DRINKING WATER QUALITY ASSESSMENT IN BASIC SCHOOLS IN PERI-URBAN AREAS - A CASE OF MTENDERERE TOWNSHIP IN LUSAKA, ZAMBIA

By

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A dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the Postgraduate Diploma in Integrated Water Resources Management (IWRM)

The University of Zambia
2011
Declarations

I, Evans Mwamba Tembo, do hereby declare that this dissertation represents my own work, and that it has not previously been submitted for a Post-graduate diploma at this University or any other University.

Signature: .............................................. Date: ..................................................
Approval

This Dissertation of Evans Mwamba Tembo has been approved as partial fulfillment of the requirement for the award of the Postgraduate Diploma in Integrated Water Resource Management by the University of Zambia.

Name of the Supervisor: Prof. Imasiku A. Nyambe

Signature: ........................................ Date: ..................................................
Abstract

Mtendere Township (meaning a peaceful township) is one the unplanned settlements situated on the eastern side of Lusaka, Zambia. The township is characterised with over-crowding, lack of adequate safe water, poor sanitation, poor hygiene practices, poverty, and poor waste management practices. The township has four Government basic schools with a total population of 10,164 pupils, and these schools are also characterised by the same challenges.

At present the studied schools are using borehole water with an assumption that it is safe water and requires no treatment. It is against this background that this study on drinking water quality assessment in four Schools in Mtendere Township was carried out to determine the suitability of the borehole water for use by the pupils and teachers.

In general, the results of this study showed that the concentration of nitrates and microbiological parameters of drinking water for New Mtendere, Mtendere and Chitukuko Basic Schools range from 19.6 mg/l – 29.66 mg/l and 4 CFU/100ml – 28CFU/100ml respectively. In comparison with the recommended ZABS / WHO guidelines for nitrates (i.e. 10mg/l) and microbiological parameters (0 CFU/100ml), these contaminants are above the recommended standards and thus making the water in studied schools unsafe for human consumption. Hence need for the school management to treat the water prior to consumption.

The study therefore recommends that drinking water quality assessment in schools should be given a priority by Ministry of Health. Additionally, the ministries of Education and Health should work together in implementing an effective health and hygiene education programme in schools in peri-urban areas. The respective school managements should be treating their water in storage tanks and also should introduce sustainable handwashing programmes with soap in schools to alleviate water re-contamination by the pupils at the point of use. Further studies should be undertaken by the Ministry of Health in collaboration with Colleges and Universities in order to investigate the trends of groundwater contamination in schools in Lusaka, and then be scaled-up to other peri-urban areas in the country particularly the Copperbelt.
Dedication

I dedicate this dissertation to my wife, Mwenya and my daughter Esther for their inspirations.
Acknowledgment

I would like to express my gratitude to Prof. Imasiku A. Nyambe for giving me the opportunity to work on this research project. I sincerely appreciate his guidance, support and patience. I would also like to thank Mrs. I. Kawesha in the IWRM Centre for her assistance in logistics. I would like to gratefully acknowledge Danida and the Danish Embassy for their sponsorship through the IWRM Centre during my graduate studies.

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Lastly but most important, I would like to express my sincere appreciation to all the Head Teachers and School Hygiene and Nutrition (SHN) Coordinators in the studied schools who made my research possible. Their willingness to know the state of the potable water which the pupils were using made my research even more interactive and interesting.
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Acronyms

ANZECC  Australian and New Zealand Environmental and Conservation Council
APHA  American Public Health Association
Cl  chlorine
EC  electrical conductivity (measure of salinity)
GDWQ  Global Drinking Water Quality
L  litre
L/day  litres per day
LWSC  Lusaka Water and Sewerage Company
MDG  Millennium Development Goal
NWASCO  National Water and Sanitation Council
SHN  Sanitation, Hygiene and Nutrition
TDS  Total Dissolved Solids
TSS  Total Suspended Solids
UN  United Nations
UNEP  United Nations Environment Programmes
UNICEF  United Nations Children Fund
WHO  World Health Organisation
WHO  World Health Organisation
ZABS  Zambia Bureau of Standards
CHAPTER 1: INTRODUCTION

1.0 Background

Safe water is fundamental to better health, alleviating poverty and community development. The United Nations International Drinking Water Supply and Sanitation Decade (1981-1990) failed to achieve its goal of universal access to safe drinking water and sanitation by 1990 (WHO, 2003a). Even though service levels rose by more than 10 percent during the decade, 1.1 billion people still lacked access to improved water supplies in 1990 (WHO/UNICEF, 2000). Reasons cited for the decade’s failure include population growth, funding limitations, inadequate operation and maintenance, and continuation of a “business as usual approach, drawing on traditional resources, policies and technologies” (WHO/UNICEF, 1992).

The world is on schedule to meet the Millennium Development Goal (MDG), adopted by the UN General Assembly in 2000 and revised after the World Summit on Sustainable Development in Johannesburg, to “halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation” (World Bank Group, 2004; WHO/UNICEF, 2004). However, it has been predicted that the success will still leave more than 600 million people without access to safe water in 2015 (WHO/UNICEF, 2000). Furthermore, according to the UNICEF Handbook on Water Quality (2008), deteriorating water quality also threatens this MDG water target.

While the world may be currently on track to meet the target in terms of numbers of sources constructed, it may not be on track if the quality of water in new sources (including boreholes in schools) is not fully taken into account (WHO/UNICEF, 2010). Thus, many more people than estimated may drink unsafe water from improved sources.

At current rates of progress, in sub-Saharan Africa the water target will not be met until 2035, based on trends in the (WHO/UNICEF, 2008).

Unsafe water is characterised by their physical, chemical and microbiological contaminants. The chemical contamination of water supplies – both naturally occurring and from pollution – has very serious health problems. But more serious still is the microbiological contamination of drinking water supplies, especially from human feaces. Feecal contamination of drinking water is a major contributor to water-borne diseases including diarrhoeal disease and cholera, which kills millions of children every year in the developing countries. As populations, pollution and environmental
degradation increase, so will the chemical and microbiological contamination of water supplies (UNICEF, 2008).

The lack of access to safe water and adequate sanitation is at the core of the main symptoms and causes of world poverty, reinforcing the cycle of poverty and incapacity that keeps people trapped and slows the development of societies. Inadequate access to safe water can cause people’s health to suffer, especially children, ranging from reduced growth and life expectancy to critical bouts of diseases, often leading to death (Mathew, 2005). The WHO (2006) estimates that 88% of diarrhoeal disease is attributed to unsafe water supply, inadequate sanitation and poor hygiene, resulting in the deaths of more than two million people every year in developing countries. The time taken to being sick, or looking after those who are sick, puts a huge drain on family resources (Mathew, 2005). Children could spend the time attending school.

Mtendere Township is a peri-urban area situated on the eastern side of Lusaka with four basic schools. These schools are crippled with overcrowding coupled with poor hygiene practices which worsen the problem of compromised drinking water quality from the boreholes. Additionally, at present the studied schools are using borehole water with an assumption that it is safe water hence needs no treatment.

It is against this background that there is need to assess the quality of drinking water in four selected basic schools of Mtendere Township of Lusaka using boreholes by undertaking the following:

i. Characterisation of borehole water in terms of physical, chemical and microbiological contaminants;

ii. Comparing the analytical results the WHO and ZABS drinking water guidelines;

iii. To make recommendations on drinking water quality monitoring in schools based on the results to relevant authorities.

1.1 Problem Statement

Lack of drinking water quality monitoring in basic schools in impoverished peri-urban areas like Mtendere Township in Lusaka, lead to consumption of unsafe drinking water which has the potential to adversely affect the health of the pupils and teachers.
1.2 **Aim**
To conduct physical, chemical and microbiological assessment of borehole water in four basic schools in Mtendere Township, Lusaka, Zambia.

1.3 **General Objective**
To assess the quality of borehole water in selected basic schools and compare results with the Zambian Standards and WHO guidelines for drinking water in order to ascertain the possible health implications that can result from drinking such water sources.

1.4 **Specific Objectives**
The specific objectives of the research are fourfold namely:

i. To determine the biological, chemical and physical characteristics of potable water quality for the selected boreholes in studied schools;

ii. To establish the suitability of drinking water for the studied schools; and

iii. To make recommendations on drinking water quality monitoring in schools based on the results to relevant authorities.

1.5 **Hypothesis**
Potable water from boreholes in four selected basic schools of Mtendere Township is unsafe for drinking.

1.6 **Significance**
Diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water in schools provide significant benefits to the health of pupils and teachers, thereby leading to improved class performance by the pupils; reduce absenteeism of pupils and teachers from school; and reduce treatment costs of pupils. In this research, the beneficiaries are the four government schools with a total population of 10,164 pupils.
1.7 Location of the study

Mtendere Township (Figure 1) (meaning a peaceful township) is located between 28.21.255 Easting and 15.24.296 Southing at an elevation of 1268.3 meters. The township is characterised with overcrowding, lack of adequate safe water, poor sanitation, hygiene practices, waste management practices and poverty.

Figure 1: Map of Mtendere Township showing the location of the four studied school, Lusaka, Zambia

The township has four government basic schools with a total population of 10,164 pupils (Table 1). The average age ranges of the pupils are 7-18 years and 7-19 years for girls and boys respectively. These basic schools are also characterised by over-population, poor personal hygiene practices and poverty.

These factors pose high potential health risks amongst the pupils and teachers with regards to water associated diseases as they may affect the drinking water quality.
Table 1: Studied schools and their population in Mtendere Township, Lusaka, Zambia

<table>
<thead>
<tr>
<th>#</th>
<th>Name of the Basic School</th>
<th>No of Pupils</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mtendere</td>
<td>1,850</td>
</tr>
<tr>
<td>2.</td>
<td>Chitukuko</td>
<td>3,705</td>
</tr>
<tr>
<td>3.</td>
<td>Mahatma Gandhi</td>
<td>2,050</td>
</tr>
<tr>
<td>4.</td>
<td>New Mtendere</td>
<td>2,559</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>10,164</td>
</tr>
</tbody>
</table>

1.8 Dissertation synopsis

This section outlines the format of the dissertation as follows:

i. Chapter 1 – Introduction;

ii. Chapter 2 - Literature review;

iii. Chapter 3 - Methodology and methods;

iv. Chapter 4 - Results and discussion; and

v. Chapter 5 - Conclusion and recommendations.
CHAPTER 2: LITERATURE REVIEW

This chapter deals with literature review on water and sanitation, millennium development goals, water sources, the hydrological cycle and water quality parameters with their respective health implications.

