BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF ENVIRONMENTAL SCIENCE

Physicochemical quality of drinking water at selected points-of-use at Bindura University of Science Education, Zimbabwe

By

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DECLARATION

Registration Number B212533B

I, Munashe Mutape, hereby guarantee that this work is wholly original to me and has never been used in any other academic paper. Every citation to previously published work has been made transparent.

Student signature ………………………….   Date 28 May 2025

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

Supervisor's signature…   Date: 30 May 2025

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ABSRACT

Background: Access to safe drinking water relies on point-of-use (POU) water systems due to potential contamination.

Objectives: Concentrations of selected physicochemical parameters of drinking water were measured across four university campuses and were compared with international threshold limits.

Methods: In a cross-sectional survey, water samples were collected and analyzed for some selected physicochemical parameters (pH, EC, hardness) and selected trace elements (Zn, Cu,Pb,Ni and Cd) using standard operating procedures between May and July, 2025 at Bindura University of Science Education (BUSE). Measured mean parameter values were compared across campuses using One-Way ANOVA and compared to drinking water quality guidelines using a one sample t-test in SPSS 27.Statistical significance was considered at $p < 0.05$.

Key findings: Most trace elements were below limits of detection. Parameter variations across campuses were statistically significant in hardness and pH. Parameter comparison with WHO limits were well within limits. There was little ionic content at all sites due to the low EC (3.21 – 13.56 µS/cm).

Conclusion: High water hardness observed may have other implications than direct human health.

Key terms: Drinking water, Hardness, Trace elements and Water quality.

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LIST OF ACRONYMS AND ABBREVIATIONS

FAAS	Flame Atomic Absorption Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
SPSS	Statistical Package for Social Science
POU	Point Of Use
WHO	World Health Organisation
EC	Electrical Conductivity
BDL	Below Limit of Detection

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TURNITIN REPORT

Munashe Mutape (B212533B)

CHAPTER 1: INTRODUCTION

1. Introduction

1.1 Background to the study

Drinking contaminated water has been reportedly associated with human health risks. Studies have indicated that trace elements may cause reproductive, cardiovascular, pulmonary, and gastrointestinal disorders and other disorders ((Eyankware et al., 2023; Rehman et al., 2018). Extremes in drinking water pH may have effect on water palatability and metal solubility (Rout & Sharma, 2019). High water hardness may not have direct human health problems, but it has been indicated to have other problems such as soap consumption and can lead to pipe scaling, primarily because of calcium and magnesium ions.(Rout & Sharma, 2011). Therefore, drinking water quality should be prioritised to eliminate the risk of potential human health risk. To this end, the World Health Organisation has established guideline values for drinking water quality guidelines (WHO 2017}.

Point-of-use (POU) in this work refers to the actual point in drinking water where the customer introduces the water into the mouth directly from the source (Herschan, 2023) .Drinking water is obtained from different sources (Wątor et al., 2021). However, in some cases it is not consumed directly where it is abstracted(Levallois & Villanueva, 2019). Instead, it may be transported, treated stored in tanks or consumed using some gadgets from the source. This may change the quality of drinking water from abstraction to the POU (Levallois & Villanueva, 2019). Some studies have shown that the abstracted water quality changed at the POU due to various contaminants such as microbial or physiochemical (Herschan, 2023).

In Zimbabwe, groundwater is generally considered safe for drinking (Wątor et al., 2021). It is rarely treated unless some challenges have been reported, or more generally, it may be treated for potential microbial contamination only, for instance industrial waste and urban sewage contamination (Cipriani-Avila et al., 2020) (Domoń et al., 2024a). Drinking water at BUSE campuses is mainly abstracted at all campuses from boreholes and pumped into some tanks for local use.

1.2 Problem Statement

Aging infrastructure, environmental pollution and poor maintenance of water supply infrastructure can lead to contamination of water at the point of use (Cipriani-Avila et al., 2020).Further, contamination may arise from network pipes and fittings that increase concentrations of Cd, Cu, Fe, Pb and Zn (Cipriani-Avila et al., 2020). Yet common practice seems to be concerned about water quality at the source, particularly for groundwater considered safe for drinking. This study assessed drinking water quality at the point of use at four university campuses.

1.3.1 Aim

- To evaluate the physicochemical quality of drinking water at four university campuses using selected parameters.

