BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF ENVIRONMENTAL SCIENCE

Pollution of lower Manyame River with effluent from a water treatment plant, Zimbabwe

BY

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A Research Project submitted in partial fulfilment of the requirements of the Bachelor of Science Honours' Degree in Safety, Health and Environmental Management

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DECLARATION

Registration Number B212838B

I Rejoice Musara, hereby declare that this project is my own work, carried out in accordance with the partial fulfilment of the requirements of Bachelor of Science Honours Degree in Safety Health and Environmental Management at Bindura University of Science Education. Any reference to published work has been clearly referenced and cited accordingly. This project has never been submitted to any academic institution before.

Student Signature Date 15/10/2025

To be compiled by the supervisor

This dissertation is suitable for submission to the faculty and has been checked for conformity with the faculty guidelines.

Signature of the supervisor Date 15/10/2025

To be compiled by the department Chairperson

I certify to the best of my knowledge that the required procedures have been followed and preparations criteria has been met for this dissertation.

Signature of chairperson

ABSTRACT

Background: Rivers are the final sink of all pollution from watershed activities. Pollutants may enter the food chain to negatively affect the ecosystems.

Objective: To determine the potential of lower Manyame River in Harare, Zimbabwe, using water quality indices, and estimate its self-purification capacity.

Methods: Selected physicochemical parameters of river water and effluent from a water treatment plant (WTP) were measured to determine the potential pollution of the river using the weighted arithmetic water quality index (WAWQI). The river's self-purification capacity was estimated over a stretch of 26.3km^2 using the upstream-downstream dilution models. Samples were collected from March to May, 2025.

Key findings: Physicochemical analysis revealed significant pollution at the discharge point due to high concentrations of Al (26.6mg/l) and Fe (3.6mg/l). The WAWQI value for the discharge point 256.7 and the furthest point 500m from it 227.3 indicated very high pollution, respectively. The overall capacity of Manyame River to naturally attenuate the estimated pollution was found to be inadequate.

Conclusion: Effluent from the WTP is polluting lower Manyame River which has a low self-purification capacity.

Key terms: dilution model; self-purification; water quality

DEDICATION

I dedicate this study to my family and all tertiary students studying safety, health and environmental management.

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Firstly, I want to thank almighty God who gave me the power and strength to carry out this project. My gratitude is also extended to my supervisor, Dr A Kanda for his guidance and support throughout this project. I also want to extend my gratitude to the laboratory technician, Mr Richakara for assisting me when carrying out experiments in the laboratory. I also thank my family for their financial support during the course of the project. Lastly I want to thank my friends who pushed me to complete this project. It is because of their unwavering support and efforts that I was able to complete my thesis.

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LIST OF ACRONYMS AND ABBREVIATIONS

COD	Chemical Oxygen Demand
SP	Sampling Point
WAWQI	Weighted Arithmetic Water Quality Index
WHO	World Health Organisation
WTP	Water Treatment Plant
WQI	Water Quality Index
ZINWA	Zimbabwe National Water Authority

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CHAPTER 1: INTRODUCTION

1. Introduction

1.1 Background of the study

River pollution caused by effluent from water treatment is a global environmental issue (Wells, 2022). This problem primarily arises because wastewater treatment plants often discharge inadequately treated effluent into rivers and lakes. Current research indicates that municipal discharges are among the leading sources of water quality impairment worldwide. These discharges contain pollutants such as nutrients, bacteria, metals, and toxic chemicals (Malikula et al., 2022). Nutrient rich effluents promote excessive algae growth, which depletes dissolved oxygen in water bodies and harms aquatic life. Contaminants pose significant risks to human health by compromising drinking water supplies and limiting recreational use (Ahmad et al., 2022).

Significant progress has been made in controlling river pollution. Secondary treatment of sewage has become mandatory to remove at least 85% of raw waste before discharging it into surface waters (Clean Water Act, 1972). Additionally, modern sewage treatment plants now incorporate advanced technologies, such as energy recovery systems, to minimize environmental impacts (Guven et al., 2023). However, the quality of discharged effluent remains a concern due to inadequate infrastructure. Studies have shown that poorly treated effluents continue to degrade river ecosystems by introducing high levels of pollutants, such as aluminium (Owhonka et al., 2021). There is an urgent need for improved management strategies to mitigate river pollution.

Literature gaps exist mainly in improving wastewater treatment processes for different pollutant type and developing sustainable management practices. Developing cost effective pollutant removal technologies and strengthening regulatory frameworks for compliance are key to sustainable environmental management (Coccia & Bontempi, 2023). Implementing holistic approaches e.g. satellite monitoring accounting for spatial and temporal water quality variations can effectively identify key pollution sources (Govedarica & Jakovljevic, 2019). Significant strides have been made in tackling river pollution through improved wastewater management practices, ongoing challenges reveal areas for further research, particularly regarding technological expansions and policy enforcement (Gulamussen et al., 2019).

