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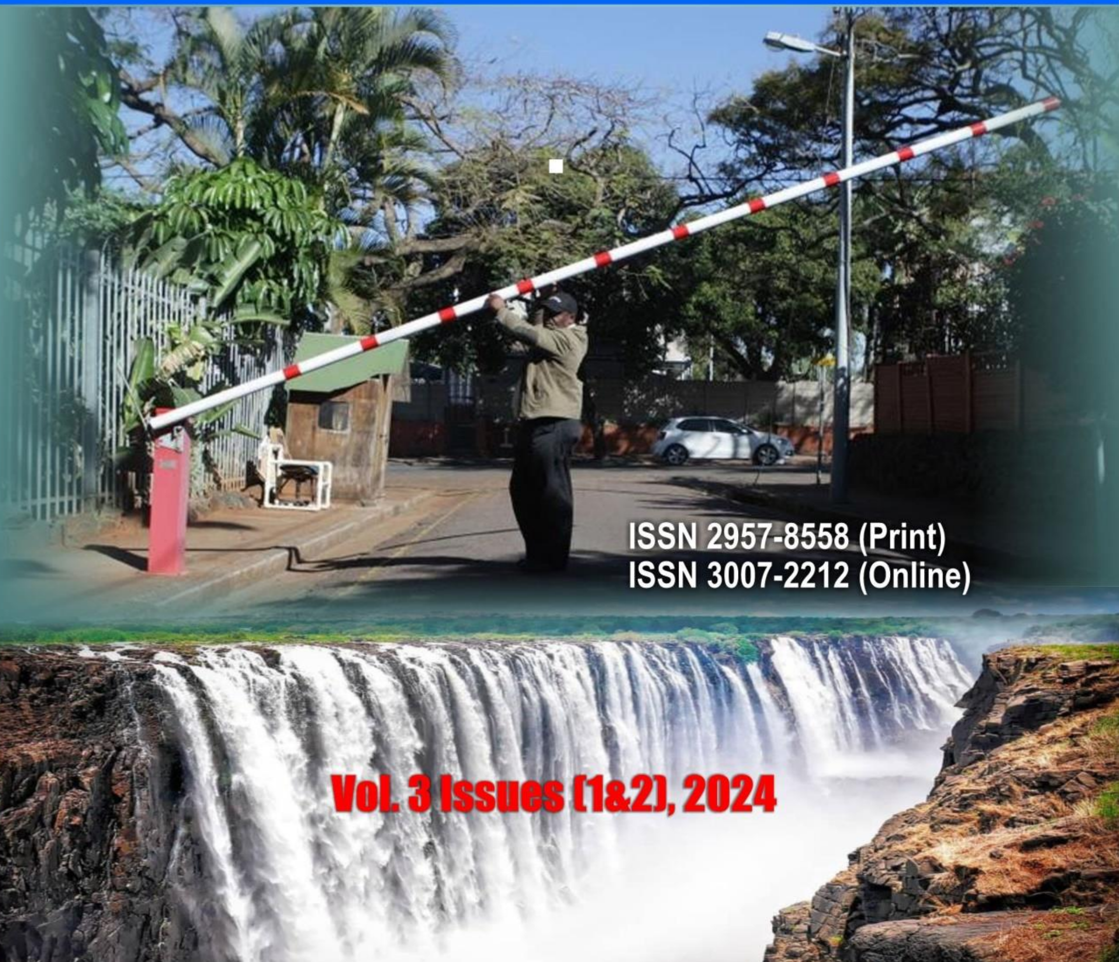
THE ZIMBABWE EZEKIEL GUTI UNIVERSITY JOURNAL
OF COMMUNITY ENGAGEMENT AND SOCIETAL TRANSFORMATION



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About the Journal

JOURNAL PURPOSE

The purpose of the *Ngenani - Zimbabwe Ezekiel Guti University Journal of Community Engagement and Societal Transformation Review and Advancement,* is to provide a forum for community engagement and outreach.

CONTRIBUTION AND READERSHIP

Sociologists, demographers, psychologists, development experts, planners, social workers, social engineers and economists, among others whose focus is on community development.

JOURNAL SPECIFICATIONS

Ngenani - Zimbabwe Ezekiel Guti University Journal of Community Engagement and Societal Transformation Review and Advancement

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SCOPE AND FOCUS

The journal is a forum for the discussion of ideas, scholarly opinions and case studies of community outreach and engagement. Communities are both defined in terms of people found in a given locale and defined cohorts, like the children, the youth, the elderly and those living with a disability. The strongest view is that getting to know each community or sub-community is a function of their deliberate participation in matters affecting them by the community itself. The journal is produced bi-annually.

Guidelines for Scholars for the Journal

Articles must be original contributions, not previously published and should not be under consideration for publishing elsewhere.

Manuscript Submission: Articles submitted to the *Ngenani - Zimbabwe Ezekiel Guti University Journal of Community Engagement and Societal Transformation* are reviewed using the double-blind peer review system. The author's name(s) must not be included in the main text or running heads and footers.

A total number of words: 5000-7000 words and set in 12-point font size width with 1.5 line spacing.
Language: British/UK English
Title: must capture the gist and scope of the article
Names of scholars: beginning with the first name and ending with the surname
Affiliation of scholars: must be footnoted, showing the department and institution or organisation.
Abstract: must be 200 words
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Italicise *et al., ibid.,* words that are not English, not names of people or organisations, etc. When you use several scholars confirming the same point, state the point and bracket them in one bracket and ascending order of dates and alphabetically separated by semi-colon e.g. (Falkenmark, 1989, 1990; Reddy, 2002; Dagdeviren and Robertson, 2011; Jacobsen *et al.,* 2012).

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DETERMINING THE SURFACE WATER QUALITY CHANGES INDUCED BY UNDERGROUND MINING IN GWANDA DISTRICT OF MATEBELELAND SOUTH, ZIMBABWE.

