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DEPARTMENT OF NATURAL RESOURCES

AN ASSESSMENT OF THE CAUSES OF WATER SUPPLY PROBLEMS IN BINDURA TOWN

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Declaration

The undersigned certify that they have read this research project and have approved its submission for marking in relation to the department's guidelines and regulations.

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Dedication

To my family and friends.

Acknowledgements

Greatly appreciate the effort put by my supervisor Dr J. Gotosa for the guidance in the formulation of this dissertation. Many thanks to Middle Mazowe Sub-Catchment and Bindura Municipality council for granting the permission to undertake this research.

To my parents, relatives and friends for the support financially and mentally, truly you are my pillar of strength.

Abstract

Water is an important resource as such equitable access to clean and safe drinking water is a requirement. However, nearly 2.3 billion people globally have no access to safe water with less economically developed countries being more affected. Rapid growth in population, industry and agriculture has resulted in a high demand for water whereas the impacts of climate change have yielded erratic precipitation leading to inconsistent and unreliable water supply. Unpredictable water supply affects good hygiene practices as people are faced with the alternative of acquiring water from unsafe sources. These alternative sources are prone to pollution resulting in the accumulation of heavy metals and infectious contaminants that cause health risks. As such, the study sought to determine the knowledge, attitude and practice of households in water conservation as well as determine the causes of water shortages, sources of water pollution and the quality of water utilised by households from selected residential areas surrounding Bindura town. The study employed a complete randomised block design with the aid of a questionnaire and observations, as well as for the collection of water samples in four different residential areas. Results showed that most respondents were female (64%), married (76%), were in the 21-40 years age group (55%), and had attained ordinary level education (42%). The most perceived causes of water shortages were increased population (43%) and lack of resources (27%) whereas the preferred water conservation methods were repairing leaks (29%) and harvesting rainwater (27%). Sewerage flow (34%) was the most identified source of water pollution, with waterborne diseases (39%) as the most known impact of water pollution. Age and educational level were strongly associated with knowledge on water conservation and pollution ($p < 0.05$), whereas gender and age were positively associated with attitude and practice on water conservation and pollution ($p < 0.05$). Water quality analysis determined that BOD, COD and DO for Garikai and Woodbrook were slightly above the EMA limits but within WHO guidelines. The concentrations of Cd and Hg were within the EMA and WHO prescribed limits in all the four sites ($p < 0.05$). Though some of the pollutants were above the regulatory limits, their concentrations were insignificant to cause deleterious effects but had the potential to do so overtime due to bioaccumulation. It is therefore recommended that residents should have a positive attitude towards water conservation and practice proper hygiene to reduce the prevalence of diarrheal diseases. Continuous monitoring of water quality should be exercised to ensure its safe for human consumption. Future studies should focus on sources of water pollution to reduce the release of contaminants into surface water.

Key words: attitude, knowledge, perception and, water conservation, pollution, and quality.

Table of Contents

CONTENTS **PAGE**

List of Tables

List of Figures

Acronyms

APA	–	American Psychological Association
APHA	–	American Public Health Association
As	–	Arsenic
B	–	Boron
BOD	–	Biological Oxygen Demand
Ca	–	Calcium
CBD	–	Central Business District
Cd	–	Cadmium
CDC	–	Center for Disease Control
COD	–	Chemical Oxygen Demand
Cr	–	Chromium
CRBD	–	Complete Randomised Block Design
Cu	–	Copper
DO	–	Dissolved Oxygen
EC	–	Electrical Conductivity
EMA	–	Environmental Management Agency
Fe	–	Iron
Hg	–	Mercury
K	–	Potassium
KAP	–	Knowledge Attitudes and Perceptions
N	–	Nitrogen
P	–	Phosphorous
Pb	–	Lead
SAZ	–	Standards Association of Zimbabwe
SI	–	Statutory Instrument
SPSS	–	Statistical Package for Social Sciences
TDS	–	Total Dissolved Substances
UN	–	United Nations
WASH	–	Water Sanitation and Hygiene
WHO	–	World Health Organisation
Zn	–	Zinc

Chapter One: Introduction

1.1 Background to the Study

Water is one of the most important natural resources (Krishna *et al.,* 2012; Mahler *et al.,* 2013) as such it is a basic requirement to have equitable access to clean and safe drinking water is a (United Nations, 2015). However, around 2.3 billion people globally have no access to safe water (WHO, 2017) with the situation widespread in developing countries (United Nations, 2015). In Bangladesh nearly 45 million people have no access to clean drinking (Guppy and Anderson, 2017) whereas 20% of the Pakistan population face water crisis (Daud *et al.,* 2017). On the other hand, approximately 30% of the population face water crisis in Nigeria (Arokoyu and Ukpere, 2014), and, almost 2.5 million are deprived the access to safe water infrastructure in South Africa (Edokpayi *et al.,* 2018). An increasing world population, industry and agriculture have all made demand for water high coupled with climate change resulting in erratic precipitation (Savage and Diallo, 2005; Edokpayi *et al.* 2018). Ultimately, water supply is inconsistent and limited.

Unreliable water supply affects good hygiene practices as people are faced with the alternative of acquiring water from unsafe sources (Craun *et al.,* 2010) which is usually utilized without treatment (Bedi *et al.,* 2015). However, these alternative drinking water sources are mostly susceptible to point and non-point sources of pollution (Chigor *et al.,* 2013) thus diseases will arise. Consumption of unsafe drinking water not only causes infectious diseases but also leads to other health risks emanating from other environmental components e.g., arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg) (Pratush *et al.,* 2018; Gabriel *et al.,* 2019). Excessive ingestion of these trace elements through contaminated drinking water may result in cancer, memory lapses, kidney failure, anaemia and damage to the reproductive system (Edokpayi *et al.,* 2018).

Given the increasing demand for water and the uncertain future in supply, it is highly important to involve the public in water conservation (Goette *et al.,* 2019). This can be achieved through identifying aspects that drive water-saving behaviour, such as attitudes, beliefs, habits, perceptions etc. (Jorgensen *et al.,* 2009). As such, determination of the knowledge, attitude and practice (KAP) is essential in establishing the baseline information and increasing awareness on water conservation. This aids participation and decision making in water conservation issues at household level (Goette *et al.,* 2019).

Of particular concern is the quality of water that is utilised by households which should conform to quality standards as it affects human health especially if it is acquired from unsafe sources (WHO, 2017). Unsafe water may be contaminated by microbes, chemicals and trace elements hence, determination of water quality might aid in preventing potential health risks that could emanate from consumption of unsafe water (Daud *et al.,* 2017). Some of the important water quality parameters include biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), nitrates, pH, phosphates, total dissolved solids (TDS) and trace elements (APHA, 2012; WHO, 2017).