1.2 Problem statement

Several studies evaluating river water quality concentrate on industrial and domestic effluent (Singh, 2025; Wang & He, 2022a), and urban and agricultural runoff (Anh et al., 2023; Pericherla & Manoj, 2025). A few studies have shown that water treatment plants (WTPs) are a source of river pollution e.g., (Heloisa et al., 2022.). The current scenario presents a unique situation where a WTP abstracts raw river water upstream and discharges its effluent downstream of the same river where the water has multiple uses. Upstream, the river receives loads of different pollutants through various means. The contribution of the WTP to the already polluted river has not been studied. Effluent from WTP contains high concentrations of heavy metals, nutrients e.g. nitrates and inorganic solids (Expert, 2023; Qrenawi & Rabah, 2021). The river self-purification capacity needs to be established to ensure sufficient pre-treatment of effluent before discharge.

The Manyame River is severely polluted by domestic waste, industrial effluent, agricultural runoff, and solid waste disposal (Muhoyi et al., 2022). Nitrogen and phosphate levels in the Marimba River, a tributary of the Manyame River, exceed the acceptable limits set by the WHO (Nyamangara et al., 2013). Reports indicate that Lake Chivero has experienced a proliferation of cyanobacteria, which poses a serious threat to wildlife, livestock, and the overall ecosystem (Dziva, 2024). Communities in Norton and Darwendale are facing health risks, including cancer and waterborne diseases such as typhoid. This situation underscores the urgent need to investigate the impact of effluents from the Morton Jaffrey Water Treatment Plant on the river's water quality.

1.3 Aim

To investigate river pollution caused by effluent discharge from a water treatment plant and estimate the river's self-purification capacity.

1.3.1 Objectives

- To determine selected physicochemical river water quality parameters (Al, Fe, Cr, Cd, Zn, Pb, Cu, TDS, EC, pH) at selected sampling sites.
- To determine the extent of river pollution using selected river water quality indices.
- To determine the river self-purification capacity using the upstream-downstream river dilution model over a stretch of 1km.

1.4 Research questions

- What are the concentrations of Al, Fe, Cr, Cd, Zn, Pb, Cu, TDS, EC, pH at the selected sampling sites along the river?
- What is the extent of pollution in lower Manyame River due to effluent received from a WTP?
- Does the river have the ability to self-purify itself after receiving WTP effluent over the studied stretch?

1.5 Significance of the study

The study will provide valuable insights into the importance of observing effluent discharge regulations by pre-treatment. It will show that a WTP is a potential point source of river water pollution. The findings may be useful to downstream water users to know the source of some of the pollutants in the water for corrective measures. The river also feeds into a lake downstream. There is a potential introduction of pollutants which may affect river ecosystem functions and aquatic life. This research will add on to existing debates on WTPs as potential sources of river water pollution.

1.6 Assumptions

- The discharged effluent negatively impacts the river's water quality.
- Morton Jaffrey Water Treatment Plant operates in compliance with EMA for effluent discharge
- The discharged effluent poses a risk to human health via direct exposure or through consumption of aquatic organisms.

1.7 Limitations

- Limited time to requirement to collect, analyse data and write repo.
- There are other sources of pollution such as industrial discharge which may alter the results.
- The shortage of funds restricts the resources for the study therefore hindering the depth and breadth of the research.

1.8 Delimitations

- The research is to be conducted over a specific time frame, which can limit the understanding of seasonal variations in pollution.
- The study is focusing on a specific geographical location of a river excluding other water bodies or regions that could provide additional context.

CHAPTER 2: LITERATURE REVIEW

2. Literature review

2.1 Introduction

This chapter reviews existing literature on river pollution from effluent discharge, with focus on water treatment plants. It examines studies related to water pollution, the effectiveness of water treatment processes and the health risks. The chapter also explores the current status of knowledge about river pollution in Zimbabwe, highlighting gaps in the literature.

2.2 The importance of rivers

Rivers are compound ecological systems with a significant hydrological function as well as crucial ecosystem services (Wang & He, 2022b) . Table 2.1 gives common functions of rivers. They hold immense cultural significance for many communities, they are integral to the cultural practices of indigenous people (Mythology, 2025). Due to the vast importance of ecosystem benefits, economic and social services that rivers provide, they are subject to increasing exploitation and degradation therefore they must be protected (WWF, 2025) . Literature shows that river play pivotal roles in ecosystem, agricultural, economic, recreational and cultural functions.

2.3 Characteristics of effluent from a water treatment plant (WTP)

The characteristics of effluent are an important indicator of treatment effectiveness (Chen et al., 2025). Effluent may contain harmful microorganisms such as bacteria, viruses, and protozoa poses significant health risks to human and aquatic life. Table 2.2. show common characteristics of effluent from WTPs. Literature shows that the river is indeed the final sink of all pollution.

Table 2.1: Importance of rivers

Category	Function	Reference
Ecosystem functions	Provide habitats for fish, birds and wildlife	Sabater et al. 2023
	Climate regulation and carbon sequestration	
	Ecological balance	
	Water purification	
Agricultural functions	Provide water for irrigation	Anderson,2019
	Provide drinking water for livestock	
	Fishing	
Recreational and aesthetic functions	Tourism	Anderson, 2019
	Fishing	
	Rafting	
	Offer scenic landscapes	

Cultural functions	Symbolism and identity	Anderson,2019
	Historical settlements and trade routes	
	Religious ceremonies	
Economic functions	Energy generation(hydro power)	UN,2018
	Water is used in manufacturing industries e.g. cooling processes.	