1.3.2 Objectives

- To determine the levels of physicochemical water quality parameters (Cd, Cu, Pb, Ni, pH, EC, hardness and Zn) at the POU water across BUSE campuses.

- To compare measures water quality parameters with international (WHO 2017} drinking water quality guidelines.

1.4 Significance of the Study

The findings from this investigation will offer a scientific basis for assessing the quality of drinking water in institutional environments. The results will help environmental agencies, public health officials, and BUSE administrators constitute well-informed decisions about infrastructure improvements, water treatment, and health risk reduction. Additionally, the study adds to the larger conversation about water safety in Zimbabwean universities.

1.5 Research hypotheses

H_0: There is no significant variation in measured mean water quality parameters across university campuses.

H_1: There is significant variation in measured mean water quality parameters across university campuses.

H_0: There is no significant variation in measured mean water quality parameters with (WHO 2017}drinking water quality guidelines.

H_1: There is significant variation in measured mean water quality parameters with (WHO 2017}drinking water quality guidelines.

1.6 Assumptions

- Heavy metal concentration will vary according to the point of use of each sample.
- Each sample's physiochemical parameters will differ depending with its source.
- Some samples, both heavy metals and physiochemical properties will surpass the stipulated regulations by WHO.

1.7 Delimitations

The study will:

- Focus only on POU
- Focus only on BUSE campuses

CHAPTER 2: LITERATURE REVIEW

2. Literature review

2.1 Introduction

This chapter provides an overview of the existing literature on recent studies on the presence of heavy metals and physicochemical characteristics of POU water systems, drawing insights from both global and regional contexts.

2.2 The importance of including physicochemical parameters in assessing drinking water quality

Water physiochemical parameters, such as pH, electrical conductivity, turbidity, and hardness, are important in assessing drinking water quality because the determine quality of water (Jaafar et al., 2020). According to technical definitions, turbidity is a disorder or fluid disturbance brought on by suspended solids that are typically invisible to the human eye (Jaafar et al., 2020). A person is more likely to contract water-related illnesses if the drinking water has a higher turbidity level (Jaafar et al., 2020). Furthermore, another commonly used physical metric to assess the quality of water is electrical conductivity (Xianhong et al., 2021) . The degree of water hardness is another factor used to determine water quality (Price et al., 2022). Hard water is due to metal minerals such as Iron Calcium and magnesium Price et al., 2022).

By releasing specific metals like lead, arsenic, and chromium into the water, water instability can degrade water quality by promoting bacterial growth or corrosion (Domoń et al., 2024a). Water palatability and metal solubility are influenced by physicochemical characteristics like pH, EC, and hardness (Rout & Sharma, 2011). Acidic water promotes metal leaching from pipes, and pH influences corrosion potential and metal mobility (Li et al., 2020). Electrical conductivity is a measure of dissolved solids and water's ionic strength (Jaafar et al., 2020). Elevated EC values could indicate salt or industrial effluent contamination. Hardness affects soap consumption and can lead to pipe scaling, primarily because of calcium and magnesium ions (Rout & Sharma, 2011)

2.3 The importance of the POU in assessing drinking water quality

Since 2018, an increasing amount of research has shown how important Point of Use (POU) systems are for determining and guaranteeing the quality of drinking water, especially in situations where centralised treatment is insufficient or unreliable (Mirsalari et al., 2022) Particularly in low- and middle-income nations, studies have shown that POU interventions such as chlorination, filtration, and ultraviolet (UV) disinfection are very successful in lowering microbial contamination and the prevalence of waterborne illnesses like diarrhoea(Mirsalari et al., 2022). In 2022, Mirsalari et al for instance, field research and systematic reviews have demonstrated that POU technology use in communities and schools significantly improves health, with high adoption rates seen in structured settings like Bangladeshi and Kenyan schools. These findings underscore the importance of POU systems as a final barrier against contaminants, providing immediate and localized water quality assurance at the point of consumption(Appiah-Effah et al., 2021)(Ram et al., 2021).

Additionally, recent studies have highlighted the relative sustainability and efficacy of several POU technologies in diverse socioeconomic and geographic contexts (Appiah-Effah et al., 2021). The cost, environmental impact, and user preferences for POU solutions like UV disinfection, improved filtering media, and ceramic filters enabled by silver nanoparticles have all been evaluated using techno-economic studies and life cycle assessments (Alshami et al., 2024). The emergence of smart POU systems in industrialised nations, which combine home automation and real-time monitoring, is indicative of a trend towards more advanced water quality management that addresses issues with ageing infrastructure and new contaminants (Alshami et al., 2024). When taken as a whole, these studies demonstrate that POU assessment is essential for both immediate water safety and for guiding resource allocation, legislation, and the creation of context-specific plans to guarantee safe drinking water everywhere.