2.1 Water and Sanitation

Water and sanitation are about much more than health (Cairncross et al., 2003). Access to safe drinking water is important as a health and development issue at national, regional and local levels. In some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, since the reductions in adverse health effects and health care costs outweigh the costs of undertaking the interventions (WHO, 2004a). Experience has also shown that interventions in improving access to safe water favour the poor in particular, whether in rural or urban areas, and can be an effective part of poverty alleviation strategies (WHO, 2004b).

The WHO report indicated that globally, the percentage of people served with some form of improved water supply rose from 79% (4.1 billion) in 1990 to 82% (4.9 billion) in 2000 (WHO, 2000). The same report indicated that over the same period, the proportion of the world’s population with access to excreta disposal facilities increased from 55% (2.9 billion people served) to 60% (3.6 billion). Hence, at the beginning of 2000, one-sixth (1.1 billion people) of the world’s population was without access to improved water supply and two-fifths (2.4 billion people) lacked access to improved sanitation.

2.2 The Millennium Development Goals

Many water and sanitation development studies published in recent years refer to the UN Millennium Development Goals (MDGs) as the driving factor to alleviate poverty and increase development. The eight MDGs were adopted in September 2000 to form a proposal agreed to by world leaders and leading development agencies, aiming to reduce the proportion of people living in poverty by half by 2015 (Mathew, 2005) and to meet the needs of the poorest. In order to meet the water supply MDG target, an additional 260,000 people per day up to 2015 should gain access to improved water sources (WHO, 2006a). However, improving community water sources is a common thread for achieving many of the MDGs, recognising the importance of providing safe
water to alleviate poverty. The targets that are directly aligned with the provision of safe water are illustrated in Table 2.

For children, for instance, the success of the MDG No 2 which advocates for achieving universal primary education largely depends on the provision of safe drinking water in schools (refer also to MDG No 7) in order to reduce the burden of the water borne diseases including diarrhoea (refer also to MDG No 6). Additionally, provision of safe water for drinking and personal hygiene will retain the girls in schools thereby contributing the success of the MDGs No 2 and 3 which advocates universal primary education as well as promotion of gender equality and empowerment of women respectively.

Table 2: UN Millennium Development Goals that are directly applicable to the provision of safe water (United Nations, 2002)

<table>
<thead>
<tr>
<th>Millennium Development Goal</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal 1: Eradicate Extreme Hunger and Poverty</strong></td>
<td><strong>Target 1.</strong> Halve, between 1990 and 2015, the proportion of people whose income is less than US$1 a day.</td>
</tr>
<tr>
<td></td>
<td><strong>Target 2.</strong> Halve, between 1990 and 2015, the proportion of people who suffer from hunger.</td>
</tr>
<tr>
<td><strong>Goal 2: Achieve Universal Primary Education</strong></td>
<td><strong>Target 3.</strong> Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling.</td>
</tr>
<tr>
<td><strong>Goal 3: Promote Gender Equity and Empower Women</strong></td>
<td><strong>Target 4.</strong> Eliminate gender disparity in primary and secondary education not later than 2015.</td>
</tr>
<tr>
<td><strong>Goal 4: Reduce Child Mortality</strong></td>
<td><strong>Target 5.</strong> Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate.</td>
</tr>
<tr>
<td><strong>Goal 5: Improve Maternal Health</strong></td>
<td><strong>Target 6.</strong> Reduce by three-quarters, between 1990 and 2015, maternal mortality ratio.</td>
</tr>
<tr>
<td><strong>Goal 6: Combat HIV / AIDS, Malaria and other diseases</strong></td>
<td><strong>Target 8.</strong> Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases.</td>
</tr>
<tr>
<td><strong>Goal 7: Ensure Environmental Sustainability</strong></td>
<td><strong>Target 10.</strong> Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation.</td>
</tr>
<tr>
<td>These indicators monitored separately for the least developed countries, Africa, landlocked</td>
<td><strong>Target 16.</strong> In cooperation with developing countries, develop and implement strategies for decent and productive work for youth.</td>
</tr>
<tr>
<td>developing countries, and small island developing states.</td>
<td><strong>Target 18.</strong> In cooperation with the private sector, make available the benefits of new technologies, especially information and</td>
</tr>
<tr>
<td></td>
<td>communications technologies.</td>
</tr>
</tbody>
</table>
The 2002 World Summit on Sustainable Development reaffirmed the MDGs which aimed to improve people’s lives while preserving earth’s resources as well as integrating economic, environmental and social decision-making. Sustainable development, defined by the United Nations as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”, calls for improving the quality of life for the entire world’s people without compromising the earth’s natural resources (United Nations, 2000).

2.3 Water sources and the hydrologic cycle

The natural process by which water is moved in the environment as well as the states in which it exists and is stored is described by the hydrologic cycle (Fetter, 2001). Understanding the hydrologic cycle is particularly important for exploring various water resources locally available and the factors that can potentially affect the quality. The following description of this cycle in Figure 2 is primarily taken from Fetter (2001).

![Hydrological cycle diagram](image)

**Figure 2: Hydrological cycle**

The hydrologic cycle encompasses the oceans, ice caps, groundwater, surface water, soil moisture and atmosphere. As most of the water is in the oceans (97.2%) it is convenient to describe the cycle...
beginning here. Water, evaporated from the surface of the oceans, is pure, leaving the salts of the sea behind as it moves through the atmosphere and condenses to form droplets during suitable atmospheric conditions. These droplets, known as precipitation, fall to the sea, onto the land surface or revaporise. Precipitation that falls on the land surface can be stored temporarily as puddles, will drain across the land as overland or surface flow, or will seep into the ground by infiltration processes. Below the land surface is the zone of aeration (or vadose zone), where pores in the soil contain both air and water, allowing the plant roots to draw in water. Once used by the plant the water is transpired as vapour into the atmosphere by the process called evapotranspiration.

Below this vadose zone the pores become saturated with water in what is known as the saturation zone depending on the porosity and permeability of the aquifers, and is called ground-water. This ground-water flows through rock and soil layers and can discharge as a spring or as seepage into a stream, river or ocean.

Knowing the source of the community water supply, whether drawn from surface or underground sources, is important for understanding catchment or aquifer characteristics and the likelihood of events that could lead to risks to health and the environment. The raw water quality can be influenced by various natural and anthropogenic factors, including climate, topography, geology and vegetation, and human impacts such as wastewater discharges, solid waste and agricultural runoff (WHO, 2004b). Groundwater from deep and confined aquifers is generally considered safe from microbial presence and is usually chemically stable in the absence of contamination (WHO, 2004b). Therefore, springs are a typically clean source of water due to the soils that the groundwater passes through acting as a sand filter by removing bacteria and particulate matter from the flow. Shallow and unconfined aquifers are more likely subject to contamination from discharges associated with agricultural practices and sanitation wastes. Hazardous situations that could have an impact on water sources that should be taken into consideration as part of source assessment include: sewage and septic discharges, variations in raw water quality, human access and land use (e.g. agriculture, animal husbandry), wildlife and livestock, inadequate buffer zones and vegetation, soil erosion, geology (naturally occurring chemicals), unconfined and shallow aquifer, climatic and seasonal variations (such as heavy rainfall and droughts) and natural disasters (WHO, 2004c). An assessment of this extent will also help develop control measures of effective resource and source protection.
2.4 Water quality in developing countries

Drinking water, or potable water, is defined as having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking (WHO, 2004b). WHO defines drinking water to be safe as long as it does not cause any significant health risks over a lifetime of consumption, and an effort should be made to maintain drinking-water quality at the highest possible level. Safe water is characterised by accessibility, sufficient quantity and good quality.

Most diarrhoeal deaths in the world (88%) are caused by unsafe water, sanitation or hygiene. Overall, more than 99% of these deaths are in developing countries, and around 84% of them occur in children (WHO, 2009). Disease burden in developing countries affects poor people greatly. The gaps between the rich and the poor are attributed to the fact that environmental interventions have neglected sanitary needs. Interventions are concentrating mainly on development of drinking water supply without a continuous water quality monitoring initiative. Water quality is affected by both natural and human activities. The quality of water varies from place to place, depending on seasonal and climatic changes. It also depends on the type of soil rocks and the surface through which it passes. It is therefore, critically important to monitor the physical, chemical and microbial quality of water in order to protect the health of the public (UNICEF, 2008).

2.4.1 Guidelines and Standards of Drinking Water

Different developing countries maintain different guideline for what constitutes safe drinking water (Gadgil, 1998). Although the World Health Organisation is the principle international health organisation, it does not promote the adoption of international standards for drinking water quality but recommends guidelines for use by a risk-benefit approach in establishing standards and regulations for the national situation. This approach is the comparison of the risk of a situation to its related benefits. To be effective, consideration of relevant local conditions (including economic, environmental, social and cultural conditions) and financial, technical and institutional resources is required. Commissioned by the Zambia Bureau of Standards (ZABS), Zambia’s national drinking water quality standards have been developed. The ZABS is the Statutory National Standards Body for Zambia established under an Act of Parliament, the Standards Act, Cap 416 of 1994 of the Laws of Zambia for the preparation and promulgation of Zambian standards including drinking water quality standards (www.zabs.org.zm).
The focus of these guidelines and standards is to retain and if possible improve the water source quality. The requirements cover the basic hazards of contaminated water to human health and the distribution infrastructure as follows:

i. It should be acceptable to the consumer. Bad taste or colour, staining, or unpleasant odour can cause a user to choose an alternative source;

ii. It should be free from disease-causing organisms (i.e. pathogens);

iii. It should be free from toxic chemicals; and

iv. It should not cause corrosion or encrustation in piped water systems or leave deposits.

The NWASCO guidelines (2001) suggest effective water testing for disease-causing organisms needs to be conducted routinely (monthly, quarterly and yearly) and any points of contamination encountered require a sanitary survey to be undertaken in order to identify the contamination source. The guidelines also recommend appropriate prevention steps be taken to isolate the contamination. The approach adopted by these guidelines involves reducing potential contamination of a water source through effective protection structures and storage systems. The guidelines are limited by several constraints, primarily the lack of funding and human resource capacity for water quality testing and monitoring programmes, as well as operation and maintenance of treatment process to improve drinking water quality. The guidelines suggest prevention and boiling before consumption as the minimal steps to be taken to ensure drinking quality water. As mentioned, these are very minimal barriers to water contamination, and boiling water is not an environmentally sustainable practice.