THOMAS MATINGO[1], RAMECK DEFE[2] AND IRONY MAZURUSE[3]

Abstract

The study engaged in an assessment of the implications of underground mining activities on the quality of surface water and its effects in Mtshabezi community Gwanda District of Matebeleland, South of Zimbabwe. The research adopted a mixed method approach that utilised both qualitative and quantitative approaches for in depth fact finding. The qualitative approach used depended on open ended questions, structured interviews, direct field observations while the quantitative approach used depended on closed ended questions, laboratory testing of water samples and use of statistical tools such as SPSS version 22.0 for data analysis. Water samples were collected to test for physiochemical parameters (temperature, pH, cyanide and concentration of Zn, Ni, Fe and Cu). The research identified the main pollutants in Mtshabezi River were caused by mining processes at Blanket mine and the main river contaminants were effluent deposited during and after gold processing is done through oxidation. It was observed that tailing dams are also a source of contaminating surface water because they contain effluents with un-extracted cyanide,

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mercury, sulphide, copper and iron among other chemicals that are used during blasting, gold extraction and processing. Results from the tests conducted show that nitrates ranged from 3.5 and 8.4 that is within the range of WHO guideline of 10mg/l. Iron concentration ranged from 0.2 to 7.3mg/l in all selected sites and this impacted on the lives of the people, their livelihoods, livestock and welfare. The study recommends regular monitoring of surface water sources undertaken by EMA and sub-catchment councils to ensure the quality of water is not compromised.

Keywords: *water quality; underground mining; pollution; surface water, community*.

INTRODUCTION

Mining has significant negative impacts on the quality of water in water bodies, both surface and underground water bodies (WHO, 2019). Underground mining can result in waste materials being carried into water sources (Dietler *et al*., 2021). Song *et al*. (2020) posit that underground mining includes human excavations beneath the ground's surface through shafts to search for, develop, or produce precious minerals. Hard minerals such as zinc, iron, gold, nickel, lead and tin can be excavated using the same various mining processes (Akter *et al*. 2016; Roy *et al*., 2019). The waste from mining activities contains poisonous substances that are harmful to wildlife and pollute water bodies. It causes a reduction of aquatic life and pollution to surface water sources because of chemical substances drained from the mining activities.

In North America, mining has resulted in long-term disturbance of aquatic and terrestrial habitats and water quality systems, with significant "off-site" repercussions, such as stream contamination (Patil *et al*., 2012; Haddaway *et al*., 2019). They extract desired minerals, heap leaching with acids using cyanide that has a significant impact on surface and groundwater. Failure of companies to comply with their mining plans in the United States has resulted in harming of aquatic life through erosion and sedimentation, dewatering wetlands, diverting and channelizing streams and contaminating surface water and aquifers with toxic chemical (Zibret *et al.*, 2018; Simonin *et al.*, 2021). Gold production in Sub-Saharan Africa has increased and it has been estimated that, Sub-Saharan Africa is contributing 35% of the region's gold (Chuhan-Pole *et al.*, 2017). Fianko (2021) postulates that, regardless of its contribution to gold production, mining has had a negative impact on Ghanaian and other countries' water bodies. Many rivers have been contaminated because of mining activities, with negative consequences for rural communities built along these rivers. River Birim in Ghana is one of the rivers impacted by the mining activities (Fianko, 2021). The River Birim has been contaminated by mining activities that has led to the loss of marine life and scarcity of drinking water in several villages along the river (Hadzi *et al.*, 2018). The rural communities that relied on rivers as a source of water faced serious health risks (Yankson and Gough, 2019).

Mater (2019) contends that mining activities in Rwanda's Burera produce effluent containing a variety of chemical pollutants, that degrade the quality of both surface and groundwater resources. The effect of degraded water quality is felt not only in the mine's immediate vicinity but also downstream of the mine. Waste rock dump effluent caused ARD into stream and river waters (Nahayo and Ntwali, 2017). Hirwa *et al.* (2019) suggest the use of lime materials and caustic soda to neutralise drainage and avoid the release of pollutants into water which that results in the lowering of pH in water.

The increase in underground mining activities has become one of the most serious problems on surface and underground water in

Zimbabwe (Arhonditsis, 2022). Underground mining activities in Gwanda accelerated the rate and degree of changes in the natural environment, through processes of blasting and drilling rocks that is done in the extraction of gold. Pollution of water sources by these mining activities has increased the threats to access clean water for domestic use at the household level. Underground mining in Zimbabwe has, however, proved to be one of the most serious problems affecting the quality of life of residents in the community. The study thus unpacks the multi-dimensional implications of underground water interacting with the communities.

PHYSICAL GEOGRAPHY OF GWANDA DISTRICT

The geographical coordinates of Gwanda District are 20º56´20.0´´S, 29º01´07.0´´E (Latitude: 20.938889; Longitude: 29.018611). As observed by Wolfram, A. (2020), the average elevation of Gwanda is 3,300 feet (1,006m) mean sea-level. The area under study is Gwanda District in Matebeleland South Province, Zimbabwe. Gwanda is located 134Kilometres (83miles), by the road, South East of the second largest city in Zimbabwe (UCZA, 2020). The district is approximately 11 000 km in length and is drained by two major rivers, the Tuli in the west and the Mzingwane in the east. The district is divided into four sub catchments (Shashe, Upper Mzingwane, Mwenezi and Lower Mzingwane) in hydrological zone B, one of Zimbabwe's six hydrological zones. Mtshabezi River is a tributary of the Thuli River in Southern Zimbabwe and it flows through Gwanda (Wardhani *et al.*, 2022). Gwanda district is in ecological region 5 that is characterised by prolonged hot summers and short cool winters. Gwanda receives rainfall that is less than 450mm. Gwanda is rather dry compared to the rest of the nation, making it vulnerable to drought, hence, the community relies on underground water and other surface sources for its existence. The map shows the geological and geographical location of the study site. The following is a graphic representation of Gwanda's location.

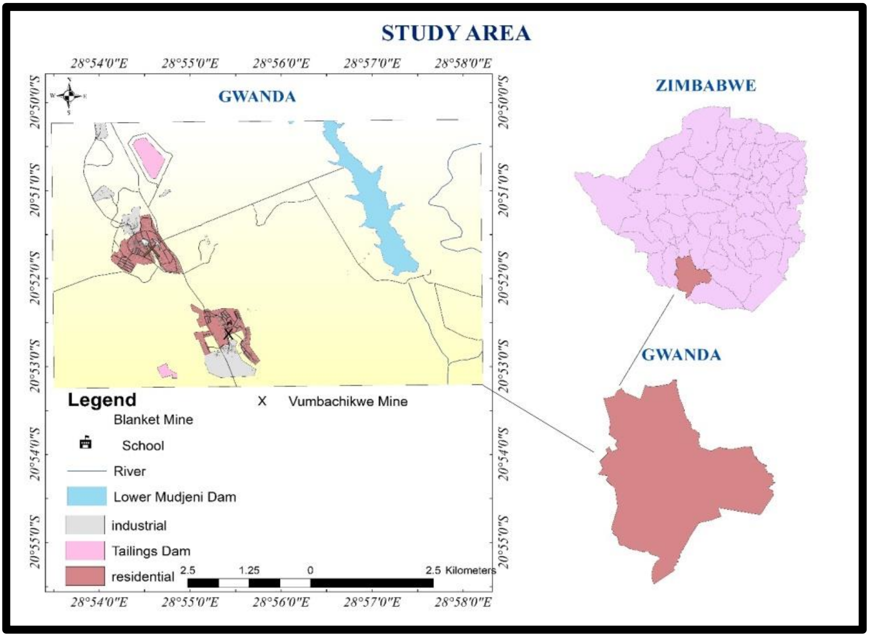

Figure 1: Map of Gwanda District (Authors, 2022)