Table 2.2: Characteristics of effluent from a water treatment plant

Category	Parameter	Characteristics	Source in treatment process	Reference
Physical	Turbidity	High turbidity of 50-100 NTU	Coagulation, flocculation, sedimentation, filtration	Soros et al. 2019
	pH	adjusted to 6.5-8.5 for optimal coagulation	pH adjustment with lime or sodium hydroxide	Yehia et al. 2021
	TSS	30-100 mg/L	Coagulation, flocculation, sedimentation, filtration	Qrenawi et al. 2021
Chemical	COD	100-200 mg/L	Coagulation, flocculation, filtration, biological treatment	Khettaf et al. 2021
	PO_4^{3-}	2-6 mg/L	Coagulation, chemical precipitation, biological treatment	Suresh et al. 2018
	NO_3^-	50-60 mg/L	Biological denitrification, chemical treatment	Mishra et al. 2022

Trace elements: Al	0.2-0.5 mg/L	Coagulation with alum or ferric chloride	Ahmad et al. 2024
Cd	0.1 mg/L	Advanced filtration, activated carbon adsorption, ion exchange	Zhao et al. 2021
BOD	30-50 mg/L	Biological treatment activated sludge, bio filters	Jabbar et al. 2022

2.4 Effectiveness of water treatment methods

One of the key debates in the literature concerns the effectiveness of current water treatment processes in reducing pollutant levels. Researchers argue that the technology used in water treatment plants is adequate, others contend that the plants are outdated and incapable of handling the increasing volume of wastewater, (Chikuni et al., 2020). The efficiency of these plants is often hindered by technological limitations and lack of advanced automation. In an article it states that the Morton Jaffrey Water Treatment Plant is grappling with significant challenges that hinder effective water supply management in Harare. The plant is over 50 years old and has seen minimal technological upgrades and currently operates at only 750 mega litres per day, while demand has soared to 1,400 mega litres.

In a study by Hoko (2021), convectional water treatment processes are ineffective. Tensions arise between economic development and environmental protection. Stakeholders prioritize economic growth through urban development, at the expense of river health and water quality. Controversy lies on the role of government regulation in ensuring that water treatment plants comply with environmental standards. Studies suggest that weak enforcement of regulations contributes to the pollution of rivers (Nkosi et al., 2019). To support this, Lake Chivero, was identified by ZINWA as one of the most polluted water bodies in Zimbabwe. The Harare City Council is a major polluter, failing to meet required standards due to subpar operations.

2.5 Potential environmental and public health effects of river water pollution

River water pollution resulting from water treatment plant effluent can lead to a range of environmental and public health concerns (Table 2.3). These include adverse effects to aquatic and also terrestrial ecosystems.

Table 2.3 Environmental and public health effects of river water pollution

Category	Effect	Impact	Reference
Environmental	Loss of biodiversity	Decreased species diversity , Death of aquatic organisms , ecosystem disruption	Kakade et al. 2022
	Eutrophication	habitat destruction	
	Hypoxia	loss of species due to suffocation.	
	Disruption of food chains	Poisoning of aquatic species which causes death	
	Habitat destruction	Loss of habitat, reduction in biodiversity, ecosystem degradation.	
	Reduced aesthetic and recreational value	Limits tourism, recreation, and community engagement with water bodies.	

Public health	Waterborne diseases	Death of people	Lin et al. 2022 Fadlillah et al. 2023
	Heavy metal contamination e.g. aluminium	Long-term health effects such as neurological issues and cancer.	
	Skin and eye irritation	skin diseases eye irritation chemical burns.	
	Drinking water contamination	chronic illnesses gastrointestinal diseases	
	Bioaccumulation bio magnification	Increased toxicity in consumed fish or water, leading to health risks like cancer and organ damage.	
	Vector borne diseases	Increased risk of vector borne diseases e.g. malaria affecting public health.	

Reproductive health issues	Reduced fertility, birth defects, developmental issues in children.

2.6 Theoretical framework

The upstream downstream water quality model is vital for tracking the impact of water treatment plant effluent on river water quality by simulating pollutant dispersion, dilution, and self-purification (Chakraborti,2021). It helps evaluate how pollutants are diluted and reduced as the river flows downstream. By calculating the dilution factor and estimating the total pollution load at different sampling sites, the model quantifies the contribution of WTP effluent. Additionally, the model uses water quality indices to provide a numerical snapshot of overall water quality (Kumar et al., 2024). This model offers insights into the river's self-purification capacity and its ability to handle the pollutants introduced by the effluent discharge.

