



WATER RESOURCES MANAGEMENT IN ZAMBIA:
A CASE OF CUMULATIVE IMPACTS
ASSOCIATED WITH COPPER MINING IN THE
UPPER KAFUE CATCHMENT, COPPERBELT
PROVINCE, ZAMBIA

By

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**A thesis submitted in partial fulfilment of the
requirements of the award of Master of Philosophy
Degree in Sustainable Mineral Resource Development**

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ABSTRACT

Water resources management is high on the agenda both locally and globally because of its important role in social, economic and environmental development. For example, as part of the 2030 Agenda for Sustainable Development, all United Nations Member States adopted 17 Sustainable Development Goals (SDGs) in 2015 that covered thematic issues including water, energy, climate, oceans, urbanization, transport, science and technology. Sustainable Development Goal (SDG) no.6, which targets universal access to safe and affordable drinking water for all by 2030, is of particular interest in this study.

The mining industry contributes to socio-economic development; however, it has also contributed to declining water quality in rivers and lakes in many regions globally. In this study, the status and governance of water resources within the Copperbelt province of Zambia over the period 2000 to 2020 was examined.

The study investigated population and economic growth within the region and its correlation with changes in water quality and quantity. The research also focused on understanding the ways copper mining is affecting local water resources. The study also investigated challenges faced by regulators and institutions in the water sector, and considered how these challenges could be addressed. Secondary data was obtained from government institutions within Zambia such as National Water Supply and Sanitation Council (NWASCO), Water Resources Management Authority (WARMA) and Zambia Environmental Management Agency (ZEMA), which are the key institutions in the water sector and the environment. Semi-structured interviews were also conducted with the three key institutions in the water and pollution control sectors.

The results showed that the total population in the Copperbelt province has increased by 20% since 2000 to a total of 1 972 317 in 2010. The population is projected to be 2 669 635 in 2020, representing about 27% increase from 2010. The rural population is projected to be 423 511 in 2020, representing about 11% increase from 2010 while the urban population will be 2 246 124 in 2020 representing about 29% increase from 2010. The majority of this growth has occurred in urban areas, which grew by about 30% from

2000 to a total of 1 595 456 in 2010. Rural population has increased by 8% since 2000 to a total of 376 861. The results also showed increased economic activities driven mainly by copper mining. Water abstraction has generally declined since 2000 mainly due to decrease in mining activities. In 2000, about 1 million m³/day was abstracted in the Copperbelt province and about 600 000 m³ per day in 2005. The reduction in 2005 could be attributed to reduction in mining activities and institutional changes in the water sector.

Water production and consumption from commercial utilities has generally been in decline from 2000 to 2017. This is also the case with water consumption per capita and water production per capita. For example, water consumption per capita per day in 2001 was 203 liters and reduced to 113 liters in 2017, representing a 44% reduction in consumption. The results showed that water consumption from 2004 to 2008 averaged 100 million m³ while the production averaged 160 million m³ per year. NWASCO attributed the general downward trend in water production and consumption in the province to maintenance and rehabilitation of water infrastructure, and investment in new infrastructure, thereby reducing the unaccounted-for water. The other reason could be that new housing developments prefer to use groundwater sources rather than utility water (supplied by water companies). The reduction could also be attributed to the cost of water and that consumers needed to adjust from the background where utility services such as water supply and sanitation were the sole responsibilities of the mines (ZCCM), prior to privatization. In terms of water supply and sanitation coverage, there has been an increased coverage since 2000. In 2001, the population that had access to water supply and sanitation was 81% and 46%, respectively. Therefore, roughly 50% of the population had no access to sanitation. However, in 2017 the population with access to water supply and sanitation was 91% and 75%, respectively. This represented only 25% of the population in serviced areas that had no access to sanitation. Between 2007 and 2008, the sanitation coverage had seen a reduction compared to the year 2006. This was due to institutional changes on the Copperbelt province, and the 2008 economic recession – the mine townships that were previously serviced by an asset holding after privatization of the mines were taken over by other utility companies. Consequently, the service delivery in the province initially dropped, but then started increasing again in 2009.

The above observations suggest that there has been growing pressure on the quality and quantity of water systems in the Copperbelt province as a result of several factors including increasing populations, increased industrial activity (particularly mining). It can also be concluded that there has been a general improvement in the overall water supply and sanitation coverage for local communities, which suggest that there has been positive progress made towards SDG no.6. Dewatering of mines continues to play an important role in improving the flows of the Kafue River especially in the dry season to meet domestic water supply demands.

Interviews conducted with regulators such as NWASCO, WARMA and ZEMA found that the institutions face challenges including a lack of adequate financing and technical support to effectively enforce regulations, governing water resources management. There is also lack of coordination in terms of which water quality parameters to test for and why those parameters and are so important, and where monitoring should be done. Concern was also expressed that the level of water infrastructure development is not adequate to support the growing population and economic growth. Additionally, old and dilapidated infrastructure have not coped with the increasing population and mushrooming of informal settlements concerning water and sanitation services.

In summary, despite evidence of an increasing population and increased level of industrial activity in the Copperbelt, quantifying the link between these activities and water quality remains a challenge. In part, this is due to insufficient data and different institutions that collect water quality data with varying parameters to test. Based on the findings of this study, it is recommended that NWASCO, WARMA and ZEMA should invest in remote monitoring of water quality and quantity in view of constrained financial resources, and in turn collect data more frequently. There is a need for more collaboration among regulators on the parameters to test for and a consolidated database for water resources. The government, through regulating agencies, should find a way of making data on water from mining companies accessible, especially to researchers so that they can inform policy on water resources management. Groundwater quality should also be monitored more frequently as most data available are skewed to surface water.

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DEDICATION AND ACKNOWLEDGEMENT

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LIST OF ABBREVIATIONS/ACRONYMS

CEP	Copperbelt Environmental Project
CSO	Central Statistical Office
CU	Commercial Utility
ICMM	International Council of Mining and Metals
JICA	Japanese International Cooperation Agency
KCM	Konkola Copper Mines
NWASCO	National Water Supply and Sanitation Council
MCM	Mopani Copper Mines
MW	Mega Watt
MWED	Ministry of Water and Energy Development
NGO	Non-Governmental Organization
SGAB	Swedish Geological AB
SWECO	Swedish Engineering Consultants
TC _{Co}	Total Cobalt
TC _{Cu}	Total Copper
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNZA	University of Zambia
WARMA	Water Resources Management Authority
WHO	World Health Organization
WWF	World Wide Fund for Nature
ZEMA	Zambia Environmental Management Agency
ZCCM - IH	Zambia Consolidated Copper Mines Investments Holdings
ZMW	Zambian Kwacha

CHAPTER 1: INTRODUCTION

1.1 Background

Water resource management is high on the agenda both locally and globally, this is owing to the fact that it is the most fundamental and indispensable of all natural resources and sustains social, economic development and environmental biodiversity (Ashton et al., 2001; UNEP, 2016a; Gurria, 2017). Water plays a critical role in the development of nations and flows through the three pillars of sustainable development – economic, social and environment (WWF, 2016). For example, the Millennium Development Goal (MDG) target 7 had aimed to half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. The Sustainable Development Goal (SDG) no.6 targets universal access to safe and affordable drinking water for all by 2030.

Water is a key component in growing food, generating energy, producing many industrial products and other goods and services, as well as in ensuring the integrity of ecosystems (Lange & Hassan, 2006). Water plays an important role in mining for production of valuable products and being a shared resource, it requires good stewardship practices. It is important that companies now consider the water-related impacts at regional scale as opposed to just focus on the impacts within their mining leases (Kunz & Moran, 2014). Water at national or global level need to be understood in terms of quality and quantity in order to promote sustainable management of the resource, this is because a local water crisis can easily become a global issue (Gurría, 2017).

Population growth, the structure and level of economic activity, urbanization and increasing standards of living, land cover and land use changes all influence the availability of water and the use of water (Rosegrant et al.,2002; Lange & Hassan, 2006; UNEP,2010;ICMM,2012; Endo et al., 2017). Climate change and social change, globalization, and urbanization are causing increased pressure on water, energy and food resources, presenting communities with an increasing number of tradeoffs and potential conflicts among these resources which have complex interactions (Endo et al., 2017).

As of mid-2017, the world population was nearly 8 billion and is expected to reach about 9 billion in 2030, 10 billion in 2050 and 11 billion in 2100 (United Nations,2017). The United Nations estimates that from 2017 to 2050, half of the world's population growth will be concentrated in just nine countries: India, Nigeria, the Democratic Republic of the Congo, Pakistan, Ethiopia, the United Republic of Tanzania, the United States of America, Uganda and Indonesia (ordered by their expected contribution to total growth). The continued increase in population, globally, has put pressure on water resources in terms of quality and quantity. The ever-increasing demands for freshwater resources are being driven by population growth, urbanization, industrialization, and increases in production and consumption (WWAP, 2015a).

Globally, water related losses account for US\$260 billion annually with the least developed countries more affected by economic impacts of water challenges (Gurría, 2017). Gurría (2017) notes that about 80% of cultivated land across the globe is rain-fed and accounts for 60% of the world crop production making the sector vulnerable to climate changes. Water crisis is of highest concern today, even for the next decade and ranks top of climate change, extreme weather events, food crisis and social instability (Dos Santos et al., 2017). Dos Santos et al. (2017) further observed that the urban areas in Sub-Saharan have better access (56%) to water compared with the rural areas.

Zambia has abundant water resources with about 8700 m³ per capita of renewable water resources. This implies that Zambia is neither a water scarce (1000 m³ per capita) nor water stressed (less than 1700 m³ per capita) country (GRZ , 2017). However, access to safe water and sanitation remains low. In 2015, 40% of households in Zambia had access to improved sources of sanitation; 27% of urban population and about 87% of the people in rural areas had no access to improved sources of sanitation (GRZ, 2017). According to the Seventh National Development Plan (7NDP), the proportion of households with access to improved sources of drinking water increased from 63% in 2010 to about 68% in 2015. In 2015, the rural population with access to improved sources of drinking water was 52% while the urban population with access to improved sources of drinking water was about 89% (GRZ, 2017).

The projected population in Zambia in 2011 was 13 718 722 and increased to 15 473 905 in 2015, representing an 11% increase (CSO, 2016). The population is projected to be 2 669 635 in 2020 (next census of population), representing about 27% increase from 2010. The country's total population is expected to further grow from about 14 million in 2011 to 18 million in 2020 and to 27 million by 2035, representing about 48% increase in population from 2011 to 2035. This means that the population will almost double during the 25-year projection period (CSO, 2013). During the period 2011-2020, Zambia's population is projected to grow at an average rate of about 3% per annum.

Zambia is one of the most urbanized countries in Sub-Saharan Africa, with about 42% of the population living in urban areas (GRZ , 2017). According to the 2010 census, the urban population represented 40% while the rural population was 60% of the national population ((Central Statistical Office, 2012). The urban population had a high growth rate of about 4% between 2000 and 2010 (Central Statistical Office, 2013a). According to the 2010 census, 36% of the urban population lived in Lusaka province while 31% were in the Copperbelt province (Central Statistical Office, 2013a).

This increase in population and urbanization poses a challenge for ensuring access to water and sanitation. Most of the urban population live in peri-urban areas or unplanned settlements. Peri-urban areas are low income areas - about 70% of the urban population live in informal settlements or peri-urban areas (Ministry of Local Government and Housing , 2015). These unplanned settlements have been growing at a fast rate, making it challenging for water utilities to cope with the growing demand. As a result, an increase in waterborne or diarrhea diseases has been reported. It is estimated that poor sanitation costs Zambia US\$194 million every year, equivalent of US\$16 per person or about 1% of the national GDP in term of treatment of waterborne diseases (Ministry of Local Government and Housing , 2015). Poor water, sanitation and hygiene (WASH) account for approximately 90% of under-five (5) deaths. According to the Zambian government, the rapid growth of the urban population and investment in urban infrastructure has not been matching with the growth in population (GRZ, 2017).

Mining in Zambia continues to be an important sector in Zambia and will continue to be so. The known large mineral resource base in Zambia include copper, emeralds, and

other minerals such as cobalt (World Bank, 2016a). The mining sector is the main sector of the economy, it contributed about 12% to GDP in 2014 and accounted for 62% of foreign direct investment (FDI); in terms of share of national formal employment the mining sector had 8% (Republic of Zambia, 2014; World Bank, 2016a). In 2014, about 28 933 and 27 896 direct and indirect jobs that were created in the mining sector, respectively (World Bank, 2015). At national level, the mining companies directly employ about 58 000 individuals representing 2% of total country's 2017 employed persons of 2 791 170 (Zambia Extractive Industries Transparency Initiative (EITI), 2019). In 2014, there were about 72 203 jobs out of 2 995 103 jobs in Zambia (Zambia Statistics Agency & Ministry of Labour and Social Security, 2020).

In 2014, copper accounted for 85% of national mining revenue (World Bank, 2016a). Despite copper mining playing a significant role in the Zambian economy, it has also brought environmental degradation through interaction with water, land, air, and associated flora and fauna (Republic of Zambia, 2014; Chanda & Wilson, 2017).

Besides copper, water is the most important natural resource in Zambia (Uhlendahl et al., 2011). Traditionally, the Copperbelt province has been the centre of copper mining in Zambia, though recently the North-Western province, commonly referred to as the "new Copperbelt", has also seen an increase in copper mining activities (ICMM & Chamber of Mines of Zambia, 2014). There are seven large-scale mining companies in the Copperbelt, and copper and cobalt being the major commodities, whereas emeralds are mined in the rural district of Lufwanyama (Tychsen et al., 2018; USGS, 2019). There are about 56 copper/cobalt mining exploration licenses and about 40 mining licenses; and about 6 mineral processing licenses in the Copperbelt region (Zambia Extractive Industries Transparency Initiative (EITI), 2019; Zambian Ministry of Mines and Mineral Development & Trimble Land Administration, 2020). The total copper contained in known deposits are about 87 million metric tonnes and about 14 million metric tonnes of undiscovered deposits in Zambia (Zientek et al., 2014). Tailings dam, and waste rock dumps occupy about 78 km² in the Copperbelt and is also a source of water and soil contamination (The World Bank, 2009).

All mining operations on the Copperbelt province lie within the catchment area of the Kafue River, which provides water for domestic use, irrigation, and fishing (Schuler & Lokanc, 2015). Water issues in Zambia have risen to prominence in recent years. This reflects a growing understanding of water's centrality in the country's economic growth, which has stood at an annual average of 6% for the last decade. However, this development also places significant pressure on water resources – agriculture, energy, and industrial and domestic water supply all have impacts on the use and governance of water (WWF, 2016).

Zambia lies entirely within two large river basins, the Zambezi River basin and the Congo River basins. Zambia has six water catchments: Zambezi, Luangwa, Kafue, Chambeshi, Luapula and Tanganyika. Zambia has three major river systems within the Zambezi River basin and two within the Congo River basin (Figure 1). The following are the major river systems in Zambia:

- The Luangwa and Kafue tributaries in Zambia join the upper main Zambezi River system. The upper Zambezi originates in Angola and flows to Mozambique after forming the border with Zimbabwe.
- The Kafue River system covers an area of 152 000 km². The river has two important dams, the Itezhi-Tezhi dam and the Kafue Gorge dam, the latter of which is used for hydropower generation.
- The Luangwa River has a catchment area of 165 000 km². It drains most of the central parts of the country and empties into the Zambezi.
- The Chambeshi River and the Luapula River are associated with lakes Mweru and Mweru-Wantipa and drain their water into the Congo River system.
- The small Tanganyika drainage system is also part of the large Congo River system.

Zambia is generally endowed with abundant surface water. However, there are seasonal variations from south to north in terms of river flow peaks between March and April and the lowest flows are recorded from September to October (Nkhuwa, Mweemba & Kabika,

2013). Nkhuwa, Mweemba and Kabika (2013) further noted that during high rainfall season, annual runoff can be as high as 130 km³ and during severe drought can be as low as 68 km³; as a result, the quantity of surface water is impacted.

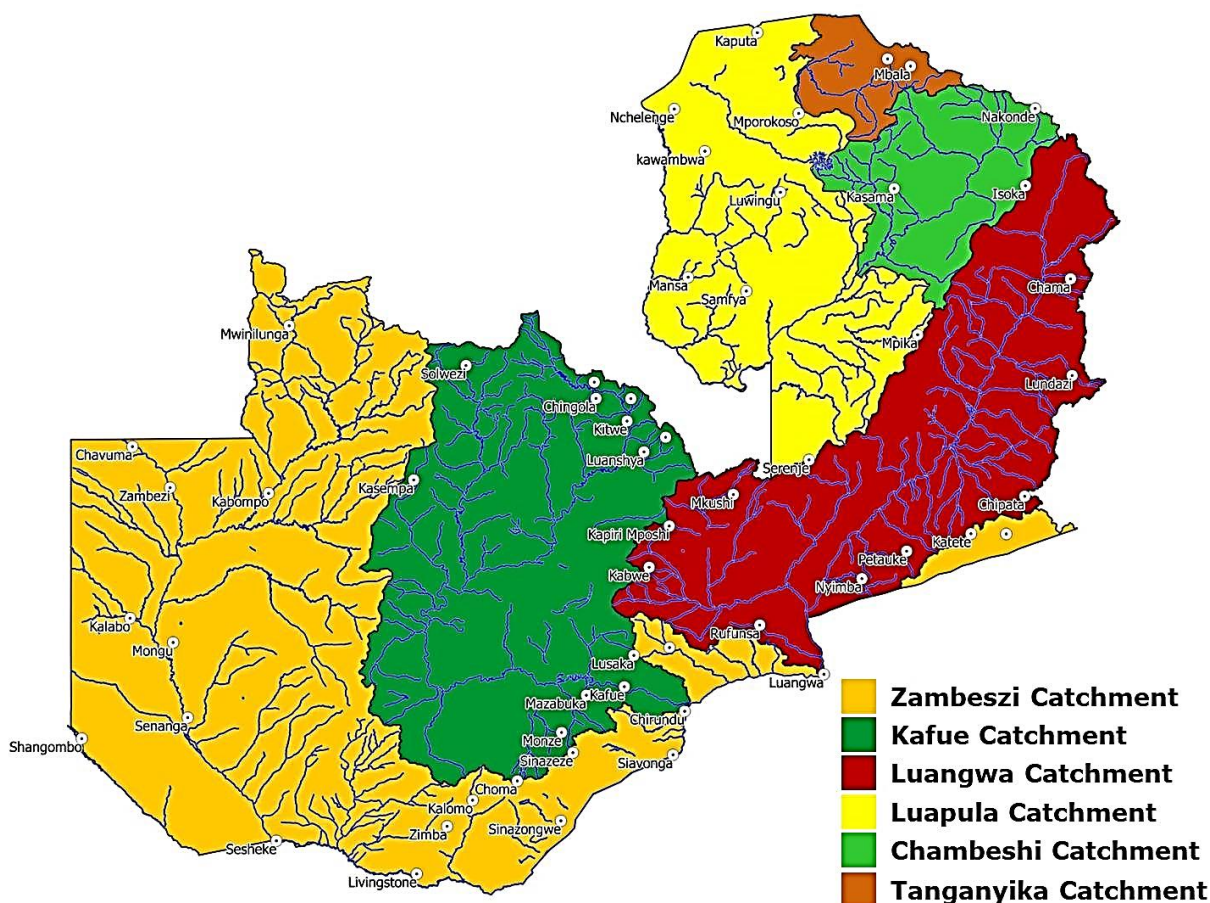


Figure 1: River catchments in Zambia (WARMA, 2020).

