

BINDURA UNIVERSITY OF SCIENCE EDUCATION
DEPARTMENT OF NATURAL RESOURCES MANAGEMENT

*AN ASSESSMENT OF IRON (Fe), ZINC (Zn) AND LEAD (Pb) POLLUTION IN
MAZOE RIVER.*



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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS OF THE BACHELOR OF SCIENCE HONOURS DEGREE IN
NATURAL RESOURCES MANAGEMENT.**

30 MAY 2026

Makaza.

Student's signature.

Date: 18 September 2026

Supervisor's name. Mr. W. Mhlanga

Supervisor's signature:

A small, square image showing a handwritten signature in blue ink on a light blue background. The signature is stylized and appears to be 'W. Mhlanga'.

Date: 18th September 2026

Chairman's signature:

Date:

Dedication

I dedicate this dissertation to Makaza family

Acknowledgements

I give gratitude to God for the wisdom through the course of this project. It was through the involvement, continuous support and encouragement of several people that made the completion of this dissertation possible. I can do all things through Christ who strengthens me.

Firstly, I'm grateful to my academic supervisor Mr. W Mhlanga for his assistance and supervision he gave during my project accomplishment.

Also, my gratitude goes to Bindura laboratory assistance Mr. Richakara who helped me throughout sample preparation and analysis process, I will forever appreciate for the help they gave.

Lastly, my gratitude goes to my friends and family they supported me in every way throughout the project.

Abstract

This purpose of the study was to assess heavy metal contamination in Mazoe River, Mashonaland Central Province, Zimbabwe with a focus on Iron (Fe), Lead (Pb) and Zinc (Zn). Water samples were collected from three sites, site A representing upstream, site B representing near the mine and site C representing downstream sections of the river during the wet season of January to February 2026. The results showed a clear spatial variation in metal concentration across the study area. Iron was the only metal that exceeded the WHO and EMA guideline value of 0.3mg/l at all three sites with the highest concentration of 14.9994 at site B. Lead was not detected in any of the samples while Zinc remained below the recommended limit of 3.0mg/l at all sites but with a highest level of 0.1301mg/l. The high concentration levels of Iron suggest that mining activities, especially acid mine drainage and mine runoff, are the main sources of pollution in the river. Lead and Zinc did not cause harm immediately in the water this shows that Mazoe River is under pressure from mining-related contamination. The findings of the study conclude that improved water control, regular water quality monitoring and seasonal sampling are needed to protect rivers and the communities that depend on it.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Mazoe River (Zimbabwe)—A major water system in Mashonaland Central, the Mazoe River experiences significant environmental risk emanating from significant mining operations. Gold and pyrite mining, as well as agricultural practices, have gradually come to dominate the catchment area of the river, exposing it to risk of heavy metal contamination in the aquatic environment (Ravengai et al., 2005; Mandizha et al., 2023). Research by Ravengai et al. (2005) found that the Iron Duke Pyrite Mine has a notable impact on water quality and aquatic organisms in the Mazoe valley, with acid mine drainage contributing to elevated metal concentrations in both the Yellow Jacket River and downstream waters. Results also found deteriorating water quality correlated with declining aquatic biodiversity, indicating negative impacts of mining-related pollution on river ecosystems. Furthermore, Nyamadzawo et al. (2007) reported only slight improvements in groundwater and river water quality following the rehabilitation of sulphate mine dumps, indicating that contamination problems may persist despite some remediation efforts.

Mazoe catchment continues to be affected by mining and agriculture as recent studies show. Mandizha et al. (2023) found that the Upper Mazoe River is affected by gold mining and farming inputs with trace elements found in the entire river system. Runoff from mining operations flows into nearby rivers and dams, significantly elevating heavy metal concentrations and damaging aquatic ecosystems (Kanda et al., 2017). Also, Mandizha et al. (2024) presented trace metal speciation trends of Mazoe Dam, confirming that pollutants from the catchment continue to move

downstream. Increased concentrations of heavy metals could potentially be dangerous for the local inhabitants if these contaminants were to enter the food chain, (Munene et al., 2023).

Iron is a major contaminant in the Mazoe system, as pyrite-rich waste and acid mine drainage can move large amounts of dissolved iron into water bodies. Geochemical processes control acid mine drainage (Magombedze 2006) and metals can be released after the waste deposit of the mine (particularly in semi-arid environments where surface exposure of the waste rock remains). Magombedze et al. (2006) confirmed that mine runoff in the Mazoe valley can impair the surface water quality by producing acid and mobilized metals. These processes are significant in the case of Mazoe Mine, which allows surface runoff, seepage, and tailings to carry iron into the river. In many mining areas, iron becomes an indicator of pollution because the local geology contains excess iron, and iron can readily be moved under acidic conditions.

Zinc and lead are equally important because they can be toxic at high concentration levels and may accumulate in sediments and aquatic organisms even when the concentration appears low. Lead can remain in the environment and pose health risks through drinking water, irrigation and food chains. Zinc is essential in small amounts but can be harmful when its levels are excessive. In the Mazoe River catchment, these metals may enter the river through mine runoff, waste seepage or sediment transport. They may also be influenced by agricultural and land use activities in the surrounding area (Mandizha et al., 2023; Charema, 2024).

The Mazoe River has an economic and social significance as a source of domestic water, for irrigation, water for livestock, and as an aquatic habitat; anything which can affect the quality of the water will affect both the ecosystem and the livelihoods of the water users as a whole. Farmers relying on the river for farming will be at risk of exposure to heavy metals through irrigation water and contaminated sediments, and these metals will impact food safety and crops. This necessitates investigating not only the water but also the broader environmental processes that regulate metal transport and storage. Seasonal change also matters since wet season dilution and dry season concentration can influence the observed levels of heavy metals in the river (Nyamadzawo et al., 2007). Mazoe River catchment has been affected, but the presence is due to the contamination by mining that continues to impact (Charema, 2024; Mandizha et al., 2023; Mandizha et al., 2024; Ravengai et al., 2005). Metals, namely Iron, Zinc and Lead, are also essential determinants of environmental stress in the river.