The BOD is the amount of DO that is required to breakdown organic matter by aerobic biological organisms in water for a given period under specific temperature (Gu *et al.,* 2013), whereas the COD is defined as the oxygen required for the biological decomposition of organic matter and dissolved solids in water by microorganisms under standard temperature (Abba and Elkiran 2017). These parameters are indicators of pollution in ground and surface water (Jain and Kumar, 2014; Abba and Elkiran, 2017). Very high BOD and COD means the oxidation of organic compounds in water is high and as such will reduce DO content (Jain and Kumar, 2014).

The DO is an indicator of a water body's condition for production and the DO concentration decrease with increasing temperature and dissolved solids as well as the presence of oxidisable organic matter from waste discharges (APHA, 2012). TDS represent the concentration of particulate matter in solution in wastewater in the form of colloids (Rhoades, 1996). Another significant water parameter is pH which is the level of acidity or alkalinity of the water and affects nutrient availability (APHA, 2012). Low pH (< 3) leads to a reduction in macronutrients, that is, K, N and P whereas high pH (>11) results in a reduced micronutrients e.g., B and Ca (Abba and Elkiran, 2017). Trace elements are poorly soluble in water, as such are undegradable thus accumulate overtime. Due to the toxicity and persistence of trace elements, they may lead to detrimental health effects (Gabriel *et al.,* 2019).

1.2 Problem Statement

There has been a significant shortage of water in Bindura which could lead to the outbreak of diarrheal diseases. Water supply from council is inconsistent and is not adequate to meet the daily requirements for most households. At times, the water is not clean prompting households to acquire water from alternative sources whose quality is not known. In addition, the knowledge, attitude and perceptions of the residents towards water conservation and pollution is not known.

1.3 Justification

Considering that water is a requirement for human health and is used in every aspect of the human daily activities. It is therefore imperative to assess the water quality in residential areas surrounding Bindura town hence determine its conformity to stipulated standards and evaluate the potential health risk it may pose if constantly consumed. The study will provide baseline information for future studies on knowledge, attitudes, and perceptions towards household water conservation as well as raise awareness on the impacts of water pollution. The study findings may aid local authority (Bindura Municipality Council) in decision making relating to water reticulation issues.

1.4 Research Aim

To investigate the causes of water shortages and the associated household knowledge, attitude, and practices towards water conservation.

1.5 Objectives

1. To determine the causes of water shortages.
2. To determine the sources of water pollution.
3. To ascertain the knowledge, attitude, and practices of households towards water conservation.
4. To determine the physicochemical properties of water (BOD, COD, DO, pH, TDS, and trace elements).

1.6 Research Questions

1. What are the causes of water shortages?
2. What are the sources of water pollution?
3. What is the knowledge, attitude, and practices of households towards water conservation?
4. What are the physicochemical properties of water?

Chapter Two: Literature Review

This chapter describes, and analyses different studies conducted on water crisis. It describes water shortages and conservation, water pollution and impacts of drinking unsafe water, as well as water quality characteristics of some researches. An evaluation of literature will be done, existing knowledge portrayed and the research gap identified

2.1 Water Shortages and Conservation

Water is a necessity as it plays a pivotal role in several aspects of the human daily activities and provision of safe drinking water is an important requirement (Krishna *et al.,* 2012). Globally, there has been an increasing demand for water due to the increasing human population (Savage and Diallo, 2005). Also, rapid demand for water has resulted from industry and agriculture which has been coupled by climate change resulting in erratic and low precipitation (Edokpayi *et al.* 2018). Water scarcity leads to the acquisition of water from alternative sources which are usually of poor quality due to pollution (Khadse *et al.,* 2012). Qualitatively, water can become unfit for human consumption due to contamination from excreta, industrial effluent or contaminants derived from the surrounding geological formations (Chigor *et al.,* 2013). The contaminated water is also used as raw due to a shortage of better sources of water. Clean water is not only essential for drinking but for purposes like food preparation, sanitation and growing crops hence it needs to be conserved.

Water conservation refers to the various methods implemented in reducing water loss through minimising usage, recycling wastewater and increasing efficient water usage (Kumari and Singh, 2016; Balasubramanian, 2019). The main goal of water conservation is to ensure sustainability, and at household level, water use varies, as a result of the household size, plumbing fixtures and garden size (Waskon *et al.,* 2018). Most water is used via laundry, toilet, bathing and watering. Some of the water conservation techniques as described by Kumari and Singh (2016) and Balasubramanian (2019) include: i) protecting water from pollution, ii) reusing water for other purposes, iii) rational use of water, iv) conservation tillage, v) mulching, vi) water harvesting, vii) reducing run-off, viii) desalination, and ix) reducing evaporation. In a study by Oremo *et al.* (2019), respondents identified deforestation, low rainfall, poor farming methods and increased population leading to water shortages. To cope with the water shortages, they resorted to alternative water sources i.e., boreholes and utilised stored rainwater.

2.2 Water pollution

Water pollution refers to the release of pollutants into a water source thus making the water not suitable for human consumption (Singh and Gupta, 2016). There are two sources of water pollution, namely point source and non-point source pollution. Point source pollution is easily identifiable, such as a leaking sewage pipe (Chigor *et al.,* 2013) whereas, non-point source pollution is difficult to identify, for example, pesticides or oil washed off the ground by a storm (Singh and Gupta, 2016). Gold panning along river beds pollute surface water through the release of mercury used in gold recovery (Velasquez-Lopez *et al.,* 2010). Improper solid waste disposal and waste generated from cleaning and maintenance of machinery and vehicles can contact surface water via run-off thus affecting its quality (Xiao *et al.,* 2017).

Mohsin *et al.* (2013) reported that sewage and industrial waste were the major sources of pollution in India. Similarly, Khan *et al.* (2012) asserted that improper solid waste disposal, sewage water, and fertilizers resulted in the contamination of water. Also, Igwe *et al.* (2017) reported that refuse dumping in water bodies and anthropogenic activities along river banks were the major causes of water pollution in Nigeria.

2.3 Impacts of drinking unsafe water

Consumption of unsafe water may lead to several adverse health effects to humans such as cholera, dysentery, and typhoid (WHO, 2002; Mohsin *et al.,* 2013). Presence of trace elements at high concentrations in water may result in serious clinical consequences or mortality (Gabriel *et al.,* 2019). Francis *et al*. (2015) determined that respondents admitted that the health impacts of unsafe water included cholera, diarrhea, and typhoid. Mohsin *et al.* (2013) reported diarrheal diseases affecting nearly 16% of the population in three residential areas. Similarly, Muleya *et al*. (2019) reported diarrheal diseases linked with quality of water in Zvishavane, with above 8000 diarrheal cases recorded. Table 2.1 summarises some of the common impacts of contaminated water.