In 2015, only 40% of households in Zambia had access to improved sources of sanitation, that is, a facility that hygienically separates human excreta from human contact (Ministry of Local Government and Housing, 2015). Additionally, 27% of people in urban areas and 85% in rural areas had no access to improved sources of sanitation. The proportion of households accessing improved sources of drinking water increased from 63% in 2010 to 68% in 2015. Households in urban areas had more access to improved sources of drinking water at 89% compared to about 52% of households in rural areas in 2015 (GRZ,

2017). National Urban water supply coverage was 85% with 63% sanitation coverage in 2017 (NWASCO, 2017). According to the 7th National Development Plan, the government intends to enhance provision of water supply and sanitation through improved water quality monitoring and capacity building in the water sector.

Major water sector reforms in Zambia started in the early 1990s and this led to formulation of the 1994 Water Policy as a framework for future water development (NWASCO, 2017). This was under the then Ministry of Energy and Water Development (MEWD).

Zambia is endowed with substantial inland fresh water but institutional capacity in water quality and quantity monitoring remains a challenge. In low-income countries, poor regulatory enforcement and insufficient resources for the personnel, equipment and logistical requirements of operating water quality testing programs are some of the constraints faced by institutions in the water sector (Peletz et al., 2018).

Kafue River is the most polluted in the Upper Kafue River sub-basin between the towns of Chingola and Kitwe of the Copperbelt province due to mining activities and other industries (WWF, 2017). The Copperbelt province has at least 21 waste rock dumps covering more than 388 hectares, nine slag dumps covering 279 hectares, and more than 45 tailing dams covering an area of around 9 125 hectares – environmental issues are directly linked to these historical mining or legacy issues (Lindahl, 2014). However, Lindahl (2014) observed that contribution to pollution from old mining legacy sites are minor compared to current mining operations.

There are media reports on the pollution of the Kafue River and its tributaries particularly by the mines upstream. In 2006, pollution of the Kafue River that affected 2000 families around Chingola town by Vedanta's Zambian subsidiary Konkola Copper Mines (KCM) were investigated and the High Court of Zambia ruled in favour of the families and US\$2m in damages was awarded in 2011 (High Court of Zambia, 2011; Foil Vendata, 2016).

Despite reports of water pollution and water management challenges, regulation and environmental compliance monitoring remain a challenge due to lack of technical capacity by regulators and lack of coordination between institutions (Nkhuwa, Mweemba & Kabika, 2013; Lindahl, 2014; Republic of Zambia, 2014). The other factor is that most data

collected by these institutions do not allow for a comparative analysis between sectors thus monitoring frequency and the specific aspect being compared are not in sync (WWF, 2017).

1.2 Problem statement

Copper mining has continued to play a significant role in the socio-economic development of Zambia, particularly in the Copperbelt province. While the economic importance of mining is known, it has also been the cause of many environmental and health problems (Voulvoulis et al., 2013).

Despite changes in institutional and legal framework in water resources management, there are growing concerns over the impacts associated with mining on water resources in the Copperbelt. However, it appears that little has been done to address these concerns. Therefore, this study aims to assess cumulative impacts associated with copper mining on water quality and quantity in the upper Kafue River of the Copperbelt province. “Cumulative impacts are the successive, incremental and combined impacts of one, or more, activities on society, the economy and the environment” (Franks, Brereton & Moran, 2010: 300).

1.3 Study area

The Copperbelt province is comprised of 10 districts, of which three are located in the rural part of the province (Figure 2). Most of the copper mines are concentrated in the north (for geological reasons) while gemstone mines (emerald) are located in the rural part of the province.

Total annual average rainfall is approximately 1 309 mm, with the majority falling during the summer months of November to April. Annual evaporation exceeds the average annual precipitation in the Copperbelt region with an average evaporation of approximately 2 073 mm against the average precipitation of 1 309 mm. The mean annual temperature measured is 19°C, experiencing warm to hot summers, reaching 32°C in October and warm winter days, but cold at night. The predominant wind direction in the Copperbelt is northeast to southwest.

Kafue River and its tributaries drain the Copperbelt province, and the entire province lies within the Upper Kafue Catchment. Therefore, the river is economically important and is a major source of domestic and industrial water supply. The river also receives effluent water from mines, domestic and other industries (Norrgren et al., 2000).

The upper Kafue catchment plays a critical role in the Zambian economy for the following reasons:

- The Upper Kafue River drains the mineral and economic heartland of Zambia.
- It has an area of 23 000 km² and covers the complete Copperbelt province as well as parts of the Northwestern and Central Provinces.
- The Copperbelt province is the center of Zambia's copper production and therefore one of the most economically significant provinces in Zambia.
- Growing competition for water resources in the catchment from mining industry, commercial agriculture and domestic water users.
- Historical significance of the Copperbelt province, politically and economically.
- Mining is also the largest single contributor to the Zambian economy, representing 15% of the National GDP and 80% of the total export value.
- The mines in the Copperbelt province use 60% of electricity produced in Zambia

Three water utility companies operate in the province. The total population serviced in the urban and peri-urban was 1 847 762 (NWASCO, 2017). However, the total population of the province based on the 2010 census was 1 972 317 and is projected to be 3 823 642 in 2035, representing an increase of 52% (Central Statistical Office, 2013a,b).

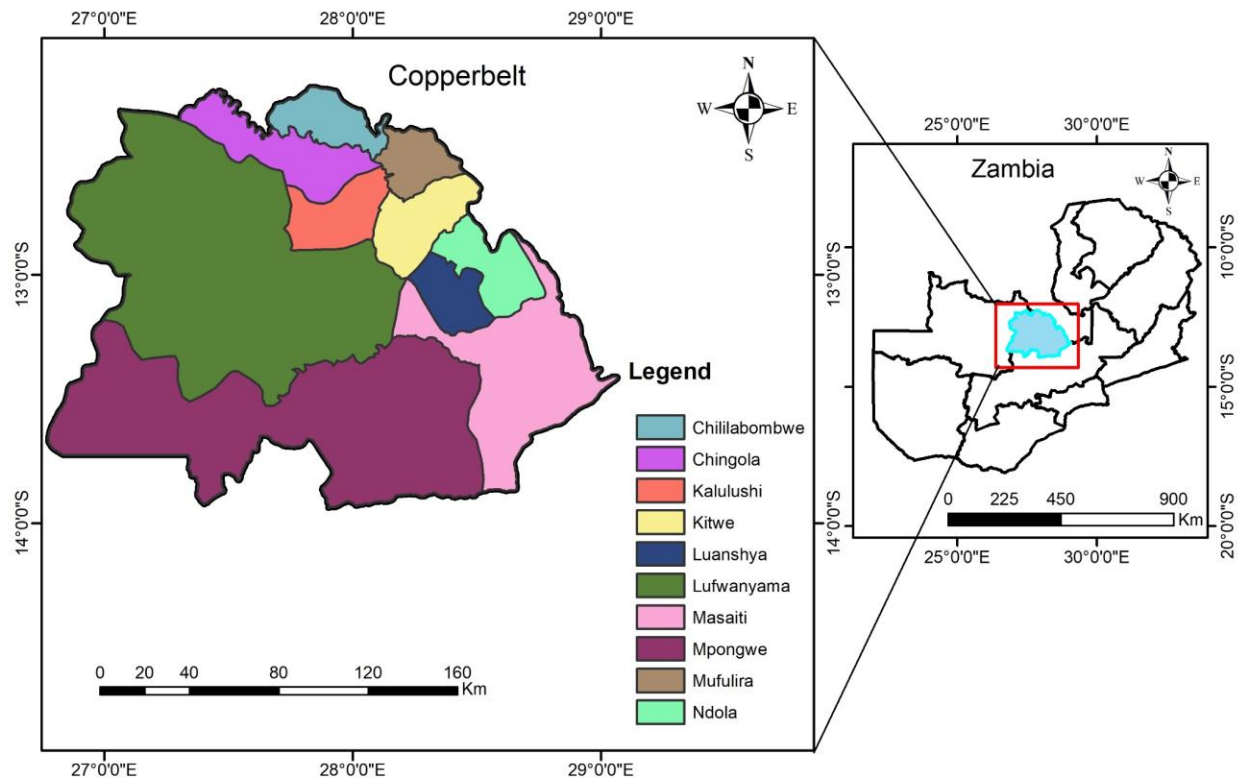


Figure 2: Map showing location of the study area (Author).

1.3.1 Mining sector in the Copperbelt province

The Copperbelt province is one of the most developed provinces in the country due to its rich mineral deposits (Figure 3). Copperbelt province has been the industrial hub of Zambia and a number of mines are located in the region largely driven by copper mining, which started in the 1920s (Sikamo, Mwanza & Mweemba, 2016; Government of the Republic of Zambia, 2017). There are 19 active large-scale copper/cobalt mining operations run mainly by seven companies, and there are about 56 exploration projects in the Copperbelt province (USGS, 2019; Zambia Extractive Industries Transparency Initiative (EITI), 2019). The old mines mainly do brown field exploration activities. There are about 21 small-scale, 19 large scale copper/cobalt mining and about six mineral processing operations in the Copperbelt region (Zambia Extractive Industries Transparency Initiative (EITI), 2019). Most of the artisanal and small-scale mining is in

the emerald mining and quite recently, there has been increased mining of old slag-dumps (Tychsen et al., 2018). The emerald mining is in the rural part of the province and accounts for about 20% of the world's production; there about three major emerald mines and over 400 licenses but only less than 30 are viable (Gilberthorpe, Agol & Gegg, 2016; Tychsen et al., 2018). The economic challenges in the provinces have huge impacts on the national economy. Commercial copper mining on the Copperbelt province started in 1928, it was nationalized in 1969 through a state owned enterprise Zambia Consolidated Copper Mines (ZCCM) (Lindahl, 2014). In the year 2000, mines were back in private ownership after a privatization process and ZCCM assets were sold to various investors.

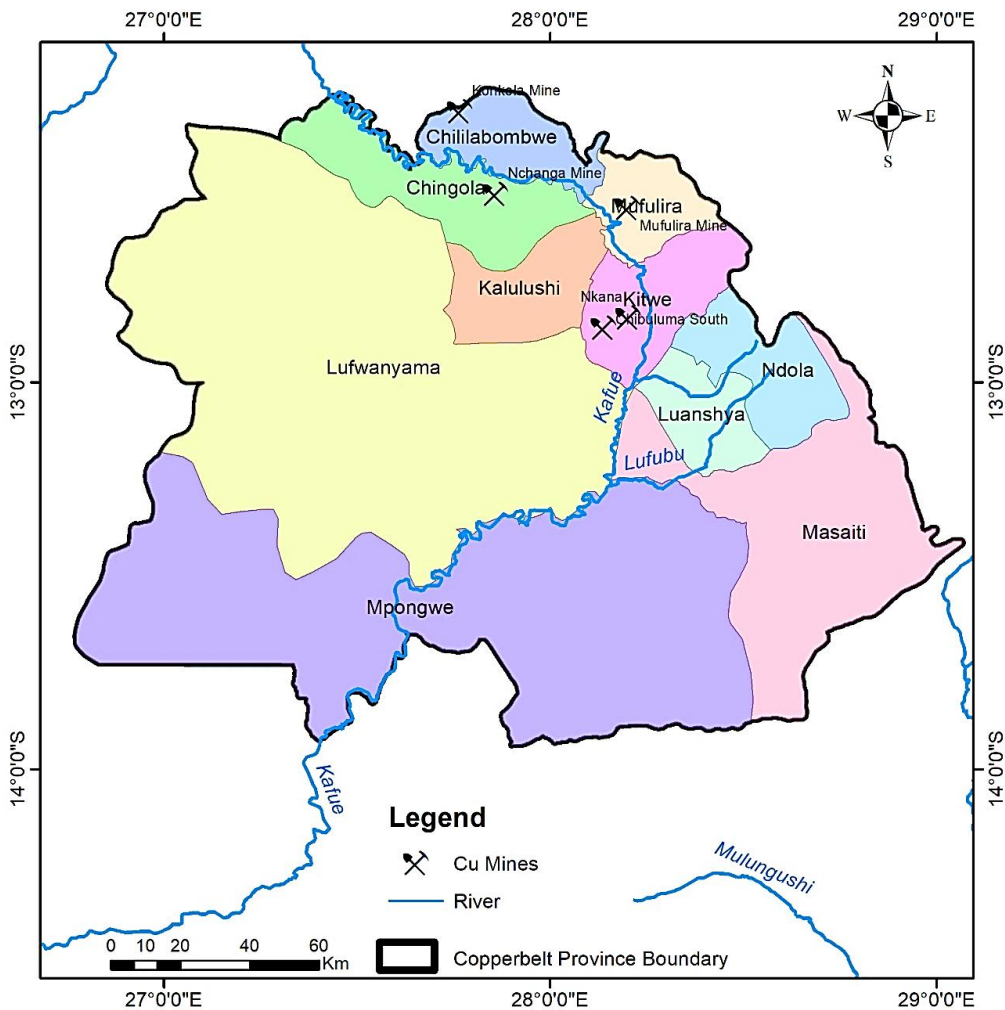


Figure 3: Copperbelt districts, mines and the Kafue River (Author)

1.4 Objectives

Therefore, this study aims to assess cumulative impacts associated with copper mining on water quality and quantity in the upper Kafue River of the Copperbelt province.

Other objectives are to:

- i. Review the institutional arrangement in water resources management, identify challenges faced, and their contribution to sustainable water use;
- ii. Review the impact of copper mining on water quality and quantity;
- iii. Review the impact of population and economic growth on water quality and quantity.

The key questions for this study are:

- i. What is the impact of population and economic growth on water quality and quantity in the Copperbelt province of Zambia?
- ii. What is the impact on water quality and quantity associated with copper mining in the Copperbelt?
- iii. What are the challenges faced by key institutions or regulators in the water sector and how are they addressing them?

1.5 Dissertation structure

The dissertation is comprised of five chapters:

Chapter One gives a brief introduction about copper mining, Zambian economy, and water resources management at global and local scales. It then sets out the objectives and research questions.

Chapter Two reviews literature on water resources management globally, population and economic growth as drivers for water resources management, and the impact of mining on water quality and quantity. The last part of the chapter looks at water resources management in Zambia with emphasis on the population and economic drivers and how

they are impacting water quality and quantity. The chapter also reviews literature on mining and water pollution on the Copperbelt province.

Chapter Three outlines the research methodology to achieve the set objectives and answer the questions. The chapter explains the process used to review reports and journal articles (the secondary data source) on water, population and economic growth in Zambia. It also considers primary data from semi-structured interviews conducted with key regulators or institutions (NWASCO, WARMA and ZEMA) in the water sector in Zambia.

Chapter Four presents and discusses the results of the study.

Chapter Five gives a summary of results and makes recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Global water resources management

There is growing interest in water resources management by many stakeholders globally. Fresh water resources are under pressure worldwide due to increased demand, water scarcity, biodiversity loss and climate change (Kunz, Moran & Kastle, 2013). This pressure entails that solutions to water issues require urgent attention. Factors such as population growth and economic development are further intensifying the challenge, with water availability becoming increasingly constrained in many areas (International Council of Mining & Metals, 2012; UNEP, 2010). At a global level, demand for water has been increasing at a rate of about 1% per year driven by population growth, economic development and changing consumption patterns, among other factors, and this will continue to grow significantly over the next 20 years (WWAP/UN-Water, 2018). Meanwhile, the impact of climate change on freshwater availability is intensifying and because of this, about 40% of the world population will be living in river basins under severe water stress by 2050 (Gurria, 2017). Climate change will continue to increase the variability and vulnerability of freshwater supplies (Loucks, 2017).

Globally, access to safe drinking water and sanitation is still a challenge. For example, more than two (2) billion people have no access to safe drinking water and more than four (4) billion people have no access to safe sanitation (WWAP/UN-Water, 2018). Unsafe drinking water has severe impacts on public health and is responsible for diarrheal diseases, viral and parasitic infections; diarrheal diseases alone account for over 5000 deaths per year particularly among children and vulnerable in low income countries (Peletz et al., 2018; Grigg, 2019). However, most low-income countries have no capacity to collect accurate data on water quality and quantity that can be analyzed to make informed decisions on water management. Peletz et al. (2018) attributed this to poor regulatory enforcement, insufficient personnel and other operational constraints. These water problems will need a multidisciplinary solution, not just engineering based solutions, but solutions that address socio-economic, political and physical impacts (Wessman et al., 2014; Gurria, 2017; Loucks, 2017).

2.2 Impact of population and economic growth on water quality and quantity

Increased population and economic activities can have significant negative impacts on water quality. Water pollution in most of the major rivers has worsened since the 1990s, it is therefore, important to have good water quality and adequate quantity in order to achieve the Sustainable Development Goals (SDGs) for health, food security and water security (UNEP, 2016b). Discharge of harmful chemicals, such as hormone disrupters, have placed pressure on freshwater systems in both developed and developing countries – one in seven rivers in Africa, Latin America and Asia are already affected (UNEP, 2016b). This has led to high treatment cost for municipal water, particularly in developing countries which have a challenge to manage expanding water supplies and sewerage, with adequate treatment of new wastewater flows (UNEP, 2016b).

Urbanization and population growth continue to put pressure on water resources leading to high consumption rates of water. Rapid urbanization and increased population growth have led to challenges in solid waste management especially in informal settlements of developing countries, which ends up contaminating water sources (Juma, Wang & Li, 2014; Mcgrane, 2016; Liyanage & Yamada, 2017). Urbanization, changes in lifestyles and urban drainage systems have also contributed to pollution of surface and groundwater (Ren, Cui & Sun, 2014; Okello et al., 2015; Admiraal et al., 2017). Rapid urbanization and population growth has also placed pressure on sewerage treatment infrastructure leading to discharge of untreated sewage in surface water and consequently leads to high nutrient loading (Juma, Wang & Li, 2014; Dos Santos et al., 2017; Liyanage & Yamada, 2017; Mhlongo, Mativenga & Marnewick, 2018). In many developing countries there are challenges to provide universal basic needs in terms of the provision of water and treatment of wastewater (Sikosana, Randall & von Blottnitz, 2017).