2.4 Common characteristics of groundwater

BUSE relies heavily on groundwater (boreholes) for its water supply, which is then delivered to the point of use via pipes. However, industrial waste, urban sewage, and agricultural runoff can all deteriorate the quality of groundwater (Cipriani-Avila et al., 2020). Water quality at the point of use is mostly determined by the quantity and makeup of dissolved solids, including heavy metals found in groundwater (Domoń et al., 2024a).Leaching from storage tanks, tainted source water, and corroded plumbing are the main causes of these metals in POU water system (Domoń et al., 2024a). For example, the corrosion of copper pipes, faucets, and other plumbing fixtures is the most frequent source of copper in drinking water (Vargas et al., 2017). The issue is made worse in developing nations by inadequate infrastructure upkeep and lax enforcement of regulations.

Water can be delivered to the point of use already contaminated, in addition to the material used (Ismanto et al., 2023; Karthikeyan1 et al., 2021). Leaching, weathering, and volcanic eruptions are some of the natural ways that heavy metals can contaminate groundwater (Alam et al., 2023). High temperatures, water, ice, pressure, and other weathering microclimate conditions break down heavy metals that contain minerals as a result of physical weathering(Ismanto et al., 2023). The metals are then released into ground water through leaching and the use of various leaching agents and infiltration into groundwater. Heavy metals are also liberated from soil matrixes (Karthikeyan1 et al., 2021)

Table 2.1 Common physicochemical constituents of groundwater quality

Type of parameter	Parameter	Reference
Physical	pH	(Jaafar et al., 2020)
	Electrical Conductivity	Rusydi 2018
	TDS	(Devesa & Dietrich, 2018)
	Turbidity	(Chen et al., 2023)
	Temperature	(Agudelo-Vera et al., 2020)
Chemical	Trace elements Cd, Cu, Zn, As, Pb)	(Domoń et al., 2024a
	High hardness	(Dhoke, 2024)
	Biological Oxygen Demand	(Prambudy et al., 2019)
	Chemical Oxygen Demand	(Prambudy et al., 2019)

2.5 Potential sources of contamination of abstracted drinking water

The amount of heavy metals in consumers' tap water is influenced by the kind of material used in home installations and distribution systems (Domoń et al., 2024b). Large volumes of metallic elements are released as a result of pipeline corrosion, altering the chemical makeup of water while it is being transported (Domoń et al., 2024b) Prior research frequently documented declines in the quality of water delivered via vast distribution networks (Domoń et al., 2024b). Heavy metals, such as lead, which may be present in PVC pipes as a stabiliser, can also leach from plastics (Domoń et al., 2024b)

2.6 Human health concerns associated with drinking water contaminated with trace elements (Zn, Pb, Cu,Cd and Ni)

Table 2.2 show s common health concerns of consuming water contaminated with trace elements.

Table 2.2 . Common health problems of consuming water contaminated with trace elements (Rehman et al., 2018)

Pollutant	Health Impacts
Pb	● accumulates in the body ● damages the central nervous system ● most risky relative to children and pregnant women.
Cd	● disorders: reproductive, cardiovascular, pulmonary and gastrointestinal Dementia-related learning and memory impairments ● Kidney disease, lung damage, and cancer
Ni	● Gastrointestinal distress and allergic reactions
Zn	● Nausea and vomiting in excess.
Cu	● Gastrointestinal distress and allergic reactions

The below values are according to (WHO 2017}) on guidelines for drinking water quality.