2.7 Summary

Although there is a growing body of literature on river pollution from effluent discharge, several gaps remain. First, there is limited research on the long term health risks associated with exposure to polluted river water in Zimbabwe. Understanding how these pollutants affect ecosystems in the long run is crucial for effective management. Second, more studies are needed to assess the effectiveness of water treatment plants in reducing pollutant levels, particularly in developing countries. There is a need for more research on innovative methods which are sustainable that can effectively remove a broader range of pollutants from wastewater before discharge. Finally, there is a need for more comprehensive data on the sources of pollution in the Manyame River, beyond effluent discharge.

CHAPTER 3: METHODS AND MATERIALS

3. Methods and material

3.1 Description of the study area

The research was conducted along the Manyame River, which is located in north eastern Zimbabwe (Fig 3.1). The river receives effluent from the Morton Jaffrey Water Treatment Plant (MJWTP). The source of the river is Seke dam and it passes through Manyame catchment area. Manyame catchment is located in the Highveld of Zimbabwe, which stretches from the Southwest to the Northeast and lies between 1220 and 1525 m above mean sea level (Masere et al., 2012). Manyame river is a tributary of Lake Chivero which has a surface area of approximately 26.3km^2 (Muchini et al.,2018).

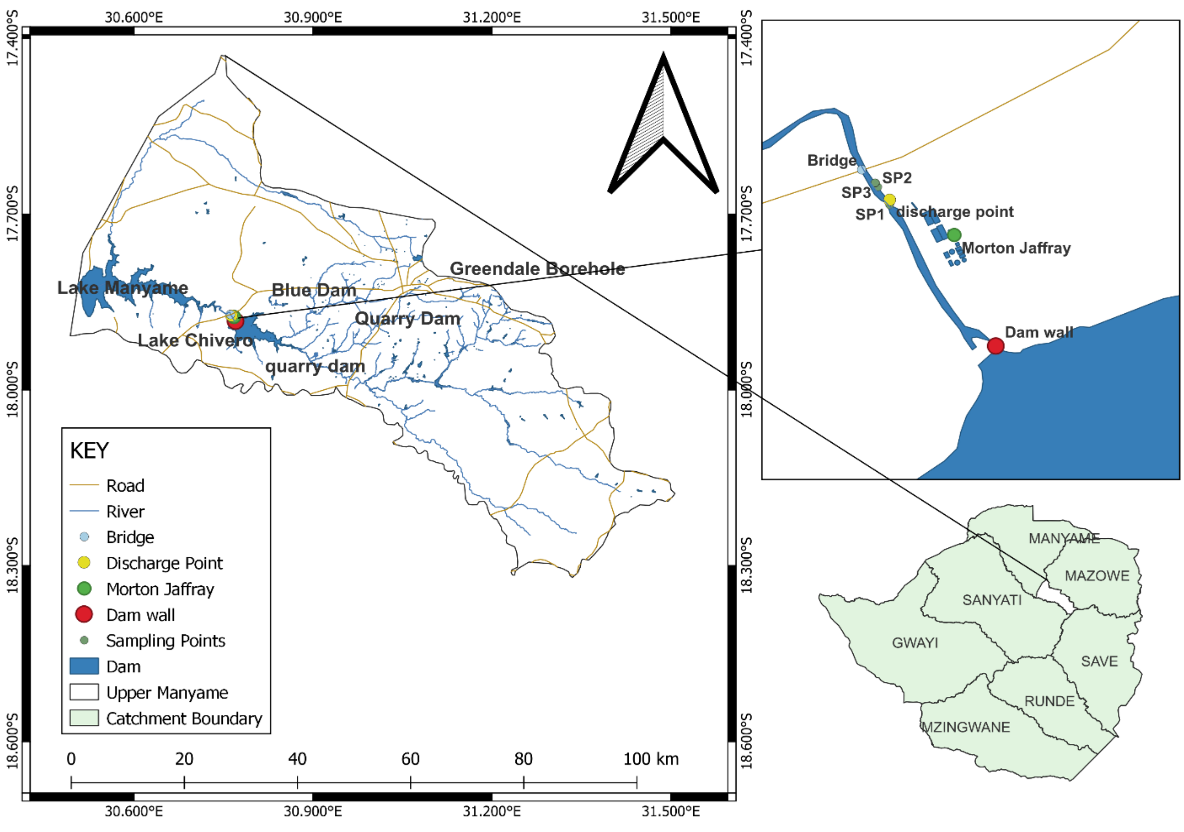

Fig 3.1. Map of Zimbabwe showing the location of Morton Jaffrey Water Works and the sampling points along Manyame River.

3.2 Research design

A cross-sectional design was adopted in this study. It provides a snapshot of water quality at a specific point in time (Maeir et al., 2023) and allows the collection of primary data upstream, near discharge point and downstream. The descriptive nature of a cross sectional study allowed the comparison of water quality parameters across different locations. A limitation of cross-sectional design is that they do not provide causal evidence (Maier et al., 2023). However, this can be addressed by triangulating data with other sources, such as old documents to strengthen the conclusions (Bhandari,2023).

3.3 Sampling points and sampling

Sampling points were established at the discharge point, upstream and downstream of the discharge point (Table 3.1).