The guidelines advise a sanitary survey be conducted on finding presence of disease-causing organisms which have potential risks that may pollute the water sources leading to poor quality water. A sanitary survey is an on-site inspection of the water supply system with particular attention paid to possible sources of contamination (Morgan, 1990). Refer to Appendix 1 for the sanitary survey form for mechanised borehole. An inspection of this kind can generate substantial information regarding hazards, pathway and indirect factors which can lead to the contamination of water sources. However, without scientific testing results can be limiting.
2.4.2 Physical and aesthetic parameters

The acceptability of drinking-water to consumers is perceived by the users’ own senses, to assess the water in terms of taste, odour and appearance. Water consumers who rely on their senses may avoid highly turbid or coloured but otherwise safe waters in favour of more aesthetically acceptable but potentially unsafe water sources (WHO, 2004b). Consumer perceptions and aesthetic criteria need to be considered when assessing drinking-water supplies and developing management guidelines (WHO, 2004a) even though they may not adversely affect human health.

Taste and odour can originate from various natural chemical contaminants, biological sources, microbial activity, from corrosion or as a result of water treatment (e.g. chlorination) (WHO, 2004b). Colour, cloudiness, particulate matter and visible organisms can also contribute to unacceptability of water sources. These actors can vary for each community and are dependent on local conditions and characteristics.

Turbidity is found to be a problematic issue in many developing communities. Although it doesn’t adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacterial growth and can be a problem with treatment processes (WHO, 2004b). Suspended mineral or organic solids and smaller colloidal particles are substances responsible for turbidity (Degrémont, 1991). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004b). Measurement of turbidity can be carried out with a simple turbidity tube that allows a direct reading in nephelometric turbidity units (NTU), determined by measuring the scattering of light as it passes through the water (WHO, 2004b).

An important operational water quality parameter is pH, although it usually has no direct impact on consumers. Low pH levels can enhance corrosive characteristics resulting in contamination of drinking-water and adverse effects on its taste and appearance (WHO, 2004b). Higher pH levels can lead to calcium carbonate deposition and encrustation of pipe networks (IRC, 2002). Careful consideration of pH is necessary to also ensure satisfactory water disinfection with chlorine, which requires pH to be less than 8 (WHO, 2004b).

Total dissolved solids (TDS) and the related parameter electrical conductivity (EC) are measures of the total ions in solution and ionic activity of a solution respectively. As TDS and EC increase, the
corrosivity of the water increases and the solubility of slightly soluble compounds such as CaCO₃ are effected (Montgomery Consulting Engineers Inc., 1985).

Temperature is another physical parameter which is measured by a thermometer in Celsius or Farenheit degree. The ideal temperature of drinking water is 4°C – 10°C (39 - 50°F). Even though temperature has no direct health impacts, cool water tastes better.

2.4.3 Chemical parameters

Assessment of water quality by its chemistry includes measures of elements and molecules dissolved or suspended in water. Chemical measures can be used to directly detect pollutants and imbalances within the ecosystem. Most chemicals from water sources are of health concern in humans as a result of exposure through drinking (Appendix 2). The chemical parameters measured included pH, iron, chloride, ammonia, nitrites, nitrates and calcium.

i. Iron

Iron is one of the most abundant metals in the Earth’s crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. It is frequently used in water distribution systems, and its corrosion is of concern. While structural failure as a result of iron corrosion is rare, water quality problems (e.g., “red water”) can arise as a result of excessive corrosion of iron pipes. The corrosion of iron is a complex process that involves the oxidation of the metal, normally by dissolved oxygen, ultimately to form a precipitate of iron (III). This leads to the formation of tubercules on the pipe surface. The major water quality factors that determine whether the precipitate forms a protective scale are pH and alkalinity. The concentrations of calcium, chloride and sulphate also influence iron corrosion. Successful control of iron corrosion has been achieved by adjusting the pH to the range 6.8–7.3, hardness and alkalinity to at least 40 mg/litre (as calcium carbonate), oversaturation with calcium carbonate of 4–10 mg/litre and a ratio of alkalinity to Cl⁻ + SO₄²⁻ of at least 5 (when both are expressed as calcium carbonate) (UNEP / WHO, 1996).

Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day. No guideline value for iron in drinking-water is proposed.
ii. Calcium
Calcium is an alkaline earth metal that reacts with water to form calcium hydroxide. It is essential for the building and maintenance of healthy bone structure. It is normally less than 10 mg/l in rainwater or soft water. High calcium concentration above 10 mg/l leads to the development of kidney stones in sensitive people (UNEP / WHO, 1996).

iii. Chloride
Chloride is the negatively charged component of table salt. Its high concentrations impart a salty taste to water and accelerate corrosion of metals. In fresh water, its concentration is less than 10 mg/l. Health effects such as nausea and vomiting may occur at concentration above 1200 mg/l in sensitive individuals (UNEP / WHO, 1996).

iv. Ammonia (NH$_4^+$)
Ammonia enters surface waters and ground waters from decomposition of nitrogenous organic matter (e.g. domestic waste) and effluents from industries. Ammonia in the amount present in natural or polluted waters is not physiologically damaging (ANZECC, 1992). However, the presence of ammonia in water supplies may indicate recent sewage pollution and should be addressed as a matter of priority. High ammonia levels could give rise to consumer complaints due to odour and taste problems. Groundwater supplies generally have low ammonia concentrations due to binding/adsorption by the soil particles (Mosley et. al, 2004).

v. Nitrate (NO$_3^-$) and Nitrite (NO$_2^-$)
Nitrate pollution may occur from discharge of human and animal waste, and fertilizer runoff or seepage into groundwater. At very high levels in drinking water, nitrate and nitrite may impact human health, particularly for infants. Infants less than 6 months of age may develop a condition called methemoglobinemia (blue baby syndrome), which causes a bluish color around the lips that spreads to the fingers, toes and face, and eventually covers the entire body. If the problem is not dealt with immediately, the baby can die. This problem occurs because human infants have bacteria in their digestive systems that convert nitrate to nitrite, a very toxic substance. When nitrites are absorbed into the blood, they make the hemoglobin (red oxygen-carrying blood pigment) incapable of releasing the oxygen, and the condition known as methemoglobinemia occurs. Consuming water from a source containing 10 or less mg/l nitrate-nitrogen provides assurance that methemoglobinemia should not result from drinking water (Mosley et. al, 2004).
Therefore, the monitoring of nitrate is recommended in many drinking water supplies and in particular those which are located in rural, peri-urban, and agricultural areas where the water supply is from a borehole or a well. In these circumstances, regular monitoring is recommended to ensure early warning of increases or when nitrate releases are highly seasonal in nature.

High nitrate levels from agricultural sources may also indicate that there may be a problem with other agricultural pollutants such as pesticides. Nitrate contamination which can be linked to a sewage discharge may also indicate unacceptably high levels of microbiological contamination and should be addressed as a matter of priority (Mosley et. al, 2004).

vi. **pH**

The pH value of water, on a scale of 0 to 14, measures the concentration of hydrogen ions. The pH represents the balance between hydrogen ions and hydroxide ions in water. Solutions with more hydrogen than hydroxide ions have a pH value lower than 7 and are said to be acidic. Solutions with pH values higher than 7 have more hydroxide than hydrogen ions and are said to be basic, or alkaline. Pure distilled water is considered neutral, with a pH reading of 7. Water is basic if the pH is greater than 7; water with pH of less than 7 is considered acidic (Mosley et. al, 2004).

For every one unit change in pH there is approximately a ten-fold change in how acid or basic the sample is. This means that each step on the scale represents a ten-fold change in the hydrogen concentration. For example, water with a pH of 5 has ten times the number of hydrogen ions than water with a pH of 6 and is ten times more acidic. The WHO recommended pH range for potable water is from 6.5 – 8.5 and that it has no direct health effects.

vii. **Other chemical parameters**

Other chemical parameters which may be present in groundwater include carbonates, dissolved metals, sulphates and total hardness. According to WHO (2004c), some of these chemical constituents are not considered as critical parameters in drinking water depending on their toxicological data.
2.4.4 Microbiological parameters

Microbial contamination refers to waterborne microorganisms from human and animals’ fecal wastes. These wastes contain a wide range of bacteria, viruses and protozoa that may be washed into drinking water supplies. A drop of fecal matter can contain millions of microorganisms, which degrade the aquatic environment and constitute a health risk due to the introduction of pathogenic microorganisms that cause water-borne diseases (UNICEF, 2008).

Most microbes that live in soil and water are harmless but some cause diseases in people. A type of microorganism called coliform bacterium was discovered in 1885 and is present in animal and human feaces and sewage.

Microbial hazards are the primary concern for both developing and developed countries (WHO, 2004b). The greatest microbial risks are associated with water contaminated with human or animal feaces, a source of pathogenic bacteria, viruses and parasites (protozoa and helminthes, or worms) (WHO, 2004a). WHO states that infectious diseases caused by these pathogens are the most common health risk associated with drinking water (WHO, 2004a). Over 3 million people die every year from diarrheal and malarial diseases of whom 90% are children under 5 and are mostly in developing countries (WHO, 2004a). This equates to approximately 400 children below age 5 die per hour in the developing world from waterborne diseases (WHO, 2006a).

Pathogens, or disease causing bacteria and viruses, can vary in characteristics such as infectivity, resistance to chlorine and source of origin, which are highlighted in Table 3. The table illustrates the extensive number of species of waterborne pathogens potentially present in water sources.

2.4.5 Microbiological indicator organisms and their importance

The concentration of pathogens (disease causing microorganisms) in natural waters is generally very low; methods for their detection and enumeration are often complex and expensive. Alternative organisms that are consistently present in fecal material, survive reasonably well in water compared to pathogens, and are easier to detect, have therefore become widely used as fecal pollution "indicators" (WHO, 2004b).