Table 2.1: Some adverse effects of consuming unsafe water

Form	Contaminant species	Ailment/Disease	Reference
Biological	*Escherichia coli*	Dysentery	CDC, 2006
	Salmonella spp.	Typhoid	Schiffers *et al.,* 2010
	Shigella spp.	Shigellosis	
	Vibrio cholerae	Cholera	

Chemical	Cadmium	Lung and kidney damage	Gabriel *et al.*, 2018 Pratush *et al.*, 2018
	Copper	Liver damage	
	Lead	Affects reproduction	
	Mercury	Affects kidneys and brain	
	Zinc	Causes cancer	

2.4 Water Quality Characteristics

Water quality is a measure of the physical, chemical, and biological characteristics of water in conformity with set standards (Mohsin *et al.*, 2013). These standards are related to drinking water safety for human consumption. There are also international standards such as WHO guidelines that control and regulate the concentrations of pollutants in drinking water (WHO, 2017). In Zimbabwe, the Standards Association of Zimbabwe (SAZ) regulates the maximum permissible limits of contaminants in drinking water rendering it safe for human consumption as decreed in the Statutory Instrument (S.I.) 6 of 2015. Table 2.2 shows the safe water quality guidelines of some selected key contaminants detrimental to human health according to S.I. 6 of 2015 and WHO (2017).

Table 2.2: Comparison of drinking water guidelines according to S.I. 6 and WHO

Parameter	S. I. 6 of 2015 Permissible limit	WHO Permissible limit
BOD (mg/L)	< 15	< 20
Cadmium (Cd) (ppm)	< 0.01	< 1
COD (mg/L)	10	< 50
Copper (Cu) (ppm)	< 1	< 2
DO (%)	> 75	> 50
Lead (Pb) (ppm)	< 0.05	< 0.1
Mercury (Hg) (ppm)	< 0.01	< 0.006
pH	6.5 – 8.5	6.5 - 8.5
TDS (mg/L)	< 100	< 600
Zinc (ppm)	< 0.3	< 0.3

Mohsin *et al*. (2013) reported water with basic pH (7.2-7.5); TDS values ranging from 290-700 ppm, and nitrate concentrations ranging from 3.2-6.4 mg/L in Bahawalpur City, Pakistan. Likewise, Ayeni (2014) observed DO, pH, salinity and water temperature outside prescribed regulations in Nigeria, indicating high concentrations of contamination in the sampled water. In another study, Edokpayi *et al*. (2018) reported pH and EC values within recommended limits by WHO in South Africa. Muleya *et al*. (2019) reported TDS concentrations within SAZ acceptable limits though the conductivity was above the set threshold from water samples in Zvishavane. In addition, trace element concentrations (Fe and Zn) were all below the SAZ limit except for Cu (Muleya, *et al.,* 2019). Similarly, Gombiro *et al.* (2014) determined that some brands of bottled water were contaminated by nitrites, Pb and Cr in Harare and were thus not safe for human consumption.

Chapter Three: Materials and Methods

3.1 Description of the study area

3.1.1 Location

The study will be carried out in the residential areas surrounding Bindura town (17^{o}18’32.92” S and 31^{o}19’57.45” E) namely Claverhill, Garikai, Greenhill and Woodbrook residential suburbs (Fig. 3.1). All study sites are within a 5km radius of Bindura central business district (CBD). Bindura town is a small mining and agricultural community situated about 88km north east of Harare and is easily accessed by road and rail.

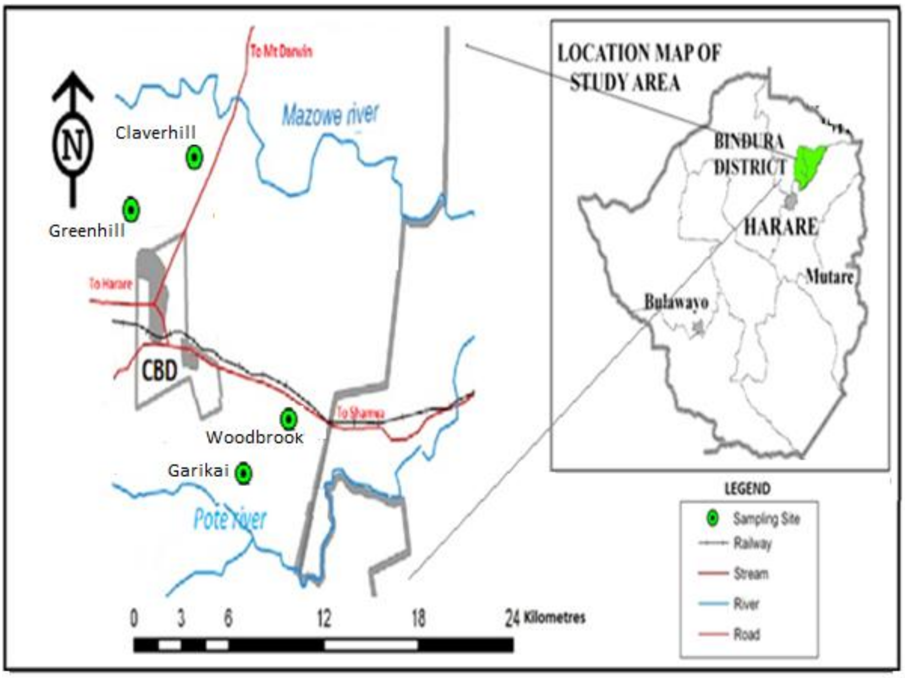

Fig. 3.1: Map showing location of study area

3.1.2 Climate

The sites are situated in region IIb Zimbabwe’s Agro-ecological zones. The region is characterised by distinct wet and dry seasons (Mugandani *et al.,* 2012). The annual precipitation ranges from 750mm to 1000mm mostly occurring from December to March. The average temperature is 26^{o}C with hottest months being October and November whereas May and June are the coldest (Mugandani *et al.,* 2012).

3.1.3 Hydrology, topography and soils

The study falls within Mazowe Catchment and the two major rivers close to the study sites are Mazowe to the north and Pote River to the south of Bindura town. These rivers are a source of water for agricultural and mining activities around the town. The town is situated on a gently undulating plain with isolated hills. The greater part of Claverhill and Greenhill are situated on hilly terrain whereas Garikai and Woodbrook are on a flat plain. Soils at Claverhill and parts of Greenhill are shallow sandy soils of the fersiallitic group that are grey in colour whereas the Garikai and Woodbrook sites have deep well drained red clay soils of the vertisol group with distinct horizons below a topsoil that is rich in organic matter.

3.2 Experimental Design

The study employed a complete randomized block design (CRBD) with the aid of a questionnaire (Gilham, 2008) and observations to collect both qualitative and quantitative data, as well as for the collection of water samples, with each residential area as a block.

3.3 Study Population and Sample Size

The study population consisted of Bindura urban households from four selected residential areas. Bindura has approximately 46 000 housing units from 10 residential areas. The sample size will be determined using Cochran's formula (Israel, 2009).

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$$n = \frac{N}{1+N(e)^2} \quad \text{………………………………………………………………. equation 1}$$

Where *n* is the sample size; *N* is target population and *e* is the level of precision.

$$n = 46{,}000 / 1 + [(46{,}000) * (0.1)^2]$$

$$99.78$$

$$\approx 100$$

Twenty people will be included as contingency thus, a total of 120 respondents will be randomly selected, 30 from each residential area.