3.4 Sample preparation and analysis

Sampling was done over a period of three months from March to May 2025. Water samples were collected at five different sites in the river every month in order to assess water quality parameters. Sampling was conducted on the first Monday of each month to standardize the collection time and ensure consistency throughout the study. Sampling was done between 9:00 a.m. and 12:00 p.m. to minimize the effects of diurnal variations in water quality such as temperature (Guo et al., 2018). Water samples were collected using the grab sampling method as described by (Ji et al., 2022).

Table 3.1 Established sampling sites along Manyame River downstream of Lake Chivero

Sampling site	Geo- References	Description
SP1	17.8672°S	50 m upstream of the discharge point
	39.9743°E	Represents river water quality with no influence of WTP effluent.
		No observable land uses along the river
SP2	17.8672°S	Discharge point
	30.9743°E	Effluent sample taken just before discharge (represents pollutant loading into the river)
SP3	17.8701°S	50m downstream of the discharge point
	30.9751°E	immediately after the effluent discharge point
SP4	17.8701°S	150m downstream of the discharge point. An accessible area after the discharge point with an open body of water , as the water body is covered with weeds.
	30.9774°E	
SP5	17.8835°S	500m downstream of the discharge point.
	30.9863°E	

Three water samples were collected at each sampling point using a Ruttner Depth Sampler (Ruttner ApS, Denmark) at three different depths; the bottom 60 cm, middle 40 cm and the top 20 cm from the surface following procedures described by EPA,2016 to give a composite to account for potential stratification of water quality parameters (Calcavante, 2016). Samples were collected into pre cleansed and rinsed 2 litre polythene bottles at each site in March, 2025. They were labelled using a permanent marker; with the sampling location, date, time and stored in an airtight container (Worrell., 2024). Parameters; pH, TDS and EC were measured onsite using a portable meter (Hach model, Hach Company, USA). The samples were transported to the laboratory within 48 hrs to maintain their integrity (Pierre et al., 2023). Collected water samples were analysed using procedures and equipment described in Table 3.2. River flow was found by measuring the cross-sectional area using a tape and the water velocity using a current meter at each sampling point. The discharge was found by multiplying the cross-sectional area by the average water velocity. The researcher carried out most of the tests (Fig 3.2).

Fig 3.2. Testing of water samples in the laboratory

Table 3.2. Physicochemical parameters tested

River water quality parameter	Analytical method	Apparatus/Materials	Reference
Ph	pH meter	pH Meter, HACH model, HACH Company, USA.	Cepria et al. 2014
TDS	Conductivity estimation based	TDS meter , HACH HQ10 Oxi3301 model , HACH Company, USA	Jouanneau et al. 2014
EC	Conductometric	EC meter , HACH HQ10 Oxi3301 model , HACH Company , USA	Carvalho et al. 2021
Al, Cd, Pb, Fe, Cr ,Zn, Cu	Atomic Absorption Spectroscopy	Atomic Absorption Spectrophotometer, PinAAcle 500 model, PerkinElmer, Inc.Company, USA	Dominguez et al. 2019

3.5 Data management

The river self-purification capacity was calculated using the upstream-downstream dilution model (Hashemi et al.,2017):

$$C_d=\frac{QrCr+QwCw}{Qr+Qw} \text{ ……………………………………..(1)}$$

Where C_d = concentration of the substance downstream (mg/l).

Qr = flow rate of the river (m^3/s)

Cr = concentration of the substance in the river before mixing(mg/l)

Qw = flow rate of the effluent (m^3/s)

Cw = concentration of the substance in the effluent(mg/l)

The following Assumptions were made (Milisic et al., 2023)

- Instantaneous and complete mixing
- No reaction or decay of the substance
- Steady flow rates

The extent of pollution was assessed using the weighted arithmetic water quality index (WQI), incorporating the selected physicochemical parameters. The WQI was calculated using the procedure described by (Tian et al., 2019). Each parameter was assigned a weight based on its importance to water quality, and a numerical value for each parameter was calculated based on its concentration relative to standard water quality thresholds (APHA, 2017).

The WAWQI was determined using the equation

$$Q_I=\frac{V_{a-}V_i}{V_{S-}V_i} \text{ ………………………………(2)}$$

Where:

- Qi= Quality rating for the i^{th} parameter
- Va= Actual measured value of the i^{th} parameter
- Vi = Ideal value of the i^{th} parameter
- Vs = Standard permissible value of the i^{th} parameter

The unit weight was determined using:

$$W_i = \frac{k}{V_s} \text{ ....(3)}$$

Where:

- Wi = Unit weight of the i^{th} parameter
- Vs= Standard permissible value of the i^{th} parameter
- K= Proportionality constant

The proportionality constant is given by:

$$k = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{V_s}\right)} \text{................(4)}$$

Finally, to give the overall WAWQI (Sutadian et al., 2018):

$$\text{WAWQI} = \frac{\sum_{i=1}^{n} W_i \times Q_i}{\sum_{i=1}^{n} W_i} \quad \text{..............(5)}$$

After calculating the WQI, the results were compared to a standardized classification table 3.1 which categorizes water quality based on the calculated index values.