1.2 Problem Statement

There is a threat of Iron, Zinc and Lead pollution due to activities at Mazowe Mine along the Mazowe River. This study seeks to assess Iron (Fe), Zinc (Zn) and Lead (Pb) in Mazowe River water and compare them with the WHO and EMA permissible limits.

1.3 Justification

Mazowe River is a water source for domestic use, irrigation, and livestock, but it is exposed to contamination from mining activities around Mazowe Mine. Therefore, there is a need to assess the concentrations of iron, zinc, and lead in the river water and compare them with the WHO and EMA permissible limits to determine whether the water is safe for use.

1.4 Objectives

- To determine the concentration of Iron, Zinc and Lead in surface water samples.
- Comparing the measured concentrations of Iron, Zinc and Lead with World Health Organization (WHO) and Environmental Management Agency (EMA) permissible limits.

1.5 Limitations

The number of sampling sites was limited to three which may not fully capture the variation along the entire river. Also, this study only covered the wet season over a two-months period, leaving seasonal variations in metal concentration unnoticed. Laboratory and financial constraints limited sample numbers, and only three heavy metals were analyzed. Lastly, the instrument detection limit may also explain the zero readings for lead, warranting confirmation with more sensitive analytical methods.

CHAPTER 2: LITERATURE REVIEW

2.1 Mining activities as source of pollution

Mining is one of the key human-induced causes of environmental degradation across all geographical regions, yet it is the main engine of economic development. Waste materials from mining activities including tailings, waste rock and effluents — can carry hazardous metals. Examples of such metals are Iron (Fe), Zinc (Zn) and Lead (Pb) in gold mining operations which are mobilized during ore extraction and processing (Akcil and Koldas, 2006).

Mining plays a role in river pollution by several processes. Rainfall-induced surface runoff has allowed loose particles and dissolved metals from exposed mine dumps to enter water near their sites. Tailings storage facilities can leach heavy metals into both surface water and groundwater. Improper disposal of mine effluents may directly discharge contaminants to rivers (Simate and Ndlovu, 2014).

The metal enters aquatic systems primarily by means of acid mine drainage (AMD). When sulphide minerals are exposed to air and water during mining, they oxidize and produce sulphuric

acid. Metal solubility increases in acidic environments (Akciil and Koldas, 2006), which increases mobility into nearby waters. Since heavy metals can dissolve or accumulate in sediments, once released into rivers, they might persist for long periods (Nriagu, 1990).

An association of long-term mining sites in Zimbabwe has led to elevated heavy metal concentrations in a number of rivers proximate to mining sectors. For instance, the Mzingwane River downstream of mining activities has been accompanied by increased metal concentrations (Mapira, 2017). The nearness of the Mazoe Mine to the Mazoe River, consequently, raises concerns about potential river system contamination by similar processes

2.2 Effects of Fe, Zn and Pb in the aquatic environment

Iron serves to sustain a critical environment, but high levels can lead to detrimental consequences. Iron (or too much) in water can cause water discoloration (reddish-brown), it also promotes the multiplication of bacteria, and it decreases the penetration of light to photosynthesis in aquatic plants. Iron reduces feeding activity, impairs growth and disrupts reproduction in fish (Grosell et al., 2007). High levels of Iron in water also cause direct damage to fish gills, thereby increasing stress and impaired respiratory performance (Val et al., 2008).

Zinc also plays a vital role in aquatic life as an essential micronutrient, but high concentrations can cause toxic effects. Zinc excess disrupts metabolic processes of fish and invertebrates resulting in decreased growth, impaired reproduction and increased mortality (Davies et al., 2009). The bioavailability of zinc is influenced by the pH and hardness of water (Bortey-Sam et al., 2015). Bioavailable zinc concentrations below 100 µg/L can be tolerated by most aquatic organisms; toxicity will be expected when the concentration exceeds this limit (Davies et al., 2009).

Lead is particularly hazardous to aquatic systems because it has no known biological function and is highly toxic even at low concentrations. Lead can accumulate in sediments and enter the food chain through benthic organisms. Chronic exposure may result in behavioral changes, gill damage, reduced growth and decreased survival rates (Nriagu, 1990). Because heavy metals are not biodegradable, they bioaccumulate and bio magnify along trophic levels, posing long-term ecological risks (Tutu et al., 2008).

2.3 Effects of Fe, Zn and Pb on human health

Zinc is only needed in trace amounts with regard to immune and enzyme support; but excessive zinc intake may result in nausea, vomiting, stomach cramps and other symptoms, and blocking other minerals such as copper (World Health Organization, 2017).

Lead is one of the most dangerous types of heavy metal for people to be exposed to. It accumulates in bones and other soft tissues and has terrible neurological effects, especially on children. Chronic

exposure to Lead causes cognitive impairment and developmental delays (Lanphear et al., 2005). Even low concentrations of Lead in drinking water are considered unsafe due to its cumulative toxicity (World Health Organization, 2017).

Lead exposure has also been linked to higher levels of blood pressure and cardiovascular diseases in adults (Weaver et al., 2018). Moreover, long-term exposure to lead via the ingestion of water can contribute to kidney impairment and renal dysfunction (Weaver et al., 2018).

While iron is necessary for oxygen transport in the blood, excessive consumption can cause health issues. High iron intake could cause gastrointestinal problems and in at-risk individuals, haemochromatosis, which damages the liver, heart and pancreas (World Health Organization, 2017). The current WHO guideline on the amount of iron in drinking water is 0.3 mg/L (World Health Organization, 2017).

2.4 Frameworks governing water quality in Zimbabwe

In Zimbabwe, water quality is regulated under the Environmental Management Act [Chapter 20:27]. It is a legal provision concerned with environmental protection and pollution control (Environmental Management Agency, 2015).