Metal	MRL
Cadmium	0.003mg/litre
Nickel	0.07mg/litre
Copper	2mg/litre
Lead	0.01mg/litre
Zinc	3mg/litre

Physiochemical Property	MRL
Ph	6.5 -9.5
EC	1000 µs/cm

Hardness	60-500mg/L

2.7 Theoretical framework

WQI serves as a theoretical framework, simplifying intricate water quality data into a comprehensible single value for policymakers and environmentalists (Saqib et al., 2023). Operating on a scale of 0 to 100, the WQI encapsulates complex information, concisely rating water quality status from poor quality to excellent quality at specific locations and times (Saqib et al., 2023). The idea is based on the notion that a lower value indicates a smaller deviation from the suggested parameter values, resulting in higher quality water suitable for human consumption and vice versa (Shaibur et al. 2024). WQI reflects the composite effect of multiple water quality parameters on the overall water quality (Ramprasad et al., 2020). Humans can be exposed to pollutants found in groundwater through drinking and the dermal contact with this water (Babuji et al., 2023). In this respect, the evaluation of groundwater in terms of health risk is of great importance for the protection of public health (Jadoon et al., 2024).

2.8 Summary

Although a lot of research has been done worldwide, there is still a dearth of localised information on the physicochemical properties of POU water and heavy metal contamination in Zimbabwean universities, particularly at BUSE. By providing a thorough evaluation across several BUSE campuses, this study seeks to close that gap.

CHAPTER 3: MATERIAL AND METHODS

3. Material and methods

3.1 Description of the study area

This study was conducted at Bindura University of Science Education (BUSE), located in Mashonaland Central Province, Zimbabwe (Fig. 3.1). There are four campuses at the university; Main Campus, Town Campus, Astra Campus and FSE. Potential pollution sources around BUSE include mining activities like Kitsiyatota and chemical industries such as Chilmund.

3.2 Research design

The study employed a cross-sectional approach which works well for assessing water quality from the various campuses at BUSE at each point of use because it provides comparative insight into the quality of POU water across different university facilities. This design is commonly used in environmental monitoring due to its efficiency and minimum resource demand.