Table 3.3 Classification of the water quality concerning the weighted arithmetic WQI (Banda et al., 2020)

Water quality index	**Water quality Classification/Status**
0-25	Class 1- Good Water Quality
26-50	Class 2-Acceptible Water Quality
51-75	Class 3-regular water quality
75-100	Class 4 -poor water quality
>100	Class 5 -very poor water quality

Data was tested for normality using the Shapiro Wilk test. On data which was normally distributed one-way ANOVA was used and on the data which was not normally distributed, non-parametric test was used which are the Kruskal-Willis test.

CHAPTER 4: RESULTS

4. Results

4.1 The variation of water quality parameters across sampling sites

Table 4.1 shows the mean monthly parameter measurements at each sampling site along the studied river stretch of lower Manyame River. Results show that pH values slightly increased downstream, gradually shifting to more alkaline conditions. Electrical conductivity and total dissolved solids peaked at SP2. Flowrate followed a similar trend, with the highest value recorded at SP2. EC and TDS decreased progressively from SP3 to SP5.

Overall, SP2 emerges as a potential pollution hotspot due to elevated levels of multiple parameters. Metal concentrations show distinct patterns. Iron (Fe) and aluminium (Al) levels increased from SP1 to SP5. Cadmium (Cd) and copper (Cu) levels were low, with their highest concentration at SP2, and then decreased from SP3 to SP5. Chromium (Cr) concentration was high at SP1 and decreased downstream. Zinc (Zn) and lead (Pb) concentrations remained low across all sampling points.

4.2 Extent of river water pollution

Table 4.2 shows the results of a water quality index(WQI) to estimate the extent of river water pollution. The results indicate a consistent trend of very poor water quality across all sampling points in the lower Manyame River. Pollution increased from sampling point 1 to sampling point 5, with a noticeable decrease downstream from sampling point 4 to sampling point 5. Sampling point 1 recorded the lowest WQI whereas sampling point 3 recorded the highest WQI.

Table 4.1 Mean monthly variation of water quality parameters across sampling sites (March – May 2025) along the lower Manyame River

Sampling points (SP)	pH	EC (mS/cm)	TDS (NTU)	AL (mg/l)	CU (mg/l)	PB (mg/l)	FE (mg/l)	CD (mg/l)	ZN (mg/l)	CR (mg/l)	Flowrates (m^3/s)
SP1	6.6 ± 0.1^{a}	2.9 ± 1.9^{ab}	382.3 ± 44.3^{aa}	14.8 ± 14.8^{ab}	0.017 ± 0.012^{ab}	-0.03 ± 0.2^{aa}	0.9 ± 0.3^{a}	0.001 ± 0.0001^{cc}	-0.04 ± 0.4^{ad}	0.04 ± 0.03^{a}	131
SP 2	6.5 ± 0.2^{b}	6.3 ± 0.4^{aa}	467.7 ± 60.9^{bb}	34.5 ± 10.3^{bb}	0.022 ± 0.11^{aa}	-0.02 ± 0.02^{ab}	4 ± 2.5^{ad}	0.001 ± 0.0008^{bb}	-0.4 ± 0.04^{ac}	0.03 ± 0.3^{b}	285.2
SP 3	6.5 ± 0.2^{b}	5.8 ± 0.2^{bb}	333.3 ± 15.9^{c}	11.6 ± 2.8^{cc}	0.017 ± 0.004^{dd}	-0.004 ± 0.002^{ad}	8.3 ± 0.4^{c}	0.016 ± 0.014^{ab}	-0.02 ± 0.2^{ad}	0.01 ± 0.006^{c}	214
SP 4	6.9 ± 0.7^{c}	6.2 ± 0.1^{cc}	317.3 ± 23.7^{ac}	5.3 ± 0.5^{dd}	0.01 ± 0.005^{a}	-0.004 ± 0.002^{cc}	6.6 ± 0.6^{d}	0.008 ± 0.006^{aa}	-0.02 ± 0.2^{ac}	0.002 ± 0.0006^{d}	174
SP5	7.3 ± 1.2^{d}	4.4 ± 1.8^{ad}	301.7 ± 21.1^{dd}	3.3 ± 1.7^{d}	0.014 ± 0.01^{bb}	-0.011 ± 0.007^{dd}	6.1 ± 0.7^{b}	0.003 ± 0.002^{cc}	-0.01 ± 0.1^{ad}	0.004 ± 0.003^{b}	113.9

Similar superscripts aa, bb or cc down a column for a given parameter indicates not significantly different between sampling points ($p > 0.05$)

Different superscripts ab, ac or cd down a column for a given parameter indicates significantly different between sampling points ($p < 0.05$)

Table 4.2 Mean monthly water quality index (WQI) values to estimate the extent of river water pollution.