Water pollution is regulated by the Environmental Management Agency (EMA), which enforces compliance and issues effluent discharge permits (Environmental Management Agency, 2015). Zimbabwe National Water Authority (ZINWA), in terms of the Zimbabwe National Water Authority Act [Chapter 20:25] (Zimbabwe National Water Authority, 2013) is responsible for water resources, monitoring water quality, and regulation of water abstraction.

Zimbabwe harmonizes water quality parameters and guidelines to meet the international standards provided by the World Health Organization (WHO) regarding drinking water quality (World Health Organization, 2017). These guidelines dictate the limits of allowable heavy metals (including Iron, Zinc and Lead) to safeguard human health.

Mining operations are regulated under the Mines and Minerals Act and mining companies are required to undertake Environmental Impact Assessments and meet effluent discharge standards to control pollution (Environmental Management Agency, 2015).

2.5 Studies on Iron, Zinc and Lead Pollution in Water

Several studies globally and regionally have documented heavy metal contamination in water bodies near mining areas. Akcil and Koldas (2006) reviewed the global impacts of acid mine drainage and documented elevated concentrations of Iron, Zinc and Lead in waters near sulphide mines.

In Africa, Simate and Ndlovu (2014) highlighted the widespread occurrence of heavy metals in mine-affected waters. In South Africa, Tutu et al. (2008) reported elevated Iron, Zinc and Lead concentrations in rivers impacted by gold mining activities.

Heavy metal contamination of various river systems was reported in Zimbabwe. Ncube et al. (2017) found that water from dams downstream of areas of effluent discharge exceeded WHO safe limits for drinking and agricultural use. Utete et al. (2013) investigated Cadmium, Copper, Iron, Lead and Zinc in the Gwebi River and reported seasonal variations in metal concentrations. Similarly, Madebwe et al. (2017) reported elevated lead concentrations in groundwater in the Upper Sanyati Catchment during the dry season.

Mapira (2017) reported elevated Lead and Zinc concentrations in the Mzingwane River downstream of mining operations, exceeding WHO guideline limits. These findings demonstrate that mining activities significantly influence heavy metal contamination in Zimbabwean river systems.

Cadmium, Copper, Iron, Lead, and Zinc were determined in water in the Gwebi River, a major tributary to Lake Manyame. Utete et al. (Aug 2013) sampled four selected sites in the wet (December-March) and dry (April-November) seasons and metal concentrations were analyzed by flame atomic absorption spectroscopy (FAAS).

Madebwe et al. (2017) studied metal concentrations in groundwater resources in Upper Sanyati Catchment, Midlands Province, and the time-weighted groundwater mean maximum Lead concentration was recorded during the beginning of the dry season in May in sub-region 2, while the lowest Lead values were recorded in February during the wet season in sub-region 2.

CHAPTER 3: METHODOLOGY

3.1 Study Area and Sampling Site Description

The study will take place along the Mazoe River in the vicinity of Mazoe Mine, Zimbabwe. Three sampling sites are selected to represent varying degrees of mining influence. The river is influenced by upstream, which is likely to be in its natural condition (upstream), midstream, directly influenced by mining activities and downstream, which is likely to be disturbed by mining activities, making it suitable for assessing heavy metals pollution (Iron, Lead and Zinc).

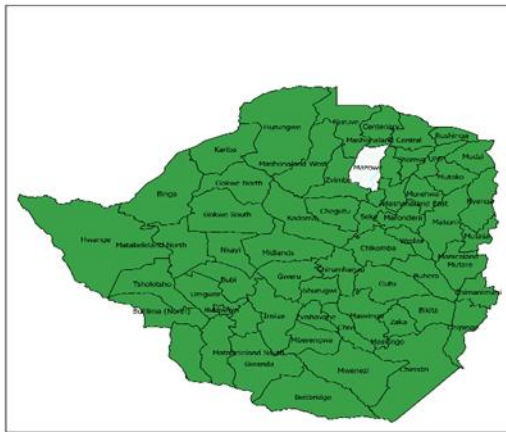


Figure 1 shows map Zimbabwe where Mazoe is located

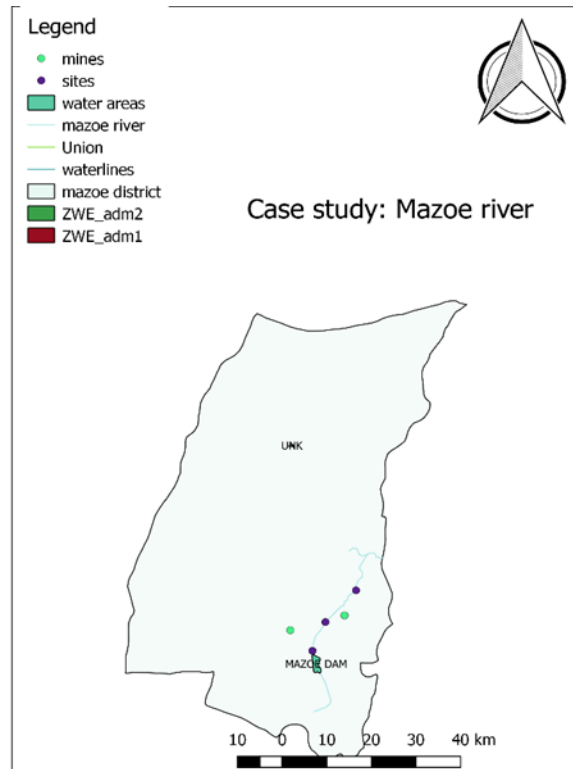


Figure 2 shows the Mazoe River and where the samples are collected

- Site 1 – Upstream

Located upstream of Mazoe Mine, where no direct mining activity occurs, represents natural background metal levels. Coordinates: (28.79 E: -19.14 S).

- Site 2 – Midstream (Point of Impact):

Positioned adjacent to the Mazoe Mine discharge area, where mining effluent is likely to enter the river. Coordinates: (27.79 E: -20.18S).