The total population size of Gwanda district comprises 7380 males and 8069 females. Gwanda district has 10 wards under the rule of 10 councillors. It comprises both private and public schools, 5 primary schools, 2 secondary schools and tertiary (UCZA, 2020). Although Shona and Basuto people live in Gwanda, Ndebele is the language that is spoken by most of the population. It is mainly based in extensive type of farming and is suitable for extensive cattle ranching. The Municipality of Gwanda town argue that Gwanda is well known for its commercial and industrial activities. Its main economic activity is mainly mining of gold at Vubachikwe Mine, Blanket Mine, Jessie Mine and Freda Mine. The mines in Gwanda use water from the Mtshabezi River during their mining activities.

THEORETICAL FRAMEWORK

The research study was underpinned by the Integrated Water Resource Management (IWRM) theory propounded by (Giordan and Shar, 2014). IWRM's fundamental tenets are to manage water resources holistically across sectors and to guarantee broad participation in decision-making. The IWRM is 'a call to stop fragmentary approaches to water management and high-handed development decisions made for the benefit of a single user group or faction' (Giordano and Shah, 2014). It is promoted to implement a legal framework, to decentralise the decision-making and to promote economic and financial sustainability. Integrated Water Resources Management has evolved since the early thinking of the 1950s and was agreed upon and discussed in depth at the Water Conference in Mar del Plata in 1977 (Dietrich, Bogardi, dan Ralf and Ibisch, 2016). Integrated Water Resources Management (as observed by Global Discourse) is a Water Resources Management Process that integrates water resources with other related resources between sectors between regions sustainably without sacrificing the environment and is organised with a participatory approach. The theory provides the basis for understanding and analysing water as the key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. However, water is only one of several vital natural resources and water issues mustn't be considered in isolation. Mining operations require significant amounts of water for various purposes like ore processing, dust suppression and cooling.

Mining activities can lead to water pollution through the release of chemicals, heavy metals and suspended solids. This can contaminate water sources used for drinking, agriculture and ecosystems. Mining can impact water quality and quantity through activities like deforestation, land disturbance and the creation of mine tailings. This can have negative consequences for aquatic ecosystems and biodiversity. By incorporating mining into IWRM, we can: Promote

Sustainable Water Use: Mining companies can adopt water-efficient technologies and practices to minimise their water footprint. Reduce Pollution: Stricter regulations and effective pollution control measures can prevent the contamination of water sources. Enhance Environmental Protection: IWRM can help mitigate the environmental impacts of mining on water resources and ecosystems. Overall, including mining in IWRM is essential for ensuring the sustainable and equitable management of water resources, protecting the environment and supporting the long-term viability of mining operations. The IWRM requires coordination between sectors.

RESEARCH METHODOLOGY

The research adopted the mixed method research design. The research design enabled the researcher to become more knowledgeable about research methods appropriate for the subject (Cresewell and Cresewell, 2017). It aided in integrating the main components of the study in a cohesive and reasonable manner, confirming that the topic was properly addressed. The research design adopted has 2 main approaches namely quantitative and qualitative. The qualitative research allowed the researcher to study things in their natural form and to elucidate facts in terms of the target population's interpretations of the effects of underground mining on surface water quality. The qualitative approach depended on interviews, open ended questions and field observations. Quantitative approach used closed ended questions, water tests and use of statistical tests to analyse data. The research targeted 410 households in Gwake, Sigodo and Mtshabezi villages of Gwanda District who directly depend on Mtshabezi River water. These were targeted to obtain data on the risk of underground mining.

Key stakeholders namely the Ministry of Mines and Mining Development of Matebeleland South, Gwanda Municipality, Zimbabwe National Water Authority (ZINWA), The Sigodo, Mtshabezi and Gwake village leaders, were also targeted to provide detailed data concerning the impacts of mining of water in Mtshabezi River. A 20% sample frame was calculated from the target population (Depoy and Gitlin, 2005). Using a 20% sampling frame, 82 households were selected for the study. Systematic random sampling was adopted to distribute questionnaires in the three villages selected. With systematic random sampling, every 10th household was selected for the study. Selection of key informants for the interviews was done using the purposive sampling. The purposive sampling technique was used to select the Municipality of Gwanda personnel, Mzingwane Catchment council manager, Ministry of Mines and Mining development personnel, Blanket mine safety officer and village leaders' and ZINWA Officer.

COMMUNITY ENGAGEMENT IN WATER QUALITY SAMPLING

The field work modalities and water sampling involved members of the community in line with Katsanou and Karapanagioti (2016) water management framing. The research selected four sampling points along the Mtshabezi River to collect the water samples. Samples were collected in May 2022 and June 2022 from 4 sites that were randomly selected along Mtshabezi River, however the sampling sites were close to the mine to note the susceptibility to pollutants through leachates and seepage. From the sampling points that were selected by the research team, there was a control point (S1) for comparison with the other three samples that were affected by the mining activities. The second site was taken up stream (S2), the sample Whites Farm (S3) was also taken since there have been cases of livestock death due to the contaminated water and the last site was taken downstream (S4) as shown in figure 2. The control point was selected by the researcher for comparison with the other three to help in identifying the underground mining physiochemical parameters that are affecting the Mtshabezi water source. Sampling locations were selected by the researcher based on the characteristics of the water condition that is its colour.