Increased economic activities leads to high energy demand, land use changes, unplanned infrastructure, and if not properly managed, this negatively impacts land cover in the water basins which leads to high salinity and suspended sediments in rivers (Juma, Wang & Li, 2014). Industrial and municipal solid wastes and wastewater management, remain a challenge in most developing countries and has impacted on water quality

leading to increase in biochemical oxygen demand, low dissolved oxygen (DO), and high total coliforms in river basins (Liyanaage & Yamada, 2017).

2.3 Impact of mining on water quality and quantity

Globally, mining consumes relatively small amounts of water but can be the major consumer in a local area where mining activities are taking place (Northey et al., 2016). Although mining consumes relatively small amounts of water globally, its impacts on water can be far reaching. Mine dewatering and excessive withdrawal of water from surrounding water sources may lead to impacts such as alteration of the river flow regimes, drawdown of groundwater aquifer levels, or the reversal of groundwater directions (Northey et al., 2016). Mining activities can also contribute to silting of waterways, or rivers (Lindahl, 2014; Schuler & Lokanc, 2015). This may lead to conflicts among competing water users. The water consumption for mining operations varies depending on a number of factors, including whether the mine site is in a water scarce or abundant region. Mine sites can be in extreme low to the high rainfall areas in the world and as such, there is no simple solution for water management (International Council of Mining & Metals, 2012). Water is an important resource in mining operations and is used in mineral exploration, mineral processing, dust suppression, slurry transport, smelting, refining and to meet employee's requirements (International Council of Mining & Metals, 2012; Acuña & Peñailillo, 2014). The sources for this water are either from groundwater or surface water.

Mining activities interact with water at multiple levels and these interactions can be complex and site specific with potential impacts on hydrology and water quality (Kemp et al., 2010; Woodley et al., 2013; Northey et al., 2016). The impacts of mining on water quality depend upon factors such as geochemistry of the ore body, strategies for managing mining effluents, types of mining utilized, mineral processing technology, and strategy for storage of mine waste (e.g., tailings) (Northey et al., 2016). Artisanal mining has more devastating impacts on the environment because of challenges in regulating the industry and poor storage of tailings (Cobbina et al., 2015).

Most artisanal mining is in the emerald mining in the rural districts of Lufwanyama, Masaiti and Mpongwe of the Copperbelt region. The sector has challenges such non-compliance to environmental regulations, and poor safety. Siltation, loss of vegetation, water pollution, air pollution, and land degradation due to poor mining methods, are some of ASM environmental issues on the Copperbelt (Tychsen et al., 2018).

Potential water problems associated with mining include acid mine drainage (AMD), seepage from tailings and mine waste discharge which result in pollution of both surface and ground water (Danoucaras, Woodley & Moran, 2014). AMD is generated from gold, coal, copper mining operations through the process of oxidation, characterized by low pH and high heavy metal content (Mhlongo, Mativenga & Marnewick, 2018). The oxidation of pyritic materials such as iron disulphide, catalyzed by bacteria, occurs to produce sulphuric acid and ferrous sulphates, and orange-red ferric hydroxide (Ochieng, Seanego & Nkwonta, 2010; Mhlongo, Mativenga & Marnewick, 2018). AMD is argued to be the most challenging environmental problem in the mining industry (Bebbington & Williams, 2008; Ochieng, Seanego & Nkwonta, 2010). The impacts of AMD include water and soil contamination, depletion of aquatic life due to high acidity and heavy metal content, and deterioration of ecosystem services (Ochieng, Seanego & Nkwonta, 2010). Therefore, it is important that the mining industry provide a leading role because of environmental, social and economic risks associated with it.

Releasing tailings and sludge into water bodies by mining companies in Africa has led to water pollution in many regions, because some mining companies employ rudimentary water management practices during exploration and mineral processing (Africa Progress Panel, 2013). Therefore, it is important that companies now consider the water-related impacts at regional scale as opposed to just focusing on the impacts related to their mining leases (Kunz & Moran, 2014). Water at a national or global level needs to be understood in terms of quality and quantity in order to promote sustainable management of the resource. The impacts on water consumption and quality by mining can lead to social tension with other competing users such as fisheries, agriculture, and other users (Northey et al., 2016; Peletz et al., 2018).

Northey et al. (2016) proposed that to mitigate these impacts on water quality, mining companies could use selective separation of acid forming minerals to reduce AMD, and dilution of the receiving environment, for example, releasing of waste when the water levels are high. Adequate financing of regulators in monitoring of mining activities will help in mitigating the negative impacts of mining on water resources (Arah, 2015).

Water quality monitoring has received global attention; however, the challenges are still many, especially with increased usage of chemicals (Peletz et al., 2018). The challenges include lack of reliable data, limited resources and limited and/or lack of regulations for water quality monitoring (McIntyre et al., 2016). Another challenge, particularly in Sub-Saharan Africa is that regulators rely on water samples provided by mining firms for water quality monitoring (Republic of Zambia, 2014; Arah, 2015).

Remote sensing and land use mapping can be an alternative for water quality monitoring. This would require more investment in human resource and infrastructure especially in developing countries. In order to have successful water quality monitoring, programs should have a wider involvement of stakeholders such as communities, government, and companies to enhance sustainability and transparency (Bebbington & Williams, 2008). Water quality programs need to be reliable so that decision makers can make informed decisions and thereby protect and the resource (Behmel et al., 2016). However, there is no one solution to water quality monitoring but a combination of local knowledge and intelligent support system (Behmel et al., 2016).

2.4 Water resources management and water sector reforms in Zambia

According to the 'Vision 2030', Zambia aspires to become a prosperous middle-income country by 2030 (Government of the Republic of Zambia, 2017). In order to achieve this goal, the government of Zambia attaches great importance to water resources infrastructure and water resources management systems because of its role as an engine and catalyst for socio-economic development. Water resources development and management is one of the 10 development outcomes of the Seventh National Development Plan (7NDP), whose main objective is to achieve economic diversification

as outlined in the Vision 2030 (Republic of Zambia, 2006; Government of the Republic of Zambia, 2017).

Besides copper, water is the most important natural resource in Zambia (Uhlendahl et al., 2011). Water issues in Zambia have risen to prominence in recent years. This reflects a growing understanding of water's centrality in the country's economic growth, which has stood at an annual average of 6% for the last decade. However, this development also places significant pressure on water resources – agriculture, energy, and industrial and domestic water supply all have impacts on the use and governance of water (WWF, 2016).

2. 4.1 Water sector reforms

Zambia has undergone major reforms in the water sector since 1990s and this led to commercialization of the water supply and sanitation sector in 2000 (Chitonge, 2011; Siwila, 2015). The 1990s reforms were intended to address challenges in water supply and sanitation services, focusing on institutional and legal framework within the sector. The challenges included deterioration of water supply and sanitation services, inadequate human resource capacity, decreasing capital investment, and inadequate stakeholder engagement (Chitonge, 2011).

One of the major outcomes of the 1990 reforms was the 1994 National Water Policy which led to the establishment of National Water Supply and Sanitation Council (NWASCO) governed by Water Supply and Sanitation (WSS) Act of 1997 (NWASCO, 2015). In order to address new challenges and global approaches in the management of water resources, the Ministry of Energy and Water Development (MEWD) started the revision of 1994 National Water Policy which led to the formulation of the 2010 National Water Policy (Kangwa, 2008; Republic of Zambia, 2010; Uhlendahl et al., 2011). Following the promulgation of the 2010 policy, the Water Resources Management Act No. 21 of 2011 was enacted to replace the 1948 Water Act and this led to the formation of Water Resources Management Authority (WARMA) (National Water Supply and Sanitation Council, 2018). However, the 2010 National Water policy focused on water development

and management and did not cover water supply and sanitation aspects; water supply and sanitation policy is being developed (National Water Supply and Sanitation Council, 2018). Under the former institutional framework, water resources management was under Department of Water Affairs (DWA) under MEWD. To better understand and manage water resources management in Zambia, a new Ministry of Water Development, Sanitation and Environmental Protection (MWDSEP) was established in November 2017, creating a new institution setup. According to NWASCO (2018), the ministry was established so that it could preside over water resources management and development, water supply and sanitation, and environmental protection and pollution control policies and associated matters. Institutions or bodies that now fall under MWDSEP are shown in Table 1.

Table 1: Summary of functions for Institutions under MWDSEP (NWASCO, 2018).

Institutions	Functions
National Water Supply and Sanitation Council (NWASCO)	Ensuring efficiency and sustainable water supply and sanitation service provision.
Water Resources Management Authority (WARMA)	Management, development, conservation, protection and preservation of the water resource and its ecosystems.
Zambia Environmental Management Agency (ZEMA)	Sets limits and standards for environmental protection
Commercial Utilities (CUs)	To provide water supply and sanitation services. All CUs are licensed and regulated by NWASCO. NWASCO also regulates Private Schemes that provide water supply and sanitation services to their employees as a fringe benefit.
Environmental Protection Fund	To assure that developers conduct environmental impact assessment in accordance the law and to assure funds for the rehabilitation of mining areas where a holder of a mining licence fails to do so.

Figure 4 shows a summary of the old and new institutional setup in the water sector. A key feature of the new setup is that all the regulators (NWASCO, WARMA and ZEMA) are under one ministry. However, NWASCO observed that the new ministry needed to provide more clarity on the ownership and responsibilities of local authorities in the management of water utilities since the ministry has assumed the role of mobilizing investments resources.

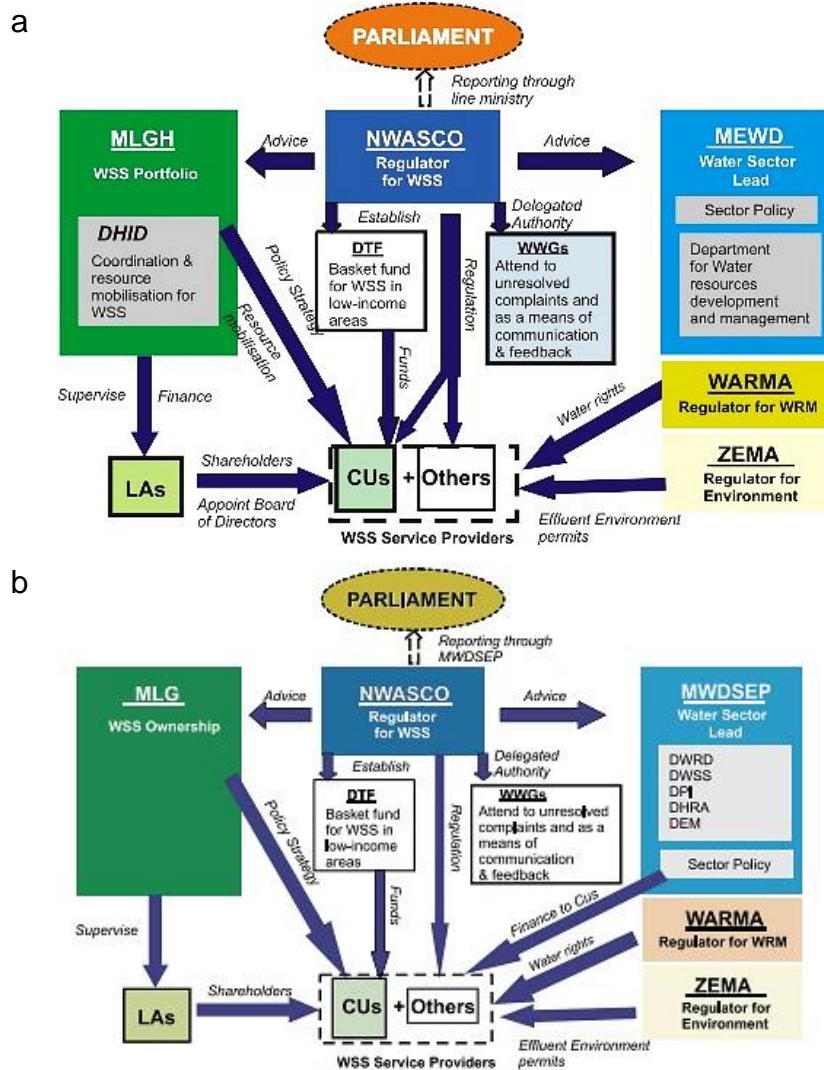


Figure 4: (a) Old and (b) New institutional arrangement in the water sector (NWASCO, 2018).

2.4.2 Water resources availability and demand

Zambia's water resources are plentiful with renewable water resources of over 105 km³/year (Pegasys and WWF, 2016). Despite Zambia enjoying a bigger share of fresh water in the Southern African Development Community (SADC), access to water and sanitation remains a challenge to many countries in the region (SADC, 2010; Nkhuwa, Mweemba & Kabika, 2013). This is largely due to poor or old infrastructure whose capacity have been overwhelmed over the years.

In 2015, the national water demand for manufacturing and mining industries stood at 163 Mm³/year and 112 Mm³/year, respectively (Pegasys and WWF, 2016). Renewable water per capita was about 8 700 m³ per year higher than the average for Sub-Saharan Africa of 7 000 m³ and the global average of 8 210 per person (World Bank, 2009). At a national level, Zambia's irrigation potential is 400,000 ha out of which only about 100 000 ha is being irrigated and hydropower potential stands at about 6 000 MW, compared to stored capacity of around 2 000 MW. Zambia, however, faces considerable variability annually and seasonally between parts of the country in terms of water resources (World Bank, 2009; SADC, 2010).

2.4.3 Water quality in Zambia

The quality of both ground and surface water is generally good in Zambia (Nyambe & Feilberg, 2009). However, there is localized pollution of water particularly in big cities. The source of pollution stems mainly from agricultural activities (pesticides), mining and untreated sewage (SGAB-SWECO-THMRO-UNZA, 2005; Nyambe & Feilberg, 2009; Sracek et al., 2012).

Zambia has been a mining country since the 1900s and the industry has contributed to social and economic development of the nation (Republic of Zambia, 2014; Makondo et al., 2015; Ministry of Mines and Minerals Development, 2016; Sikamo, Mwanza & Mweemba, 2016; World Bank, 2016b). Mining on the other hand has had negative effects on the environment, especially on surface water quality arising from accidental acid spills, discharge of tailings, and legacy issues (tailings dam and geotechnical integrity of waste

dumps) (SGAB-SWECO-THMRO-UNZA, 2005; Lindahl, 2014; Republic of Zambia, 2014). According to Lindahl (2014), mineral waste covered an area of about 10 000 ha, with most waste rock dumps lacking geotechnical integrity thereby contaminating both ground and surface water through seepages and runoffs.

The drivers of water quality in the Copperbelt are very complex. Most of the pollutants in the Kafue River and its tributaries that drains the Copperbelt province are heavy metals (e.g., copper, cobalt), and untreated sewage (ZCCM-IH, 2002; SGAB-SWECO-THMRO-UNZA, 2005; Lindahl, 2014; WWF, 2018). Fortunately, the underlying geology (carbonate rocks), extensive dambos and wetlands, and the low sediment yield and densely vegetated banks of the Kafue River help in minimizing the negative impacts of mining on water quality in the province (Norrgrén et al., 2000; Pettersson & Ingri, 2001; SGAB-SWECO-THMRO-UNZA, 2005; Sracek et al., 2012; Lindahl, 2014). The carbonates rocks buffer acidification, and this is why the occurrence of acid mine drainage (AMD) is rare in the Copperbelt province (Sracek et al., 2012; Lindahl, 2014). The Kafue River in its natural state carries about 10 000 tonnes of sediment whereas tailings discharges from the mines to the river are about 115 000 tonnes/year (SGAB-SWECO-THMRO-UNZA, 2005). In view of the low sediment capacity of the Kafue River, the mines need to take special responsibility in ensuring adequate tailings management (SGAB-SWECO-THMRO-UNZA, 2005).

However, it is important to investigate further the buffering capacity with regard to impact of climate change and increased urbanization. The buffering capacity of dambos, wetland, and lush vegetation on the banks of the Kafue River have been impacted due to rapid changes in land use, deforestation, and settlements on the banks of the river, and droughts (Sibanda, 2007; Karen, El-fahem & Museteka, 2015; Sichilima, Makondo & Lungu, 2015).

Water pollution issues on the Copperbelt province have attracted the attention of the public, NGOs and government especially with regard to spillages from tailings and other industrial effluents into the Kafue River and its tributaries. A case in point is the 2006 tailings spillage by Konkola Copper Mines (KCM), a subsidiary of British miner Vedanta Resources Plc, which affected the water quality of the Kafue River and the livelihoods of

about 2000 farmers (Figure 5) of Chingola town (Kangwa, 2008; Foil Vedanta, 2016). In 2007, the 2000 affected residents sued KCM in the High Court of Zambia, and in its 2011 judgement, the court found KCM guilty and ruled that the residents be awarded \$2m in damages (High Court of Zambia, 2011; Foil Vedanta, 2016). However, in 2012, KCM decided to appeal the Judgement in the Supreme Court of Zambia in which it upheld the judgement of the High Court but without damages (Foil Vedanta, 2016; The Lusaka Times, 2018; Sambo, 2019). The Supreme Court judgement that removed damages led 1 826 claimants to sue Vedanta's subsidiary KCM in the London courts and on 10 April 2019, the Supreme Court ruled that the Claimants could have their case tried in the UK courts (Foil Vedanta, 2019; Hughes-Jennett, 2019). This case is a demonstration that local water problems can become global. It is important that a mine appreciate the competing demands for water and perceptions from other stakeholders or communities within their operations.



Figure 5: Pollution from a mining company (Foil Vedanta, 2016).

Arising from public concerns on the negative impacts of mining on the Copperbelt, the Government of the Republic of Zambia through the Auditor General office carried out a study, 'Management of Environmental Degradation Caused by Mining Activities in Zambia' and the following were some of the findings (Republic of Zambia, 2014):

- i) Mining companies are failing to produce monthly returns or biannual report on air emission to the environment.
- ii) Both surface and ground water are also being polluted.
- iii) Management of dumps and dams (tailing storage facility) was also poor.
- iv) Monitoring and evaluation has also been ineffective as various departments were carrying out environmental monitoring activities independently and there was no coordination in the collection of information and its storage.
- v) ZEMA has had to rely on the test results provided by mining companies through bi annual reports a practice that renders the test results unreliable, as ZEMA has no means of verifying them.

CHAPTER 3: METHODOLOGY

3.1 Study Design

The study involved reviews of published literature, papers, institutional database, and reports for projects, which were implemented in the Copperbelt province. The following flowchart summarizes the steps taken to achieve the objectives of the study (Figure 6).