- Site 3 – Downstream (Recovery/Accumulation Site):

Located several kilometers downstream of Mazoe Mine to capture cumulative contamination effects. Coordinates: (27.45E: -21.12S).

3.2 Sampling Design and Frequency

To ensure suitable time-based representation and statistical reliability, sampling will be conducted three times during the study period. Water samples were collected every two weeks over a period of two months, covering the wet season of February and March. During each sampling trip at each site, three (3) independent water samples will be collected. In total per trip, 3 sites $\times$ 3 samples = 9 samples. Over the entire study (3 trips): 9 samples $\times$ 3 trips = 27 water samples

3.3 Materials and Equipment

- Pre-cleaned polyethylene bottles (500ml)
- Griffin beakers assorted sizes or equivalent
- Ripped Watch Glasses
- Graduated cylinder
- Electric hot plate (Kjeldal digestion with a tray of sand)
- Atomic Absorption Spectrophotometry (AAS) machine
- Lab coats
- GPS device
- Sample labels and permanent markers
- Field notebook
- Gloves (latex)
- Qualitative Filter papers
- filter funnels
- Reagents
- Distilled water
- Reagents for water quality analysis
- Standard solution of Fe, Zn, Pb
- Hydrochloric acid (HCl)
- Nitric acid (HNO₃)

3.4 Sampling Procedure

All water samples will be collected using standard methods consistent with heavy metal monitoring protocols and in line with the sampling procedures.

Samples labelling

- I. Site name
- II. GPS coordinates
- III. Date and time
- IV. Sample replicate number

- Polyethylene bottles will be prewashed with de-ionized/distilled water.
- At each sampling point, bottles will be rinsed three times with river water before sample collection
- Surface water samples are to be collected at approximately 20-30 cm below the water surface

AAS Preparation—

- A well-mixed samples of 100ml were transferred to a beaker
- added 2ml of nitric acid and 5ml of hydrochloric acid.
- The samples were covered with a ribbed watch glass and heated on a steam bath,
- hotplate at 90 to 95°C.



CAUTION: The samples were not boiled.

Figure 3 Kjeldahl digestion with samples

the beaker walls and watch glass with reagents, water, and filtered the sample silicates and other insoluble material.



Figure 4 Kjeldahl digestion with a tray of sand

- The beaker was removed when the volume was 15 -20 ml and allowed to cool and wash down

- Then adjusted to the final volume to 100ml with reagent water including the blanks. Blanks were carried out throughout the entire sample preparation and analytical process. These blanks were important in determining if samples were being contaminated or not.
- Water samples were analyzed in duplicate for each metal concentration to improve the accuracy of results. Conducted using air/acetylene flame atomic, Hollow cathode lamp and Absorption Spectrophotometry (AAS). The water samples were then analyzed for total heavy metal amounts in an Atomic Absorption Spectrometer



Figure 4 Atomic Absorption Spectrophotometry (AAS)

- Water samples will be analyzed for Iron (Fe), Zinc (Zn), and Lead (Pb) using Atomic Absorption Spectrophotometry (AAS) and then compared with standards of the concentration results and those of the World Health Organization and Environmental Management Agency limits.

CHAPTER 4: RESULTS

Table 1:Concentration of Iron (Fe)

SITE	A	B	C
MEAN (mg/l)	5.6507	14.9994	12.25195
SD	0.0554	0.4525	0.2198

Table 2: Concentration of Lead (Pb)

SITE	A	B	C
MEAN (mg/l)	0	0	0
SD	0	0	0

Table 3: Concentration of Zinc (Zn)

SITE	A	B	C
MEAN (mg/l)	0.0983	0.10985	0.1301
SD	0.0345	0.01785	0.0143

CHAPTER 5: DISCUSSION

The study shows the difference in heavy metal concentrations across the three sampling sites: Site A (upstream), Site B (close to Mazowe Mine) and Site C (downstream). Iron was the only metal that exceeded the WHO and EMA permissible limits in all three sites. The mean concentration of Iron (Fe) was 5.651 mg/l at Site A, 14.999 mg/l at Site B and 12.252 mg/l at Site C which are above the WHO and EMA aesthetic guideline of 0.3 mg/l (WHO, 2017; EMA, 2007). Lead (Pb) was not found in all three sites (0.000 mg/l), placing it within the WHO and EMA maximum acceptable concentration of 0.01 mg/l. Zinc (Zn) concentrations were low, 0.098 mg/l at site A , 0.110 mg/l at site B and 0.130 mg/l at site C, which is below the WHO and EMA aesthetic guideline of 3.0 mg/l.

Iron concentration was very high at site B, which is the closest to Mazowe Mine and is the discharge area, with $14.999 \text{ mg/l} \pm 0.453$, which is above the WHO aesthetic guideline value of 0.3 mg/l. Site C $12.252 \text{ mg/l} \pm 0.220$ is located downstream. It holds high Iron levels which exceed the guideline value. Site A $5.651 \text{ mg/l} \pm 0.055$ is upstream of mine with low levels, but it exceeded the guideline. The pattern shows that Mazowe Mine activities are the main source of Iron in the river. The decline from site B to C suggests that some dilution and sedimentation processes occurred but not enough to reduce the iron to safe levels. Nyamadzawo (2007) reported that Iron Duke Mine is the only iron pyrite miner in Zimbabwe. The waste rock dump has developed over more than seventy years of mining. This mine is representative of this trend where AMD is the primary pollutant in river water sources.

Ravengai et al. (2005) reports that oxidation of pyrite and other Iron sulphide minerals in the Mazoe valley leads to acid mine drainage and the release of iron-rich acid water into the Yellow Jacket River with very low pH and high dissolved Iron. The same way Iron levels were found in the study suggests that pollution from Mazoe mine through surface runoff, seepage from tailings and mine effluent, because site A still recorded 5.651mg/l which is above the WHO guideline of 0.3mg/l .This points to background Iron pollution above the mine which may be linked to the greenstone belt geology of the area, farming runoff or small-scale mining activities . Maposa (2022) reported a similar pattern in the Mazoe River with Iron ranging from 6.278mg/l upstream to 12.890 mg/l near the mine, showing that Iron levels in this catchment are naturally high and affected by human activity.