SAMPLE SITES AND COORDINATES

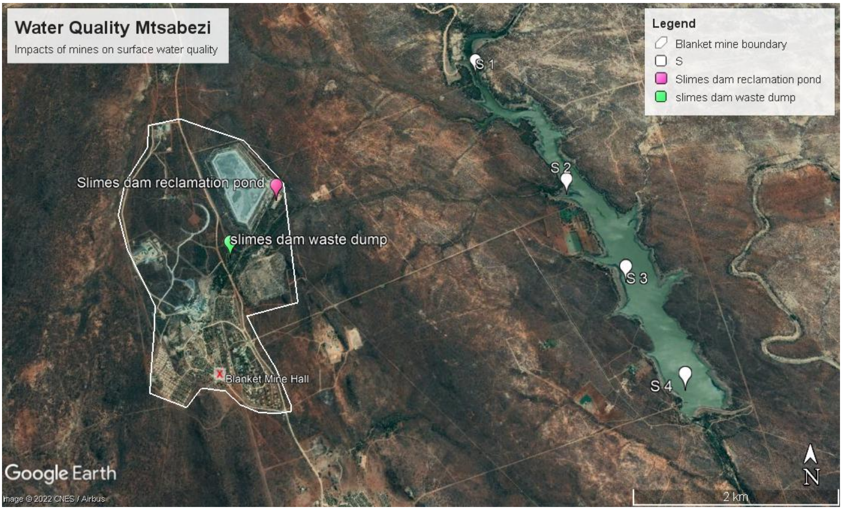

Figure 2: Map showing sampling site, Mtshabezi River and Blanket mine

The research used questionnaires composed of both closed-ended and open-ended questions. The questionnaires were distributed to the targeted villagers in Gwanda District that included Mtshabezi village, Sigodo village, Gwakwe. The questionnaire was alienated into three sections: A, B and C. Section A of the questionnaire contained personal information such as their gender, occupation, age and education level. Section B contained questions related to objective number one, that is to identify main pollutants Mtshabezi River and Section C contained questions related to objective number three, that is to assess the effectiveness of the existing policies, their implementation and performance over the past 10 years. Eighty-two (82) questionnaires were self-administered to the selected households in Gwanda district that use the Mtshabezi River. The research conducted interviews on a face-to-face basis with key informants who were selected using purposive sampling namely, Municipality of Gwanda Officer, ZINWA (Mzingwane catchment council), Ministry of mines and mining development, Blanket mine leaders and village leaders near the river. An interview guide was used to guide the discussion and the guide was designed as observed by specific objectives of the study.

FINDINGS

Data analysis is the process of gathering, modelling and analysing data to obtain insights that aid decision making (Calzon, 2022). Qualitative data were subjected to content analysis. Presentation and analysis of data are very essential in research because raw data are difficult to understand, hence data collected by the researcher was summarized, processed and analysed for better understanding. The data presentation requires skills and knowledge of the data. To reach a more meaningful and robust conclusion this research employed descriptive analysis to analyse the field obtained data. Data from the respondents of the questionnaires was analysed using descriptive analysis, thus all the quantitative data that was obtained was analysed using Statistical Package for Social Scientists (SPSS) technique as it was ideal for expressing a measure of central tendency. The analysed data were then presented on bar graphs, pie charts and tables using SPSS. Data analysis enabled the researcher to draw conclusions concerning the impacts of underground mining on surface water quality in Mtshabezi River. Narrative analysis was used by the researcher to analyse the responses from the interviewees. The analysed qualitative data were then presented on tables and graphs using Microsoft excel.

The researcher employed the Standard Operation Procedures (SOP) for Chemistry Methods (CM) and Biological Methods (BM) used at Environmental Management Agency Laboratory (EMAL) for laboratory analysis. The results were authorized to the Standards Association of Zimbabwe's standards SAZS 560:1977. The methods and water quality parameters used in solving the problem are presented in Table 3.4. When heavy metals were being tested in water, samples were digested with a 5ml di-acid solution (HNO_3: $HClO_4$: 9:4 ratio) on a hot plate. After that, 0.45 m filter sheets were used to filter the acidified water samples into 50 ml volumetric flasks. The concentrations of Zinc, Nitrates, Iron and Copper were examined using an inductively couple's plasma spectrometer. In essence, pH was determined using a pH meter. The tube was rinsed with the water sample after each test's procedure. To prevent skin, contact with the water, gloves were put on. To mix the samples, they were covered and inverted multiple times. The test tube was placed inside the Wide Range pH Comparator that was then exposed to light. The sample colour was compared to a standard colour and the pH value was determined. Turbidity was determined using the turbid meter. A control sample was prepared using recorded formalin and distilled water. Distilled water was used to dilute the waste water samples. The turbid meter was then used to measure and record the samples. Utilising UV-Vis Spectrophotometric SOP/CM23, nitrate levels were calculated. A conical flask with a ground glass stopper was filled with a sample of water. After bringing the pH down to 9.0 with 2.0 ml of the buffer solution and vigorously mixing the mixture for 5 minutes, 5.0 mL of a 20 percent naphthalene solution in acetone was added. Filtration on a glass filter was used to separate the generated solid mass that was made up of naphthalene and the metal complex. Water was used to clean the residue, that was then dried in the fold of the filter glass. The solid mass was dissolved in DMF (Dimethylformamide) and brought to volume in a 5.0 mL volumetric flask using the same solvent. The complex's absorbance was expressed in mg/L. Aliquots were tested daily over the duration of the test's seven working days and the mean value was calculated.

The research identified the main pollutants in Mtshabezi River caused by the mining practices being done. From the data that was collected, it was identified that the main pollutants in Mtshabezi River were caused by mining processes at Blanket mine. The data that was collected indicated that 26% of the respondents postulated that the main river contaminants were effluent deposited during and after gold processing was done through oxidation. Key informants that gave this detailed information were the workers who work at Blanket Mine and are familiarised with different activities. The laboratory analysts postulated that the processes involve biological oxidation where the sulphates that will be coating the gold will be removed through the use of different chemicals including mercury, sulphate and cyanide. After the process of removing ore the slurry is pumped into tailing dams, the effluent is seeped down contaminating groundwater that is the major source of surface water. 8% of the respondents confirmed that tailing dams are also a source of contaminating surface water. The reason could be due to the fact that they contain effluents with un-extracted cyanide, mercury, sulphide, copper and iron among other chemicals that are used during blasting, gold extraction and processing.

All this is deposited into the Mtshabezi River affecting the aquatic life that people from Gwake, Sigodo and Mtshabezi village depend on for enhancing their diet. This finding is in line with Makoni (2015) who also found out that, a major source of water pollution from mining activities is the tailing dams that pollute the environment through overflowing and evaporation causing acid rain which cycles back to the environment.11% of data collected from the field showed that, there are effluent control ponds at Blanket mine that have an impact on the river and the community at large. Through seepage, leaching and overflow during the rainy season it has been discovered that the ponds are contributing efficiently to pollution in the community and the river. This was also postulated by ZINWA personnel during an interview who confirmed that the soil from the surroundings was contaminated as observed by the test they conduct yearly and this was attributed to runoff that occurs during ponds and slurry dam overflow.