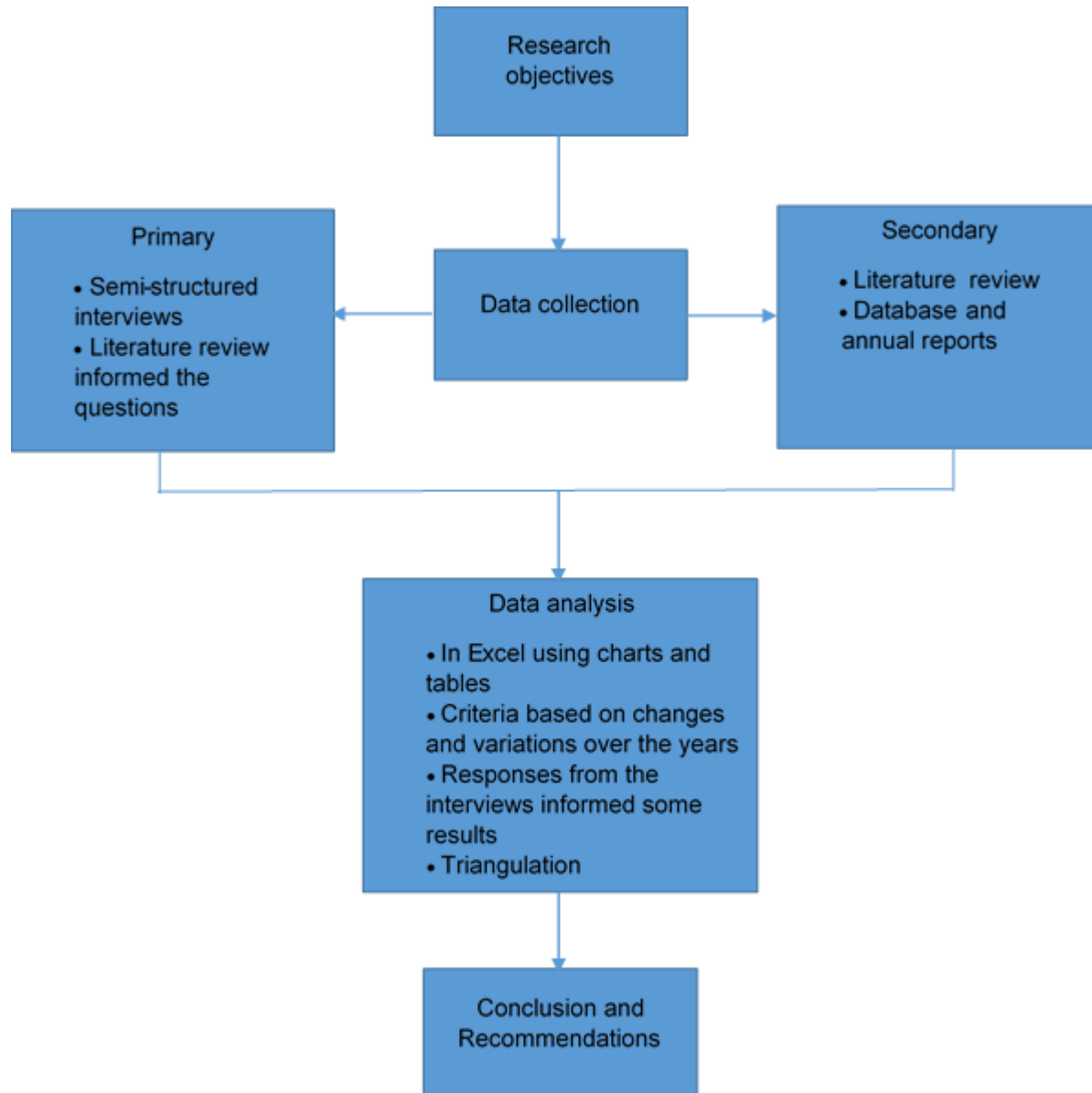


Figure 6: Methodology flow chart

Based on the Zambian context in terms of water quality monitoring and the data related to water quantity, key institutions in the water sector were consulted as well as reports that have been written about the sector in Zambia. These were the key sources for quantitative data. The quantitative data was analysed in Excel and presented in the form of graphs. This was for observing trends in water resources management and sanitation, in relation to population and economic growth. The quantitative datasets were based on the period 2000 to 2017. This is because the period 2000 to 2017 has seen a significant investment in the mining and water sectors. During this period, the water sector in Zambia has recorded good progress in terms of reforms; that is, 2010 National Water Policy (Chitonge, 2011; Uhrendahl et al., 2011) which led to the formation of water resources management authority (WARMA). Privatization of the mines that began in the mid-1990s were completed in 2000, subsequently new mines were opened, and old ones were recapitalized. There are currently about 40 mining operations and 56 exploration projects (Zambian Ministry of Mines and Mineral Development & Trimble Land Administration, 2020)

Semi-structured interviews were conducted with NWASCO, WARMA and ZEMA that are key institutions in the water sector; this was done to get more feedback (triangulate) on the secondary data. One semi-structured questionnaire was sent to each of the three institutions before the interviews were conducted. ZEMA responded via email while the responses from NWASCO and WARMA were recorded during the interviews. This formed the qualitative component of the study.

3.2 Data sources

Most of the data collected were from secondary sources. Key institutions where data was collected included Water Resources Management Authority (WARMA), National Water Supply and Sanitation Council (NWASCO), and Zambia Environment Management Agency (ZEMA). The other sources were from the National Water Resources Master Plan, Copperbelt Environmental Projects and from national census reports. The sources of datasets are summarized in Table 2.

3.2.1 Brief description of the institution/statutory bodies in the Zambian water sector

National Water Supply and Sanitation Council (NWASCO) – Established by the Water Supply and Sanitation Act No. 28 of 1997 for ensuring efficiency and sustainable water supply and sanitation service provision.

Water Resources Management Authority (WARMA) – Established by Water Resources Management Act No. 21 of 2011 – for management, development, conservation, protection and preservation of the water resource and its ecosystems.

Zambia Environmental Management Agency (ZEMA) - Established by the Environmental Management Act No. 12 of 2011 for protection of the environment. The Statutory Instrument No. 112 of 2013, of EM Act No. 12 of 2011, The Environmental Management (Licensing) Regulations of 2013: Sets limits and standards for environmental protection.

Table 2: Sources of data

Name of organization	Functions/core business	Data collected
Water Resources Management Authority (WARMA)	Responsible for managing and regulating at a national level all uses of Zambia's water resources in an integrated, participatory and sustainable manner based on human, land, environmental and socio-economic consideration	Flow volumes, water quality (pH, EC, TDS, DO, Pb,Zn,Mn,Fe,Cd), total hardness, Ca, K, Mg, Na, alkalinity, nitrates, HCO ₃ ⁻) and quantity
Zambia Environmental Management Agency (ZEMA)	Mandated to do all such things as are necessary to protect the environment and control pollution, to provide for the health and welfare of persons, animals, plants and the environment.	Water quality (TSS, TDS, Sulphur, biological oxygen demand (BOD), chemical oxygen demand (COD))
National Water and Sanitation Council (NWASCO)	To regulate the provision of water supply and sanitation services for efficiency and sustainability	Water production, water quality, costs and revenues
Central Statistical Office (CSO)	Department under the Ministry of National Development Planning. The department is charged with the responsibility of coordinating all statistical activities in the country and is a major producer of official statistical information to various users.	Copper production, environmental statistics, population census and GDP
Reports		Surface and groundwater resources

3.3 Data collection criteria

The population census data was collected for all the districts in the province but water supply data from NWASCO only covered towns that are serviced by water utility companies. There are seven districts out of 10 that are serviced by water utility companies and these include Kitwe, Ndola, Luanshya, Chingola, Chililabombwe, Mufulira and Kalulushi (Figure 7). The districts that are not serviced by water companies are Masaiti, Mpongwe and Lufwanyama. Lufwanyama is predominantly an emerald mining rural

district whereas as Masaiti is mainly for industrial minerals such as limestone, and cement manufacturing. The main economic activity in Mpongwe district is agriculture and now some mines for industrial minerals have been opened (Tychsen et al., 2018).

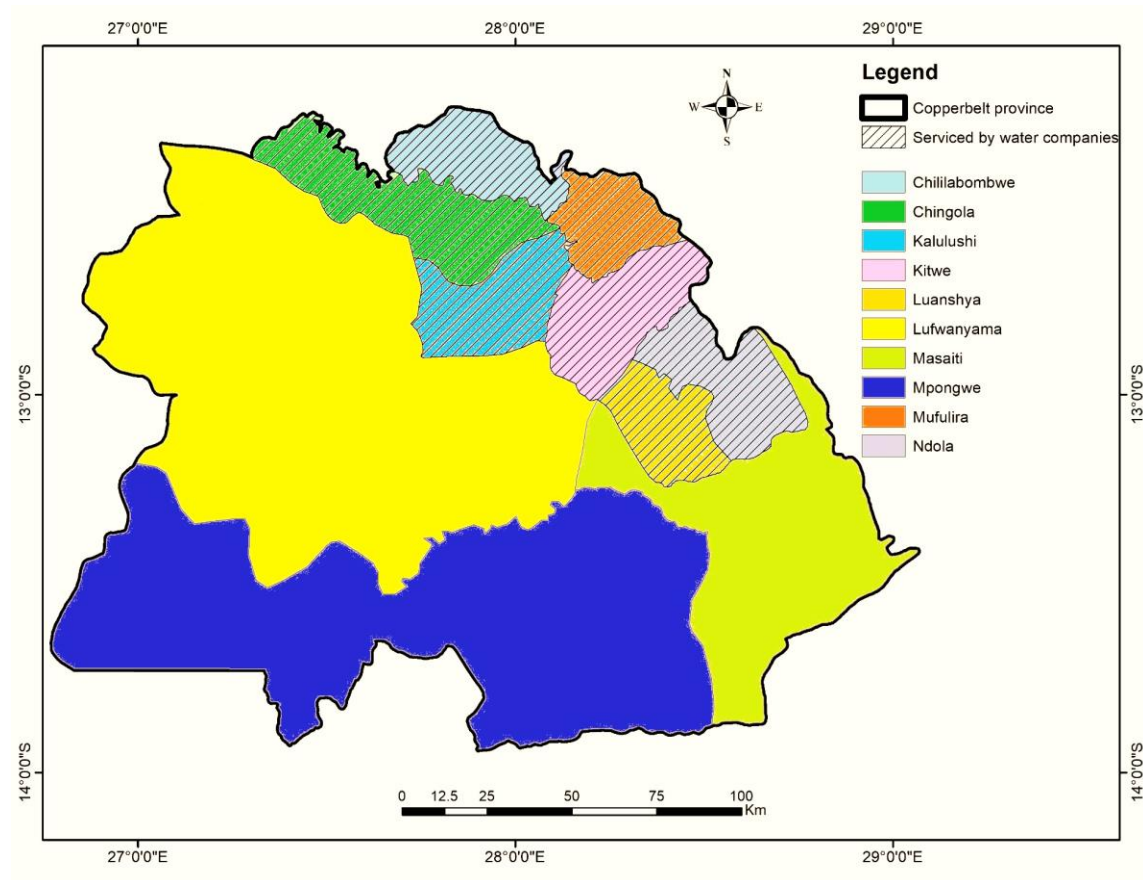


Figure 7: Map showing location of districts that are serviced by water companies in the Copperbelt province (Author).

3.4 Quantitative data

Data on water production and consumption from 2000 to 2017 was compiled from NWASCO urban and peri-urban water supply and sanitation reports. The reports capture all commercial water utilities and private schemes. “Private schemes are business entities that provide water supply and sanitation services as a fringe benefit to their employees” (National Water Supply and Sanitation Council, 2018: 44). The data collected from NWASCO did not give a complete picture of the water production in the province

since some mines produce their own water (private schemes) while the other population also depend on groundwater and surface water as private schemes or individuals (boreholes). For example, Lufwanyama district is not serviced by the commercial utilities. In order to bridge this gap, water permit register for the upper Kafue catchment was obtained from WARMA to provide information on areas that are not serviced. The permits show the volumes of water to be abstracted and for what purpose.

Since the Kafue River drains most of the province, flow data was also obtained from WARMA. This was done in order to see changes in flows from 2000 to 2017 and also to link the changes in the flow to water quality. The other reason for this data was also to consider the impact of mining on the upper Kafue River (

Figure 8) in terms of flow volumes and water quality. Data on population and housing, and economic growth (GDP) was compiled from national statistics or accounts published by Central Statistical Office (CSO). This was done to assess the cumulative impact of population and economic growth on water resources.

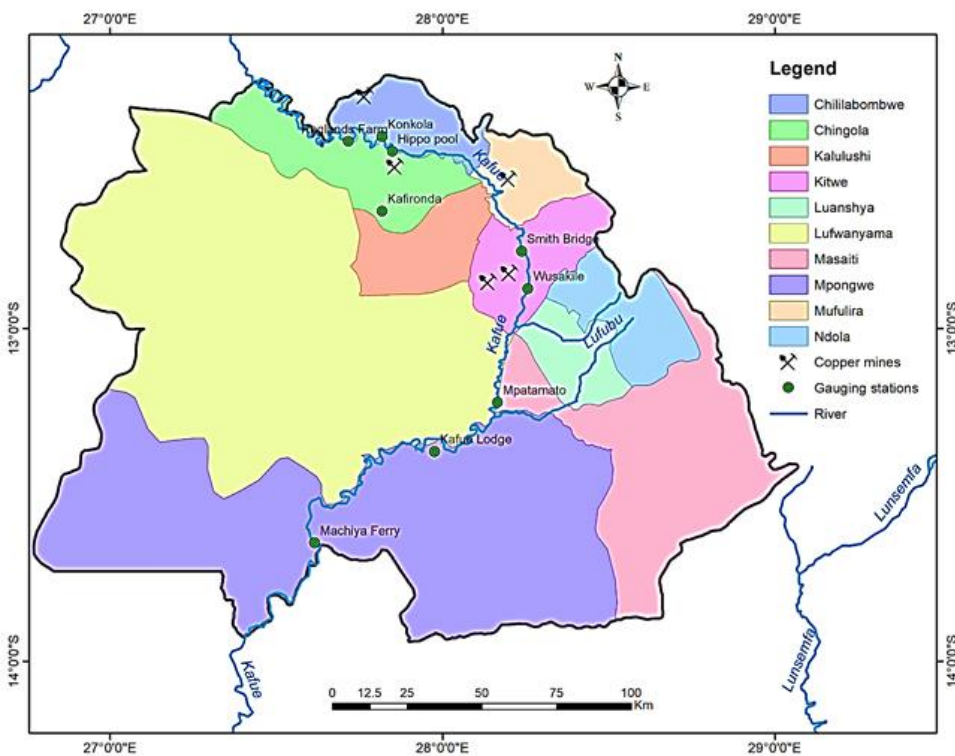


Figure 8: Map of the Copperbelt showing copper mines and sampling (gauge) stations along the Kafue River (Author).

3.5 Semi-structured interviews

Most of the secondary data collected from the institutions (NWASCO, ZEMA and WARMA) had gaps, especially for the study period (2000-2017). In order to understand the reasons behind the gaps and to appreciate how the three institutions function, and to understand institutional challenges, semi-structured interviews were conducted with the three key government institutions or agencies in the water sector. This was one way of validating the data or triangulating multiple sources of data (Peletz , 2018).

WARMA and NWASCO responded upon being asked questions while ZEMA responded to the questions via email. For example, the questions for WARMA sought to find out the gaps in flow data in the Upper Kafue River, water quality parameters and monitoring, and challenges faced by the institutions. Key items for the interviews are shown in Table 3, and the questions used during interviews are in Appendix A.

Table 3: Key items for the Interview

Name of institution	Key items for the interviews					
	Water quality parameters	Frequency of water quality monitoring	Compliance monitoring	Public access to data	Challenges	Collaboration with stakeholders
ZEMA	x	x	x		x	x
NWASCO	x	x	x	x	x	x
WARMA	x		x	x	x	x

Note: x means that the question was asked to the respective institution during the interviews.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter discusses the impacts of population and economic growth (GDP), water consumption and production as well as challenges faced by institutions in the water sector and how these impact water quality and quantity. The chapter also discusses the impacts associated with copper production on water resources.

4.1 Population and economic growth

Central Statistical Office (CSO) conducts census of population every 10 years except the first post-independence census, which was done in 1969, five years after Zambia got her independence in 1964. This was followed by the census in 1980, 1990, 2000 and 2010, and the next census of population will be in 2020. The CSO also conducts economic surveys. For the purpose of this study, only the census of 2000 and 2010 were considered as well as the projected population growth (2011 to 2020). The population growth for 2000 and 2010 is based on the census conducted while the period 2011 to 2020 represents the projected population growth (Figure 9). The population in 2000 was 1 581 221 and increased to 1 972 317 in 2010, representing a 20% increase in population. It is projected to increase from 1 972 317 in 2010 to 2 669 635 in 2020, representing about 27% increase in population. According to the 2000 census, the Copperbelt province had a population distribution of 16% while Lusaka province (capital city) had 14%. The population density in 2000 was 51 persons per square kilometre and increased to 63 persons per square kilometre in 2010 (Central Statistical Office, 2014). However, population density in the province varies from district to district. For example, in 2010, Kitwe district had a population density of 666 persons per square kilometre, which was the highest in the province.

The rural population increased from 350 093 in 2000 to 376 861 in 2010, representing an increase of 8% between the two census years. The population in urban areas grew by about 30% from 1 231 128 in 2000 to 1 595 456 in 2010 (Central Statistical Office, 2010). The rural population is projected to be 423 511 in 2020, representing about 11% increase

from 2010 while the urban population is will be 2 246 124 in 2020 representing about 29% increase from 2010 (Central Statistical Office, 2013b; 2014).

The population grew at an average rate of 1% in 2000 (Central Statistical Office, 2003). The population growth rate for the Copperbelt province between 2000 and 2010 was about 2% while the national growth rate for the same period was approximately 3%. As of the 2000 census, the growth rate (1990 – 2000) for Coperbelt province was about 1% compared to the national growth rate of about 2%. This lower growth rate from 1990 to 2000 was attributed to lower economic activity arising from the privatization of the mines.