The WHO also sets an Iron limit of 0.3 mg/l in drinking water as high Iron affects taste, color, and stains surfaces (WHO, 2017). The same limits are used by the EMA under the Environmental Management Act [Chapter 20:27] (EMA, 2007), and all three of the sites were above the EMA standard in the present study, which is indicative that river water does not meet the mandated standards throughout the study area. Water with Iron above 0.3mg/l often turns reddish-brown, tastes metallic, stains clothes, teeth and pipes; it also encourages iron-oxidizing bacteria that form slimy layers, block pipes and generate noxious odors (Lenntech, n.d., 2025).

James (2023), in a similar study of Mazowe Dam recorded a mean of Iron concentrations of 9.866 mg/l at one site which is also above WHO limits and shows that Iron pollution is still a problem across the Mazoe catchment. High Iron in freshwater can damage fish by causing stress, harming their gills and making breathing difficult (Val et al., 2008). It can also settle on the riverbed, cover the habitats of small water animals and reduce the variety of aquatic life. Ravengai et al. (2005) observed a decline in aquatic species diversity including macroinvertebrates and fish in the Yellow Jacket River downstream of the Iron Duke Pyrite Mine because of Iron pollution and acid mine drainage.

The Iron concentrations found in the present study match those reported in other studies done in the Mazoe River catchment and other similar rivers in Zimbabwe. Maposa (2022) assessed Iron, Lead, Zinc and Cadmium in water and sediments from four sites along the Mazowe River and found Iron concentrations of 6.278 mg/l at site 1, 12.890 mg/l at site 2, 8.808 mg/l at site 3 and 10.893 mg/l at site 4. The concentrations in the present study are 5.651mg/l, 12.252mg/l and 14.999 mg/l which fall within the same range showing a similar pattern of Iron buildup in the river. The small differences between the studies may be due to different sampling points, different seasons and the time gap between when the studies were done.

Maposa (2022) noted that Iron concentrations in the Mazoe River were far above WHO standards and the conclusion is applicable to the present study. James (2023) assessed heavy metals in Mazowe Dam as the main dam on the Mazowe River and recorded the mean of Iron concentrations ranging from 5.862 to 9.863 mg/l across four sites, with Site A (dam wall) recording the highest value. These values are lower than the peak recorded at Site B in the present study. The difference may be due to dilution and mixing of water as contaminated river water enters the dam. The alignment between these studies concludes that Mazoe Mine activities and other catchment sources are consistently keeping Iron levels above permissible limits.

Utete et al. (2013) assessed Cadmium, Copper, Iron, Lead and Zinc in the Gwebi River, a tributary to Lake Manyame and reported mean Iron concentrations of 0.79 mg/l in both wet and dry seasons, which exceeded WHO limits but still much lower than the levels recorded in the current study and other studies in the Mazoe Valley. This difference shows that Iron contamination is more severe in the Mazoe catchment than in other Zimbabwean rivers because of the greenstone belt geology and the heavy pyrite mining activity in the area (Ravengai et al., 2005). Mudyazhezha et al. (2014) also found very low Iron levels in the Ngwablozi River in Bulawayo ranging from 0.1mg/l to 0.11 mg/l across four sites well within WHO limits. The contrast between these rivers and the present study suggests that the Mazoe River is affected by stronger mining-related pollution and acid mine drainage while the Bulawayo River does not have the same kind of input.

Lead was not detected at any of the three sampling sites throughout the study period which indicates that lead was absent from the river water at the time of sampling and that the first and second objectives were achieved. The WHO and EMA aesthetic guideline for Lead in drinking water is 0.01mg/l. Gold mining operations do not always cause Lead contamination unless the ore

contains Lead bearing minerals such as galena lead sulphide. Mazoe Mine mainly works with gold in greenstone belt rocks that are usually Lead. This geological context explains the absence of Lead enrichment in river water. Nriagu (1990) notes that Lead often binds to sediment and organic matter especially when pH is close to neutral so it may still be present in the riverbed even when it is not seen in water. Maposa (2022) also found high Lead levels in Mazoe River sediments, showing that Lead can be stored in the sediment while remaining undetectable in the water during the wet season. Madebwe et al. (2017) reported that Lead levels were highest at the start of the dry season and lowest in February during the wet season, which suggests that strong wet season flows may have diluted Lead in the study, below the detection limit. For this reason, dry season sampling may still be needed to check whether Lead becomes measurable when river flow is low. Several environmental assessments have been conducted in the area, including research on seasonal changes in the Yellow Jacket and Mazowe Rivers (Magadza and Masendu, 1986; Gratwicke, 1999).

Lead is undetectable in all sites the measured concentrations are within the WHO maximum allowed concentration of 0.01 mg/l in drinking water and the EMA corresponding standard (WHO, 2017; EMA, 2007). This is a good result but it should not be taken to conclude that there is no Lead risk in the river system. Lead can build up in river sediments and then enter aquatic organisms through contaminated particles so, bottom-dwelling invertebrates and fish may still be exposed even when water samples show no Lead (Maposa, 2022; Nriagu, 1990). Lead can harm the nervous system and affect children's brain development even at low levels. Dry season sampling and sediment testing are still important to get a full picture of the risk (Lanphear et al., 2005; WHO, 2022).

The zero Lead result in the present study aligns with findings from James (2023) who also recorded lead concentrations of 0.000 mg/L at all four sites in Mazowe Dam. This agreement between two studies in the same catchment suggests that Lead is likely absent from the water column during wet season conditions in this area. In contrast Ncube et al. (2017) found Lead levels of 0.13mg/l to 0.28 mg/l in dams below effluent discharge zones in Bulawayo and these values were above WHO limits for drinking water. Madebwe et al. (2017) also reported a maximum Lead level of 0.07mg/l in groundwater from the Upper Sanyati catchment which is above the WHO guidelines and differs from the Mazoe River result. These findings show that Mazoe Mine's main pollution problem in the wet season appears to be Iron rather than Lead.