3.4 Data Collection

3.4.1 Questionnaire survey

The data was collected through a questionnaire (Cohen and Morrison, 2011) with both close-ended and open-ended questions. Questionnaire dissemination will be done through face-to-face interviews to acquire information on KAP on water conservation, sanitation and hygiene and water pollution. Further, observations to augment the questionnaire was done during a walk-around the residential areas to identify sources of pollution, households' hygiene, and water conservation practices.

3.4.2 Water samples collection

Water samples were collected randomly in triplicates from water sources (tap, boreholes, and wells) within each residential area whereas EMA and WHO guidelines were used as controls. The water samples were collected using standard procedures (APHA, 2012) in 2 litre plastic containers, properly labelled, sealed, and taken to the Laboratory for property analysis using standard procedures described by Esterfen *et al.* (2013). The water properties that were determined included BOD, COD, DO, EC, pH, TDS, and trace elements (Cd, Cu, Hg, Pb and Zn).

3.7 Statistical Analysis

Data collected through the questionnaire was coded, and entered in the Statistical Package for Social Sciences (SPSS) for analysis using descriptive statistical techniques. The chi-square test was used to determine the relationship between socio-demographic characteristics of respondents and KAP on water conservation. A 95% confidence level were used and $p < 0.05$ considered statistically significant. Also, a multivariate analysis at $p < 0.05$ level of significance will be used to test for significant differences of water quality parameters across the sites.

Chapter Four: Results

4.0 Introduction

4.1 Sociodemographic characteristics of respondents

Table 4.1 shows the demographic characteristics of the respondents. A total of 120 respondents were interviewed comprising 36% were males and 64% were females. Over 75% of the respondents were married and 55% were within the 21-40 years age group with the majority attaining ordinary level of education. The highest number of respondents had lived in Bindura for a period of more than 10 years and the modal house size was more than 6 people.

Table 4.1: Socio-demographic characteristics of the study respondents

Characteristic (n = 120)		Frequency n (%)
Gender	Male	43 (35.8)
	Female	77 (64.2)
Marital status	Married	92 (76.6)
	Divorced	17 (14.2)
	Single	11 (9.2)
Age	< 20 years	14 (11.7)
	21-40 years	66 (55.0)
	41-60 years	31 (25.8)
	> 60 years	9 (7.5)
Level of education	None	5 (4.2)
	Primary	12 (10.0)
	Ordinary level	51 (42.5)
	Advanced level	35 (29.2)
	Tertiary	17 (14.1)
Period lived in Bindura town	< 1 year	9 (7.5)
	1-5 years	11 (9.2)
	6-10 years	26 (21.7)
	> 10 years	74 (61.6)
Household size	< 3 people	5 (4.2)
	4-6 people	44 (36.6)
	> 6 people	71 (59.2)

4.2 Knowledge, Attitude and Practices on Water Conservation

Fig. 4.1 shows the perceived causes of water shortages in Bindura by respondents from the four residential areas. The notable significant causes of water shortages were increased population 43.3% and lack of resources (26.7%). All perceived causes of water shortages were significantly different ($p < 0.05$) except for pollution and Other causes (which included low rainfall, old infrastructure, and vandalism).

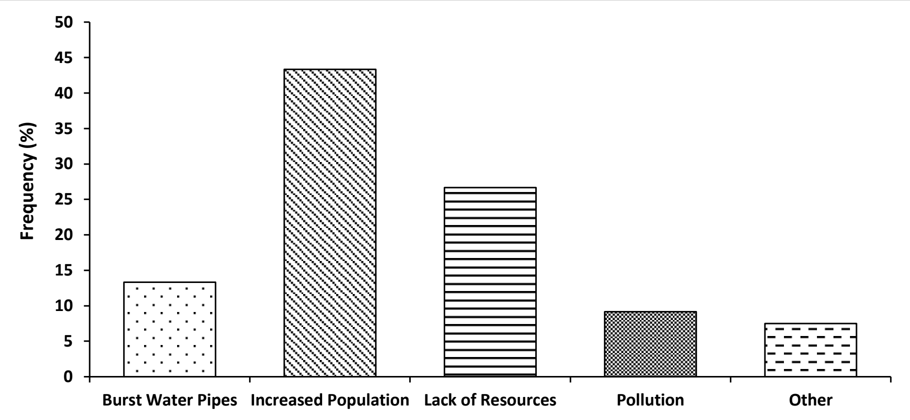

Fig. 4.1: Perceived causes of drinking water shortages in Bindura

The water conservation methods known by respondents included; closing taps when brushing teeth; harvesting rainwater; not doing laundry daily; protecting water from pollution; reducing runoff; repairing leaking taps; using a bucket instead of shower; washing dishes in a bowl; and watering plants when necessary. However, the most practised water conservation techniques were repairing leaks (29%) and harvesting rainwater (27%) (Fig. 4.2).

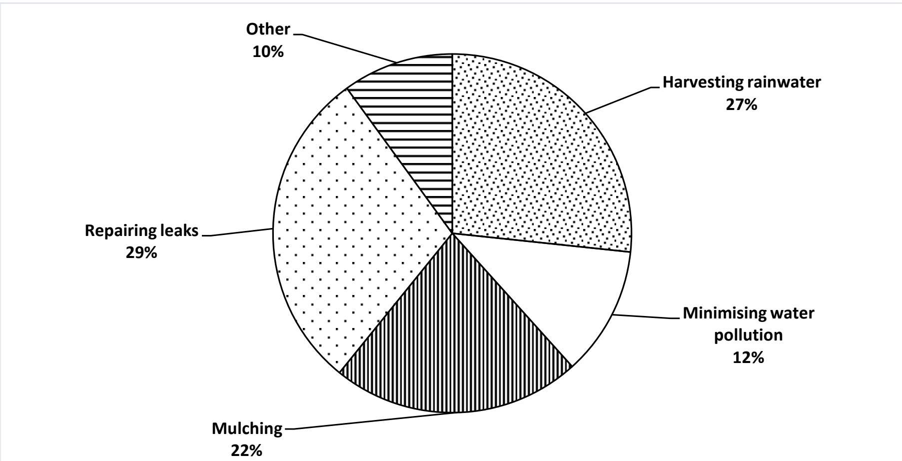

Fig. 4.2: Water conservation methods practiced by respondents

Nearly 65% of respondents had received education/awareness on health and hygiene with close to 87% having knowledge of illnesses caused by poor hygiene. However, water shortages were closely associated with occurrence of diarrheal diseases as influenced by poor sanitation and hygiene. Over 73% of respondents admitted to have been diagnosed with either cholera, diarrhoea, dysentery or typhoid. Diarrhoea (36.7%) was the significantly highest illness to befall the respondents whereas dysentery (4.2%) was the significantly lowest (Fig. 4.3). In addition, almost 58% of the respondents had been diagnosed with either of the diarrheal diseases in the past six months.