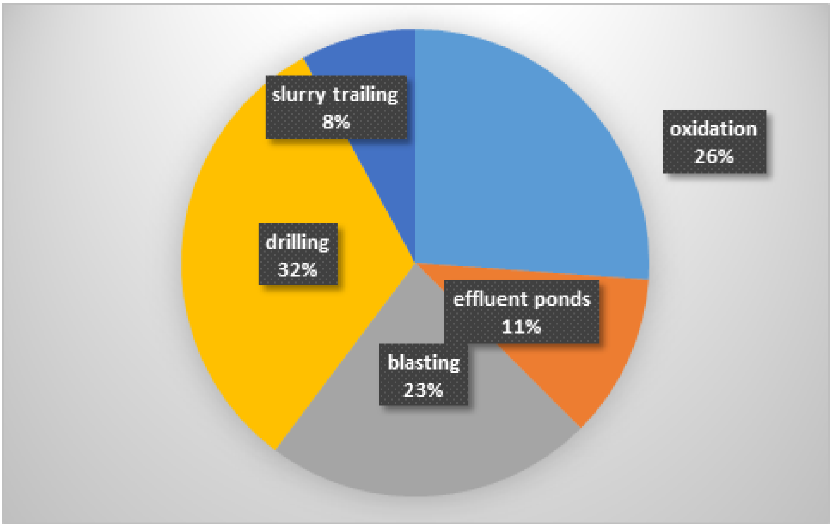

Figure 3: Sources of pollutants that affect Mtshabezi River.

Moreover, from the questionnaires that were collected it was discovered that 32% indicated that drilling was affecting water quality and 23% indicated that blasting also contributed to water pollution. There is contamination of water caused by the release or spillage of the blasting chemicals during the processes of drilling and blasting. Sulphides in the rock form sulphuric acid when they are excavated and exposed to water and air during mining. This acidic water then dissolves other hazardous metals in the surrounding rock. Runoff into river then occurs as the acid mine drainage is not controlled. This is in agreement with Bhebhe (2012) who attests to the fact that the process of rock blasting and rock drilling that is done in the extraction of gold alters the natural parameters in both the water and the soil such as pH levels, iron level and copper levels because of chemicals and explosives used during the process. Therefore, this supports the view that was generalised by the locals among the three villages about the two processes that resulted in the contamination of Mtshabezi River at large.

THE SOCIO-ECONOMIC EFFECTS OF MINING ON THE COMMUNITY

Although the mining industry remains the backbone of many economies in the developing world, there is a need for close monitoring of pollution of local rivers in general. The mineral mined is usually of higher economic value to the miner than its adverse impact on the surrounding environment. This accounts for why most mineral explorers pay little or no attention to the impacts on the environment. For a better future, in addition to developing more accurate monitoring models to detect potential pollution, it is important to prevent pollution before it occurs, preserving the health of residents and the sustainability of the environment and economic and social development. The research discovered that deleterious impacts, such as depletion of water resources by dewatering, or the pollution of surface watercourses by poor quality mine waters and mine waste leachates, demand careful scrutiny. Because some of these impacts can persist for centuries and even millennia after mine closure, routine approaches to the management of industrial discharges may not be wholly suited to the regulation of the impacts of mining on the water environment.

One of the interviewed key informants argue that, while a mine is operational the act of mining itself, that is, the sinking of shafts or open pits and the excavation of overburden and ore can have a significant impact on the natural water environment. This is because mining activities inevitably disrupt pre-existing hydrological pathways within the host strata.

While underground mining tends to have less conspicuous impacts on surface water features than an open pit surface mine has, all types of mining have the potential to directly disrupt groundwater flow (Booth 2002), that in turn can affect surface waters that are in hydraulic continuity with the affected groundwater systems. Agricultural production is also being compromised due to the negative effects of mining. The Agritex officer lamented that, there is lowering of the water table in areas where surface runoff was previously being generated saturated ground can induce further recharge to the subsurface (albeit this may locally be at the expense of wetland habitats). Water can also be induced to enter the subsurface directly through the beds of nearby streams and rivers. Therefore, it is against this background that food security itself is being compromised as irrigation will now going to be thing of the past as drilling of boreholes will become expensive because the water table will be deeper than before.

Another key informant argue that the diet of residents may be negatively affected as usually low-income people in rural areas of Zimbabwe depend on subsistence farming and some cannot even afford to frequently visit the butchery to buy meat or fish hence they rely on fishing in the local river Mtshabezi River. Many mine waters contain reactive metals and other components that consume oxygen. They can have very strong impacts on the biota, often resulting in a complete loss of invertebrates and fish in affected reaches. Besides these indirect effects, elevated suspended sediment loads have many direct effects on fish, principally due to clogging of the gills (limiting the flow of oxygen-bearing water over them) and abrasion of the gill epithelium (i.e. damaging the sensitive tissues that transfer oxygen to the bloodstream). Whilethese effects are only likely to be lethal to most adult fish where exposure to high sediment concentrations ($>1000 mg \cdot L^{-1}$) continues for several days (Hodgson 1994), much lower sediment concentrations ($90\text{-}100 mg \cdot L^{-1}$) acting over much shorter time periods have been found to reduce fish life expectancy and increase susceptibility to disease under laboratory conditions. In addition, the accumulation of sediments (including ochre precipitates) on biological surfaces such as gills, eggs or other tissues has frequently been reported to affect the survival, reproduction and behaviour of aquatic animals, for example suffocation of trout eggs, precipitates on the gills of *Ephemeropterans* and caddis larvae; Vuori 1995). For instance, the dewatering of an open pit limestone mine in Poland induced varying amounts of inflow from the Vistula River that accounted for as much as 80% of the total water made (Motyka and Postawa, 2000). In extreme cases, dewatering can lead to streams drying up altogether for part of their course and/or for part of the year. Examples of the latter are particularly common in the mining districts of Mediterranean Europe.