Maposa (2022), detected small but measurable amounts of Lead in Mazowe River water with mean values ranging from 0.010mg/l to 0.0225 mg/l across the four sites. These values were close to the WHO limit of 0.01 mg/l. The difference from the present study where Lead was recorded as zero may be due to differences in season (Magadza and Masendu, 1986; Gratwicke, 1999), sampling points or detection limits since Maposa's study was not limited to the wet season. Maposa (2022) also linked the slight downstream increase in Lead to diffuse sources of contamination. This

suggests a limit depending on conditions which shows why monitoring across different seasons is important.

Zinc levels in this study were low in all three sites 0.098 mg/l at Site A, 0.110 mg/l at Site B and 0.130 mg/l at Site C with a slight rise from upstream to downstream. This pattern points to some influence from mine activity at site B and possible assessed input from farming or urban runoff by the time the river reaches site. However, all the values were still far below the allowed limit so Mazoe Mine does not seem to be a major source of Zinc pollution in the river at present. Bortey-Sam et al., (2015) explain that Zinc from mining can enter water through ore processing and acid mine drainage but its movement depends a lot on pH. At low pH, Zinc stays dissolved and is easier to absorb by living things while at neutral pH it tends to stick to sediment and organic matter. This may explain the low dissolved Zinc levels in the river during the wet season. Maposa (2022) also found much higher Zinc levels in Mazowe River sediments than in water, which suggests that Zinc is being held in the riverbed rather than staying in the water.

All Zinc levels found in this study ranging from 0.098mg/l to 0.130 mg/l are well within the WHO aesthetic guideline of 3.0 mg/l for drinking water (WHO, 2017). The EMA uses the same standards, so all the measured Zinc values are still within acceptable limits. These levels are less than 5% of the limit, they do not pose a serious risk to drinking water use or the river ecosystem. Davies et al., (2009) note that most freshwater organisms can tolerate dissolved Zinc below 0.1 mg/l and the slight rise at sites B and C is only a small increase that is unlikely to cause harm to aquatic life.

James (2023) recorded mean Zinc concentrations of 0.060mg/l to 0.417 mg/l across four sites in Mazowe Dam, with the upstream site D recording the highest value of 0.417 mg/l and Site A (dam wall) recording the lowest of 0.060 mg/l. Contrasting with the spatial pattern in the present study, where Zinc increased slightly from upstream site A to downstream site C of the mine. James (2023) noted that Zinc showed a significant difference between sites in the dam with the upstream inlet recording the highest concentration suggesting that Zinc enters the dam from the river catchment not being generated in the dam. The present study, which slightly increases the downstream gradient, is consistent with this interpretation. Maposa (2022) recorded mean Zinc concentrations in Mazowe River water of 0.015 mg/l at site 1 to 0.048 mg/l at site 2 which are lower than the values in the present study.

However, both studies showed Zinc levels that were still within the WHO guideline although the slightly higher values in the present study may be due to changes in runoff during different seasons and small contributions from farming in the catchment between the two study periods. In contrast, Utete et al. (2013) recorded extremely high Zinc concentrations of 715.42 mg/l in the Gwebi River far exceeding WHO thresholds and contributing to specific industrial Zinc discharges in that catchment. The present study on Mazowe River Zinc concentrations is lower, indicating that zinc contamination from Mazowe Mine is currently minor to industrial zinc pollution in other

Zimbabwean river systems. This is mainly because Mazoe Mine is focused on gold, so Zinc-bearing minerals are not a major part of the ore being worked

All three metals, the pattern of concentrations is consistent with Mazowe Mine being the main source of heavy metal enrichment in the river system. Iron is the only metal to exceed regulatory limits, concentrations increased from Site A at 5.651 mg/l to Site B at 14.999 mg/l, representing about 165% increase linked to mine inputs before declining on Site C at 12.252 mg/l as dilution and sedimentation processes take effect downstream. This clear increase from upstream to the mine area shows that pollution is coming from a specific source. The fall from site B to site C suggests that natural cleaning processes are happening, but they are not strong enough to bring Iron back to safe levels within the study area. Even though the wet season helps to dilute the river water the amount of iron coming from mine activities and acid mine drainage seems to be high for the river to handle.

Maposa (2022) also showed that iron levels in the Mazoe River were highest near the mine and then gradually reduced downstream, although they still did not return to background levels. That is consistent with the current study and represents the continued pattern of contamination over time. No evident mine-related pattern was found for zinc and lead. Zinc increased only slightly downstream which could be attributed to agricultural or urban runoff rather than a direct mine source, and lead was not detected at all. This trend aligns with the geology of gold mining hotspots in greenstone belts which release iron and sulphur at a higher rate than lead and zinc (Ravengai et al., 2005) in the absence of abundant galena or sphalerite in the ore body.

The fact that iron exceeded the WHO and EMA limits at all three sites, including the upstream and livestock, is exposed to water that is not acceptable in appearance and may be unsafe near mine. Children and adults are at risk of stomach disturbances, tooth staining, and possible iron overload at around 15 mg/l of iron (James, 2023). The elevated iron levels at Sites B and C pose a crucial risk to aquatic biodiversity. Val et al. (2008) showed that increased iron in freshwater fish causes gill damage, oxidative stress, and impaired respiration. Iron precipitation deposits can smother benthic habitats, reduce invertebrate diversity, and disrupt the food web that supports fish populations, including commercially important species in downstream Lake Kariba. Mhlanga (2000) observed seasonal breeding and feeding patterns in fish populations in the Sanyati River, a tributary of Lake Kariba, noting that degraded water quality and habitat disturbance can affect breeding success and species abundance.

