of clean water. The transfer of contaminants from one water body to another is a major challenge (Li et al., 2017). According to Behmel et al. (2016) and Khan et al. (2013) the decline of water quality in rivers, lakes and groundwater has progressively become a global issue of concern. Northey et al. (2016) reported that mining operations have significant adverse water quality impacts. Mining is associated with risks such as: potential flooding of pits, uncontrolled discharges and catastrophic collapse of water pollution control dams. Gao et al. (2017) indicated that the coal mining industry is facing complex water resource management challenges such as avoiding non-compliant discharge of mine affected water. Traditional measures of developing water storage infrastructures are unable to entirely address the spill-over of worked water.

Innovative measures are required to mitigate the risk of unregulated discharges including water quality monitoring, which is the standardised measurement and observation of the aquatic environment used in order to define status and trends (Behmel et al., 2016). Water quality monitoring is a growing challenge in the 21st century since a large number of chemicals are used in our everyday lives and make their way to the water sources. Various water-polluting activities take place in the water catchments. Water contamination could compromise natural ecosystems that support human health, biodiversity and food production (Salem and Amin, 2012). Jadhav et al. (2016) noted that contaminants occur naturally or as a result of human-induced elements and can result in significant deterioration of water quality. According to Baptista and Santos (2016), monitoring plays a key role in understanding the anthropogenic impact on natural ecosystems, thus offering an important tool in the management of natural areas. In South Africa, the quality of water is monitored, measured and reported periodically in accordance with a drinking water quality

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standard (South African National Standard (SANS) 241:2015).

Mining poses a great risk for people accessing clean drinking water (Khan et al., 2013). The mining sector is one of the pillars of the South African economy. One challenge for the industry is acid mine drainage, which has the potential to decant into surface water sources. In South Africa, Emalahleni Local Municipal jurisdiction, in Mpumalanga, has a high concentration of coal mining activities. There are twenty-four coal mines active along the main water source catchment, as shown in Fig. 1. The catchment area is in need of diligent and effective water quality monitoring and purification to prevent potential health risks.

1.1. Mine waste water effluent

Acid mine drainage is a mine waste water effluent which is mostly generated from gold, coal and copper mining operations. It is characterised by low pH content and high heavy mineral content (Regmi et al., 2009). According to Mulopo (2015) acid mine drainage is also characterised by high total dissolved solids (TDS), high sulphates and high levels of heavy metals, particularly iron, manganese, nickel and cobalt. Acid water drainage occurs when mining operations associated with pyritic materials (iron disulphide) are exposed to oxygen and water. As a result, a reaction catalysed by bacteria occurs in water-soluble iron sulphates. Pyrites undergo oxidation in two phases, producing: (i) sulphuric acid and ferrous sulphate, and (ii) orange-red ferric hydroxide and more sulphuric acid. The generation of acid mine drainage was explained by Akcil and Koldas (2006).

Akcil and Koldas (2006) reported that chemical, physical and biological factors are important for determining the rate of acid generation. High permeability translates to high oxygen ingress, contributing to a high chemical reactivity. This reaction is accelerated increased by high temperatures. Bacteria generates rapidly under favourable environmental conditions associated with both pH and temperature. Bacterium accelerates the oxidation of sulphides of antimony, molybdenum, gallium, arsenic, copper, cadmium, nickel, cobalt, zinc and lead. The oxidation of sulphide minerals results in acid production. Water can serve as a medium of transporting contaminants. The broader sources of acid mine drainage are mine rock dumps, tailing impoundments, underground and open pit mine workings, pumped or nature discharge of underground water and diffused seeps from replaced overburden and rehabilitated areas. According to Brown (1993), an increase in sulphate content serves as an indicator for salinity. According to Van Zyl et al. (2001), Witbank Dam had a sulphate content of 20–40 mg/l prior to mining operations and this has since escalated to an average range of 120–160 mg/l. Their paper suggests an association between underground water contamination and mining activity.

1.2. Prior studies on the problem statement

Adeleke and Bezuidenhout (2011) reported that in South Africa, the required fresh water is limited and vulnerable in terms of availability, quantity and quality. The solution of water management requires improving on social and environmental conditions and using available technology to increase the accessible quantity of water. The Department of Water and Sanitation (DWS) has implemented an incentive-based programme (Blue and Green Drop) as a quality measure of the microbiological and chemical qualities of drinking water and effluent. Nkhonjera (2017) indicated that Olifants River had a decline in water availability due to

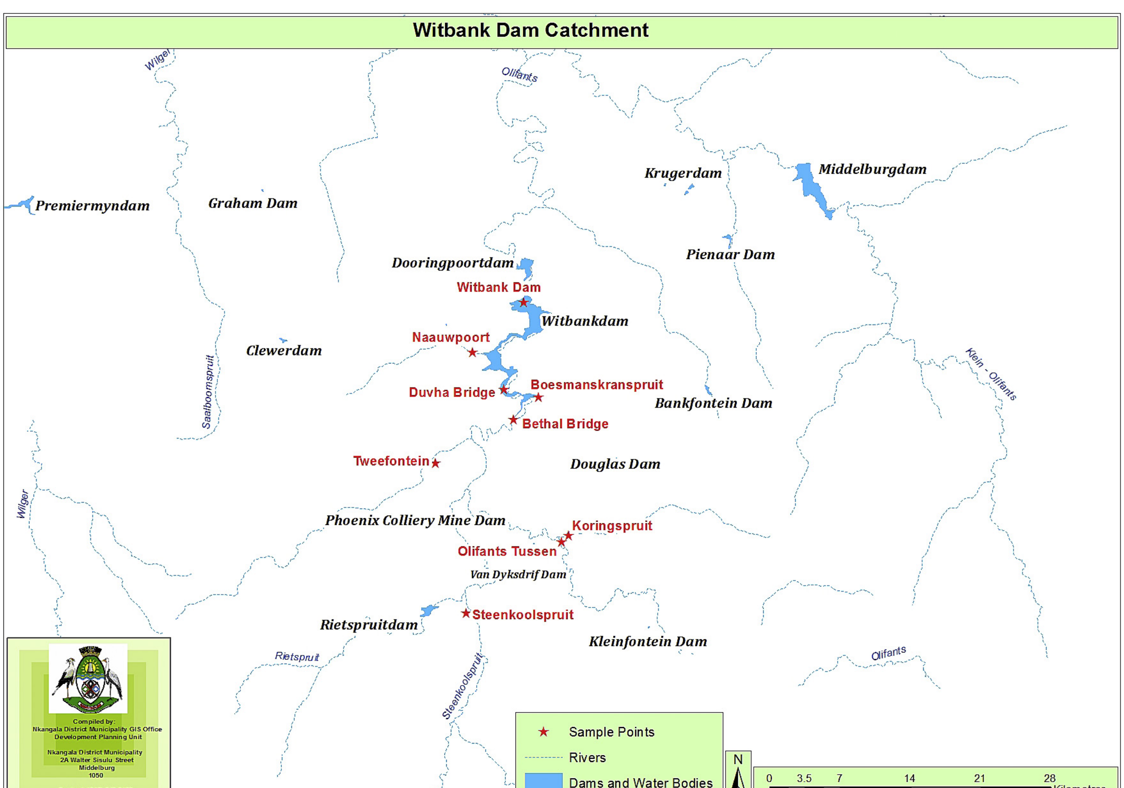

Fig. 1. Witbank Dam catchment indicating location of sampling station (Source: Nkangala District Municipality, 2017)