The most commonly used indicator organisms are the coliform bacteria, including their subset, the fecal coliforms. Coliform bacteria have for almost a century, been used as indicators of the bacterial
safety of drinking-water. The term “coliform organisms” refers to Gram-negative, rod-shaped bacteria capable of growing in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties and able to ferment lactose at 35-37 °C with the production of acid, gas, and aldehyde within 24-48 hours. They are also oxidase-negative and non-spore-forming (WHO, 2003b). These bacteria live in large numbers in the intestines of human, warm and cold-blooded animals. Coliform bacteria are needed in the process of food digestion. This group includes *Escherichia coli* (*E. coli*), which is separated from total coliform group by its ability to grow at high temperatures and its characteristics of being associated with only faecal material of warm-blooded animals. Water-related diseases include diarrheal diseases due to pathogenic microorganisms and chemicals in drinking water. Diarrhoea is one of the principal causes of morbidity and mortality in developing countries. About 1.8 million people die from diarrheal disease every year, of which 90% are children under 5 years (WHO, 2003c).

Table 3: Waterborne pathogens and their significance in water supplies (Source: WHO, 2004a)

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Health significanceb</th>
<th>Persistence in water supplies²</th>
<th>Resistance to chlorine¹</th>
<th>Relative Infectivity*</th>
<th>Important animal source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Burkholderia pseudomallei</em></td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td><em>Campylobacter jejuni, C. coli</em></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Escherichia coli – Pathogenic³</em></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td><em>E. coli – Enterohaemorrhagig</em></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Legionella spp.</em></td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Moderate</td>
<td>No</td>
</tr>
<tr>
<td><em>Non-tuberculous mycobacteria</em></td>
<td>Low</td>
<td>May multiply</td>
<td>High</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa²</em></td>
<td>Moderate</td>
<td>May multiply</td>
<td>Moderate</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td><em>Salmomella typhi</em></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>Other salmonellae</td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Shigella spp.</em></td>
<td>High</td>
<td>Short</td>
<td>Low</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td>High</td>
<td>Short to long⁴</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>Moderate</td>
<td>Long</td>
<td>Low</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Adenoviruses</em></td>
<td>Moderate</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Enteroviruses</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Astroviruses</em></td>
<td>Moderate</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Hepatitis A virus</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Hepatitis E virus</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Noroviruses</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>Potentially</td>
</tr>
<tr>
<td><em>Sapoviruses</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>Potentially</td>
</tr>
<tr>
<td><em>Rotavirus</em></td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acanthamoeba spp.</em></td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Cryptosporidium parvum</em></td>
<td>High</td>
<td>Long</td>
<td>High</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Cyclospora cayetanensis</em></td>
<td>High</td>
<td>Long</td>
<td>High</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Entamoeba histolytica</em></td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Giardia intestinalis</em></td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Naegleria fowleri</em></td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Moderate</td>
<td>No</td>
</tr>
<tr>
<td><em>Toxoplasma gondii</em></td>
<td>High</td>
<td>Long</td>
<td>High</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Helminths</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Enterococcus mediterranea</em></td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td><em>Schistosoma spp.</em></td>
<td>High</td>
<td>Short</td>
<td>Moderate</td>
<td>High</td>
<td>Yes</td>
</tr>
</tbody>
</table>

¹ Resistance to chlorine: 1 = low, 2 = moderate, 3 = high
² Persistence: 1 = short, 2 = moderate, 3 = long
³ Pathogenic
⁴ Significant for water rescuers
⑤ Persistence: 1 = short, 2 = moderate, 3 = long

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Note: Waterborne transmission of the pathogens listed has been confirmed by epidemiological studies and case histories. Part of the demonstration of pathogenicity involves reproducing the disease in suitable hosts. Experimental studies in which volunteers are exposed to known numbers of pathogens provide relative information. As most studies are done with healthy adult volunteers, such data are applicable to only a part of the exposed population, and extrapolation to more sensitive groups is an issue that remains to be studied in more detail.

i. This table contains pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies.

ii. Health significance relates to the severity of impact, including association with outbreaks.

iii. Detection period for infective stage in water at 20° C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1 month.

iv. When the infective stage is freely suspended in water treated at conventional doses and contact times and pH between 7 and 8. Low means 99% inactivation at 20° C generally in <1 min, moderate 1–30 min and high >30 min.

v. It should be noted that organisms that survive and grow in biofilms, such as Legionella and mycobacteria, will be protected from chlorination.

vi. From experiments with human volunteers, from epidemiological evidence and from animal studies. High means infective doses can be 1–102 organisms or particles, moderate 102–104 and low >104.

vii. Includes enteropathogenic, enterotoxigenic and enteroinvasive.

viii. Main route of infection is by skin contact, but can infect immunosuppressed or cancer patients orally.

ix. Vibrio cholerae may persist for long periods in association with copepods and other aquatic organisms.

x. In warm water.

For pathogens transmitted by the faecal-oral route, drinking-water is only one vehicle of transmission (Figure 3). Contamination of food, hands, utensils and clothing can also play a role, particularly when domestic sanitation and hygiene are poor. Improvements in the quality and availability of water, in excreta disposal and in general hygiene are all important in reducing faecal-oral disease transmission.

![Diagram of transmission pathways for and examples of water-related pathogens](Source: WHO, 2004b)
2.4.6 Public health aspects

Outbreaks of waterborne disease may affect large numbers of persons, and the first priority in developing and applying controls on drinking-water quality should be the control of such outbreaks. Available evidence also suggests that drinking-water can contribute to background rates of disease in non-outbreak situations, and control of drinking-water quality should therefore also address waterborne disease in the general community (WHO, 2004b).

Experience has shown that systems for the detection of waterborne disease outbreaks are typically inefficient in countries at all levels of socioeconomic development, and failure to detect outbreaks is not a guarantee that they do not occur; nor does it suggest that drinking-water should necessarily be considered safe. Some of the pathogens that are known to be transmitted through contaminated drinking-water lead to severe and sometimes life-threatening diseases. Examples include typhoid, cholera, infectious hepatitis (caused by hepatitis A virus [HAV] or HEV) and disease caused by Shigella spp. and E. coli O157. Others are typically associated with less severe outcomes, such as self-limiting diarrhoeal diseases (e.g., Norovirus, Cryptosporidium) (WHO, 2003b).

The effects of exposure to pathogens are not the same for all individuals or, as a consequence, for all populations. Repeated exposure to a pathogen may be associated with a lower probability or severity of illness because of the effects of acquired immunity (WHO, 2003b).

For some pathogens (e.g., HAV), immunity is lifelong, whereas for others (e.g., Campylobacter), the protective effects may be restricted to a few months to years. On the other hand, sensitive subgroups (e.g., the young, the elderly, pregnant women and the immunocompromised) in the population may have a greater probability of illness or the illness may be more severe, including mortality. Not all pathogens have greater effects in all sensitive subgroups (WHO, 2003b).

Not all infected individuals will develop symptomatic disease. The proportion of the infected population that is asymptomatic (including carriers) differs between pathogens and also depends on population characteristics, such as prevalence of immunity. Carriers and those with asymptomatic infections as well as individuals developing symptoms may all contribute to secondary spread of pathogens (WHO, 2003a).
CHAPTER 3: METHODOLOGY

This chapter gives a description of the sources of data collection, water sampling and analytical procedures as well as data analysis.

The overview represented in Figure 4 summarises the general outline of a model plan for the drinking water quality assessment in schools’ research in order to achieve the desired outcomes.

![Flowchart showing the steps of the study](image)

**Figure 4: An overview of the steps carried out in this study**

3.1 Study Methods and Design

This was a cross sectional, analytical study on the quality of drinking water in the Chitukuko, Mtendere, New Mtendere and Mahatma Gandhi Basic Schools in the Mtendere Township within the Lusaka District of the Lusaka Province, Zambia.

Water samples were collected and analysed according to the standard methods for the examination of water and wastewater (APHA, 1998). The questionnaire used was designed to capture the demographic information, drinking water and associated health implications, handwashing facilities and practices as well general observations of the water sources (Appendix 3). One questionnaire
was administered per school by the author during the water sampling survey. In all the instances, it was advised by the heads of the schools that the questionnaires be answered by the Sanitation, Hygiene and Nutrition (SHN) Coordinator or the SHN Committee Member in absence of the SHN Coordinator.

Permission to conduct this study in the selected schools was granted by the Head Teachers in the respective schools. Verbal informed consent was obtained from a responsible SHN Coordinator in the studied schools before the interview. Respondents were also told that their participation was voluntary. To ensure privacy, interviews were conducted inside their offices.

3.2 Water Sample Collection

For chemical and physical quality analysis, non-sterile plastic bottles were washed with dishwashing liquid soap, rinsed well with sterile water and air-dried. For microbial quality analysis, glass bottles were washed, rinsed well and sterilized in an autoclave machine. Microbial water samples need to be cooled from the point of collection up to point of analysis, so a cooler box with ice blocks was carried along during water sample collection. The cooling process is to prevent multiplication of microorganisms in the water sample bottles.

3.3 Collection of water from the taps

Water samples for the physical and chemical were collected directly using plastic bottles. For the microbiological parameters, water samples were collected from the flamed taps using the sterile glass bottle. The inside of a tap was sterilized by dipping cotton wool into methylated spirit, inserting it into the opening of the tap and burning that cotton wool, until the tap became warm. Water was then allowed to run to waste from the tap for at least three minutes (according to Standard Methods for the Examination of Water and Wastewater APHA, 1998) before samples were taken.

3.3.1 Mahatma Gandhi Basic School

Water sample collection was done during March and April 2011. Two samples for each chemical and microbial analysis were taken from the tap. The school uses two water sources thus borehole and piped water which then mix at some point just near the borehole, and that the pump attendant who was suppose to close the valve for tap water was not around at the time of sampling. For this
reason, the first water sample collected was mixed water. Borehole water was only collected in the second phase of the water sampling.

3.3.2 Chitukuko Basic School

Water sample collection was done during March and April 2011. Two water samples for each chemical and microbial analysis were taken from the tap. The school uses two separate water sources namely borehole and piped water, but only borehole water was sampled because piped water was not available at the times of sampling.

3.3.3 Mtendere Basic School

Water sample collection was conducted during March and April 2011. Two water samples for each chemical and microbial analysis were taken from the borehole. The school uses only borehole water both for drinking and sanitation needs.