Sampling point (SP)	Mean±SE| WQI |	Classification	Water quality status
SP 1	105.9±57.6	5	Very poor water quality
SP 2	256.7±107.1	5	Very poor water quality
SP 3	327.2±203.2	5	Very poor water quality
SP 4	228.5±151.9	5	Very poor water quality
SP 5	227.3±141.2	5	Very poor water quality

4.3 Pollutant loading along Manyame River selected sampling points

Table 4.3 shows pollutant loading along Manyame River at selected sampling points of the studied river stretch. The results indicate a general decline in most parameter concentration from upstream to downstream. TDS, pH and EC show a decreasing trend across the sampling points. Aluminium and copper concentration decreased from upstream to downstream with the highest concentrations recorded at sampling point 1. Metals such as iron (Fe) and cadmium (Cd) displayed fluctuating patterns. Iron showed a rising trend downstream with its highest concentration recorded at sampling point 5. Zinc (Zn) and lead (Pb) had negative low values at all sampling points.

4.4 Manyame River self-purification capacity over the studied river stretch

Table 4.4 shows the river self-purification capacity of Manyame River along the studied stretch based on the upstream-downstream river dilution model. The results indicate a clear pattern of an increase in the rivers self-purification capacity across sampling points for most parameters e.g. aluminium (Al). There was uneven pollutant removal in the river for elements such as Fe, Cd and Zn which indicated negative values.

Parameters like aluminium (Al), copper (Cu), lead (Pb) and chromium (Cr) had high purification capacity which increased from sampling point 2 to sampling point 5. The rivers self-purification capacity for TDS, pH and EC decreased from SP3 to SP5 with the highest value recorded at sampling point 3 for all the parameters. The overall pattern shows that Manyame River has a significant self-purification system, especially in midstream.

Table 4.3 Mean monthly pollutant loading of Manyame River along the studied stretch.

Sampling point (SP)	Pollutant loading (mg/s) = Concentration (mg/l) X River discharge (m^3/s) (mean of three months)									
	TDS	PH	EC	AL	CU	PB	CD	FE	ZN	CR
SP 1	688.1	11.9	5.7	31.1	0.03	-0.05	0.002	1.6	-0.07	0.07
SP 2	420.9	5.9	5.2	26.6	0.02	-0.02	0.0001	3.6	-0.36	0.03
SP 3	133.3	2.6	2.3	4.6	0.01	-0.02	0.001	3.3	-0.01	0.004
SP 4	253.8	5.2	5	4.2	0.01	-0.003	0.006	5.3	-0.02	0.002
SP 5	271.5	6.5	4	3	0.01	-0.001	0.003	5.5	-0.001	0.004

Table 4.4 Mean monthly river self-purification capacity of Manyame River along the studied stretch.

Sampling point (SP)	River self-purification capacity % = $\frac{\text{difference brtween pollutant loadings of upstream and downstream sampling points(mean of 3 months)}}{\text{upstream pollutant load}}$ x 100									
	TDS	PH	EC	AL	CU	PB	CD	FE	ZN	CR
SP1(17.8672°S 39.9743°E)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SP 2	38.8	50.4	8.7	14.5	33.3	60	95	-125	-414.3	57.1
SP 3	80.6	78.1	59.6	85.2	66.7	60	50	-106.3	85.7	94.3
SP 4	63.1	56.3	12.3	86.5	66.7	94	-200	-231.2	128.6	97.1
SP 5	60.5	45.4	10.5	89.8	66.7	98	-50	-243.8	98.6	94.3

CHAPTER 5: DISCUSSION

5.0 Discussion

5.1 Introduction

This chapter discuss the key findings from chapter 4 regarding water quality parameters, the extent of river water pollution, pollutant loading and self-purification capacity of the Manyame River.

5.2 The variation of water quality parameters across sampling sites

Water quality parameters varied significantly across sampling points, with some sites showing higher levels of pollutants. This suggests strong influences from point and non-point pollution sources. The high values of EC, TDS and pH and certain heavy metals e.g. al at SP2 indicates a high load of suspended solids and dissolved ions, supporting the hypothesis that SP2 is the discharge point, which is the primary pollution hotspot. The significant increase in iron (Fe) and cadmium (Cd) from SP2 to SP3 aligns with findings from industrial zones, where metals accumulate due to poor effluent treatment (Debnath et al., 2021a).

Low concentration of metals suggests rapid removal through assimilation and adsorption (Tshithukhe et al., 2021). The significant increase in iron and cadmium from SP2 to SP3 aligns with findings from studies on river water quality in urban areas, where metals accumulate due to poor effluent treatment. The decline in concentration downstream in these parameters points to the natural self-purification capacity of the river through dilution. Such trends are similar in other research whereby in urban catchments increased impervious surfaces and inadequate waste management contribute to water quality degradation (Anh et al., 2023b).

5.3 Extent of river water pollution

The general increase in pollution from upstream to midstream, with a slight decrease downstream indicate partial dilution. The high variability in WQI values, as shown by large standard errors, points to fluctuating pollution levels over time. This is due effluent discharge, agriculture runoff and different rainfall patterns (Azlina et al., 2022). Despite spatial trends, all sampling points remain within the worst water quality classification, suggesting that Manyame River has many sources of instantaneous pollution. This further on reflects environmental stress on the river system(Nash & Galal, 2020).

These results are consistent with similar studies conducted on urban rivers in Zimbabwe, such as Mukuvisi River where water quality was found to deteriorate sharply downstream of agricultural and industrial zones (Chimuriwo, 2016). Rivers receiving untreated wastewater exhibit poor water quality and limited self-purification capacity. Furthermore, factors such as inadequate waste management, poor enforcement of environmental laws and informal settlements contribute to pollution (Anh et al., 2023a).