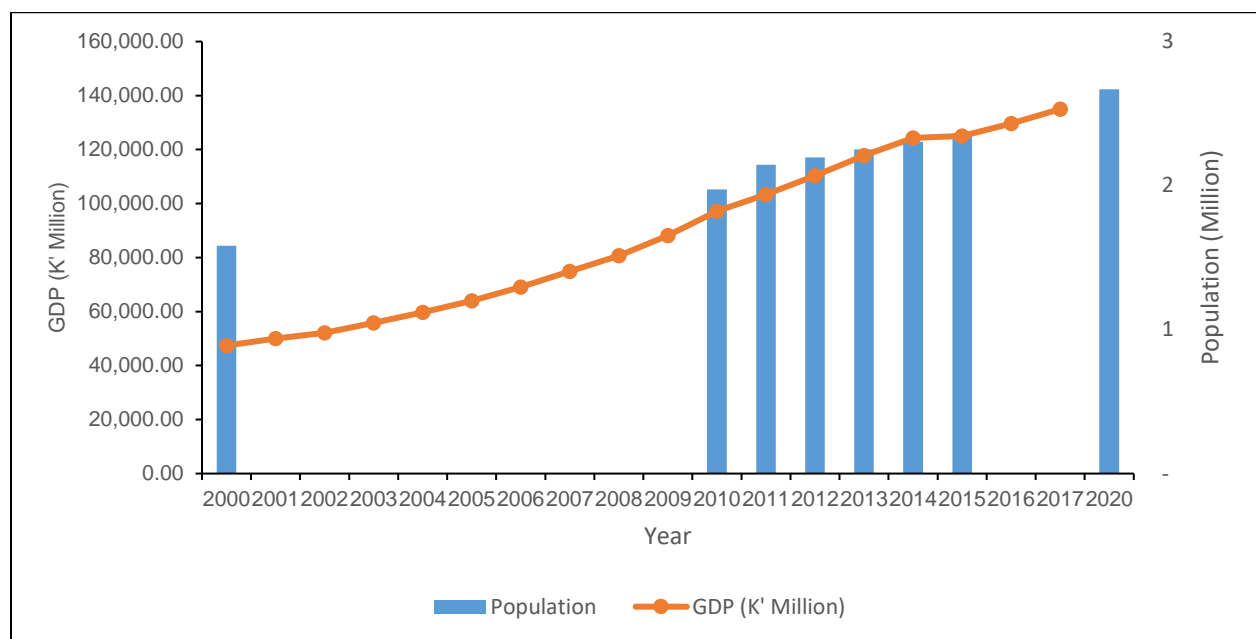


Figure 9: GDP and population growth in the Copperbelt province

According to the 2010 census, about 81% of the population was living in urban areas (CSO, 2014). In the Zambian context, an urban area is defined as a locality with at least 5,000 people, half of whom are not engaged in agriculture (Central Statistical Office, 2013a). Urbanization has placed pressure on water and sanitation supply. Arising from population pressures, the government of the republic of Zambia (GRZ) in 2007 degazetted about 4500 hectares of forest to allow for infrastructure development, and agricultural activities (Sibanda, 2007). This has led to increased silting of streams and rivers, and in some cases drying up of rivers since most of the forest are key river catchments. The demand for land and water increases due to the ever increasing

population (Abughlelesha & Lateh, 2013). Higher population and economic growth and the lack of wastewater management systems have primarily contributed to poor water quality, especially for lower and middle-income countries (WWAP (United Nations World Water Assessment Programme)/UN-Water, 2018).

As the population grows the demand for water resources also increases and this leads to mounting pressure on the availability of the resource (Population Action International, 2011). This is also coupled by rapid urbanization (mushrooming of settlements) posing a challenge for service delivery (Ntengwe, 2006). People prefer to settle in some communities rather than others, increasing the population density that puts more pressure on water and sanitation facilities. As a result, people end up drinking contaminated water from shallow well and streams. Most of the urban population in Sub-Saharan Africa reside in informal settlement, this accelerated urbanization has contributed to the widening gap between the demand for water and available supply (Dos Santos et al., 2017). High population growth has continued to pose challenges on deforestation and forest degradation, soil erosion and fertility loss; and biodiversity loss (Central Statistical Office, 2014). A study by Nyambe and Feilberg (2009), noted that increase in population and the desire by people to have an affluent life, have had an impact on surface cover changes leading to deforestation. This in turn increases runoffs into streams, which impacts water quality and quantity because of sediments and nutrient loading.

In some cases, commercial utilities cannot cope with the demand and people end up drilling their boreholes and construct septic tanks with no regard to safe distance from water sources and septic tanks (Nkhuwa, Mweemba & Kabika, 2013). This scenario results in water pollution due to industrial effluents and fecal matter from pit latrines or poorly designed septic tanks thus contaminating surface and groundwater. To avert the water pollution in urban areas especially, WARMA, NWASCO and local authorities are working together to monitor housing developments to regulate the sanitation facilities design. Despite knowing that the population has been increasing on the Copperbelt, quantifying the impact of this increase on water quality remains a challenge due to insufficient data ; and that water quality data is collected by different institutions with varying parameters to test for in water (Nyambe, 2008; Uhlendahl et al., 2011; Peletz et

al., 2018). The production of copper at national level has seen an increase mainly due to the opening of three (3) large scale mines (Kansanshi, Lumwana and Kalumbila) in North-Western province or 'new Copperbelt'. From 2006, the Copperbelt province has been contributing about 50% to the national copper production. However, 2016 and 2017 figures are less than half of the national copper production (Figure 10). This is because the 2016 and 2017 national production figures were based on the Chamber of Mines and not the CSO reports. Copper production is the major economic driver in Zambia as well as in the Copperbelt province. It is a major contributor to the national GDP. This leads to increased economic activity, affluent life and increased food production. These activities result in high water abstraction and production in order to meet the increasing demand by industry and domestic consumption. Despite its important economic role in Zambia, mining has had negative impacts on the quality of water in the Copperbelt province. Mining activities have negative impacts on water, land, aquatic and human life, and these may continue even after the mines have closed (Republic of Zambia, 2014). For example, the mining industry, discharges effluent from tailings to the Kafue River and its tributaries adding up to 500 000 m³/day. Dewatering of the mines impacts the aquifers and surface water quality of streams into which they are released (SGAB;SWECO;THOMRO;UNZA, 2005; Nyambe & Feilberg, 2009; Government of Zambia (GoZ), 2014; Pegasys and WWF, 2016). However, the dewatering of the mines have positive impacts in terms of making water available downstream for agricultural and domestic use (SGAB-SWECO-THMRO-UNZA, 2005). The GDP has been increasing since 2000 at the back of increased copper production (Figure 10).

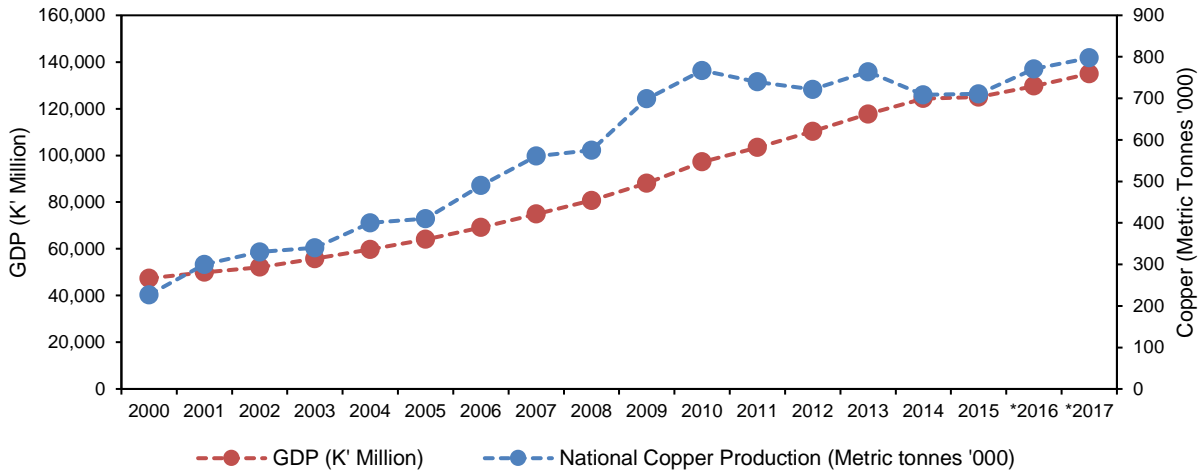


Figure 10: GDP and national copper production (CSO reports).

Note: * Copper production based on Chamber of Mines reports (Zambia Chamber of Mines, 2019).

Gross Domestic Product (GDP) contribution for the period 2006 to 2016, from the mining sector was about 13% (Government of the Republic of Zambia, 2017). The Copperbelt province contributed about 30% to the national GDP; in 2015 and 2016 contributed about 29% and 30%, respectively (Central Statistical Office, 2017; *Zambian Business Times*, 2020).

At provincial level (Table 4), the GDP share of mining is about 26% while agriculture and forestry is at 4% (Central Statistical Office, 2015). The mining industry continues to play a significant role in the economic growth of the province. For example, the mining industry contributed about 30% and 26% to the provincial GDP in 2014 and 2015, respectively (Table 4). At national level, the Copperbelt contributed about 29% to the GDP in 2014, 2015 and 2016 (Central Statistical Office, 2017; *Zambian Business Times*, 2020). It was, however, difficult to get the provincial GDP for the other years.

Table 4: Contribution of industry to total provincial GDP in the Copperbelt (CSO, 2017).

Industrial activity	2014	2015
Agriculture, forestry and fishing	3.5	3.5
Mining and quarrying	29.4	25.6
Manufacturing	12.6	12.7
Electricity generation	0	0.3
Water supply, sewage	0.3	0.4
Construction	5.1	5.9
Wholesale and retail trade	17	17.7
Transportation and storage	6	7.1
Accommodation and food service	0.4	0.3
Information and communication	2.2	2.8
Financial and insurance activities	3.5	4.4
Real estate activities	2.1	2.5
Professional, scientific	0.5	0.4
Administrative and support	0.8	0.9
Public administration and defense	4.6	4.7
Education	5.2	5.3
Human health and social work	0.8	0.8
Art, entertainment and recreation	0.3	0.3
Other services	0.3	0.2

Note: Other services is an aggregate of the industries not included in the table.

4.2 Water quality and quantity

Copper and water production from the Copperbelt region has generally been on the decrease since 2000. Water abstraction data from 2000 to 2004 was not available at the time of the study (Figure 11). A decrease in water production could be attributed to decrease in mining activity during the period. A decline in copper production in the Copperbelt could be attributed to under-investment, the use of inefficient and outdated technology and the exhaustion of low cost ore reserves, and policy changes in the mining sector (ZCCM-IH, 2002).

PEGASYS and WWF (2016) observed that the mines in the upper Kafue consumes about 68% of electricity. This in turn, increases competition for water from agriculture and

manufacturing industries. Agriculture, energy production, industrial uses and human consumption are the major sources for water demand (UN Water, 2009).

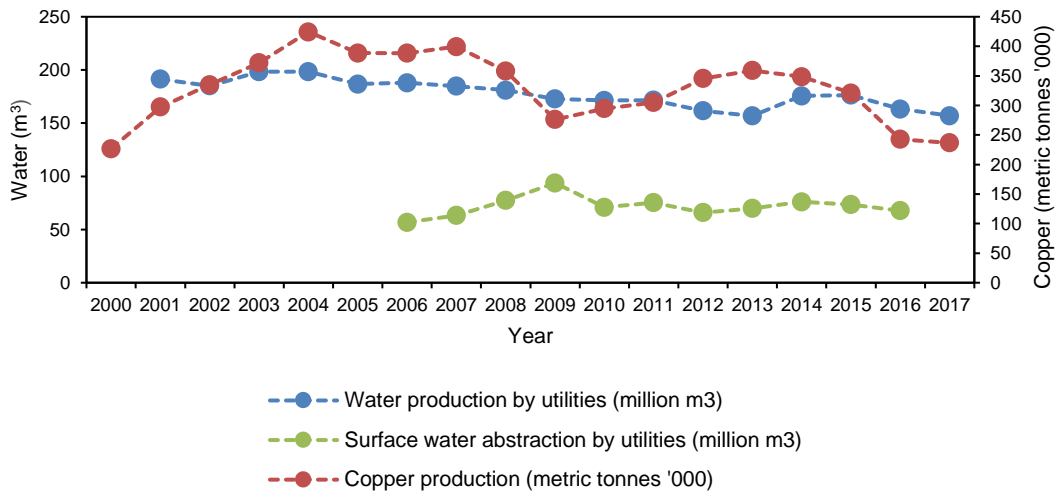


Figure 11: Copper and water production from the Copperbelt province

4.2.1 Water permits

Prior to the formation of WARMA in 2011, Water Development Board (WDB), which was under Ministry of Energy and Water Development (MEWD) was responsible for issuing of water rights (now referred to as water permits) but this mandate now falls under a new ministry where WARMA falls. The water permits are separated into valid or pending (not yet approved by WARMA) status. Ideally, it is only those with valid water permits that are supposed to abstract water but this may not be the case, and thus making it difficult to compare the actual water usage with the given water permits (SGAB-SWECO-THMRO-UNZA, 2005). For example, in 2000, about 1 000 000 m³/day was abstracted on the Copperbelt province based on 126 valid water permits issued (World Bank, 2000). The water which was pumped from the Kafue River system based on valid permits in 2005 was about 600 000 m³/day and dewatering from the mines ranged from 860 000 to 1 040 000 m³/day (SGAB-THOMRO-SWECO-UNZA, 2005). Konkola mine (underground) alone pumps about 300 000 m³/day (groundwater through dewatering) that is discharged

directly into the Kafue River. However, when you take into account about 16 pending permits in 2005, the total amount of water abstracted was about 2 238 100 m³/day. According to the WARMA database, the valid water permits in 2017 accounted for about 3 083 331 m³/day but if pending water permits are taken into account the water abstracted would be about 8 244 930 m³/day. This implies that if all the pending water permits are approved the Kafue River (with total natural inflow to the Copperbelt is 3 240 000 m³/day) will not be able to supply all users (SGAB-SWECO-THMRO-UNZA, 2005; Uhlendahl et al., 2011; Pegasys and WWF, 2016). To that effect, WWF (2016) observed that there should not be additional issuance of water permits until a full water balance is completed. Much as water potential maybe enough to meet the demand, but the rising demand from agriculture and variability will influence this trend (Chomba & Nkhata, 2016). Information on water demand is not accurate and there is also uncertainty on the future demand from the mining due to decrease in copper prices (Chomba & Nkhata, 2016). Water commercial utilities (companies) abstract mostly surface water for domestic supply and partly from groundwater (Figure 12).

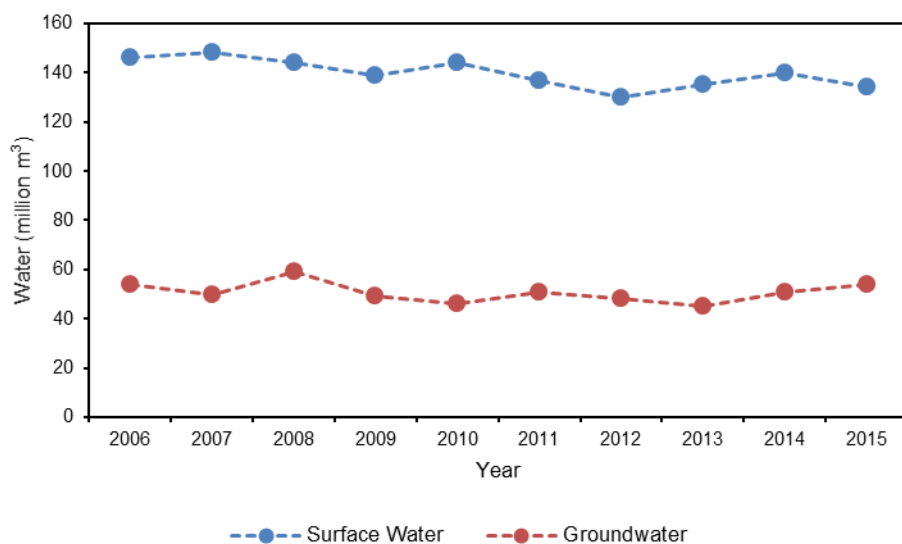


Figure 12: Fresh water abstraction by commercial utilities (Central Statistical Office, 2018).

Despite increased population and economic activities in the province, domestic or municipal water production and consumption has generally been decreasing (Figure 13).

This is also the case with water consumption per capita and water production per capita. For example, water consumption per capita per day in 2001 was 203 liters and reduced to 113 liters in 2017, representing a 44% reduction in consumption. The results in Figure 14 show that water consumption from 2004 to 2008 averaged 100 million m³ while the production averaged 160 million m³ per year. Based on the interviews that were conducted with NWASCO, the general downward trend in water production and consumption in the province could be attributed to maintenance and rehabilitation, and new investments in the water infrastructure, thereby reducing the unaccounted for water. The other reason could be that the new housing development are preferring to use groundwater sources to utility water (Nkhuwa, Mweemba & Kabika, 2013).

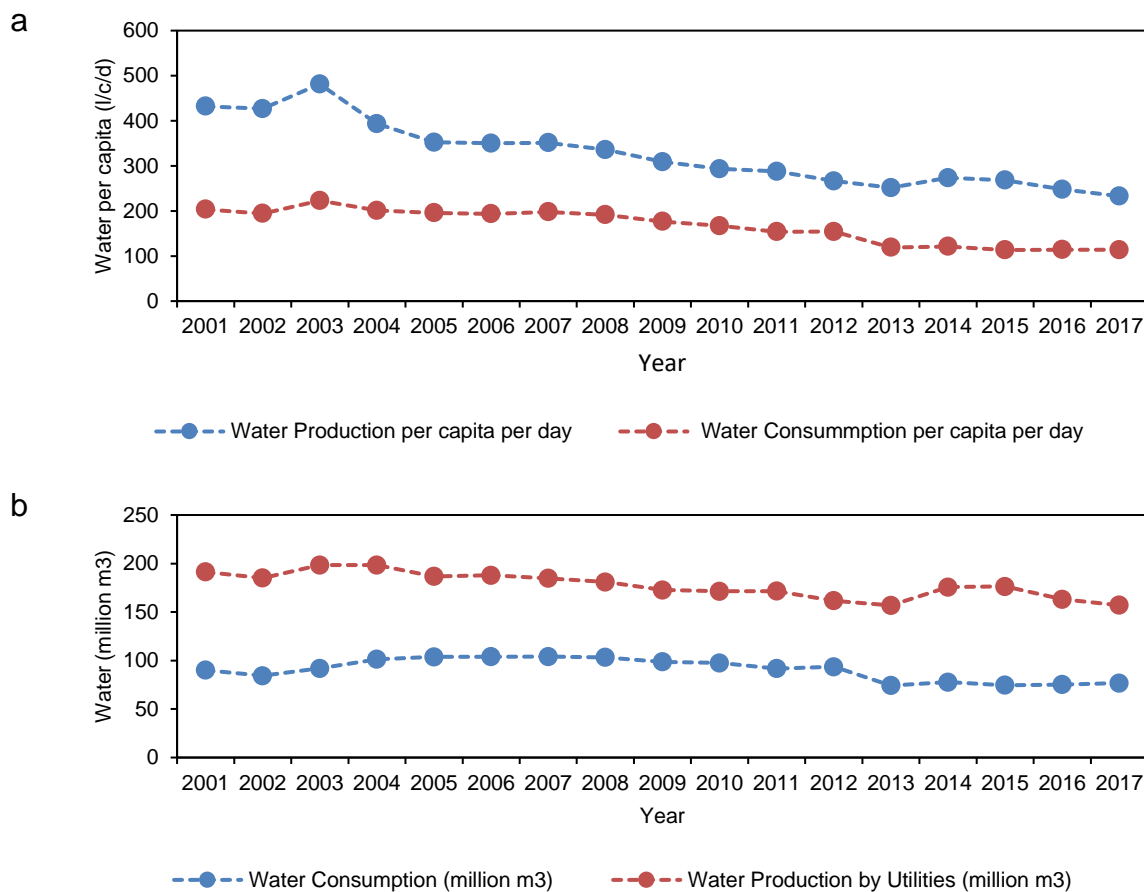


Figure 13: (a) Water production and consumption per capita (b) Water consumption and water production by utilities in the Copperbelt province (NWASCO reports, 2001-2017).