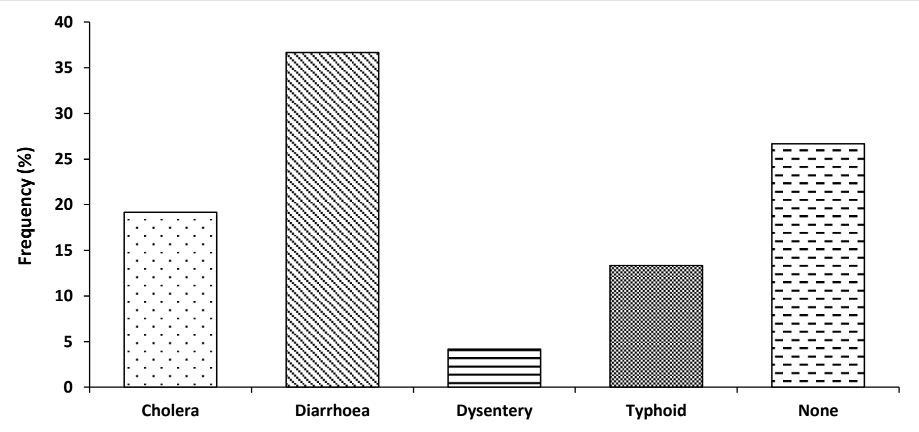

Fig. 4.3: Frequency of waterborne diseases that have been diagnosed to respondents

Majority of the respondents had high knowledge on water pollution and its impacts, and indicated several sources of water pollution. Some of the mentioned sources of water pollution were, agricultural waste; domestic waste dumping; gold panning; industrial waste; laundry along riverbanks; river-sand abstraction; sewage flow; and stormwater run-off. However, the most known sources of water pollution identified by respondents around Bindura as shown in Fig. 4.4 were sewage flow (34%) and domestic waste dumping (28%).

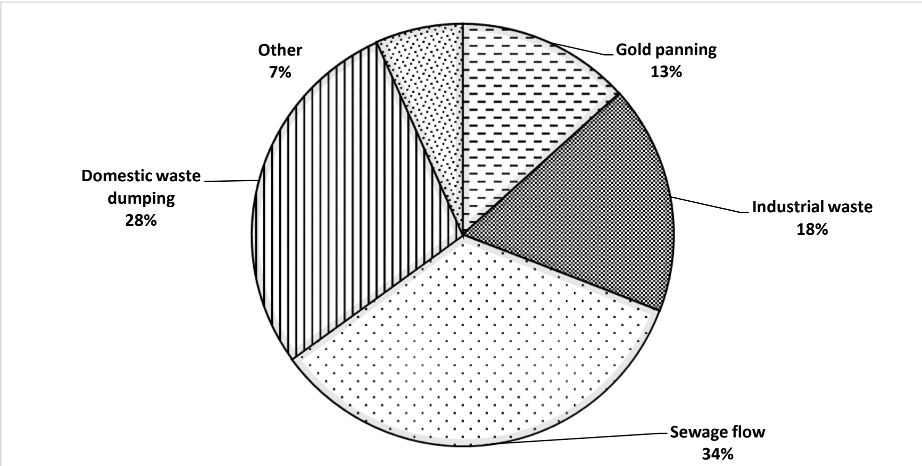

Fig. 4.4: Sources of water pollution identified in Bindura

Fig. 4.5 shows the most significantly recognised impacts of water pollution by respondents in Bindura. It was acknowledged that water pollution leads to the emergence of waterborne diseases (39%) and poor water quality (28%). Other mentioned impacts included affecting crop productivity and aquatic organisms and causing eutrophication

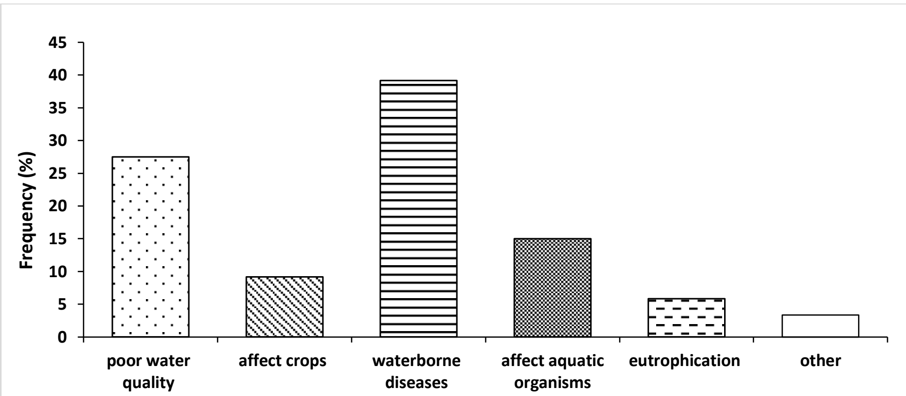

Fig. 4.5: Impacts of water pollution known by respondents in Bindura

Table 4.2 shows the association of socio-demographic characteristics with knowledge, attitudes and perceptions towards water conservation and water pollution. Age (X^2=17.4; p=0.01) and educational level (X^2=14.5; p=0.04) significantly influenced knowledge on water conservation and water pollution. On the other hand, gender (X^2=43.6; p=0.03), age (X^2=31.9; p=0.01) and residential area (X^2=16.3; p=0.04) were significantly related to attitude and practice on water related issues. The highest knowledge score was attained by tertiary education level (8.7±2.5) whereas the females (14.1±1.4) had the highest attitude and practice score (Table 4.2).

Table 4.2: Association of socio-demographic characteristics with knowledge, attitude and practices on water conservation in Bindura town

Characteristic (*n* = 120)		Knowledge			Attitude and practice		
		Score	P	X^2	Score	P	X^2
Gender	Male	7.2±2.5	0.354	2.97	12.5±1.8	0.0362*	43.6
	Female	8.3±2.9			14.1±1.4		
Marital status	Married	6.5±1.9	0.165	6.09	11.9±2.0	0.3419	68.1
	Divorced	6.1±2.6			11.4±2.1		
	Single	6.8±2.3			11.8±2.3		
Age	< 20 years	6.3±1.4	0.012*	17.4	11.1±2.4	0.0184*	31.9
	21-40 years	7.1±2.6			12.0±3.0		
	41-60 years	7.8±2.4			13.6±1.9		
	> 60years	6.8±1.1			12.4±2.5		
Educational level	None	5.8±2.1	0.043*	14.5	11.7±1.8	0.4763	24.6
	Primary level	6.2±2.6			11.8±2.1		
	Ordinary level	7.9±2.3			12.5±1.5		
	Advanced level	8.7±2.5			12.8±3.2		
	Tertiary level	9.3±3.2			13.3±2.7		
Residential area	Claverhill	6.3±1.3	0.062	9.08	9.8±2.7	0.044*	16.3
	Garikai	6.8±1.7			10.2±2.4		
	Greenhill	7.6±2.5			12.6±4.3		
	Woodbrook	7.2±2.1			11.7±3.8		

*Significantly different at ($p < 0.05$)

4.3 Drinking Water Quality in Claverhill, Garikai, Greenhill and Woodbrook

Table 4.3 shows the characteristics of drinking water from different residential areas around Bindura town in comparison with SI 6 of 2015 and WHO drinking water guidelines. Results show that there were some variations in water quality at the four residential areas. The pH and TDS at all sites were within the safe limits of 6-8.5 and 600 mg/L respectively. However, BOD and COD for Garikai and Woodbrook were above the regulatory limits of SI 6 but below the WHO limit. Also, DO content for Garikai (65%) and Woodbrook (63%) were marginally outside the SI 6 permissible guideline (below 75%) (Table 4.3).