3.3.4 New Mtendere Basic School

Water sample collection was done during March and April 2011. Two water samples for each chemical and microbial analysis were taken from the borehole. The school uses only borehole water both for drinking and sanitation needs.

3.4 Analytical Methods

The following methods were used to test for the chemical, physical and microbiological contaminants in the laboratory and onsite. The reader is referred to the UNICEF Handbook (1999) and the WHO global drinking water quality (WHO, 2006b) for a comprehensive listing of laboratory methods for specific chemicals that have guideline values. The main laboratory techniques used in this study are briefly summarized below.

3.4.1 Colorimetric Method

This method is based on measuring the intensity of colour of a reaction product or a coloured target chemical. The optical absorbance is measured using light of a suitable wavelength. The concentration is determined by means of a calibration curve obtained using known concentrations of the determinant (WHO, 2006a).
3.4.2 Electrode methods

Ion-selective electrodes can measure the concentration of certain ions in the water sample. pH, turbidity, Total Dissolved Solids (TDS), temperature and electrical conductivity (EC) are readily measured with an electrode and meter.

A Wagtech Digital meter was used to for onsite testing of the pH, total dissolved solids, electrical conductivity and the temperature of the water samples taken from the four basic schools.

3.4.3 Atomic Absorption Spectrometer (AAS)

This method is used to analyze the presence of metals. Atomic Absorption Spectrometry (AAS) is based on the phenomenon that free atoms in the ground state can absorb light of a certain wavelength. Each element has its own specific absorption, meaning no other elements absorb this wavelength when light is passed through the atom in its vapour state. As this absorption of light depends on the concentration of atoms in the vapour, the concentration of the target element in the water sample can be determined (UNICEF, 2008).

3.4.4 Chromatography

This is a separation method based on the affinity difference between two phases: stationary and mobile. A sample is injected into a column either packed or coated with the stationary phase, and separated by the mobile phase based on the difference in interaction (distribution or adsorption) between compounds and the stationary phases. Compounds with a low affinity for the stationary phase move more quickly through the column and are removed earlier than those with the high affinity for the stationary phase. A suitable detector measures the compounds that are removed from the column. There are many types of chromatography: ion chromatography, liquid chromatography and gas chromatography, which are used to identify metallic, inorganic and organic compounds (UNICEF, 2008).

3.4.5 Microbial Water Analysis using Membrane Filtration Method

Membrane Filtration Method was used for the capturing of any sediment present in water. An amount of 100 ml of water was added to a filtration bottle, with filter paper to absorb all sediments. A suction pump was connected to the filtration bottle so that all the water was sucked out of the bottle. The filter paper was removed with sterile forceps from the bottle and placed onto an eindo
media in the petri dish and incubated at 37°C for 24 hours. Coliforms (total and feacal coliforms) found on the culture media were then counted (WHO, 2004b).

3.5 Data Analysis

Results of water analysis were organized in a data-recording sheet (Table 8) and were compared against the standards set by ZABS and WHO (2004a). The results were analyzed using Microsoft Office Excel 2007.
CHAPTER 4: INTERPRETATION AND DISCUSSION OF RESULTS

In this chapter the results of the study collected from the survey questionnaires, sanitary inspection and the water quality analysis are interpreted and discussed.

4.1 Mahatma Gandhi Basic School

According to the study survey and sanitary inspection conducted on 21st March, 2011, it was discovered that the school was using two water sources namely the borehole and piped water from the Lusaka Water and Sewerage Company (LWSC) which was interconnected at some point with a high health risk.

The following outlines the results obtained from the social and physical surveys conducted during the site visit on the 21st March, 2011. A summary of the results of preliminary social and physical surveys are tabulated in Table 4.

Table 4: Survey questionnaire and sanitary inspection results from Mahatma Gandhi Basic School

<table>
<thead>
<tr>
<th>Location</th>
<th>Mtendere North</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS reading</td>
<td>28.21.089E &amp; 15.24.008S</td>
</tr>
<tr>
<td>Population of pupils</td>
<td>2,050 (1,012 Females &amp; 1,038 Males)</td>
</tr>
<tr>
<td>Population of teachers</td>
<td>47 (40 Females &amp; 7 Males)</td>
</tr>
<tr>
<td>Age range of pupils</td>
<td>7 – 16 yrs (Females) &amp; 7 – 16 yrs (Males)</td>
</tr>
<tr>
<td>Water source</td>
<td>Borehole &amp; Piped</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Nil (no need)</td>
</tr>
<tr>
<td>Water quality problems</td>
<td>Bad taste</td>
</tr>
<tr>
<td>Water associated diseases</td>
<td>Nil (no data)</td>
</tr>
<tr>
<td>Hand washing facilities</td>
<td>4 taps</td>
</tr>
<tr>
<td>Hand washing with soap</td>
<td>Nil (except for the grade ones)</td>
</tr>
<tr>
<td>Person hygiene practices by pupils</td>
<td>Poor (lack of motivation in hygiene education at household level)</td>
</tr>
<tr>
<td>Hygiene Education (HE) in schools</td>
<td>Poor HE to the pupils and the community</td>
</tr>
<tr>
<td>Potential source of contamination</td>
<td>Borehole within 10 meter of pit latrines for the drinking places</td>
</tr>
<tr>
<td></td>
<td>Borehole within 100 meter of illegal dumpsite for solid waste</td>
</tr>
<tr>
<td>Overall Health Risk</td>
<td>High</td>
</tr>
</tbody>
</table>

From Table 4, it is concluded that even though the borehole is regarded as a protected water source, its water may not necessarily be safe for drinking. This is because of the presence of potential faecal and chemical contaminations from pit latrines and the solid waste dumpsite within the proximity of the water source.
Lack of hygiene education coupled with absence of soap for hand washing could aggravate the situation. Drinking water from that source posed serious health risks and hence need for chlorination.

4.2 Chitukuko Basic School

According to the study survey and sanitary inspection conducted on 21st March, 2011, it was clear that teachers and pupils are encouraged to use borehole water which is assumed to be cleaner than piped water from the Lusaka Water and Sewerage Company hence the focus on borehole.

The following outlines results obtained from the social and physical surveys conducted during the site visit on the 21st March, 2011. A summary of the results of preliminary social and physical surveys are tabulated in Table 5.

Table 5: Survey questionnaire and sanitary inspection results form Chitukuko Basic School

<table>
<thead>
<tr>
<th>Location</th>
<th>Mtendere East</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS reading</td>
<td>28.21.255E &amp; 15.24.296S</td>
</tr>
<tr>
<td>Population of pupils</td>
<td>3,705 (1,835 Females &amp; 1,870 Males)</td>
</tr>
<tr>
<td>Population of teachers</td>
<td>52 (41 Females &amp; 11 Males)</td>
</tr>
<tr>
<td>Age range of pupils</td>
<td>7 – 19 yrs (Females) &amp; 7 – 20 yrs (Males)</td>
</tr>
<tr>
<td>Water source</td>
<td>Borehole &amp; Piped (borehole is clean)</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Nil (it is expensive)</td>
</tr>
<tr>
<td>Water quality problems</td>
<td>Nil (it is not dirty)</td>
</tr>
<tr>
<td>Water associated diseases</td>
<td>Nil (no health register for the school)</td>
</tr>
<tr>
<td>Hand washing facilities</td>
<td>4 taps in the school (in addition to those in the ablutions)</td>
</tr>
<tr>
<td>Hand washing with soap</td>
<td>Nil (except for the grade ones)</td>
</tr>
<tr>
<td>Person hygiene practices by pupils</td>
<td>Poor (lack of motivation in hygiene education at household level)</td>
</tr>
<tr>
<td>Hygiene education in schools</td>
<td>Poor HE to the pupils and the community</td>
</tr>
<tr>
<td>Potential source of contamination</td>
<td>Borehole within 10 meter of ablution block ‘s septic tank</td>
</tr>
<tr>
<td>Overall Health Risk</td>
<td>Low</td>
</tr>
</tbody>
</table>

From Table 5, it is deduced that even though the borehole is regarded as a protected water source, its water might not necessarily be safe for drinking. This is because of the presence of potential faecal and chemical contaminations from pit latrines and the septic tank within the proximity of the water source. That water needed to be chlorinated prior to drinking it even though it was characterised by low health risks. The problem of groundwater contamination in this area is crucial because of the presence of pit latrines in the neighbouring households.
4.3 Mtendere Basic School

According to the study survey and sanitary inspection conducted on 21st March, 2011, it was discovered that the school uses a borehole as its water source. The following outlines results ascertained from the social and physical surveys conducted during the site visit on the 21st March, 2011. A summary of the results of preliminary social and physical surveys are tabulated in Table 6.

Table 6: Survey questionnaire and sanitary inspection results Mtendere Basic School

<table>
<thead>
<tr>
<th>Location</th>
<th>Mtendere Central</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS reading</td>
<td>28.21.255E &amp; 15.24.296S</td>
</tr>
<tr>
<td>Population of pupils</td>
<td>1,850 (951 Females &amp; 899 Males)</td>
</tr>
<tr>
<td>Population of teachers</td>
<td>34 (29 Females &amp; 5 Males)</td>
</tr>
<tr>
<td>Age range of pupils</td>
<td>7 – 18 yrs (Females) &amp; 7 – 18 yrs (Males)</td>
</tr>
<tr>
<td>Water source</td>
<td>Borehole</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Nil (it is expensive)</td>
</tr>
<tr>
<td>Water quality problems</td>
<td>It is quite dirty with a bad taste</td>
</tr>
<tr>
<td>Water associated diseases</td>
<td>Not sure (because of lack of health register for the school)</td>
</tr>
<tr>
<td>Hand washing facilities</td>
<td>2 taps</td>
</tr>
<tr>
<td>Hand washing with soap</td>
<td>Nil (lack of funds to buy soap)</td>
</tr>
<tr>
<td>Person hygiene practices by pupils</td>
<td>Poor (lack of motivation in hygiene education at household level)</td>
</tr>
<tr>
<td>Hygiene education in schools</td>
<td>Poor HE to the pupils and the community</td>
</tr>
<tr>
<td>Potential source of contamination</td>
<td>Pit latrines from the Mtendere Township</td>
</tr>
<tr>
<td>Overall Health Risk</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 6 shows that the water source was not treated for microbiological contaminants. It is concluded that even though that borehole is regarded as a protected water source, its water may not necessarily be safe for drinking. This is because of the presence of potential feecal and chemical contaminations from pit latrines and poor solid waste management by the neighbouring households.