Table 2: Quality of water in Mtshabezi River

Parameter	Sample site 1	Sample site 2	Sample site 3	Sample site 4	WHO recommendations
Mercury Hg	<0.006	<0.006	<0.0069	<0.006	0.006
Iron Fe	0.2-1.3 (0.8 ±0.4)	2.2-4.7 (3.4±0.6)	2.5-3.9 (3.2±0.5)	1.6-7.3 (4.8 ±1.5)	0.3
Cyanide CN	<0.006	<0.006	<0.006	<0.006	0.006
Ph	7.2-7.4 (7.3±0.1)	6.6-7.2 (6.8±0.3)	7-7.4 (7.3± 0.1)	7-7.3 (7.2± 0.1)	6.5-8.5
Temperature	15.6°C	16.1°C	16.1°C	15.7°C	
Nitrates	0.8-9 (4.5 ±2.3)	3-8.7 (5.3 ±2.2)	2-3.9 (2.9 ±0.8)	1.8-8 (4.9 ±2.2)	0.01-2
Zinc	0.4-1.7 (1.6±1.0)	1.3-3.8 (2.0± 0.6)	1.8-3.7 (2.9±0.4)	0.8-3.8 (1.4± 0.3)	3-5

The range, average and standard deviation is based on 4 values for 4 sampling points

Nitrates concentration ranged from 3.5 and 8.4 and these were the WHO guideline of 10mg/l. Therefore, their impact on the environment was not vigorously felt as evidenced by the data collected from the questionnaire who never complained about stunt infant growth. From the data that was collected although the nitrates were within the recommended range it was observe how the concentration deviated from the control point. There was high concentration in site 2 and 3 and this indicated areas of direct deposit of contaminants and there was decrease in site 4 this might be due to water dilution from different tributaries. The effects of nitrates were not highlighted by respondents from the three villages that include slow infants' growth that is indicated by Moyo (2015) who postulated that high nitrates in a specific environment may affect the growth of infants.

Potential Hydrogen (pH) values from all selected points in the Mtshabezi River were ranging between 6.6 to 7.4 throughout the sampling period. This was presented on table 4.2 and figure 4.1. All the results that were obtained are within the recommended drinking water standards by WHO. Thus, the pH values for all sites are generally neutral showing that level of alkalinity and acidic contents were neutral. Water with high acidic levels will be <4.0. From the results that were obtained from the samples indicated that the aquatic life was living in a highly recommended environment. However, from the response of the residents it showed that there was a great change and possibly of self-purification of the water in the river as they had postulated that there was a massive death of aquatic life in the month of January and February 2022 and from the data that was provided by the laboratory analyst from blanket mine it showed that the water was highly acidic. This is further supported by Shoko (2002), who observe how alteration in acidic contents in the river can result in a massive death because aquatic lives took time to evolve and adapt to the alteration hence massive death can be encountered in the early period. Therefore, because of the high death rate of the aquatic life the mine was suspended from using the river source of water neither depositing its effluent in it. Therefore, when samples were collected during data collection indicated that there was low pH showing that the mine was complying with the recommendation that was set against it.

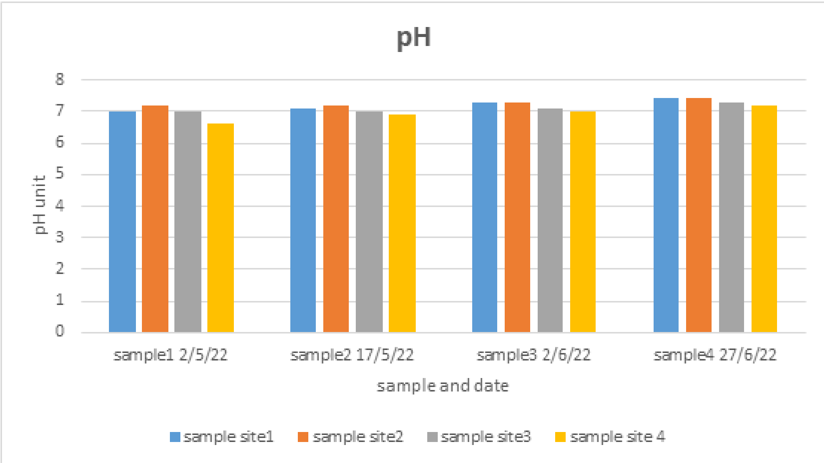

Figure 4: pH level deviation across 4 sites in Mtshabezi River from 02 May to 27 June 2022

Iron concentration ranged from 0.2 to 7.3mg/l in all selected sites as presented on table 4.2 and fig 4.2. From the data that was collected only 20% is within the range and limits that was recommended by WHO that is 0.3mg/l and this was found in sample site 4 that were located downstream of Mtshabezi River. Low levels of iron were scientifically proven to be a result of natural river self-purification and dilution since it was on the downstream and most tributaries will be joined there. This is further supported by Nkuli (2008), who observe how at the downstream of a river there are a high number of tributaries that make the waters less polluted as they are frequently diluted. High level of iron in site 2 and 3 was maybe because of direct deposition from the mine and also because of its near proximity to the mine. Iron in site 1 that is the control point was slightly lower than that in site 2 and 3 this is because there is limited mine effluent deposition into the environment.

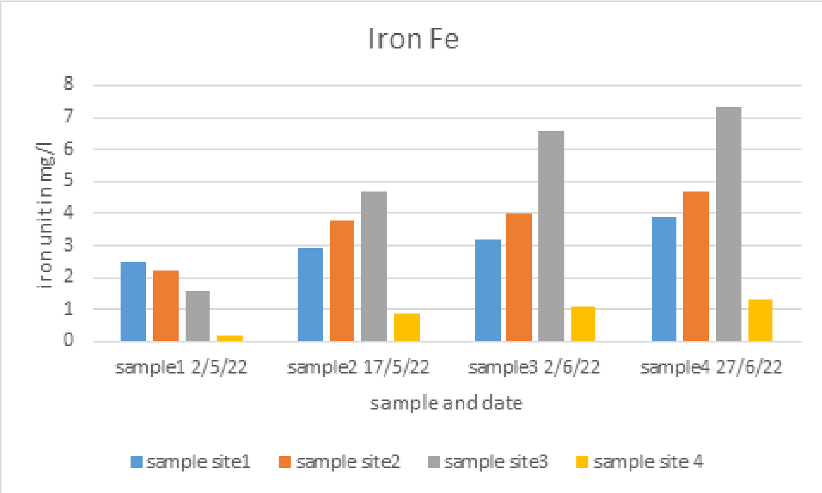

Figure 5: Iron, Fe level deviation across 4 sites in Mtshabezi River from 02 May to 27 June 2022

The level of zinc concentration in Mtshabezi River was ranging from 0.4 to 3.8mg/l as shown in figure 4.3 and table 4.2. The ranges of zinc concentration were the limits of WHO guideline of 1-5mg/l. The control point (sample site 1) that was located in the upper stream measures low volumes of zinc compared to other sites. This indicated that Blanket mine activities seriously influenced and impacted Mtshabezi river water chemistry that later impacted the locals and the surrounding environment. This is further supported by Nkuli (2008) who postulates that mining activities that involve galvanising releases high levels of zinc that poses dangerous threats to the environment and this was the case with Gwanda District. The researcher found high volumes of zinc in site 2 and 3 and there was a decrease in site 4, the control point that was site 1 had the lowest of them all showing that there was no contamination. High concentration of zinc posed a serious threat for the survival of different species that depend on a certain environment. This was in agreement with Murwira *et al.* (2014) who sated that high concentration of zinc poses serious threat to the survival of aquatic life. This was further evidenced by the information that was obtained from the questionnaire that were distributed and interviews conducted that highlighted that in January 2022 and February 2022 103 cattle died and massive aquatic lives and gastric, nausea and headaches that were complained by the locals in Gwake, Sigodo and Mtshabezi villages.