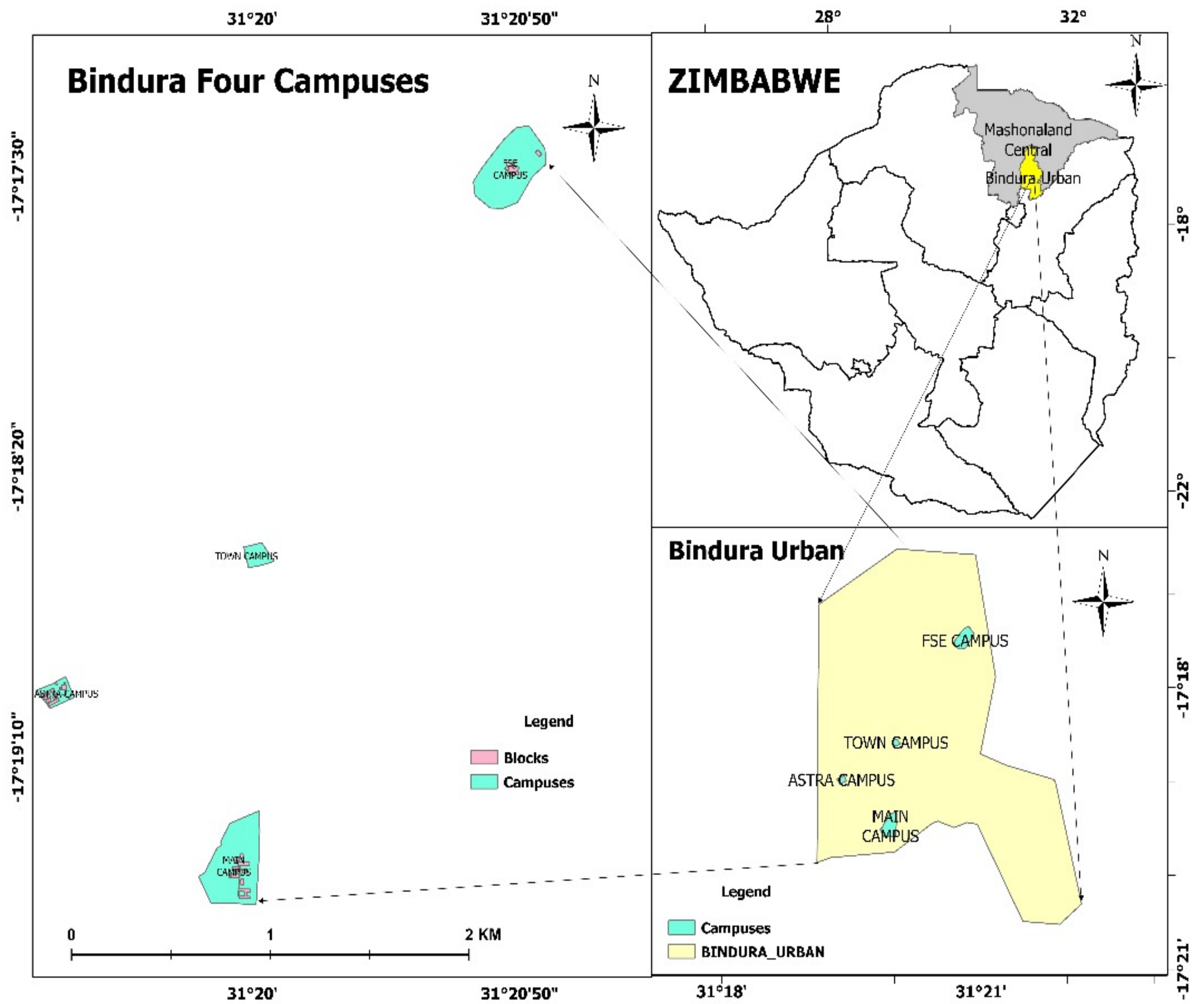

*Fig. 3.*1 Location of BUSE on the Zimbabwe map and university campuses on the local map

3.3 Sampling

Samples were collected into pre-cleaned 500 mL polyethylene bottles were used to collect samples at each location between May and July, 2025. The containers were accordingly labelled and preserved in ice-cooled containers below 4°C. Some water quality parameters (e.g., pH and EC) were measured onsite using portable instruments. Table 3. 1 gives a summary of analytical methods used. Details for the procedures are given in the Appendices.

Table 3.1 Analytical procedures used for water quality analyses

Parameter	**Instruments/equipment (Model, Company & country of manufacture)**	**Reference**
Ph	pH Meter (1400F)	APHA 2017
EC	EC meter (AD3000)	Rusydi 2018
Total Hardness	EDTA Titration	(Dhoke, 2024)
Trace elements (Cd, Cu, Ni, Zn , Pb)	Atomic Absorption Spectrometry	(Kumar et al., 2020)

3.4 Quality control procedures

Blank samples were used during the whole sample preparation and analysis procedure for every analytical batch of samples processed. Sampling and sample analysis were replicated. Standard methods of water quality sampling and analysis were used. Reagent-grade chemicals were used. Sample bottles were pre-cleaned and rinsed before sampling. FAAS were optimised for analysis using the manufacturer's instructions. The pH meter was calibrated using pH buffer solutions. Maximum holding times for samples were observed.

3.5 Data management

Laboratory data were entered into MS Excel and checked for errors. Data were imported into SPSS version 27 for analysis. Data were tested for normality using Shapiro Wilkins test and. It was found to be normally distributed and one-way ANOVA was used for data analysis. To determine the variation of water parameters across campuses one way ANOVA was used. To compare measured water quality parameters with (WHO 2017}drinking water guidelines One-Sample t test was used. All statistical analyses were considered to be statistically significant at $p < 0.05$.

CHAPTER 4: PRESENTATION OF RESULTS

4. Results

4.1 Test for normality

The Shapiro Wilk Test was used to assess the normality of the data. As shown below, the p-values for all the tested factors was above 0.05, indicating that the data was normally distributed

Parameter	Statistic
pH	0.935
Hardness	0.922
EC	0.918
Nickel	0.944

4.1 The variation of measured physicochemical water quality parameters

Table 4.1 shows the variation of measured physicochemical water quality parameters across the four university campuses. Results show that only Ni was determined and the other were below the limit of detection (BLD).All statistical analysis were considered to be statistically significant at $p < 0.05$. Hardness and EC were statistically significant with values less than 0.05.