4.4 New Mtendere Basic School

According to the study survey and sanitary inspection conducted on 21st March, 2011, it was discovered that the school uses a mechanised borehole. This was the cleanest school in Mtendere Township even though drinking water was not treated coupled with poor hygiene education.

The following outlines results obtained from the social and physical surveys conducted during the site visit on the 21st March, 2011. A summary of the results of preliminary social and physical surveys are tabulated in Table 7.
Table 7: Survey questionnaire and sanitary inspection results from New Mtendere Basic School

<table>
<thead>
<tr>
<th>Location</th>
<th>Mtendere North</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS reading</td>
<td>28.21.612E &amp; 15.243.969S</td>
</tr>
<tr>
<td>Population of pupils</td>
<td>2,568 (1,247 Females &amp; 1,312 Males)</td>
</tr>
<tr>
<td>Population of teachers</td>
<td>( Females &amp; Males)</td>
</tr>
<tr>
<td>Age range of pupils</td>
<td>7 – 16 yrs (Females) &amp; 7 – 18 yrs (Males)</td>
</tr>
<tr>
<td>Water source</td>
<td>Borehole</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Nil (only chlorinated last year)</td>
</tr>
<tr>
<td>Water quality problems</td>
<td>None</td>
</tr>
<tr>
<td>Water associated diseases</td>
<td>Diarrhoea, malaria and bilhazia (no health register for the school)</td>
</tr>
<tr>
<td>Hand washing facilities</td>
<td>4 taps</td>
</tr>
<tr>
<td>Hand washing with soap</td>
<td>Nil (except for the grade ones)</td>
</tr>
<tr>
<td>Person hygiene practices by pupils</td>
<td>Poor</td>
</tr>
<tr>
<td>Hygiene education in schools</td>
<td>Poor HE to the pupils and the community</td>
</tr>
<tr>
<td>Potential source of contamination</td>
<td>Pit latrines from the Mtendere Township</td>
</tr>
<tr>
<td><strong>Overall Health Risk</strong></td>
<td>Low</td>
</tr>
</tbody>
</table>

From Table 7, it is concluded that even though the school surrounding is very clean and green, its borehole water might not necessarily be safe for drinking. This is because of the presence of potential feecal and chemical contaminations from pit latrines, septic tanks and the solid waste dumpsite in the neighbouring communities.

4.5 Population of pupils

The total population of the pupils in the respective studied schools is 10,164 consisting of 5,119 males and 5,045 females respectively (Figure 5).

![Figure 5: Total number of pupils in the studied schools, Mtendere Township, Lusaka, Zambia](image)

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From Figure 5, it is concluded that the more pupils a school has, the greater the potential health risks should there be a disease outbreak like water-borne diseases cholera. Therefore, Chitukuko Basic School with 3,705 pupils has the greatest potential health risks. This is true more especially with the prevailing high levels of microbiological and nitrate contamination in drinking water. For this reason, drinking water from this school should be treated coupled with the introduction of hygiene education programmes amongst the pupils to avoid recontamination of the treated water.

4.6 Number of teachers

The total number of the teachers in the studied schools is 170 consisting of 141 female and 29 male teachers respectively (Figure 6).

![Bar chart showing the number of teachers in different schools.]

**Figure 6: Number of teachers in the studied schools in Mtendere Township, Lusaka, Zambia**

Lack of clean water in the studied schools will increase the workloads of the female teachers when they have to spend more time caring for the sick pupils at school. This may have secondary effects such as reduced teaching periods and teacher – pupil contact time which may negatively impact on the general performance of the pupils thereby decreasing the chance of meeting the MDG No. 2 for universal primary education by 2015.

4.7 Handwashing facilities

The total number of the handwashing facilities in the respective studied schools is given in Figure 7. It was noted that the pupils do not wash their hands with soap after using the toilet and before
eating, and also that handwashing without soap was only practiced by the pupils after using the toilet. Lack of financial resources by the respective school management to buy soap for hand washing for the pupils was cited for the failure to providing soap.

However, grade ones in all the four schools were being encouraged to be coming with soap for handwashing.

![Graph showing no of taps for hand washing in different schools](image)

**Figure 7: Handwashing facilities in the studied schools in Mtendere Township, Lusaka, Zambia**

Comparing Figure 5 and Figure 7, it can be deduced that Chitukuko and Mtendere Basic have insufficient number of taps for handwashing servicing about 725 pupils per tap per day, followed by New Mtendere with about 640 pupils per tap and Mahatma Gandhi with about 512 pupils per tap per day. With the provision of unsafe drinking water at Chitukuko, Mtendere and New Mtendere basic schools, the potential health risks for the water-borne disease outbreak is synergistically high. Therefore, drinking water should be treated and the number of taps be increased to carter for at least 300 pupils per tap per day (i.e. 30 pupils per tap per hour).
4.8 Laboratory Results

Drinking water quality analysis for the studied schools was carried out at the University of Zambia under the Environmental and Civil Engineering Department, Environmental Engineering Laboratory (Table 8). The water test results where then compared with the recommended ZABS and WHO Guidelines for such parameters respectively.

Table 8: water quality analysis results compared with WHO and ZABS standards.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>New Mtendere Basic Sch</th>
<th>Mtendere Basic Sch</th>
<th>Chitukuko Basic School</th>
<th>Mahatma Gandhi Basic Sch.</th>
<th>WHO Guideline Limits</th>
<th>ZABS Standards Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample No:</td>
<td>110236</td>
<td>110560</td>
<td>110237</td>
<td>110561</td>
<td>110238</td>
<td>110562</td>
</tr>
<tr>
<td>pH</td>
<td>5.97</td>
<td>6.17</td>
<td>6.60</td>
<td>6.77</td>
<td>6.27</td>
<td>6.5</td>
</tr>
<tr>
<td>Conductivity (mMhos/cm)</td>
<td>873</td>
<td>895</td>
<td>657</td>
<td>710</td>
<td>750</td>
<td>770</td>
</tr>
<tr>
<td>Total Dissolved</td>
<td>436</td>
<td>449</td>
<td>328</td>
<td>355</td>
<td>374</td>
<td>384</td>
</tr>
<tr>
<td>Solids (mg/l)</td>
<td>Temperature (°C)</td>
<td>27.3</td>
<td>26.3</td>
<td>26.9</td>
<td>27.8</td>
<td>27.2</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.21</td>
<td>0.33</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Ammonia (as NH₄-Nmg/l)</td>
<td>0.05</td>
<td>0.14</td>
<td>0.08</td>
<td>0.06</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Chlorides (mg/l)</td>
<td>106.0</td>
<td>122.0</td>
<td>48.0</td>
<td>42.0</td>
<td>78.0</td>
<td>69.8</td>
</tr>
<tr>
<td>Nitrites (as NO₂-Nmg/l)</td>
<td>0.097</td>
<td>0.009</td>
<td>0.024</td>
<td>0.008</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nitrites (as NO₃-Nmg/l)</td>
<td>23.30</td>
<td>19.6</td>
<td>20.95</td>
<td>8.96</td>
<td>26.30</td>
<td>29.66</td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>32.0</td>
<td>36.0</td>
<td>40.0</td>
<td>42.2</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Bacteriological Results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total coliforms (#/100ml)</td>
<td>12</td>
<td>28</td>
<td>26</td>
<td>0</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>Feecal coliforms (#/100ml)</td>
<td>4</td>
<td>9</td>
<td>8</td>
<td>0</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

Tests carried out in conformity with “Standard Methods for the Examination of Water and Wastewater APHA, 1998”.

On the days of sampling the physical, chemical and bacteriological quality of the water, all the parameter were good and water was fit for drinking for Mahatma Gandhi Basic School only (Table 8). For Chitukuko, Mtendere and New Mtendere Basic Schools, water is unsafe for drinking because nitrates and bacteriological parameters (i.e. total coliforms and faecal coliforms) were more than the ZABS and WHO guidelines. The interpretation of the drinking water analytical results (Table 8) for the studied schools is summarised in Table 9.
Table 9: Interpretation of the water quality analysis results in four schools of Mtendere Township, Lusaka, Zambia

<table>
<thead>
<tr>
<th>Name of the Basic school</th>
<th>New Mtendere</th>
<th>Mtendere</th>
<th>Chitukuko</th>
<th>Mahatma Gandhi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Is water safe for drinking?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Possible contaminants (parameters found to be higher than WHO / ZABS Standards)</td>
<td>Nitrates</td>
<td>Iron</td>
<td>-</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>Feecal Coliforms</td>
<td>Feecal Coliforms</td>
<td>Feecal Coliforms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Coliforms</td>
<td>Total Coliforms</td>
<td>Total Coliforms</td>
<td></td>
</tr>
<tr>
<td>3. Possible sources of contaminations</td>
<td>Pit latrines</td>
<td>Pit latrines</td>
<td>Pit latrines</td>
<td>Pit latrines</td>
</tr>
<tr>
<td></td>
<td>Septic tanks</td>
<td>Septic tanks</td>
<td>Septic tanks</td>
<td>Septic tanks</td>
</tr>
<tr>
<td></td>
<td>Solid waste seepage</td>
<td>Solid waste seepage</td>
<td>Solid waste seepage</td>
<td>Solid waste seepage</td>
</tr>
<tr>
<td></td>
<td>geology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Potential health effects</td>
<td>Water-borne diseases (e.g. diarrhoea, cholera, dysentery)</td>
<td>Water-borne diseases (e.g. diarrhoea, cholera, dysentery)</td>
<td>Water-borne diseases (e.g. diarrhoea, cholera, dysentery)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>Blue baby syndrome</td>
<td>Blue baby syndrome</td>
<td>Blue baby syndrome</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tiredness</td>
<td>Tiredness</td>
<td>Tiredness</td>
<td></td>
</tr>
<tr>
<td>5. Proposed remedial measures</td>
<td>Water treatment</td>
<td>Water treatment</td>
<td>Water treatment</td>
<td>Hygiene education</td>
</tr>
<tr>
<td></td>
<td>Hygiene education</td>
<td>Hygiene education</td>
<td>Hygiene education</td>
<td></td>
</tr>
</tbody>
</table>

### 4.8.1 Physical and aesthetic parameters

All the tested physical parameters of water from the studied schools are within the stipulated ZABS and WHO guidelines. This is because all the electrical conductivity readings are less than 1500 mMhos/cm and Total Dissolved Solids are less than 1000 mg/l respectively.