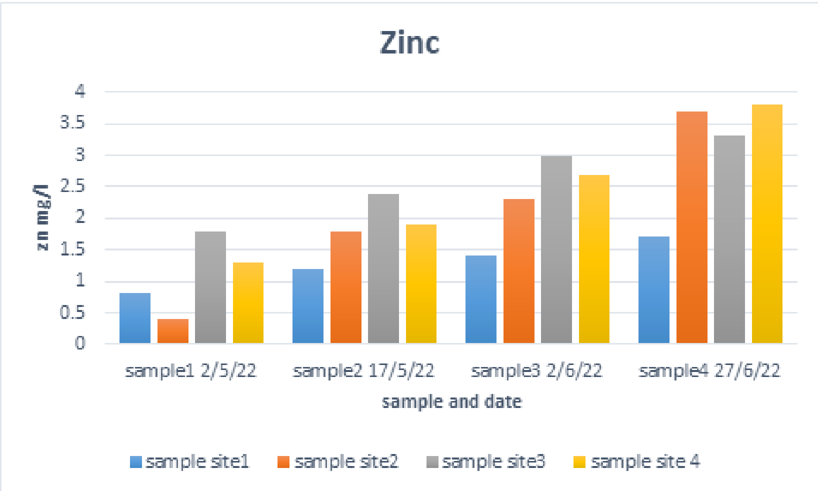

Figure 6: Zinc level from 02 may to 27 June 2022

The concentration values of mercury and cyanide elements were generally low in water. The levels of potential heavy metals mercury and cyanide were the method detection limits of <0.006mg/l by using Inductively Coupled Plasma Optical Emission Spectrometer (ICP), the reason for these elements being low could be because the mine was not frequently using these elements more frequently as compared to the others. However, in site 3 there was an increase in mercury level this was because of gold panners that were found in the area along the river.

EFFLUENT CONTROL PONDS RESULTS ANALYSIS RESULTS

Slimes dam reclamation pond and slimes dam waste dump are Blanket mine effluent control ponds that are standing water bodies. The chemical concentration in these ponds exceeds WHO recommended limits for effluent discharge. These ponds were considered as heavy rains might influence the discharge into Mtshabezi River. However, the results that were obtained after the experiments showed that they did not serve their purpose of reducing the level of direct effluent discharge into the environment.

Table 3: Effluent control ponds

Parameter	Slimes dam reclamation pond	Slimes dam waste dump pond
Ph	7.1-7.8 (7.4 ±0.2)	3.8-6.9 (5.1±1.1)
Temperature	22.5-26(26 ±1.2)	23.6-28 (26 ±1.2)
Nitrates	4.9-8.4(6.3 ±1)	3.5-7(4.7 ±1.2)
Cyanide	<0.006	<0.006
Iron	5.4-6.7(6 ±0.5)	2-12.5(8.5 ±36)
Mercury	<0.006	<0.006
Zinc	4-12.6(8.2 ±4)	9.3-28(18 ±6)

pH concentration range 3.8 to 7.8, this is a significantly 6.5 to 8.5. This was also influenced by runoff effluent that include frothier, potassium amyl xanthate all this are used in the recovery of gold from the sulphide. Iron concentration ranges from 2.0 to 12.5 mg/l in all effluent ponds' points. The results obtained were over the expected WHO limits of 3mg/l. The major reason being the ponds are in contact with trailing storage facility in the mine that constitute heavy metals. This affected greatly the aquatic behaviour when directly discharged. Iron existence is influenced by pH and oxidation reduction. Moreover, zinc concentration range between 4.0 to 28mg/l in all ponds and all the values of zinc concentration are limit recommended by WHO guideline. From the information that was obtained from data collection it was observe how zinc was from decaying carbon zinc discarded batteries. This is further supported by Lennech (2004) who observes how discarded batteries affect the environment through pollution of the soil and water by increasing the already existing heavy metals that later affect survival of different species. It was seen that all effluent ponds had exceptionally high concentrations of all elements investigated with exception to mercury, cyanide and nitrates that were found to be the method detection limit of <0.005 mg/l. High concentrations of these parameters could have an impact on surface and groundwater system if management strategies are not established. Nitrates concentration ranged from 3.5 and 8.4 were within range of WHO guideline of 10mg/l therefore their impact to the environment were not vigorously felt.

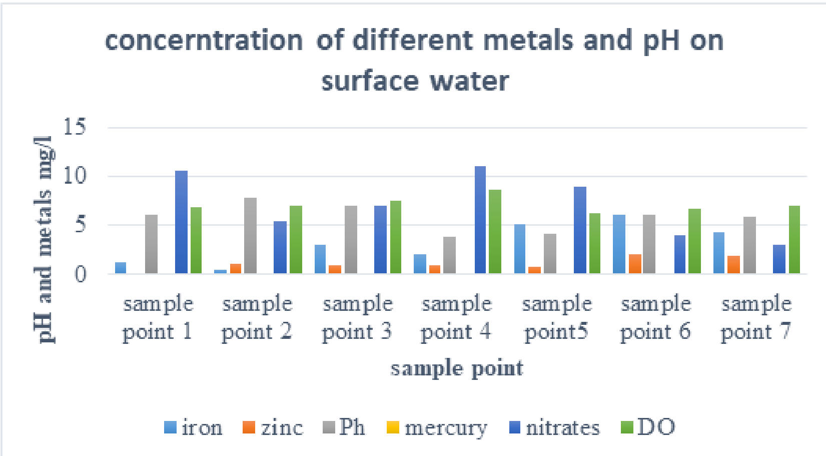

Figure 7: Concentration of different metals

TOWARDS A FRAMEWORK TO ENHANCE WATER QUALITY INDUCED BY UNDERGROUND MINING

To achieve a zero-harm environment, environmental management is a crucial component that should be taken into account and improved. The inclusion of local stakeholders is one of the most effective and crucial actions to be taken in terms of environmental management

(Gerasidi *et al.*, 2009). Stakeholder involvement is acknowledged as a key component in the successful execution of water management strategies, particularly when attempts are made to address competing and conflicting needs in regions susceptible to water scarcity. A deeper knowledge of the various parties with an interest in water management is made possible by including stakeholders. Feresu (2010) argues that those who purposefully or unintentionally pollute the environment should face consequences. The polluter pays principle can help to improve this. The Water Act of 1998 and Environmental Management Act of 2002 requirements, that noted the application of the polluter pays principle can manage the discharge licenses and the environmental charges based on the volumes and quality of the effluent released to the environment by a specific individual, further support this. As failing to comply with the rules will result in harsh penalties and fines, this will reduce the pollutants emitted into the environment. Additionally, improving the currently in place environmental management tools that regulate water might help prevent the discharge of chemicals into the environment that might contaminate it.