The other reason could be attributed to the cost of water and that consumers needed to adjust from the background where utility services such as water supply and sanitation were the sole responsibilities of the mines prior to privatization. During one party state, the government was running companies as parastatals and Zambia consolidated copper mines (ZCCM) was one such parastatal. ZCCM was in charge of all the mines in the country and subsidized the socio-economic aspect of the mineworkers as well as corporate social responsibility. The subsidized services that ZCCM provided included water supply and sewage, solid waste collection, and road maintenance (World Bank, 2002). After privatization, the government formed an asset holding company, ZCCM investment holding (ZCCM-IH) to provide some of the services but could not do everything that was done under ZCCM. Privatization of the mining saw the formation of water utility companies and took up the delivery of water and sanitation facilities to mine township. This is because private mine owners did not regard water supply and sanitation as part of their core business.

In terms of water supply and sanitation coverage, there has been an increased coverage since 2000. The results for water supply and sanitation coverage are based on the data from water commercial utilities operating in the Copperbelt province (Figure 14).

According to NWASCO definition, water coverage represents the proportion of population serviced by domestic connections through individual household connections, kiosks, public stand posts and shared/yard taps. Sanitation coverage consists of the population serviced by offsite (centralized system) and septic tanks only. However, sanitation coverage does not consider pit latrines for urban sanitation (NWASCO, 2017).

Water scarcity is not necessarily a problem in Zambia or in the Copperbelt but service provision by water utilities has been a challenge. The available water per capita in Zambia is about around 8,700 m³ per year, which is almost 24% more than the average for southern Africa and about 6% more than the global average (Chomba & Nkhata, 2016). In 2001, the population that had access to water supply and sanitation was 81% and 46%, respectively (Figure 14). This represented about 50% of the population, which had no access to sanitation. However, in 2017 the population with access to water supply and sanitation was 91% and 75%, respectively. This represented about 15% of the population

in serviced areas that had no access to sanitation. According to the 2010 census, the Copperbelt province had a population of 1 972 317 out of which 1 801 888 was the total population in areas serviced by water utility companies. The population figure reported by NWASCO may differ from that reported by the Central Statistical Office (CSO) because of the differences in the way rural and urban areas are delineated (NWASCO, 2017). What CSO calls a rural area may not necessarily be rural according to NWASCO, if that area is serviced.

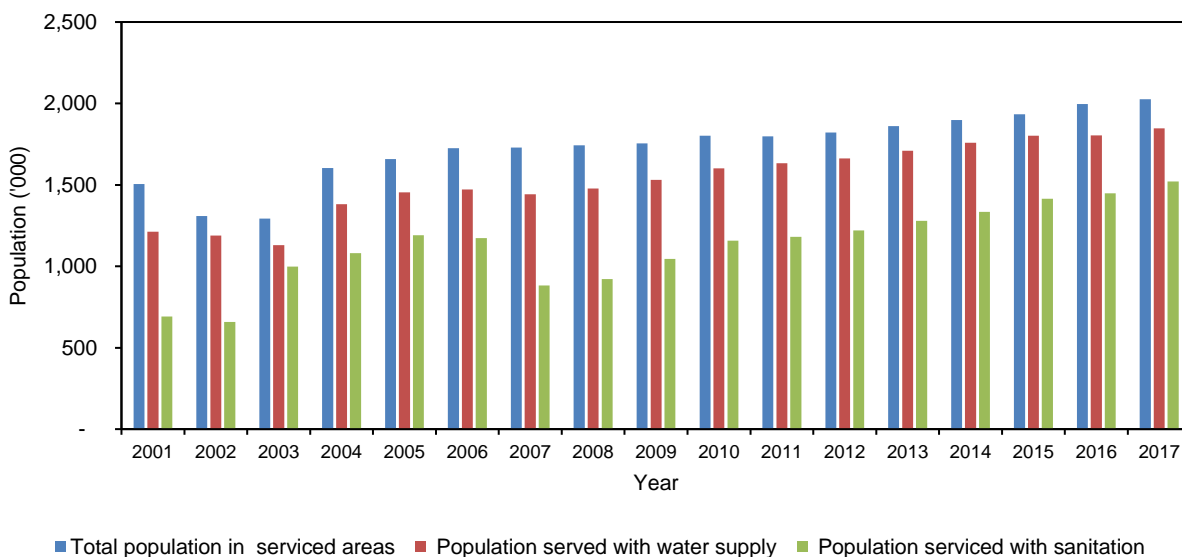


Figure 14: Population served with water supply and sanitation coverage in the Copperbelt province (NWASCO reports, 2001-2017).

Between 2007 and 2008, the sanitation coverage had seen a reduction compared to the year 2006 (Figure 15). This was due to institutional changes on the Copperbelt province – the mine townships that were previously serviced by an asset holding after privatization of the mines were taken over by other utility companies (National Water Supply and Sanitation Council, 2008). Consequently, the service delivery in the province dropped and started increasing in 2009 (Figure 15). Based on the Interviews conducted with NWASCO, increased funding in the sector as well as rehabilitation of old infrastructure (e.g. treatment plants) and construction of new ones have contributed to increased

access to water and sanitation services. It is also worth noting that water infrastructure development is not matching population growth.

Access to improved water and adequate sanitation can lower the incidences of waterborne diseases and thereby enhancing good health for the population, especially for women and children (Population Action International, 2011). On the other hand, poor access to drinking water is the major cause of diarrheal diseases and death, especially for developing countries and accounts for about 500 000 deaths annually (Peletz et al., 2018). Some of the major causes of infant mortality include infectious diseases like pneumonia, diarrhea, malaria and measles (Central Statistical Office, 2014).

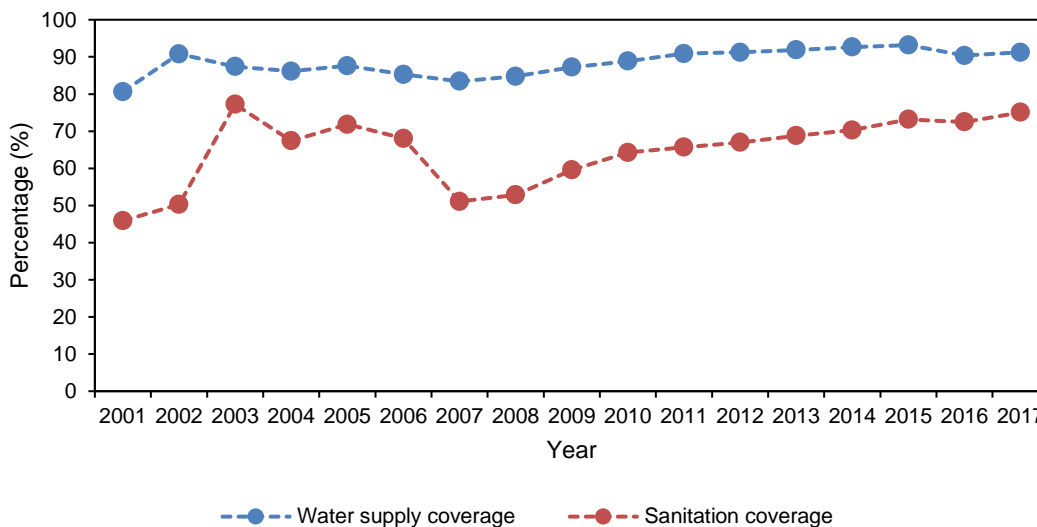


Figure 15: Water supply and sanitation coverage on the Copperbelt province (NWASCO reports).

The mining sector in Zambia has continued to play a significant role in economic growth, however the sector has also had negative impacts on the environment (Republic of Zambia, 2014). The mining sector has also positive impacts on the flows in the Kafue River – Konkola mine discharges about 3000 m³/day in the dry season thereby enhancing the water levels in the River (SGAB-SWECO-THOMRO-UNZA, 2005).

Monitoring of flow volumes down and upstream of the Kafue River (basin) is observed at different hydrometric stations. The Upper Kafue River catchment has several hydrometric

stations and the monitoring plays a major role especially that the main economic stay of the catchment is mining. However, there has been a general decline in frequency of monitoring of the flows as can be seen in the data gaps (Figure 17). WARMA attributes this to financial challenges and institutional changes. The Raglan and Machiya stations are background and reference stations, respectively. The data for stream discharge was collected from WARMA database from 2000 to 2012. The stream discharge data is measured for the period January to December though WARMA takes measurements from October to September of the following year. This is because the rainy season is from October to April which entails that surface water levels are expected to start rising in the Kafue River during the period

Raglan Farm station (Figure 16) captures the water head as it enters Chingola district from Kipushi; it gives the background flows (inflow) to the Copperbelt province. The nearest copper mine to this station is Konkola mine which discharges about 3000 m³/day (3.5m³/s) into the Kafue River (SGAB-THOMRO-SWECO-UNZA, 2005). This water is essentially due to dewatering (groundwater) from the aquifer systems of Konkola mine (underground) which is said to be one of the wettest mine in the world (Ian H., Louis, n.d.). The mean annual flow rate at Raglan station ranged from 21 m³/s to 121 m³/s for the period 2000 to 2012 (Figure 16). However, the period was characterized by data gaps.

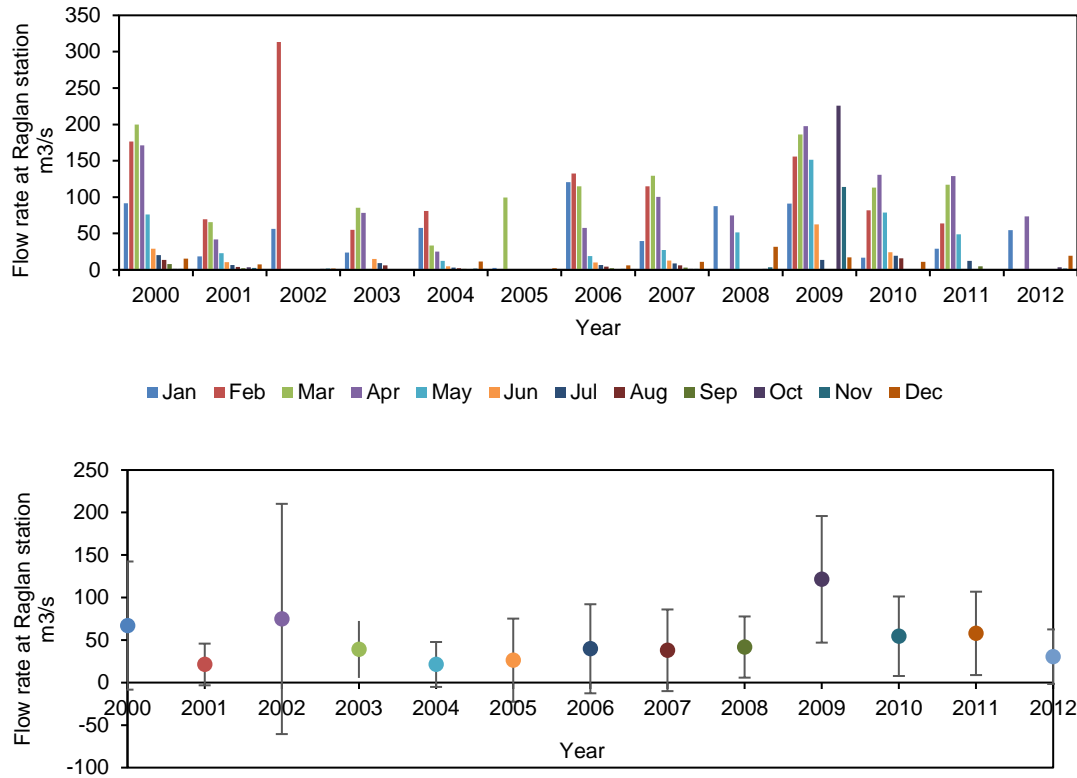


Figure 16: Ragland Farm station to monitor background conditions

Note: The year 2000 means 2000/1. This implies that data for October, November and December is for the year 2000 while January to September is for the year 2001.

The annual mean flow rates for Smith Bridge ranged from 11 to 130 m³/s (Figure 17) while the Wusakile station had the flow rates ranging from 35 to 139 m³/s (Figure 18). These gauge stations monitor discharges from tailings dam and copper refinery around Kitwe (Nkana copper refinery, Chambishi mine, Muntimpa and Mindolo dams).

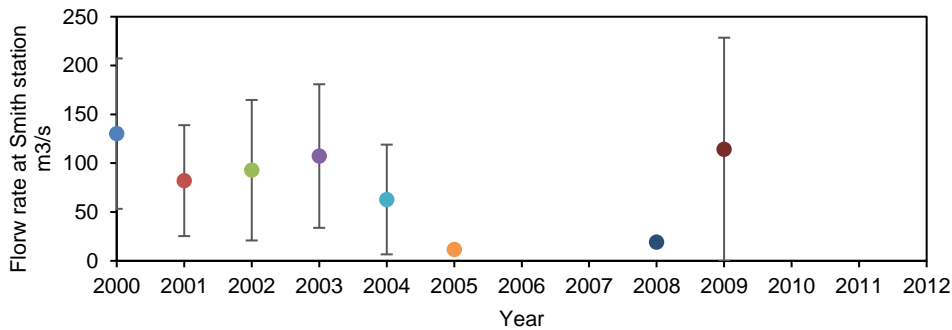
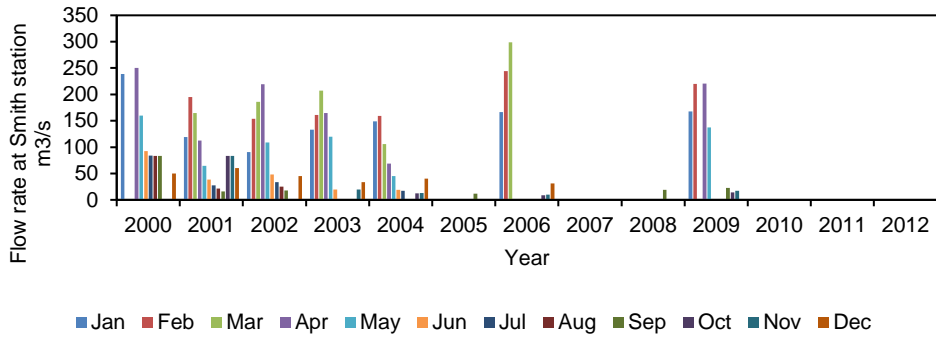


Figure 17: Smith's Bridge gauge station.

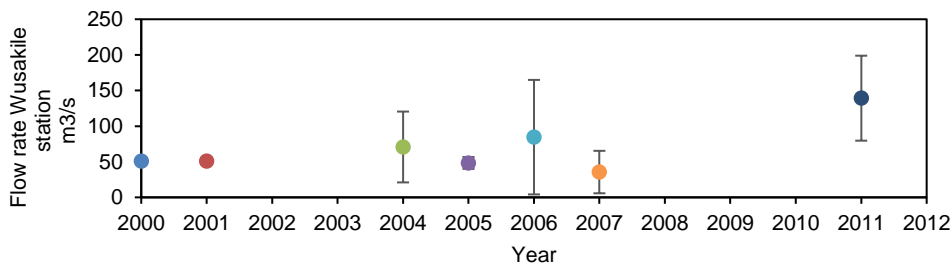
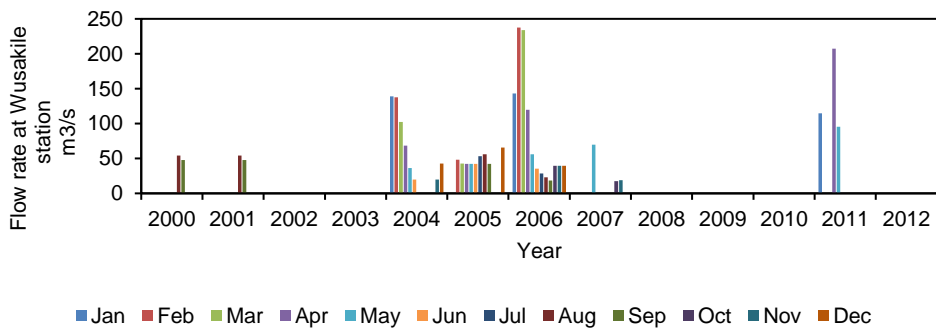


Figure 18: Wusakile gauge station

Mpatamato gauge station measures discharges from copper and cobalt mines as well as the from the Nkana copper refinery. It also measures discharges from the Kafubu emerald area. Annual flow rates at Mpatamato station ranged from 36 to 164 m³/s (Figure 19). However, the figure shows many data gaps owing to lack of data collection and financial challenges faced by the department of water affairs.