### 4.8.2 Chemical parameters

(a) pH

The pH of the borehole water is slightly acidic for both New Mtendere and Chitukuko Basic schools because in the two schools the pH is below the recommended limits of 6.5 – 8.5 (Figure 8). This low in pH could be attributed to infiltration of humic acid from decaying solid waste and organic matter.
Figure 8: pH variations in the four studied schools in Mtendere Township, Lusaka, Zambia

(b) Nitrates

The concentration of nitrates in borehole water is above 10 mg/l for the studied schools except for Mahatma Gandhi Basic whose concentration is about 2.0 mg/l. The three schools’ nitrates are far much beyond the recommended WHO limits (Figure 9) and this has the potential of causing blue baby syndrome and tiredness. In Mtendere Township, nitrate pollution may occur from discharge of pit latrines and leachete from solid waste dumps as seepage into groundwater.

Figure 9: Nitrates variations in the four studied schools in Mtendere Township, Lusaka, Zambia

(c) Iron

The concentration of iron in four studied schools is below the ZABS and WHO guideline (0.3mg/l) except for Mtendere Basic School whose concentration is 0.33 mg/l. According to the WHO, iron
has no other serious health implications apart from turning the water brownish when in contact with the atmospheric oxygen or chlorine which is capable of oxidizing and precipitating iron (II) to iron (III).

(d) **Other chemical parameters**

The rest of the chemical parameters in the water tested in four studied schools are within the ZABS/WHO guidelines. These include nitrites (<0.10mg/l), ammonia (<1.5mg/l), chlorides (<250mg/l) and calcium (<200mg/l) respectively.

**4.8.3 Microbiological parameters**

With exemption of Mahatma Gandhi Basic, the concentration feacal and total coliform bacteria in borehole water for the studied schools range from 4 – 14 CFU/100ml and 12 – 28 CFU/100ml respectively in comparison with the ZABS/WHO guideline of 0 CFU/100ml. Hence making borehole water unsafe for drinking in the three studied schools (Figure 10).

![Diagram showing microbiological variations in the studied schools in Mtendere Township, Lusaka, Zambia](image)

Figure 10: Microbiological variations in the studied schools in Mtendere Township, Lusaka, Zambia

The presence of the feacal and total coliform bacteria in three studied schools is an indication of feacal contamination mostly from pit latrines and septic tanks seepage within the township. This in
Figure 8: pH variations in the four studied schools in Mtendere Township, Lusaka, Zambia

(b) **Nitrates**

The concentration of nitrates in borehole water is above 10 mg/l for the studied schools except for Mahatma Gandhi Basic whose concentration is about 2.0 mg/l. The three schools’ nitrates are far much beyond the recommended WHO limits (Figure 9) and this has the potential of causing blue baby syndrome and tiredness. In Mtendere Township, nitrate pollution may occur from discharge of pit latrines and leachete from solid waste dumps as seepage into groundwater.

Figure 9: Nitrates variations in the four studied schools in Mtendere Township, Lusaka, Zambia

(c) **Iron**

The concentration of iron in four studied schools is below the ZABS and WHO guideline (0.3mg/l) except for Mtendere Basic School whose concentration is 0.33 mg/l. According to the WHO, iron
has no other serious health implications apart from turning the water brownish when in contact with the atmospheric oxygen or chlorine which is capable of oxidizing and precipitating iron (II) to iron (III).

(d) **Other chemical parameters**

The rest of the chemical parameters in the water tested in four studied schools are within the ZABS / WHO guidelines. These include nitrates (<0.10mg/l), ammonia (<1.5mg/l), chlorides (<250mg/l) and calcium (<200mg/l) respectively.

**4.8.3 Microbiological parameters**

With exemption of Mahatma Gandhi Basic, the concentration feecal and total coliform bacteria in borehole water for the studied schools range from 4 – 14 CFU/100ml and 12 – 28 CFU/100ml respectively in comparison with the ZABS / WHO guideline of 0 CFU/100ml. Hence making borehole water unsafe for drinking in the three studied schools (Figure 10).

![Graph showing microbiological variations in the studied schools in Mtendere Township, Lusaka, Zambia](image)

**Figure 10: Microbiological variations in the studied schools in Mtendere Township, Lusaka, Zambia**

The presence of the feecal and total coliform bacteria in three studied schools is an indication of feecal contamination mostly from pit latrines and septic tanks seepage within the township. This in
return poses potential health risks to the pupils and teachers with respect to water-borne disease outbreaks.

4.9 Discussion

Results showed that all water points (i.e. boreholes) in the studied schools except for Mahatma Gandhi had the concentration of nitrates ranging from 19.6 mg/l – 29.66 mg/l and fecal contaminations ranging from 4 CFU/100ml – 28CFU/100ml. Nitrates are naturally occurring as part of the nitrogen cycle. High concentration of nitrates in groundwater in Mtendere is caused by seepage from septic tanks, solid waste dumps, pit latrines and sewage. Main health concern of nitrates is methaemoglobinemia, commonly known as blue baby syndrome that occurs in infants that are usually bottle fed. Symptoms include shortness of breath and their skin turning blue due to the lack of oxygen (WHO, 2004b). Additionally, the source of the microbiological contaminants in the three studied schools included seepage from septic tanks, solid waste dumps, pit latrines and sewage within the township. Therefore, there is need to chlorinate water for drinking as safety measure.

According to the WHO Drinking Water Guidelines (2004c), the health risks associated with microbiological contamination of drinking water are categorised according to the number of counts of fecal and total coliforms (Table 10).

Table 10: Microbiological Health risks (Source: WHO, 2004b)

<table>
<thead>
<tr>
<th>Count per 100ml</th>
<th>Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Conforms with WHO Guidelines</td>
</tr>
<tr>
<td>1 – 10</td>
<td>Low Risk</td>
</tr>
<tr>
<td>10 – 100</td>
<td>Intermediate Risk</td>
</tr>
<tr>
<td>100 – 1000</td>
<td>High Risk</td>
</tr>
<tr>
<td>&gt; 1000</td>
<td>Very High Risk</td>
</tr>
</tbody>
</table>

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Using Table 11, the results showed that the health risks for the studied schools are between low to intermediate risks.

**Table 11: Microbiological Health risks in the studied school in Mtendere Township, Lusaka Zambia**

<table>
<thead>
<tr>
<th>Basic School</th>
<th>Health Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahatma Ganghi</td>
<td>No Risk</td>
</tr>
<tr>
<td>Mtendere</td>
<td>Intermediate Risk</td>
</tr>
<tr>
<td>New Mtendere</td>
<td>Intermediate Risk</td>
</tr>
<tr>
<td>Chitukuko</td>
<td>Intermediate Risk</td>
</tr>
</tbody>
</table>
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

This chapter gives the conclusions and recommendations on the drinking water quality assessment which was carried out in the four basic schools in Mtendere Township in Lusaka, Zambia.

5.1 Conclusion

In general, the results of this study showed that the concentration of nitrates and microbiological parameters of drinking water for New Mtendere, Mtendere and Chitukuko Basic Schools range from 19.6 mg/l – 29.66 mg/l and 4 CFU/100ml – 28CFU/100ml respectively. In comparison with the recommended ZABS / WHO guidelines for nitrates (i.e. 10mg/l) and microbiological parameters (0 CFU/100ml), these contaminants are above the recommended standards and thus making the water in studied schools unsafe for human consumption. Hence need for the school management to treat the water prior to consumption.

5.2 Recommendations

The study therefore recommends the following:

i. Drinking water quality assessment in schools should be given a priority, be integrated into the ministries of Health and Ministry of Local Government and Housing water quality surveillance programmes if we are to achieve the MDG for universal primary education;

ii. The ministries of Education and Health should work together in implementing an effective health and hygiene education programme in schools in peri-urban areas which lack proper sanitation facilities, quality water and personal hygiene practices.

iii. The respective school managements should be treating their water in storage tanks by adding chlorine before use for prevention of multiplication of microorganisms. Addition of chlorine to water only applies to water sources with nitrate concentration less than 10 mg/l;

iv. The respective school managements should introduce sustainable handwashing programmes with soap in schools to alleviate water re-contamination by the pupils at the point of use.

v. Further studies should be undertaken by the Ministry of Health in collaboration with Colleges and Universities in order to investigate the trends of groundwater contamination in the studied schools, and then be scaled-up to other peri-urban areas of Lusaka.
REFERENCES


WHO, 2005. *The international network to promote household water treatment and safe storage.*


WHO, 2006b. *Global drinking water quality report,* Section 8.3.


URL:

www.zabs.org.zm
APPENDIXES

APPENDIX 1: SANITARY INSPECTION FOR MECHANISED BOREHOLES

I. General information
   1. Supply zone:
   2. Location:
   3. Code Number
   4. Date of Visit
   5. Water sample taken? ........... Sample No ........... FC/100ml ...........

II. Specific Diagnostic Information for Assessment

   1. Is there a nearest latrine or sewer within 100m of pumphouse Y/N
   2. Is the nearest latrine unsewered Y/N
   3. Is there any source of other pollution within 50m Y/N
   4. Is there an uncapped well within 100m Y/N
   5. Is the drainage around pumphouse faulty Y/N
   6. Is the fencing damaged allowing animal entry Y/N
   7. Is the floor of the pumphouse permeable to water Y/N
   8. Does water forms pools in the pumphouse Y/N
   9. Is the well seal insanitary Y/N

   Total Score of Risk ............9

   Risk Score: 7-9 = High; 3-6 = Medium; 0-2 = Low

III. Results and Recommendations:

   The following important points of risk were noted: (list numbers 1-9)

   Signature of the Health Inspector / Assistant:

   Comment:
APPENDIX 2: POTENTIAL HEALTH EFFECTS OF CHEMICALS

The effect of the contaminant on human health depends largely upon the type of contaminant, its concentration, the length and frequency of exposure. The user’s age, physical health condition and immunity can also have a large influence on the resulting health effect. A list of chemical contaminants, the health impacts they pose, and potential contamination sources are provided in the following table.