It is advised that metals be precipitated out of the effluent of the control ponds to lessen their mobility through seepage. In order for the effluent from the ponds to leave with low concentrations of metal solids, it was also advised to build additional ponds with adequate retention durations that can boost the removal and retention of metals. Nkuli (2008) claims that acid mine drainage and low pH in Effluent Control Ponds are caused by the weathering of sulphides. Liming techniques and caustic soda can be used to neutralise the drainage and prevent the discharge of pollutants from the sulphides.

In accordance to the objectives of the national poverty relief strategy, miners should get education on the effects of heavy metal pollution.

This supports both the National Strategy for Growth and Poverty Reduction and the MDGs for environmental sustainability. The mine should make sure that there is absolutely no contamination of surface water that comes from the mining site. To determine the various tolerance levels of aquatic species found in the river, a study on species diversity is advised in the study region. Most of the contaminants analysed had high concentrations in the river that could be hazardous to aquatic life.

Moreover, there should be specific statutory instruments that monitors use of highly toxic metal by farmers and toxic substance released by miners. Feresu (2010) opines that this will further support requirements of EMA chapter 20:27 in section 140 that manage hazardous waste that affect the environment. It will be under these regulations that no person will generate, store, sell, use, discharge hazardous waste to the environment except under licence. Therefore, this will enhance environmental protection. There should be enhancement of the Environment Impact Assessment for every project that is further supported by Bond (2010) who posited that, enhancing environmental impact assessment of every project undertaken in a specified area is an essential tool that help manage the environment as far as the release of contaminants into the environment is concerned. This will make it easier to pinpoint environmental problems and suggest alternatives for a current project. In addition, environmental legislation should be properly implemented and followed up on to promote effective environmental conservation. The Environmental Management Act, Chapter 20:27, Section 140 and the Statutory Instrument 7 of 2007 support each other in regulating waste. Therefore, fines should be implemented as necessary to prevent endangering the environment.

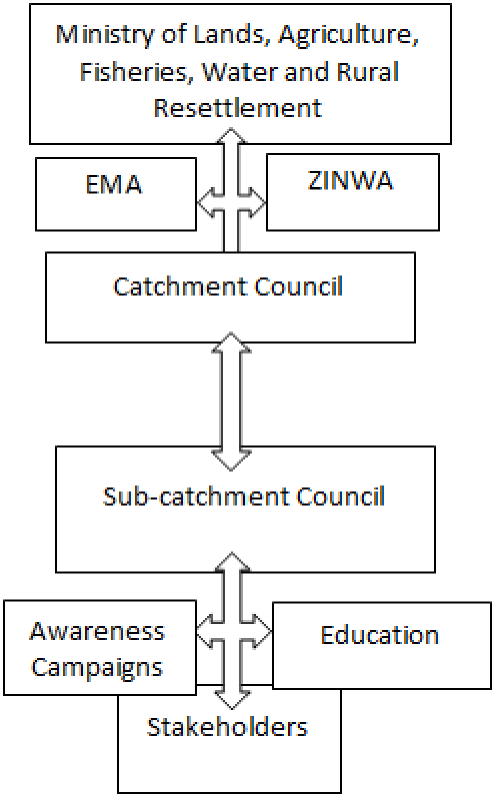

Figure 8: Framework on Water Quality Management

CONCLUSION AND RECOMMENDATIONS

It can be concluded that the main pollutants in Mtshabezi River result from the effluent deposition during and after gold processing is done, the process of blasting and drilling rock done in the extraction of gold that alters the natural parameters (pH, iron level and copper levels) in both the water and soil and through the processes of seepage, leaching and overflow pollution occurs in the community and the river. The researcher assessed the physiochemical parameters of water quality in Mtshabezi River. Results show that the physiochemical parameters that had a negative impact on water included iron that ranged from 0.2 to 7.3mg/l in all selected sites, from the data that was collected only 20% was within the range and limits that was recommended by WHO that is 0.3mg/l, high level of iron in site 2 and 3 was because of direct deposition from the mine also because of it near proximity to the mine. The level of zinc concentration also had a negative impact on the Mtshabezi River. Zinc was ranging from 0.4 to 3.8mg/l of zinc concentration that is the limits of WHO guideline.

The effectiveness of the existing policies, their implementation and performance over the past 10 years was also assessed in this research. Results from the data collected show that Blanket mine is no-longer following some of the policies put across by EMA, this is evidenced by the presence of huge mountains of mine tailing that contain toxic contents affecting water quality, lack of analysis to enhance improvement on the level of contamination done by mine effluents that are discharged into the environment and lack of enforcement and enhancement to reach the required WHO guidelines for drinking water. 22% of the respondents also observe how EMA lacks consistency on enforcing laws that protects the environment that has resulted in the continual of pollution levels in Mtshabezi River.

A framework of water quality management that can be employed to reduce the impacts of underground mining on surface water quality of Mtshabezi River was also developed. Stakeholder participation must be embraced to improve environmental management, stiff penalties and fines for those that intentionally and non-intentionally pollute the environment must be put in place and enhancement of the already existing environmental management instruments that govern water. Education of miners on the effects of heavy metal pollution, there should be specific statutory instruments that monitor the use of highly toxic metal by farmers and toxic substances released by miners and there should be proper implementation and follow up of environmental legislation to enhance proper environmental conservation.

Blanket Mine is recommended to build more ponds with sufficient retention durations to improve metal removal and retention so that the effluent from the ponds can have low amounts of metal solids. Education of miners on the effects of heavy metal pollution in relation to the national poverty relief strategy goals must be done by EMA, ZINWA and Catchment councils to reduce heavy metal pollution on surface water. Specific statutory instruments that monitors use of highly toxic metal by farmers and toxic substance released by miners must be put in place by EMA to help in reducing the rate of surface water pollution.

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