5.4 Pollutant loading along Manyame River selected sampling points

The data reveals a general decrease in pollutant loadings from upstream to downstream due to natural purification processes along the river. Decreasing trend of pH, TDS, and EC suggest natural attenuation and reduced pollutant input downstream (White et al., 2021). Metals which have fluctuating patterns are due to intermittent discharges and pollution from localized contamination sources. Negative values for some metals reflect concentrations which are below detection limits. An increase in iron reflect accumulation and increased leaching from sediments (Debnath et al., 2021). Overall, the results indicate that while some pollutants reduce with distance, others increase, implying both self-purification and ongoing input from various sources e.g. industries and agricultural runoff.

Similar studies conducted have reported comparable trends where pollutant loading peak at discharge points and decrease downstream due to dilution (Yuan, 2023). The variation in pollutant loadings is influenced by seasonal flowrates. land use practices and inadequate wastewater treatment infrastructure in the study area. Natural river systems recover downstream through self-purification if pollution inputs are not continuous, this suggest why there is a partial decline in certain pollutants observed in this study (Zhang et al., 2023).

5.5 Manyame River self-purification capacity over the studied river stretch

Significant spatial variation has been shown across sampling points with metal parameters having high purification capacity due to strong metal binding and in the river ecosystem. Negative purification values indicate remobilization from sediments and additional non-point source inputs along the river. Seasonal variations also influence these anomalies (Lei et al., 2010). However, the decline and stagnation in purification for certain parameters highlight potential pollution sources and ecological stress, therefore limiting natural recovery downstream. These findings align with studies conducted on similarly stressed water bodies, such as Lake Chivero, where heavy metal accumulation and fluctuating purification efficiencies were attributed to urban wastewater discharge and limited riparian vegetation (Siebel, 2022).

The observed trends are caused by both natural and anthropogenic factors in the study area. The initial increase in purification from SP2 to SP3 is due to wider river channels, natural aeration facilitating oxidation and bio filtration. The subsequent inconsistencies at SP4 and SP5 suggest proximity to pollution hotspots such as agricultural zones, where runoff reintroduces contaminants. Seasonal variations such as rainfall and flow rate influence dilution and transportation of pollutants (Cruz et al., 2019). The results indicate that Manyame River possesses a moderate self-purification capacity and it is highly dependent on local environmental conditions.

5.6 LIMITATIONS OF THE STUDY

The study findings are not generalizable to other rivers and water treatment plant (WTPs) due to specific catchment characteristics and pollution sources of the Manyame River. The use of models validated elsewhere introduces uncertainties. To minimize these limitations, the study focused on specific sampling points and parameters relevant to the Manyame river context.

5.7 SUMMARY

Key issues discussed include variations in water quality, pollutant loading, and self-purification. Literature highlights the importance of managing pollution in rivers with mixed land use. This discussion tackled localized pollutant loading and self-purification aspects specific to the Manyame river.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study concludes that Manyame River along the studied stretch has very poor water quality due to heavy pollution from a WTP. Although the river shows a strong self-purification capacity for some heavy metals, its water quality remains very poor. Natural processes are insufficient to restore the rivers condition therefore effective pollution management strategies are required. The study focused on a stretch along Manyame River directly affected by WTP effluent, highlighting its impact on pollution dynamics. The findings are vital for public health protection, as communities reliant on the river are at risk of hazardous exposure. This study underscores the urgent need for pollution control and stricter enforcement of environmental laws. To assess the ecological impacts of metal pollution, future studies must us biological indicators such as fish.

6.2 RECOMMENDATIONS

Based on the findings, the following recommendations are proposed

- Implement effective wastewater treatment and management systems to reduce pollution from WTP.
- Enforcement of environmental laws to control pollution.
- Educate local communities on environmental and health risks of river pollution.

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APPENDICES

Appendix 1:

RM FINAL.sav (Command Line)

SPSS OUTPUT ..spv (Command Line)

Appendix 2:

DEPARTMENT OF ENVIRONMENTA SCIENCE

Bindura University of Science Education

Bag 1020 **BINDURA, Zimbabwe**
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BINDURA UNIVERSITY OF SCIENCE EDUCATION

30 March 2025

Dear Sir/Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

PROJECT TITLE: ***Pollution of Manyama river treatment plant effluent, Zimbabwe***

ACADEMIC SUPERVISORS: Dr A Kanda

This letter serves to inform you that **Musara Rejoice S, Registration Number (B212838)** is a fourth year student at Bindura University of Science Education, in the Department of Environmental Science. During her fourth year of study she is supposed to do a research project in her area of specialisation.

Please assist in any possible way. Data collected will be used for academic purposes only and will not be published without your prior consent.

Thank you for your assistance.

Yours faithfully.

Mr T. Nyamugure
DEPARTMENT OF ENVIRONMENTAL SCIENCE

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
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Appendix 3:

Methods 3015a.pdf (Command Line)