**Potential Health Impacts of Chemical Contamination**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Potential Health Effect from Drinking Water</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Little indication that orally ingested aluminium is acutely toxic. No health based guideline is proposed.</td>
<td>Naturally occurring; most abundant metal. Aluminium salts are widely used in water treatment as coagulants to reduce organic matter, colour, turbidity and microorganism levels.</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Ammonia in drinking water is not of immediate health relevance. No health based guideline is proposed.</td>
<td>Sewage, industrial processes, and agricultural activities</td>
</tr>
<tr>
<td>Antimony</td>
<td>Itchy, rough and broken skin. Eczema and dermatitis result from long term and regular contact with antimony.</td>
<td>High concentrations may occur from mining operations and active volcanic areas.</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Skin disease (melanosis and keratosis). May lead to lung, bladder, kidney, skin, liver, and prostate cancer. Also known to cause vascular diseases, neurological effects, and infant developmental defects.</td>
<td>Naturally occurring; also used commercially and industrially in the manufacture of transistors, lasers and semi-conductors. Some areas have relatively high concentrations of arsenic in groundwater.</td>
</tr>
<tr>
<td>Barium</td>
<td>No evidence that barium is carcinogenic or mutagenic.</td>
<td>Used in a variety of industrial applications; however barium in water comes mainly from natural sources.</td>
</tr>
<tr>
<td>Boron</td>
<td>Toxic to the male reproductive tract and may cause developmental toxicity.</td>
<td>Used in the manufacture of glass, soaps and detergents and as flame retardants. Found naturally in groundwater, but its presence in surface water is frequently a consequence of the discharge of treated sewage that contains detergents. Conventional water treatment does not significantly remove boron.</td>
</tr>
<tr>
<td>Cadmium</td>
<td>High doses can cause kidney damage.</td>
<td>Used in the steel industry, plastics and in batteries. Released in wastewater, fertilizers and local air pollution. Contamination in drinking water may also be caused by galvanized pipes, solders and metal fittings. Food is the main source of exposure.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Essential element for human nutrition. No health based guideline is proposed.</td>
<td>Naturally occurring.</td>
</tr>
<tr>
<td>Chemical</td>
<td>Potential Health Effect from Drinking Water</td>
<td>Source</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Chloride</td>
<td>Several studies have suggested that the chloride may play a role in kidney function and nutrition.</td>
<td>Chloride in drinking water comes from natural sources, sewage, industrial effluents, and from urban runoff containing de-icing salt. Main source of human exposure is the addition of salt to food.</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Effects are not likely to occur at levels of chlorine that are normally found in the environment. High dose of chlorine irritates the skin, the eyes, and the respiratory system.</td>
<td>Produced in large amounts and widely used industrially and domestically as an important disinfectant and bleach.</td>
</tr>
<tr>
<td>Chromium</td>
<td>No significant health effects have been attributed to chromium due to lack of toxicological data.</td>
<td>Naturally occurring. Food appears to be the major source of uptake.</td>
</tr>
<tr>
<td>Copper</td>
<td>Copper is both an essential nutrient and drinking water contaminant. Can effect the gastrointestinal tract, impact may be greater on sensitive populations such as the carriers of the gene for Wilson disease and other metabolic disorders.</td>
<td>Used to make pipes, valves and fittings. Copper sulphate pentahydrate is sometimes added to surface water to control algae. Primary source in drinking water is the corrosion of copper plumbing. Food and water are the primary sources of copper exposure in developed countries.</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Long-term consumption effects the thyroid and the nervous system.</td>
<td>Can be found in some foods, particularly in some developing countries, and occasionally found in drinking water from industrial contamination.</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Low concentrations (0.5 – 1.0 mg/L) provide protection against dental caries, especially in children. Higher levels can cause mottling of teeth and dental fluorosis. Much higher levels can result in skeletal damage.</td>
<td>Naturally occurring; used widely in industry; used to produce phosphate fertilizers. In most circumstances food is the main source of intake. Some areas have relatively high concentrations of fluoride in groundwater.</td>
</tr>
<tr>
<td>Iron</td>
<td>Essential element for human nutrition. No health based guideline is proposed.</td>
<td>Naturally occurring; one of most abundant metals. Also found in drinking water from corrosion of steel and cast iron pipes.</td>
</tr>
<tr>
<td>Lead</td>
<td>Infants, children and pregnant women are most susceptible. Infants and children: Delays in physical or mental development; deficits in attention span and learning abilities. Adults: Kidney problems; high blood pressure.</td>
<td>Used in the production of lead-acid batteries solder and alloys. Lead in drinking water is usually from household plumbing systems that use lead in pipes, solder and fittings.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Essential element for human nutrition. Adverse effects can result from both deficiency and overexposure.</td>
<td>Naturally occurring; one of most abundant metals, usually found with iron. Used in manufacturing and in cleaning, bleaching and disinfection products. Food is the main source of exposure.</td>
</tr>
<tr>
<td>Mercury</td>
<td>Causes neurological symptoms and kidney damage.</td>
<td>Used in the mining industry, production of chlorine, electrical appliances, and in dental amalgams. Food is the main source of exposure.</td>
</tr>
<tr>
<td>Chemical</td>
<td>Potential Health Effect from Drinking Water</td>
<td>Source</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Essential element for human nutrition. High doses may cause liver dysfunction and joint pain in the knees, hands and feet.</td>
<td>Naturally occurring; relatively rare element. Used in manufacturing of special steels, used as lubricant additives and in agriculture to prevent molybdenum deficiency of crops. May be found in high concentrations near mining sites.</td>
</tr>
<tr>
<td>Nickel</td>
<td>Higher chances of lung cancer, nose cancer, birth defects, allergic reactions, heart disorders.</td>
<td>Naturally occurring; used in the production of stainless steel and nickel alloys. Food is the main source of exposure. However, nickel in water can be significant in areas where there is heavy industrial pollution or relatively high concentrations in groundwater.</td>
</tr>
<tr>
<td>Nitrate and nitrite</td>
<td>Main health concern is methaemoglobinemia, or blue baby syndrome, that occurs in infants that are usually bottle fed. Symptoms include shortness of breath and their skin turning blue due to the lack of oxygen.</td>
<td>Naturally occurring as part of the nitrogen cycle. Nitrate is used in fertilizers and sodium nitrite is used as a food preservative. Concentration of nitrate in groundwater and surface water is caused by agricultural runoff; leaching from septic tanks, and sewage. Nitrite is from microbial activity and may be intermittent.</td>
</tr>
<tr>
<td>Potassium</td>
<td>Essential element for human nutrition. No health based guideline is proposed. Increased exposure could result in health effects in people with kidney disease or who are taking medication that interferes with normal potassium functions in the body.</td>
<td>Naturally occurring; not commonly found in drinking water at levels that are a concern to human health. However, drinking water treated by water softeners using potassium chloride may significantly increase exposure and result in adverse health effects in susceptible individuals.</td>
</tr>
<tr>
<td>Silver</td>
<td>No health based guideline is proposed. Only a small percentage of silver is absorbed by the body.</td>
<td>Naturally occurring; occasionally found in groundwater, surface water and drinking water. Silver salts are sometimes used by HWT technologies to reduce bacteria (i.e. ceramic filters).</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>Although there are no direct health concerns, very low or high concentrations may cause an objectionable taste.</td>
<td>TDS in drinking water comes from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary greatly in different geological regions.</td>
</tr>
</tbody>
</table>

(Adapted from WHO, 2006a)
APPENDIX 3: DRINKING-WATER QUALITY ASSESSMENT QUESTIONNAIRE /
CHECKLIST

THE UNIVERSITY OF ZAMBIA
IWRM CENTRE
SCHOOL OF MINES

DRINKING-WATER QUALITY ASSESSMENT IN SCHOOLS IN PERI-URBAN AREAS
(A CASE OF MTENDERERE TOWNSHIP)

Date: ____________________________________________

Basic School: ______________________________________

Questionnaire number: _____________________________

A. Information on the school

A1) School No: ________________________________

A2) Total No of teachers __________ Female: _______ Male___________

A3) Total No of pupils ________________ Female: _______

Male______________

A4) Age range of pupils: Female: ________________ Male: ________________

A5) Name of head of Teacher: _________________________
B. Water

B1) Do you treat your drinking water?
☐ yes  ☐ no

If yes how?
☐ Boil  ☐ chlorinate  ☐ sand filtration  ☐ other

B2) If you don’t treat your water what is the reason:
☐ It is expensive  ☐ no need  ☐ it is safe  ☐ other

B3) what are the benefits of your drinking water supply?
☐ improved quality of water  ☐ decreased diarrhoea
☐ more water for domestic use
☐ Effect on other health problems. If yes, what? Tick water related problems
☐ Scabies  ☐ eye infections  ☐ guinea worm  ☐ other
☐ Other

B4) Are there any problems with your water supply?
☐ yes  ☐ no

If yes, what are they?
☐ It is dirty  ☐ it is irregular  ☐ it is a long way
☐ It is expensive  ☐ periods when it dries up  ☐ Management issues
☐ Caretaker  ☐ water treatment  ☐ Breakdown of pump
☐ Other
C. Handwashing

C1) Do the majority of pupils wash their hands after using toilets?
○ Yes ○ No

If no, what is the reason for this?
○ Insufficient ○ has no health implications ○ Other

If yes, when do you wash your hands?
○ Before eating ○ after defecation ○ other ____________________________

C2) Why do you wash your hands?
○ keep free of germs ○ don’t know ○ other ________________________

C3) What do you use to wash your hands?
○ Use water only ○ ash ○ soap ○ other ________________________

C4) How do you wash your hands?
○ under a running tap ○ in a bowl ○ water poured over hands from a
  container ○ other ________________________________

Observation for hand washing

C5) Observation: Is there a hand washing facility in the house?
○ yes ○ no
C7) What are the three diseases that your school has suffered from since the borehole was installed? (Please tick)

○ Diarrhoea  ○ malaria  ○ Dysentery  ○ respiratory infection

○ Any other ___________________________

C8) What causes diarrhoea?

○ germs  ○ dirty objects  ○ dirty food  ○ dirty fingers

○ dirty fluid  ○ flies  ○ open defecation

○ other __________________________________________

C9) What is the best way to prevent diarrhoea?

○ washing hands  ○ use of latrines  ○ use of safe drinking water

○ other __________________________________________

Any additional information?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Thank you very much for your time spent on the completion of this Questionnaire