Table 4.3: Comparison of water physicochemical properties from four residential suburbs in Bindura with EMA and WHO guidelines

Sampling site	Water characteristic				
	pH	BOD (mg/L)	COD (mg/L)	DO (%)	TDS (mg/L)
Woodbrook	7.9 ± 0.5^{a}	17.2 ± 8.3^{a}	14.6 ± 3.4^{a}	63.3 ± 0.4^{a}	94.1 ± 24.8^{a}
Garikai	7.5 ± 0.3^{a}	18.7 ± 3.2^{a}	13.3 ± 7.1^{b}	65.1 ± 0.9^{a}	92.3 ± 32.3^{a}
Greenhill	7.2 ± 0.8^{b}	12.2 ± 5.1^{a}	8.2 ± 6.2^{a}	87.4 ± 0.3^{a}	88.0 ± 54.1^{a}
Claverhill	7.6 ± 0.2^{b}	13.2 ± 1.9^{b}	8.7 ± 4.9^{c}	83.3 ± 0.7^{b}	77.5 ± 19.6^{b}
EMA	6-8	< 15	< 10	> 75	< 100
WHO	6.5-8.5	< 20	< 50	> 50	< 600

Different superscripts a, b, c down a given column indicate significant differences ($p < 0.05$).

The concentrations of trace elements in the drinking water from four residential areas around Bindura town are shown in (Fig. 4.6a to 4.6e). The concentrations of Cd were within both EMA and WHO prescribed limits in all the four sites. Woodbrook recorded the significantly highest Cd concentrations (0.010±0.000ppm). In addition, all sites were significantly different in Cd concentrations ($p < 0.05$) (Fig. 4.6a). The concentrations of Cu for Claverhill (1.27±0.03ppm) and Greenhill (1.65±0.15ppm) were above EMA limits but within the WHO permissible limits. Also, all the residential areas were significantly different in Cu concentrations ($p < 0.05$) (Fig. 4.6b). Garikai and Woodbrook recorded Hg concentrations above the WHO limit but were within the EMA threshold attaining values of 0.008±0.0ppm and 0.009±0.0ppm respectively. Also, all residential areas were significantly different in Hg concentrations ($p < 0.05$) (Fig. 4.6c).

The Pb concentrations were significantly higher than the required EMA and WHO threshold in Garikai and Woodbrook attaining values of 0.16±0.01ppm and 0.17±0.01ppm respectively. In addition, Claverhill and Greenhill were significantly different from Garikai and Woodbrook in Pb concentrations ($p < 0.05$) (Fig. 4.6d). The concentrations of Zn in drinking water for Claverhill and Greenhill were above both EMA and WHO tolerable standards attaining values of 0.65±0.03ppm and 0.54±0.03ppm respectively. Also, Garikai and Woodbrook were not significantly different in Zn concentrations ($p > 005$) (Fig. 4.6e). The total trace element concentrations in drinking water increased in the order Hg < Cd < Pb < Zn < Cu whereas by residential area it followed the trend Claverhill > Greenhill > Woodbrook > Garikai.

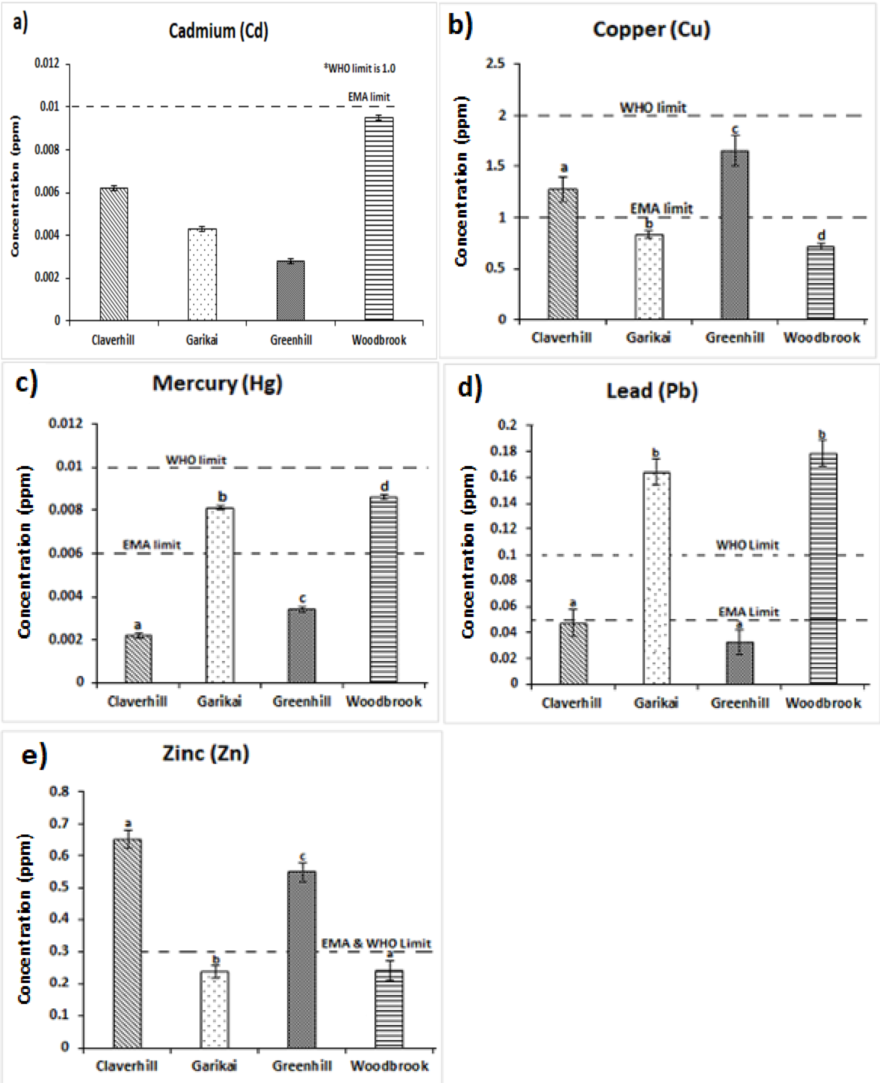

Fig. 4.6: Concentrations of trace elements in drinking water from four residential areas around Bindura

Chapter Five: Discussion

5.1 Knowledge, Attitude and Practices Towards Water Conservation

The most mentioned causes of water shortages in the low-density areas (Claverhill and Greenhill) were lack of resources, vandalism and old infrastructure resulting in burst water pipes whereas in the high-density areas (Garikai and Woodbook) population increase and sewage flow were the major causes of water crisis. Likewise, Ndunguru and Hoko (2016) reported that poor water loss management and ageing infrastructure were the major drivers of water shortages in Harare due to frequent pipe bursts and leakages. The most practised water conservation methods were repairing leaks, rainwater harvesting and mulching were the most frequent methods. Similarly, Schafer and Mihelcic (2012) asserted that many households resorted to storing water in tanks and other containers to adapt to water crisis.