Iron enrichment of the Mazowe River is not just a local environmental issue, but risks impacting on the larger Zambezi system making it potentially a cross-border issue (Maposa, 2022). All three sites exceeded EMA guidelines which indicate a lack of control over mine waste management at Mazoe Mine. Mining companies are supposed to regulate discharges and prevent pollution from exceeding set limits under the Environmental Management Act [Chapter 20:27] and the Mines and Minerals Act (EMA, 2007). On the basis of these mines should improve the effluent treatment, tailings handling and runoff control to reduce further pollution.

The study only took place in the wet season between January and February 2025 so it captured runoff at its peak but did not observe the dry season: metal levels could rise, since there is less water in the river. Madebwe et al. (2017) and Utete et al. (2013) reported increased/decayed heavy metal levels in Zimbabwean rivers with season. Studies are that of Magadza and Masendu (1986) and Gratwicke (1999) that demonstrated that seasonal variations are reported for Yellow Jacket and Mazowe Rivers, meaning that this assessment is also less complete when dry season data are not available. The study also sampled only from three sites, enough to demonstrate upstream, mine and downstream changes, but insufficient to cover the entire length of the river. More downstream sites would also help to demonstrate how far the iron pollution has spread, and whether it has returned to normal before reaching Mazowe Dam on their own. Only three metals, Fe, Zn, Pb have been tested, however, Mazowe Mine and the larger Mazowe Valley are also shown to have an association with cadmium, copper, nickel and arsenic at other locations (Ravengai et al., 2005). Missing these metals is a weakness, especially given that James (2023) found elevated cadmium at Mazowe Dam and Maposa (2022) has also reported metal build-up in sediments and maize plants. The zero-lead result might also be a case of the AAS instrument failing to capture very small amounts of lead — but not of lead being entirely absent. Maposa (2022) had reported the amount of lead in the Mazowe River water (0.010–0.023 mg/l) with ICP-OES, indicating the need for a more sensitive process, such as that of ICP-MS, to aid in dispelling the mystery. No sediment or aquatic organisms were tested in the study even though lead and zinc are found to accumulate in river sediments at higher concentrations than the water column (Maposa, 2022; Nriagu, 1990). For that purpose, sediment and biota testing should be future contamination investigations.

In short, the study shows that Mazoe Mine is contributing to Iron pollution in the Mazoe River because Iron levels at all three sites, including the upstream site, were above the WHO and EMA aesthetic guideline of 0.3 mg/l. The mine's effect is clear at Site B, where the mean is 14.999 mg/l, and partial dilution downstream at Site C, with a mean of 12.252 mg/l. Lead was not detected, and Zinc remained within permissible limits at all sites, indicating that these metals do not currently seem to be major dissolved water problems during the wet season. These results agree with earlier work in the Mazoe catchment, notably Maposa (2022), Ravengai et al. (2005) and James (2023), as well as the documented history of acid mine drainage from the Iron Duke Pyrite Mine and associated operations in the Mazowe valley. Regulatory enforcement improved mine effluent treatment in different seasons and multi-parameter monitoring is urgently required to protect the communities, ecosystems and downstream water resources dependent on the Mazowe River.

CHAPTER 6: CONCLUSION

The study concluded that the Mazoe River is affected by mining-related pollution. Iron exceeds the limits of the WHO and EMA, showing the highest concentration among all three metals assessed. Zinc concentration levels were generally low and within the permissible limits of the WHO and EMA. Lead was not detected even at a lower level, indicating that Iron pollution is the main problem in the river. The findings show that Mazoe Mine activities are playing a role in reducing the quality of water in the river.

6.1 RECOMMENDATION

Mazoe Mine should improve waste management and reduce the release of polluted runoff into the river. Water quality testing must be done in both wet or dry conditions to capture seasonal variations and the Environmental Management Agency and other relevant authorities should carry out routine inspections and enforce water pollution regulations. Since the safety and security of water resources are important in today's life.

6.2 REFERENCES

- Akcil, A. and Koldas, S. (2006) Acid mine drainage (AMD): causes, treatment and case studies. *Journal of Cleaner Production*, 14 (12–13), pp. 1139–1145.
- Bortey-Sam, N., Fianko, J.R., Donkor, A.K. and Adotey, D.K. (2015). Heavy metal contamination in surface water and groundwater around the gold mining areas of Tarkwa, Ghana. *Environmental Monitoring and Assessment*, 187 (7), pp. 1–17.
- Charema, J. (2024). Heavy metal contamination and its spatial distribution from mining wastes in the receiving environments of Mazowe District, Zimbabwe. University of the Witwatersrand, Johannesburg. Available at: [Wits University Repository] (<https://preservation.wits.ac.za/items/e3fa5ad5-5f8d-4524-bcf5>).
- Davies, T.C., Ndungu, K. and Njuguna, G.W. (2009). Heavy metals in freshwater systems: sources and effects. *Physics and Chemistry of the Earth*, 34 (13–16), pp. 831–838.
- Environmental Management Agency (EMA) (2007). Environmental Management Act [Chapter 20:27] Water Quality Standards. Harare: Government of Zimbabwe.
- Environmental Management Agency (2015) Environmental Management Act [Chapter 20:27]. Harare: Government of Zimbabwe.
- Grosell, M., Blanchard, J., Brix, K.V. and Gerdes, R. (2007) Physiology is pivotal for interactions between salinity and acute copper toxicity to fish and invertebrates. *Aquatic Toxicology*, 84 (2), pp. 162–172.
- James, T. (2023). Assessment of heavy metal concentrations in Mazowe Dam, Mashonaland Central Province, Zimbabwe. Unpublished BES dissertation. Bindura: Bindura University of Science Education.
- Kanda, A., Ncube, F., & Takura, R. (2017). Potential ecological risk assessment of a stream in Shamva, Zimbabwe. *Environment, Earth and Ecology*, 1(1), 67–80. Available from: <https://doi.org/10.24051/ee/68608>.
- Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T. and Rothenberg, S.J. (2005) Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environmental Health Perspectives*, 113 (7), pp. 894–899.