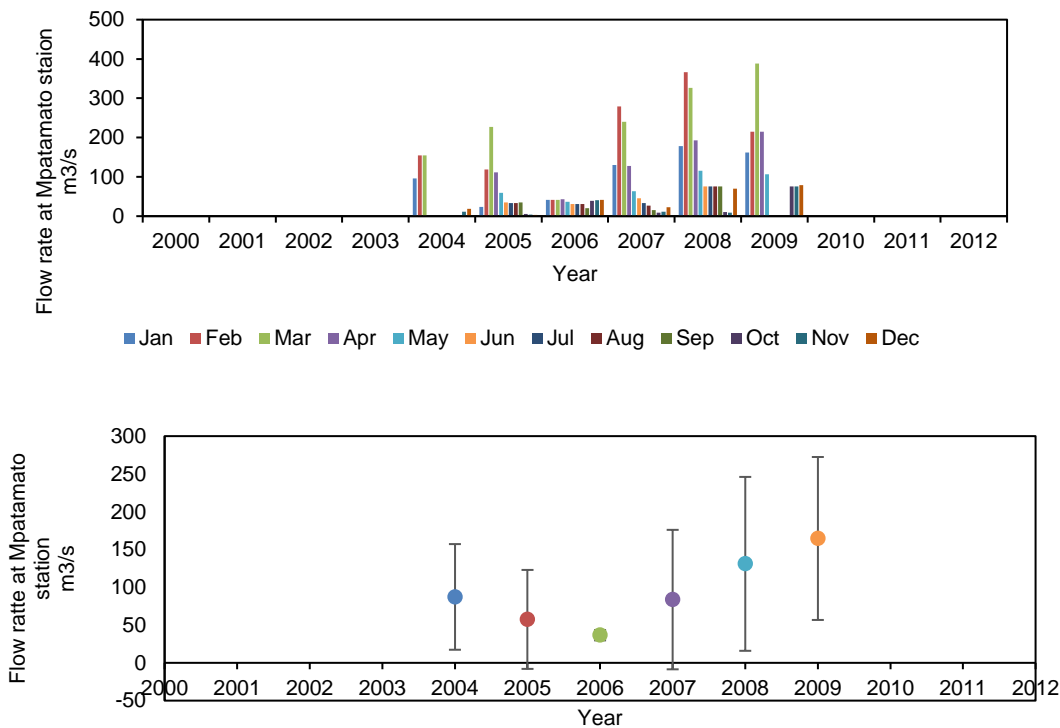


Figure 19: Mpatamato gauge station to monitor discharges from copper and cobalt mines as well as emerald mines.

Machiya gauge station is a reference site, which is located relatively far downstream of the Copperbelt province. Annual flow rates for Machiya station ranged from 12 to 93 m³/s. However, the data for Machiya was for the period 2000 to 2004 (Figure 20), which had several months of no measurements or missing data.

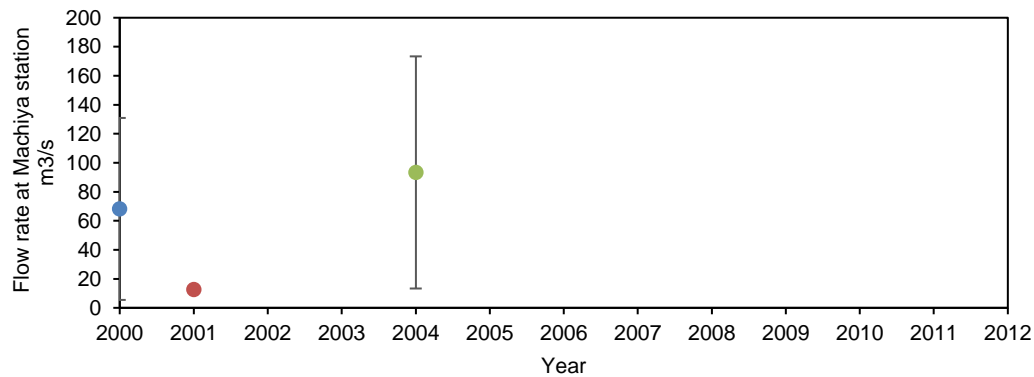
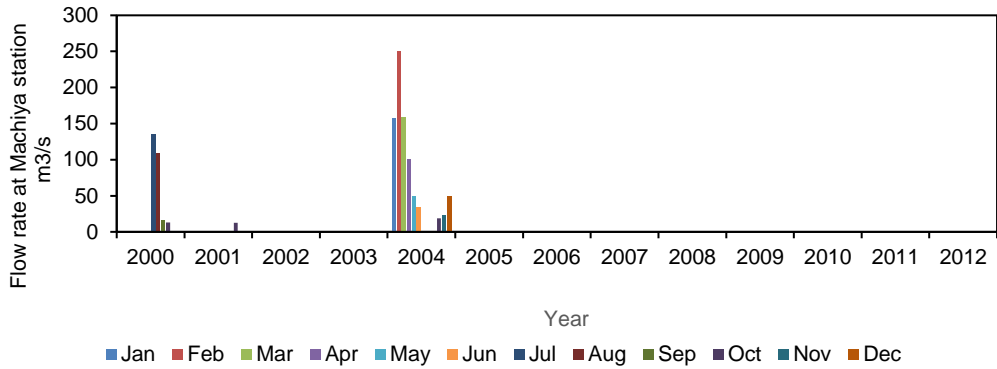


Figure 20: Machiwa gauge station monitors discharges downstream of the Copperbelt province.

Despite the fact that Zambia has a bigger share of fresh water in Southern Africa Development Community (SADC), access to water and sanitation is still a challenge. For example, monitoring of flow rates (stream discharge) in the upper Kafue River has been inconsistent, especially after 2000. WARMA attributes this to manual data collection, malfunctioning gauge stations, human resource and financial constraints. The data for all the stations is presented in Appendix B.

Water quality monitoring is done by different organizations, consequently posing a challenge for data access. A report by GoZ (2014), observed that there has been no coordination by various departments in the collection and storage of information, leading to ineffective monitoring and evaluation. The following results were obtained from WARMA database, reports and literature (Table 5). The results for Table 5 were compared with Zambia Bureau of Standard (ZABS) for potable water and World Health

Organization standards (WHO). However, the data was not enough draw conclusions from since the sample analyzed was based on once off values, which were collected in March of each year. More frequent and consistent measurements should be taken for better observations of trends.

Table 5: Water quality of the upper Kafue River collected in March of 2011 and 2012 (WARMA).

Parameter s	Units	Gauge Stations							ZABS (Potable)	WHO
		Raglan's Farm (Background)		Smith Bridge		Wusakile		Machiya Ferry (Reference)		
		2011	2012	2011	2012	2011	2012	2012		
pH		7.1	9.19	7.4	8.62	7.2	8.59	8.8	6.5-8.0	6.5-8.5
EC	µS/cm	110	377	260	581	270	570	280	1500	1500
TDS	mg/L	50		120		130			1000	
Ca	mg/L	11.2	24.8	36.8	17.2	28	23.5	22.8	200	
SO ₄	mg/L	5.65	4.45	55.7	4.6	65.1	3.2	1.75	400	250
Cd	mg/L		<0.002		<0.002		<0.002	<0.002	0.3	0.003
Co	mg/L		<0.005		<0.005		<0.005	<0.005	0.5	
Cu	mg/L		<0.003		0.01		0.04	<0.003	1.0	
Pb	mg/L		<0.01		<0.01		<0.01	<0.01	0.01	0.01
Mg	mg/L	5.3	5.96	4.4	24.32	21.9	10.24	19.12	150	200
PO ₄	mg/L		4.2		4.1		12.2	5.3	5000	
NO ₃	mg/L	1.15	0.2	0.2	0.29	<0.1	0.04	0.18	0.2-0.5	10
Fe	mg/L		0.29		0.29		0.22	0.29	0.3	0.3

The following results were obtained from a paper which assessed impact of population growth on water quality (Sichilima, Makondo & Lungu, 2015). The water quality was assessed in Uchi stream, a tributary of the Kafue River and from randomly selected wells in compounds or unplanned settlements (Table 6). The water samples from the well were collected in winter (cold season) and summer (hot season). Most of the results analyzed for groundwater were outside the Zambia Bureau of Standards (ZABS) for drinking water. Most of effluents discharged into Uchi stream are from Nkana Copper Refinery, Mopani Copper Mines and other industries (e.g. sawmills). Samples were collected during winter season and summer seasons. Only one sample was collected from each well whose

depths ranged from 10 to 13 m, radii of 1 m and pit latrines in the proximity of 15 m to 20 m. Each well was sampled for six months in winter and four months in summer periods, and average values were recorded accordingly. However, the data was not enough to draw conclusions from since the samples analyzed were average values for each season and did not have standard deviation because raw data was not available from the literature.

Table 6: Groundwater quality in compounds (unplanned settlements) of Kitwe in 2014 (Sichilima et al., 2015).

Sampling Point	Results (Winter;Summer)						
	pH	Temp (°C)	Turbidity (NTU)	Nitrates (mg/l)	Phosphates (mg/l)	Feecal Coiliforms (100ml)	Toatal Coiliforms (100ml)
Mulenga Compund							
Well 1	7.21	22.6	6	13.6	12	61	348
Well 2	7.3	22.2	0	70.00	6.80	93.00	615
Well 3	5.6	22.40	4.00	19.50	0.06	43.00	312
Musonda Compund							
Well 1	6.05	23.40	33.0	2.80	0.20	31.00	88
Well 2	7.15	23.6	2.00	1.70	0.09	67.80	192
Well 3	5.95	22.8	22.0	0.60	0.04	63.00	168
Luangwa Compund							
Well 1	5.75	22.6	17	0.35	0.01	76.00	236
Well 2	6.25	22.6	15	1.00	<0.01	69.00	161
Well 3	5.58	22.7	11	1.00	<0.01	33.00	484
Zambia Bureau of Standards for Drinking Water							
	6.5-9	N/A	3-5	10	0.4-5	0.00	20
Summer Results							
Sampling Point	pH	Temp (°C)	Turbidity (NTU)	Nitrates (mg/l)	Phosphates (mg/l)	Feecal Coiliforms (100ml)	Toatal Coiliforms (100ml)
Mulenga Compund							
Well 1	7.00	23.0	10.3	13.3	12.8	25.00	201
Well 2	6.90	22.20	2.00	73.00	6.23	30.00	415
Well 3	7.00	22.60	9.00	120.80	0.01	20.00	150
Musonda Compund							
Well 1	7.50	23.00	21.00	2.80	0.20	14.00	75
Well 2	8.01	23.20	2.00	1.70	0.10	56.00	102
Well 3	5.80	22.90	15.00	0.60	0.04	60.00	91
Luangwa Compund							
Well 1	5.25	22.60	13.00	0.35	0.01	45.00	98
Well 2	5.00	22.60	10.00	1.00	<0.01	67.00	190
Well 3	5.90	22.70	13.00	1.00	<0.01	39.00	450
Zambia Bureau of Standards for Drinking Water							
	6.5-9	N/A	3-5	10	0.4-5	0.00	20

The results (Table 7) for dissolved oxygen (DO) fell within the ZEMA statutory limit (not less than 5 mg/l). However, Sichilima, Makondo and Lungu (2015) observed that lower values of DO along the stream were linked to wastes from sawmills which had an impact on turbidity, pH, temperature, nitrate, phosphate, width and depth of the stream. The incubation of the samples for DO were based on Winker's Method. However, the data is not enough to draw conclusions from since they were based on once off values.

Table 7: Dissolved oxygen (DO) in Uchi Stream before and after 5 days of incubation (Sichilima et al., 2015).

Sample Reference	Before 5 days of incubation			After 5 days of incubation		
	Initial (ml)	Final (ml)	DO (ml)	Initial (ml)	Final (ml)	DO (ml)
Blank	8.6	16.2	7.6	0.0	7.2	7.2
A	16.2	24.4	7.4	7.2	12.4	5.2
B	24.4	32.6	8.2	12.4	19.8	7.4
C	32.6	41.6	9.0	19.8	27.6	7.8
D	41.6	48	6.4	27.6	33.6	5.6

Table 8 shows results from samples (control, A, B, C and D) that were collected along the Uchi stream where sawmills are located. All results for turbidity were more than 150 NTU recommended for a receiving water body. Results for total suspended solids (TSS) for the same samples were also above the limit of 100 mg/l. Elevated levels of TSS and turbidity have a negative impact on quality of water and consequently on aquatic life.

Table 8: Turbidity and TSS in Uchi Stream at different sampling points in 2014.

Sample Reference	Turbidity (NTU)	Total Suspended Solids (mg/l)
Control	89	40
A	170	89
B	172	190
C	178	206
D	261	265

The water quality conducted in the Uchi stream, a tributary of the Kafue River and also from wells in unplanned settlements (compounds) of Kitwe district revealed that the

results were outside the limits for drinking water under ZABS (Sichilima, Makondo & Lungu, 2015). Major sources of contaminants in Uchi were due to industrial water discharge from the cobalt and the copper chemical processing plant in Kitwe and washout of fines from the large slag deposits at Ndola Smelter (Sracek et al., 2012). The results from the wells had high faecal and total coliforms, an indication of poor sanitary facilities in the townships making shallow wells susceptible to contamination from runoffs.

The results in Table 9 show the mean annual values for physiochemical parameters for the Kafue River (Makondo et al., 2015). The results for cobalt (Co) in Uchi stream were particularly higher than the ZEMA limit of 1 mg/l. However, lead, arsenic and copper were below the statutory limits. As for pH, it was generally within the statutory limits of 6-9 except for upper Kafue River, northwest of Chingola district.

Table 9: Water samples and associated levels of different parameters for tributaries of the Kafue River, 2009–2013 (Makondo et al., 2015).

Sampling Period & Name of Stream	Annual Mean Concentration (in mg/L except pH)						
	pH	Cu	Pb	Mn	Cd	Co	As
Uchi Stream (Kitwe South)							
2009	5.10	0.61	0.02	4.45	0.02	9.61	<0.01
2010	6.20	0.40	0.02	2.61	0.01	28.30	0.02
2011	5.57	0.43	0.07	2.10	0.03	12.00	0.01
2012	6.37	0.37	0.01	3.13	0.05	22.10	<0.01
2013	7.02	0.34	0.11	4.30	<0.01	32.00	<0.01
Mindolo Stream (Kitwe Northwest)							
2009	5.02	0.43	0.01	1.37	0.03	4.28	0.00
2010	6.00	0.61	0.03	3.21	0.01	1.96	0.00
2011	7.36	0.55	0.02	3.51	0.04	2.13	<0.01
2012	7.12	0.43	0.04	2.11	0.01	1.91	<0.01
2013	7.60	0.33	<0.01	2.72	0.02	3.90	0.00
Up Kafue River (Chingola Northwest)							
2009	3.40	0.52	0.13	1.78	0.04	1.87	0.02
2010	4.50	0.31	0.10	3.01	0.01	2.21	0.01
2011	4.02	0.32	0.01	1.98	0.03	1.99	0.01
2012	7.32	0.04	0.16	1.74	0.02	1.08	0.00
2013	5.50	0.05	0.11	1.21	<0.01	1.71	<0.01
Down Kafue River (Sabina-Kitwe North)							
2009	6.50	0.71	0.12	1.61	0.01	0.81	0.01
2010	7.20	0.57	0.08	1.33	<0.01	0.12	0.02
2011	7.10	0.98	0.06	1.62	0.02	0.13	0.01
2012	7.30	0.59	0.31	0.67	0.01	0.34	0.01
2013	6.96	0.65	0.01	0.92	0.01	0.51	<0.01
Statutory Limits	6.5-9	1.5	0.5	1	0.5	1	0.05

Most of the studies ((Japanese International Agency (JICA) -Ministry of Energy and Water Development (MEWD), 1995; Pettersson & Ingri, 2001; Pettersson, 2002; SGAB-SWECO-THMRO-UNZA, 2005; World Bank, 2009; Sracek et al., 2010; 2012) done on the Copperbelt province have concluded that the surface water is polluted, and that mining is the major source of this pollution. With regard to acid mine drainage (AMD) contamination in the Kafue River and its tributaries, the impact is limited due to high neutralization capacity of the carbonate rich rocks (Pettersson, 2002; Sracek et al., 2012). The high neutralizing or buffering capacity is because of underlying geology (carbonate-rich shales, argillite, and sandstone), and wetlands that control the rapid precipitation of iron oxides and hydroxides as well as adsorption and/or co-precipitation of copper, and cobalt, which does not result in major production of AMD (Pettersson, 2002; SGAB-SWECO-THMRO-UNZA, 2005; Sracek et al., 2010; 2012). Nevertheless, that may not hold during accidental spills (Pettersson & Ingri, 2001; Pettersson, 2002; Sracek et al., 2010; 2012). The neutralization capacity is attributed to the underlying geology (carbonate-rich shale, argillite, and sandstone), and wetlands or dambos (Sracek et al., 2012). The report by WWAP/UN-Water (2018), noted that there has been increased attention for nature-based solutions (NBS) for their contribution to water management and rehabilitation of natural ecosystem. The report also observed that NBS enhances access to water supply and sanitation services, and reduces risks associated with water-related disasters. WWAP/UN-Water (2018) believes that NBS will play a critical role in achieving the 2030 Agenda for Sustainable Development. However, the neutralization capacity of the Copperbelt province has not been quantified and should therefore be cautiously considered. The World Bank Copperbelt Environmental Project (CEP) whose aim was to address environmental liabilities after the privatization of the mines and prepare a consolidated environmental management plan (CEMP); the reports assessed the water quality on the Copperbelt and was compared with WHO drinking water guidelines (ZCCM-IH, 2002). The report identified that the main source of water pollution was from raw sewage and mine effluents discharged into surface waters. The report observed that discharges to the Kafue River generally meets Zambian effluent guidelines but some effluents do not. Based on the interviews that were conducted with

ZEMA and NWASCO, raw sewage disposal and mine effluents remain a challenge though there has been quite some improvement.

The results (Table 10), for the streams located in active mine areas show that parameters such as TSS, copper (Cu), cobalt (Co) were above the limits set by ZEMA for effluents into open environment. TSS were comparable higher in most of the streams. The streams (Kakoso, Nchanga and Lubengele) with elevated values are located north of the Copperbelt, and are within the Konkola Copper Mines (KCM) operations whose main minerals mined and processed are copper and cobalt. KCM operates both open and underground mines. KCM is the largest integrated copper producer in Zambia, its operations comprise of open pit and underground mines, concentrators, smelter, a tailings leach plant and a refinery. There have also been reports of pollution particularly for KCM operations. The main sources of pollution are mainly from runoffs, leakage from waste rock dump, and tailings dam, which ends up into nearby streams. The company was sued by 2000 residents for pollution, and the court ordered each to be paid four million Kwacha (K4m) or US\$1 286 as general damages and one million Kwacha (US\$321) as punitive damages (Schuler & Lokanc, 2015); total amount paid was ten billion Kwacha (K10 billion) or about US\$3 214 607.