Though the majority of respondents had received health education/awareness, cases of diarrheal diseases were high mainly attributed to attitude and malpractices in sanitation and hygiene. This was evident in the absence of waste storage facilities in some households leading to the dumping of domestic waste thus creating a conducive environment for disease carrying vectors. In addition, children could be seen playing close to raw sewage unaware of the potential health risk it might cause. Bedi *et al.* (2015) concluded that 80% of diarrheal diseases in the city of Ludhiana, Pakistan was a result of poor hygiene. Also, Francis *et al*. (2015) deduced that some respondents did not pre-treat water they sourced from unsafe sources leading to many diarrheal cases. In a study by Eck *et al*. (2019), it was reported that majority of respondents had knowledge on water related issues however, most could not determine the safety of their drinking water. Ultimately, most respondents changed their behaviour towards water issues based on the study.

Age and level of educational attained were highly associated with knowledge on water conservation and water pollution. The 21-40 years and 41-60 years age groups were mature enough and valued the importance of water as a finite resource. Similarly, those who reached advanced level and tertiary education had better knowledge scores attributed to the ability to acquire information from diverse sources. Gender, age, and residential area were strongly related to attitude and practice on water related issues. Females and older respondents had higher attitude and practice towards water related issues compared to other groups. In addition, respondents from densely populated areas (Garikai and Woodbrook) behaved better than those from lowly populated areas (Claverhill and Woodbrook). This could have been a result of unpredictable supply of piped water whereas in some instances absence of piped water in the high-density areas. The long distances travelled to, and the long hours spent collecting water in the high-density areas changed their behavior.

The results are similar with the findings of Kausar *et al.* (2009), who stressed that there is a strong connection between people's literacy and income with water quality and health issues. More literate respondents and high-income earners are able to protect their families from waterborne diseases. In the present study, residents from Claverhill and Greenhill (low-density) areas earn better than those in Garikai and Woodbrook (high-density) areas. In addition, in low density areas there are less people hence water shortages are not more pronounced as compared to high density areas where water demand is very high.

5.2 Sources of Pollution, and Water Quality in Claverhill, Garikai, Greenhill and Woodbrook

The most identified sources of water pollution were illegal dumping of domestic waste and sewage flow. Other related sources of water pollution were agricultural and industrial waste, laundry on riverbanks and stormwater run-off. These activities release contaminants into water thus reducing its quality. Daud *et al.* (2017) reported sewage mixing with drinking water due to poor sanitation and sewerage system, with industrial effluents, fertilizers and domestic waste as dominant sources of water contamination. Igwe *et al.* (2017) asserted that densely populated areas are heavily impacted by water pollution as individuals and industries regard surface water bodies as waste disposal sites. This was apparent in Garikai and Woodbrook where domestic waste dumping was rampant and the unreliable refuse collection worsened the conditions. Also, there were many observed incidents of flowing sewage which could have potentially reached the ground water via seepage thus contaminating it.

Water quality assessment deduced that pH was neutral and the TDS were within normal range thus conformed with the EMA and WHO standards. These results are similar to those of Bedi *et al*. (2015) who deduced pH 7.05 and TDS below 400 mg/L. However, there was a relatively high BOD and COD for Garikai and Woodbrook which led to reduced DO. These areas are mainly high-density areas relying mostly on ground water. This is a result of high organic matter content reaching ground water due to sewage flow and leaching of fertilizers. WHO (2008) states that indicators of water contamination are low DO and high BOD compared with the WHO guidelines.

The concentrations of Cd and Hg were below the threshold level and insignificant to cause any detrimental effects to humans. However, these trace elements may accumulate overtime and pose a potential health risk. The traces of Cd could have emanated from battery residues derived from dumped used batteries or soldered plumbing material. In addition, Rahmanian *et al.* (2015), asserted that Cd enters through groundwater or surface water, and emanates from paints, electroplating, fossil fuels, fertilizer, and disposal of sewage sludge which were the typical activities in the study areas. On the other hand, Hg concentrations could have been derived from the amalgamation technique used in gold recovery by gold-panners (Velasquez-Lopez *et al.,* 2010). The Hg is not soluble and cannot be recovered hence it is lost to the environment eventually reaching water sources. Gold-panning activities release Hg along Mazowe River which is situated upstream of Mwenje Dam the main source of raw water that is processed and distributed to residents in Bindura.

The high Cu and Zn concentrations above EMA and WHO permissible limits for Claverhill and Greenhill could have resulted from the corrosive action of water leaching Cu from copper pipes in buildings. In addition, high DO concentrations accelerate copper corrosion whereas dissolution of zinc pipes leads to the presence of Zn in drinking water (WHO, 2017). In the present study, most houses were fitted with copper and zinc pipes and the water is supplied through old galvanised materials. Consequentially Garikai and Woodbrook had higher Pb concentrations in drinking water resultant of exhaust fumes from automobiles, that are powered by gasoline, also from motor-vehicle tyres and oils from heavy volumes of traffic (Nawrot *et al.,* 2020) deposited on to the soil and percolates into the ground affecting ground water quality.

The likely clinical effects resulting from continued consumption of contaminated water in Greenhill and Shashi-view are Cu and Zn toxicity leading to, kidney and lung failures, high blood pressure and cancer, (Gabriel *et al.,* 2019). On the other hand, the reproductive and nervous systems for those in Garikai and Woodbrook might be affected (Pratush *et al.,* 2018). When water is severely polluted, it cannot be cleaned-up totally thus it is safer and wiser to prevent its occurrence by eliminating disposal of toxic substances into the environment.

Chapter Six: Conclusion and Recommendations

6.1 Conclusion

The findings of the present study indicated that the respondents had a better KAP on water conservation and pollution. However, they had negative attitudes and bad practices towards conservation. This was observed through illegal dumping of domestic waste, which led to pollution via surface run-off. The most practiced water conservation methods were repairing leaks, rain-water harvesting and mulching. Respondents managed to identify several sources of water pollution with the most mentioned being illegal dumping of domestic waste, industrial waste, and sewerage flow.

Water quality analysis determined that BOD, COD and DO for Garikai and Woodbrook were above the SI 6 permissible limits. In addition, the concentrations of Cd and Hg were within the EMA and WHO prescribed limits in all the four sites ($p < 0.05$). Claverhill and Greenhill had Cu and Zn traces above EMA and WHO tolerable standards whereas Pb concentrations were significantly higher in Garikai and Woodbrook. Though some of the pollutants were above the regulatory limits, their concentrations were insignificant to cause deleterious but had the potential to do so overtime due to bioaccumulation.