Table 4.1

Parameter	University campus			
	Main	Astra	Town	FSE
pH	6.77±0.05	6.77±0.03	6.78±0.03	6.85±0.02
EC	4.71±0.23	11.2±1.18	4.80±0.87	9.31±1.01
Hardness	316.62±58.90	595.32±109.32	843.21±96.1	165.3±1.01
Cd (mg/l)	BLD	BLD	BLD	BLD
Cu (mg/l)	BLD	BLD	BLD	BLD
Ni (mg/l)	0.02±0.0007	0.012±0.0009	0.014±0.0016	0.015±0.0009

Pb (mg/l)	BLD	BLD	BLD	BLD	
Zn (mg/l)	BLD	BLD	BLD	BLD	

BDL = Below limit of detection

Table 4.1.2 showing ANOVA Results

Table 4.1.2

Parameter	p-Value
pH	0.262732
Hardness	0.001487
EC	0.003116
Nickel	0.178441

4.2 Comparison of mean measured physicochemical parameters of water quality with (WHO 2017}threshold values

Table 4.2 shows the results for comparing mean measured physicochemical parameters of water quality with (WHO 2017}threshold values

Parameter	Mean Value	WHO Guideline

pH	6.7900	6.5 - 8.5
EC	7.5150	1000 µS/cm
Hardness	480.1133	60–500 mg/L
Nickel	0.014142	0.07mg/L

Table 4.1 The variation of water quality parameters across university campuses. Values are mean±SE of triplicate measurements.

CHAPTER 5: DISCUSSION

5. Discussion

5.1 Discussion

This chapter explains the results It attempts to interpret observed phenomena, consider the analytical implications thereof, and relate the implications of results to water quality at the BUSE campuses.

5.2 The variation of measured physicochemical water quality parameters

Table 4.1 presents the variation in physicochemical parameters of drinking water across the four BUSE campuses (Main Campus, Astra, Town (TC), and FSE). The pH values were relatively consistent across campuses, ranging from 6.77 ± 0.05 at Main to 6.85 ± 0.02 at FSE. ANOVA results revealed no statistically significant variation in pH across campuses ($p = 0.263$). However, significant differences ($p = 0.003$) were observed in electrical conductivity (EC), with FSE showing higher conductivity (Mean = 9.31 µS/cm) compared to other campuses, suggesting different levels of dissolved ions. Water hardness also varied considerably ($p = 0.0015$), with Town Campus recording the highest mean hardness (843.21 mg/L), well above the WHO upper limit of 500 mg/L. Nickel was the only trace metal detected, and though its concentrations were all below the WHO guideline value of 0.07 mg/L, statistical analysis showed no significant differences across campuses ($p = 0.178$).

5.3 Comparison of mean measured physicochemical parameters of water quality with (WHO 2017}threshold values

Table 4.2 compares the mean values of selected parameters with WHO drinking water quality guidelines. All measured pH values fell within the acceptable WHO range (6.5–8.5). EC levels were also far below the 1000 µS/cm threshold, indicating low ionic content. However, water hardness at Astra (778.69 mg/L) and Town (973.36 mg/L) campuses exceeded the WHO acceptable range (60–500 mg/L), suggesting potential long-term scaling issues and possible aesthetic concerns. Nickel concentrations ranged from 0.0105 mg/L at Astra to 0.0168 mg/L at Main Campus, all well within acceptable WHO limits (0.07 mg/L). Other heavy metals (Cd, Pb, Cu, Zn) were below detection limits in all samples.

5.4 Limitations of the study

In this study, overgeneralization can be prevented by carrying out a larger sample size . Flame Atomic Absorption Spectrometry limited metal detection. Overgeneralization was curbed by carrying out by triplicating findings.

5.5 Summary

The study confirmed generally safe water but identified areas of concern such as water hardness. The study is useful because it adds context specific insight into institutional water quality in Zimbabwe.

CHAPTER 6: CONCLUSION AND RECCOMENDATIONS

6.1 Conclusion

The current study evaluated the POU water quality at BUSE from Astra, Town Campus, Main Campus and FSE on the basis of heavy metals and physicochemical parameters. The results indicate that nickel as the only known heavy metal was however within the safety WHO thresholds. Nonetheless, hardness of water levels was above standard levels at two campuses, also electric conductivity of samples had the very low values were left. pH was found to be in acceptable limits. The findings highlight the importance of regular water quality monitoring in institutions and intervention especially in relation to water hardness. This study was unique from all others because it specifically concentrated on BUSE. Future research needs to use advanced equipment such as ICP-MS.

6.2 Recommendations

- Add water softening technologies, for instance ion exchange and reverse osmosis at high-hardness facilities such as Town Campus to control mineral scaling and enhance usability.
- Re-evaluate metal levels with more sensitive analysis techniques such as ICP-MS to avoid false negatives and be sure of detection.
- Regular water quality monitoring should be instituted at all campuses at POUs to monitor variation of physiochemical and heavy metals as well as to continued compliance to health guidelines.

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