- Lenntech (n.d.) Iron in groundwater, Lenntech Water Treatment Solutions [online]. Available from: <https://www.lenntech.com/groundwater/iron.htm> [Accessed: January 2025].
- Madebwe, V., Madebwe, C. and Mavhura, E. (2017). Assessment of groundwater quality in Upper Sanyati Catchment, Midlands Province, Zimbabwe. *Physics and Chemistry of the Earth*, 100, pp. 131–138.
- Magadza CHD and Masendu H (1986) Some observations on effluent in the Yellow Jacket stream, Zimbabwe. *Zim. Science. News* 20 11-15.
- Mandizha, N., Kugara, J., Mombeshora, E. T., & Zaranyika, M. F. (2023). Elemental composition and speciation trends in Upper Mazowe River, a typical sub-tropical river ecosystem impacted by gold mining and agriculture in Zimbabwe. *Environmental Advances*. Available at: [Science Direct Article] (<https://www.sciencedirect.com/science/article/pii/S2666765723001011>).
- Mandizha, N., Kugara, J., Mombeshora, T., & Zaranyika, M. F. (2024). Trace metal speciation trends in Mazowe Dam, Zimbabwe, a typical sub- dam ecosystem impacted by gold mining and agriculture. Available at: [ResearchGate Preview] (<https://www.researchgate.net/publication/382653358>).
- Maposa, R. (2022). Assessment of heavy metal concentrations in water, sediments and maize plants in the Mazowe River, Mashonaland Central Province, Zimbabwe. Unpublished BES dissertation. Bindura: Bindura University of Science Education.
- Mapira, J. (2017) River pollution in the Mzingwane Catchment, Zimbabwe. *Journal of Sustainable Development in Africa*, 19 (5), pp. 56–70.
- Mhlanga, L. (2000) Seasonal dynamics and production of benthic macroinvertebrates in the Sanyati basin, Lake Kariba, Zimbabwe. *African Journal of Ecology*, 38 (2), pp. 141–151.
- Mudyazhezha, S., Kanhukamwe, R., Ndhlovu, P. and Chikurunhe, O. (2014). Physico-chemical monitoring of surface water quality in Ngwablozi River, Bulawayo, Zimbabwe — implications for domestic and agricultural use. *International Journal of Engineering Science and Technology*, 3 (4), pp. 90–96.
- Munene, E. N., Hashim, N. O., & Ambusso, W. N. (2023). Human health risk assessment of heavy metal concentration in surface water of the Sosian River, Eldoret town. Available from: <https://doi.org/10.1016/j.mex.2023.102298>.
- Ncube, S., Madanhire, I. and Mbohwa, C. (2017) Heavy metal contamination in dams downstream of effluent discharge zones in Bulawayo, Zimbabwe. *International Journal of Environmental Science and Development*, 8 (5), pp. 356–362.
- Nriagu, J.O. (1990) Global metal pollution: poisoning the biosphere? *Environment*, 32 (7), pp. 7–33.

- Nyamadzawo, G., Mapanda, F., Nyamugafata, P., & Wuta, M. (2007). Short-term impact of sulphate mine dump rehabilitation on the quality of surrounding groundwater and river water in Mazowe District, Zimbabwe. *Physics and Chemistry of the Earth*, 32(15–18), 1376–1383. Available at: [ResearchGate Article] (https://www.researchgate.net/publication/229239131_Short-term_impact_of_sulphate_mine_dump_rehabilitation_on_the_quality_of_surrounding_groundwater_and_river_water_in_Mazowe_District_Zimbabwe)
- Ravengai, S., Love, D., Owen, R., Hoko, Z. and Meck, M. (2005). Evaluation of heavy metal contamination of water in the Iron Duke Pyrite Mine (IDPM) and Yellow Jacket River, Mazowe valley, Zimbabwe. *Physics and Chemistry of the Earth*, 30 (11–16), pp. 797–803.
- Ravengai, S., Love, D., Gratwicke, B., et al. (2005). Impact of Iron Duke Pyrite Mine on water chemistry and aquatic life – Mazowe Valley, Zimbabwe. *Water SA* 31(2), 219–228. Available at: [ResearchGate PDF] (https://www.researchgate.net/publication/228612088_Impact_of_Iron_Duke_Pyrite_Mine_on_water_chemistry_and_aquatic_life_-_Mazowe_Valley_Zimbabwe).
- Simate, G.S. and Ndlovu, S. (2014) Acid mine drainage: challenges and opportunities. *Journal of Sustainable Mining*, 13 (2), pp. 18–25
- Tutu, H., McCarthy, T.S. and Cukrowska, E. (2008). The chemical characteristics of acid mine drainage in the Witwatersrand Basin, South Africa. *Mine Water and the Environment*, 27 (4), pp. 1–10
- Utete, B., Fregene, B., Chiwara, A. and Mapika, P. (2013) Heavy metal concentrations in water, sediments and common carp (*Cyprinus carpio*) in Gwebi River, Zimbabwe. *International Journal of Environmental Science and Technology*, 10 (4), pp. 741–748.
- Val, A.L., De Menezes, G.C., Wood, C.M. and Wilson, R.W. (2008). The physiology of fish in acidic water: responses to iron and aluminum. *Fish Physiology and Biochemistry*, 34 (2), pp. 143–155.
- World Health Organization (WHO) (2017) Guidelines for drinking-water quality, 4th edition. Geneva: WHO Press.
- World Health Organization (WHO) (2022) Lead in drinking water: health risks, monitoring and corrective actions (Technical brief) [online]. Available from: <https://www.who.int/publications/i/item/9789240055278> [Accessed: January 2025].
- Weaver, V.M., Griswold, M., Todd, A.C., Jaar, B.G. and Ahn, K.D. (2018). Associations between lead exposure and renal function in adults. *Environmental Health*, 17 (1), pp. 1–12
- Zimbabwe National Water Authority (2013) Zimbabwe National Water Authority Act [Chapter 20:25]. Harare: Government of Zimbabwe