6.2 Recommendations

- Residents should have a positive attitude towards water conservation and practice proper hygiene to reduce the prevalence of diarrheal diseases.
- Continuous monitoring of water quality should be exercised to ensure its safe for human consumption.
- Local authority to provide skip bins and frequently collect domestic waste thus reduce illegal waste dumping.
- Local authority should improve water infrastructure to ensure reliable water supply.
- Further studies should focus on sources of water pollution to reduce the release of contaminants into surface water.

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Appendices

Appendix I: Research Questionnaire

Good morning/afternoon. My name is **SAMANTHA DZUDA**. I am a student in the department of Natural Resources (Reg. number: B000000) at Bindura University of Science Education. I am undertaking research on *"An assessment of water crisis in urban settings. A case study of Bindura town."*. I am inviting you to participate in the study by answering a few questions on the topic. Your participation in this study is voluntary. I guarantee you that information shared will be treated as confidential and your identity will not be disclosed. The study findings will be used to make recommendations on food safety and hygiene in Zimbabwe. Answering the questions takes about 15 minutes of your time.

Interview guide No: .... **Date: ....**

SECTION A: DEMOGRAPHIC INFORMATION *(please tick appropriate)*

1) Gender: male ☐ female ☐

2) Marital status: married ☐ divorced ☐ single ☐

3) Age: <20yrs ☐ 21-40yrs ☐ 41-60yrs ☐ >60years ☐

4) Level of education: none ☐ primary ☐ ordinary level ☐ advanced ☐ tertiary ☐

5) Years living in Bindura: <1yr ☐ 1-5yrs ☐ 6-10yrs☐ >10yrs☐

6) Number of people in household: 1-3 ☐ 4-6 ☐ >6 ☐

SECTION B: WATER SUPPLY AND SANITATION

7) What is your main source of water? household tap ☐ well ☐ public tap ☐ community borehole ☐ other, specify ……..

8) Is the source of water always working? yes ☐ no ☐ not sure ☐

9) Do you perceive the water to be safe? yes ☐ no ☐

10) If no, specify ……………………………………………………………………………………………………

11) How far (in meters) is the water source that you use? <100m ☐ <500m ☐ >500m ☐

12) How long does it take to fetch water and return home? <1hr ☐ 2-3hrs ☐ >5hrs ☐

13) What is the frequency of water supply? daily ☐ 3times a week ☐ once a week ☐

14) Is the frequency enough for your needs? yes ☐ no ☐

15) On the days that you get water, how many hours do you usually get water for? <3hrs ☐ 4-6hrs ☐ 7-9hrs ☐ 10-12hrs ☐ >12hrs ☐

16) What could be the cause of water shortages? increased population ☐ pollution ☐ burst water pipes ☐ lack of resources ☐ vandalism ☐ drought ☐ low rainfall ☐ dilapidated infrastructure ☐

17) How many months of the year do you face water scarcity? 1 month ☐ 2-4 months ☐ 5-6 months ☐ 7-9 months ☐ 10-12 months ☐

18) Generally, how does the water smell? no smell ☐ foul smell ☐ don't know ☐

19) Generally, does the water have a taste? yes ☐ no(tasteless) ☐

20) Generally, what does the water look like? clear ☐ cloudy ☐ dirty ☐

21) Do you pay for water? yes ☐ no ☐

22) Are the bills accurate? yes ☐ no ☐

23) Overall, are you satisfied with your drinking water service? yes ☐ no ☐

24) What type of sanitation facility do you use? flush to septic tank ☐ flush to municipal connection ☐ BVIP ☐ simple pit latrine ☐ other, please specify ……………………………..

25) Do you wash your hands after using the sanitation facility? yes ☐ no ☐ sometimes☐

26) Do you have a waste storage receptor/facility? yes ☐ no ☐

27) If No, where do you deposit waste generated at your household? Please specify ……………………………….

28) What type of waste storage receptors do you use? plastic bags ☐ plastic containers ☐ aluminum containers ☐ skip bins ☐ other, please specify ………………………………………………………………

29) How often are the waste receptors emptied? daily ☐ weekly ☐ monthly ☐ not sure ☐

SECTION C: HEALTH AND HYGIENE

30) Have you received education/awareness on health and hygiene? yes ☐ no ☐

31) If Yes, by who? ministry of health ☐ NGO ☐ other, please specify ……………………………………

32) Do you do any health and hygiene discussions in your community? yes ☐ no ☐

33) If yes, how often? weekly ☐ fortnightly ☐ monthly ☐ quarterly ☐

34) Which diseases are caused by poor hygiene? *(Tick as many as possible)* bilharzia ☐ cholera ☐ diarrhoea ☐ dysentery ☐ malaria ☐ typhoid ☐

35) Have you ever been diagnosed with any of the diseases caused by poor hygiene? yes ☐ no ☐

36) If yes which one/(s)? cholera ☐ diarrhoea ☐ dysentery ☐ typhoid ☐

37) When was your last illness? <6 months ☐ 6-12 months ☐ >12 months ☐

SECTION D: WATER CONSERVATION AND POLLUTION

38) Do you conserve water at home? yes ☐ no ☐

39) How often do you conserve water? daily ☐ weekly ☐ monthly ☐

40) Which water conservation methods do you know? closing taps when brushing teeth ☐ repairing leaking taps ☐ using a bucket instead of shower ☐ not doing laundry daily ☐ washing dishes in a bowl ☐ watering plants when necessary ☐ harvesting rainwater ☐ mulching ☐ protecting water from pollution ☐ reducing runoff ☐

41) Of the methods mentioned above, which ones(s) do you practice? closing taps when brushing teeth ☐ repairing leaking taps ☐ using a bucket instead of shower ☐ not doing laundry daily ☐ washing dishes in a bowl ☐ watering plants when necessary ☐ harvesting rainwater ☐ mulching ☐ protecting water from pollution ☐ reducing runoff ☐

42) What is water pollution? *(Please explain)* …………………………………………………….…………………...
………

43) What sources of surface water pollution do you know? stormwater run-off ☐ sewage ☐ industrial waste ☐ agricultural waste ☐ river-sand abstraction ☐ gold panning ☐ domestic waste dumping ☐ laundry along rivers ☐ other, please specify ………………………..

44) In your community, what are the sources of water pollution? stormwater run-off ☐ sewage ☐ industrial waste ☐ agricultural waste ☐ river-sand abstraction ☐ gold panning ☐ domestic waste dumping ☐ laundry along rivers ☐ other, please specify ………………………………………………………………

45) From the following, what are the impacts of water pollution? poor water quality ☐ affect crops ☐ waterborne diseases ☐ affect aquatic organisms ☐ eutrophication ☐ other, please specify ……

END OF INTERVIEW ………………………. THANK YOU