Several studies done on the Upper Kafue River have indicated that pollution on the Copperbelt is present and have had negative impacts on water quality and aquatic life (JICA-MEWD, 1995; Norrgren et al., 2000; Ashton et al., 2001; ZCCM-IH, 2002; SGAB-SWECO-THMRO-UNZA, 2005; M’Kandawire, 2010; Sracek et al., 2012; Sichilima, Makondo & Lungu, 2015; Mwansa, 2016). Most of the mines on the Copperbelt lie within the catchment of the Kafue River thus exacerbating the pollution of surface and groundwater (Schuler & Lokanc, 2015). Consequently, pollution of the river has resulted in high cost of water treatment for commercial water utilities. For example, in 2006, the water utility made losses amounting to US\$43 000 due to closure of the plant after the discharge of effluent by Konkola Copper Mines (Foil Vendata, 2016). In order to treat water to potable standards, the utilities spent significant money but concentration of some heavy metals such as manganese remain beyond treatable limits (Schuler & Lokanc, 2015). Most of the effluents discharged in the Kafue River are from the mining activities ,

nutrient loading from agricultural activities, sewerage from ponds, and from industrial processing activities (Chomba & Nkhata, 2016).

Table 10 : Surface water quality for the Kafue River tributaries (Republic of Zambia, 2014).

		Nchanga Stream				Lubengele Stream - Lubengele Dam				Kakoso Stream				Uchi Stream-Kitwe South & North			
		TFe	TSS	TCo	TCu	TFe	TSS	TCo	TCu	TFe	TSS	TCo	TCu	TFe	TSS	TCo	TCu
2009	Jan	75.0	3400	4.1	192.9	-	39	-	<0.01	0.3	156	0.0	1.2	1.7	-	0.7	-
	Feb	226.0	5521	7.1	159.3	-	1036	-	4.2	0.2	157	2.1	1.8	2.5	-	13	-
	Mar	191.3	5936	1.9	120.7	-	178	-	0.7	0.5	159	2.2	1.8	1.7	-	0.9	-
	Apr	114.2	3137	2.9	102.8	-	322	-	2.1	1.6	179	0.1	1.3	2	-	0.7	-
	May	46.6	1893	6.3	31.7	-	86	-	0	1.1	147	0.0	0.7	3.3	-	0.5	-
	Jun	15.1	1802	0.7	29.0	-	32	-	0.4	0.3	147	1.6	1.9	2.2	-	0.6	-
	Jul	-	-	-	-	-	376	-	8.5	0.4	129	2.6	2.2	1.2	-	3.7	-
	Aug	-	-	-	-	-	193	-	2.0	0.5	340	5.9	3.3	1.2	-	0.4	-
	Sep	-	-	-	-	-	66	-	2.4	6.6	134	0.1	0.9	1.9	-	0.5	-
	Oct	-	-	-	-	-	8	-	0.1	0.2	183	2.6	2.1	2.2	-	1.0	-
	Nov	-	-	-	-	-	10	-	10.3	0.6	103	12.2	14.1	0.9	-	0.8	-
	Dec	-	-	-	-	-	18	-	1.7	1.0	381	8.1	8.3	1.2	-	0.5	-
2010	Jan	119.0	183	0.7	106.0	-	15	-	3.0	3.1	266	0.1	7.9	1.2	-	1.0	7.5
	Feb	40.4	324	1.1	248.0	-	2741	-	5.6	2.2	208	0.0	2.5	2.9	-	3.9	3.1
	Mar	365.0	647	0.8	36.0	-	62	-	2.7	1.6	371	0.1	1.4	0.9	-	2.9	2.8
	Apr	365.0	2443	0.5	36.0	-	37	-	4.0	2.3	240	0.2	2.9	0.6	-	1.8	8.2
	May	115.0	224	0.7	502.0	-	67	-	0.9	1.4	235	0.3	1.4	1.2	-	3.7	0.8
	Jun	6752.0	2942	2.2	79.0	-	53	-	0.1	0.2	166	0.0	0.2	1.6	-	0.7	1.9
	Jul	9.7	474	0.9	91.0	-	26	-	0.2	3.9	184	0.2	3.1	0.8	-	1.9	-
	Aug	1.4	112	0.2	0.1	-	70	-	0.9	1	229	0.1	1.5	2.5	-	3.5	-
	Sep	47.7	1370	0.9	45.7	-	1724	-	9.8	5.4	248	0.1	4.5	4.9	-	4.3	-
	Oct	11.9	396	0.5	9.0	-	2873	-	17.6	3.7	277	0.1	2.2	1.2	-	4.0	-
	Nov	5.1	493	0.4	5.1	-	-	-	*	2.5	182	0.1	1.6	2.2	-	1.9	-
	Dec	1.9	677	0.3	0.7	-	-	-	*	0.6	152	0.0	1.1	1.6	-	1.9	-
2011	Jan	1.3	187	1.2	0.6	-	-	-	1.9	96	0.1	1.2	2.1	-	0.9	7.0	
	Feb	126.5	896	1.1	38.8	-	-	-	5.8	120	0.5	3.8	1.8	-	0.8	8.4	
	Mar	189.2	638	2.5	75.8	-	13	-	0.7	4.5	217	0.2	3.1	1.5	-	1.1	5.8
	Apr	69.9	1118	1.2	32.4	-	16	-	0.5	1.5	191	0.2	0.9	0.5	-	3.4	2.9
	May	128.9	930	3.2	99.9	-	32	-	0.4	3.2	104	0.1	1.8	1.0	-	0.4	2.0
	Jun	217.0	975	1.8	1.8	-	13	-	0.3	2.5	151	0.9	1.6	6.3	-	2.4	2.0
	Jul	155.7	749	1.1	76.9	-	9	-	0.3	6.5	139	0.2	4.2	1.1	-	0.5	5.8
	Aug	1045.0	2330	-	109.7	-	17	-	0.1	5.5	130	0.1	2.6	1.5	-	1.1	3.8
	Sep	176.9	2145	0.3	82.4	-	11	-	0.2	7.0	88	0.1	0.5	0.3	-	1.1	4.0
	Oct	142.8	1393	0.1	99.5	-	14	-	0.2	5.8	67	0.3	1.4	0.9	-	1.0	13.1
	Nov	53.6	1690	0.0	36.1	-	19	-	0.7	2.1	116	0.1	1.8	0.7	-	0.6	3.0
	Dec	132.8	1909	0.2	63.5	-	25	-	0.8	3	80	0.1	1.8	0.7	-	0.6	4.5

ZEMA Limit	TFe	TSS	TCo	TCu
	2.0	100	1.0	1.5

Note:

- All units are in mg/l
- No records or results

Groundwater quality is also affected by mining activities in the Copperbelt province. The results shown in Table 11 were monitored from 2009 to 2011 for Mopani Copper Mines (MCM) facilities – the water quality results were based on bi-annual reports that were submitted to ZEMA (Republic of Zambia, 2014). Major water quality issues included low pH and elevated levels of cobalt and copper (Table 11).

Table 11: Groundwater quality around MCM facilities (Republic of Zambia, 2014).

		MCM-Mufulira acid loading bay borehole No.16					MCM - Mufulira borehole No.18 between tank house and refinery change house					MCM - Nkana cobalt plant deep borehole					MCM -Nkana old CVW borehole				
		pH	TSS	TDS	TCo	TCu	pH	TSS	TDS	TCo	TCu	pH	TSS	TDS	TCo	TCu	pH	TSS	TDS	TCo	TCu
2009	Jan	6.2	24.0	63.0	<0.1	0.6	6.8	396.0	1820.0	<0.1	1.4	4.2	-	2547.0	442.0	6.5	2.9	-	1135.0	1.1	3.1
	Feb	6.2	39.0	1400.0	<0.1	1.9	6.4	1500.0	<0.1	<0.1	6.1	5.7	-	2198.0	130.0	38.2	3.3	-	1769.0	1.3	3.7
	Mar	5.9	12.0	61.0	<0.1	0.9	6.3	2400.0	<0.1	<0.1	5.6	-	-	-	-	-	-	-	-	-	-
	Apr	7.2	32.0	1700.0	<0.1	0.7	7.6	600.0	<0.1	<0.1	2.2	6.3	-	1795.0	16.3	0.4	5.4	-	1031.0	0.9	2.1
	May	6.3	15.0	1100.0	0.1	0.4	6.7	300.0	-	<0.1	0.9	6.2	-	2196.0	13.6	1.0	3.4	-	1431.0	1.3	4.4
	Jun	-	-	-	-	-	-	-	-	-	-	6.3	-	2234.0	28.4	1.3	2.9	-	1541.0	1.4	5.8
	Jul	6.9	1.0	1200.0	0.1	1.0	6.9	975.0	200.0	0.1	2.1	6.2	-	2234.0	7.9	0.7	-	-	-	-	-
	Aug	7.0	20.0	800.0	<0.1	0.9	7.0	197.0	400.0	<0.1	0.2	6.2	-	2227.0	7.6	0.6	3.1	-	1476.0	0.8	3.8
	Sep	6.8	1.0	1000.0	0.1	4.2	6.8	160.0	1246.0	<0.1	1.9	-	-	-	-	-	-	-	-	-	-
	Oct	6.4	4.0	1000.0	<0.1	10.0	6.4	1408.0	140.0	<0.1	1.5	6.4	-	2161.0	6.3	0.9	-	-	-	-	-
	Nov	6.5	2.0	1200.0	0.3	10.0	6.5	5304.0	300.0	<0.1	3.5	6.3	-	2048.0	5.8	0.7	3.2	-	1336.0	0.4	0.9
	Dec	6.4	5.0	1100.0	0.2	12.7	6.4	3501.0	200.0	<0.1	11.8	4.7	-	2470.0	290.3	7.3	3.5	-	1423.0	1.6	5.7
2010	Jan	6.1	2.0	1400.0	<0.1	7.0	6.1	736.0	1000.0	<0.1	3.0	3.3	-	964.0	3992.3	52.8	3.1	-	1543.0	1.2	5.5
	Feb	6.4	2.0	2000.0	0.1	7.5	6.4	160.0	1200.0	0.1	0.5	4.2	-	1822.0	295.1	8.4	3.0	-	1551.0	1.0	4.5
	Mar	7.9	9.0	1103.0	0.4	10.9	7.9	3845.0	2130.0	0.4	5.3	4.6	-	1901.0	320.1	10.4	3.8	-	1480.0	1.3	3.7
	Apr	6.7	2.0	2144.0	0.4	11.0	6.7	3788.0	561.0	0.2	10.7	3.0	-	11063.0	2200.0	50.0	3.0	-	1612.0	0.9	3.6
	May	6.4	1026	0.1	0.3	9.2	6.4	717.0	400.0	0.1	3.3	3.0	-	10567.0	2342.0	55.5	3.0	-	1455.0	0.6	3.2
	Jun	6.8	31.0	1010.0	0.2	11.5	6.8	17.0	312.0	<0.1	1.7	3.4	-	10582.0	4200.0	60.0	3.2	-	1560.0	1.0	3.3
	Jul	6.9	251.0	1782.0	0.3	7.5	6.9	693.0	312.0	<0.1	1.1	3.2	-	-	3029.0	58.5	3.2	-	-	0.4	3.2
	Aug	7.2	18.0	1866.0	0.5	9.8	8.1	1251.0	294.0	<0.1	2.7	3.2	-	-	2402.0	118.0	3.2	-	-	0.8	2.1
	Sep	6.9	1973.0	1943.0	0.3	8.9	7.6	27.0	637.0	0.1	1.9	3.1	-	-	1340.0	98.0	3.2	-	-	300.0	96.9
	Oct	7.7	12.0	1961.0	0.2	7.4	8.1	2102.0	180.0	0.1	5.3	3.2	-	-	515.0	63.0	3.7	-	-	1.8	7.0
	Nov	7.4	19.0	4230.0	<0.1	2.3	7.6	1048.0	752.0	<0.1	8.7	4.8	-	1599.0	240.0	0.5	3.4	-	14360.0	0.7	0.9
	Dec	6.6	15.0	2959.0	<0.1	4.1	6.8	10563	2576.0	<0.1	19.0	4.7	-	2199.0	2.9	0.8	3.5	-	1366.0	0.7	1.0
2011	Jan	6.3	5.0	2699.0	0.1	-	6.7	2318.0	2422.0	<0.1	3.7	4.3	-	3870.0	320.0	12.3	3.4	-	1465.0	0.6	3.3
	Feb	6.5	3.0	2005.0	0.1	1.9	6.5	381.0	101.0	0.4	1.6	3.2	-	5831.0	9.0	20.1	3.2	-	1602.0	1.2	4.3
	Mar	6.8	-	1922.0	0.1	0.7	6.3	-	1988.0	0.1	1.9	3.9	-	2113.0	1570.0	20.8	3.3	-	1482.0	0.3	2.8
	Apr	6.5	14.0	288.0	<0.1	0.3	6.5	165.0	561.0	<0.1	0.8	5.4	-	-	75.4	3.4	3.5	-	1513.0	1.2	4.9
	May	6.7	5.0	1369.0	<0.1	0.4	6.2	12.0	543.0	<0.1	0.5	6.0	-	2213.0	14.0	0.4	3.9	-	-	1.0	7.8
	Jun	7.2	10.0	1767.0	<0.1	-	7.2	34.0	277.0	<0.1	0.2	6.1	-	2213.0	157.0	12.6	5.7	-	1699.0	0.8	5.8
	Jul	6.7	4.0	1977.0	0.1	1.0	6.6	819.0	285.0	<0.1	1.2	-	-	-	-	-	-	-	-	-	-
	Aug	6.4	70.0	1943.0	<0.1	0.7	6.4	4881.0	251.0	<0.1	6.3	3.5	-	7511.0	112.3	24.9	3.2	-	1982.0	0.2	4.0
	Sep	7.2	10.0	1457.0	<0.1	0.2	7.8	3196.0	171.0	<0.1	4.7	-	-	-	-	-	-	-	-	-	-
	Oct	7.6	21.0	1103.0	<0.1	<0.1	7.2	1370.0	152.0	<0.1	5.4	3.3	-	10190.0	123.1	30.8	3.2	-	2033.0	0.6	5.3
	Nov	6.3	60.0	1442.0	0.1	0.9	-	-	-	-	-	6.4	-	434.0	<0.1	<0.1	3.3	-	2102.0	0.6	6.1
	Dec	6.5	84.0	1953.0	<0.1	3.7	-	-	-	-	-	3.5	-	809.0	58.6	30.1	3.2	-	2064.0	0.5	5.0

ZEMA Limit	pH	TSS	TDS	TCo	TCu
	6-9	100	3000	1.0	1.5

Note:

- All units are in mg/l except pH
- No records or results
- CVW (Central Vehicle Workshop)

There is a strong link between water and development for all societies and this development is driven by sectors such as agriculture, energy and industry which all have impacts on the use and governance of water (WWAP (United Nations World Water Assessment Programme), 2015b). The Kafue River with its tributaries is economically important to the Copperbelt province and Zambia at large, but economic and anthropogenic activities contaminate the surface water (Sracek et al., 2012; Sichilima, Makondo & Lungu, 2015).

Poor water quality due to nutrients loading into the Kafue River and its tributaries on the Copperbelt has had a bearing on the cost of water treatment. This is why companies should not just focus on water related impacts within their operational boundaries but also at a large scale (Kunz & Moran, 2014). There has been a steady increase in treatment cost per m³ (Figure 21) for water, and this has been attributed (based on NWASCO interviews) to cost of chemicals such as coagulants (for removal of heavy metals). The raw sewage discharged into the Kafue River and its tributaries has contributed to eutrophication (Sibanda, 2007). One of the weeds that have thrived in this is the water hyacinth (Kafue weed). According to the study by (Mbula, 2016), water hyacinth has been a major problem in Kafubu River since the 1990s. Anthropogenic activities (raw sewer discharge into rivers), dilapidated and old water infrastructure (algae growth) leading to high chlorine or aluminum sulphate demand account for the rising cost of production. The other factor that contributed to this is depreciation of the local currency (Kwacha) to the US Dollar since most of these chemicals are imported. According to Trottier (2007), increased nutrient concentration and minerals loads in the Kafue basin, increases the treatment costs for water before it is distributed to consumers. This implies that more chemicals (such as chlorine and aluminum sulphate) were used to treat water to potable standards. A study on Lake Victoria, concluded that the eutrophication of the lake was as a result of nutrient loading – population and economic growth being major drivers (Juma, Wang & Li, 2014).

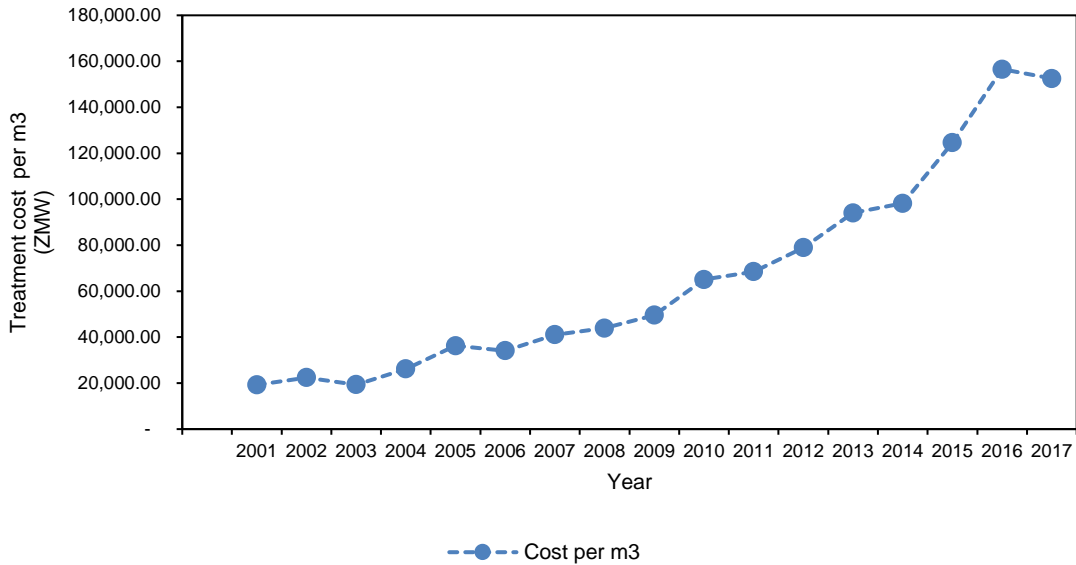


Figure 21: Water Treatment cost by water utilities on the Copperbelt (NWASCO reports).

Note: The average exchange rate from 2000 to 2011 was K5 to US\$1; 2014 (K6=US\$1); 2015 (K8=US\$1) and the average rate from 2016 to 2017 was K10 to US\$1.

4.3 Water sector reforms

Water sector reforms in Zambia have been on-going since the 1990s and these have led to new institutional arrangements (Chitonge, 2011; National Water Supply and Sanitation Council, 2018). The change to multiparty democracy introduced general reforms in public service and the liberalization of the economy, creating a conducive environment for reforms in the water sector. Through the adoption of the 1994 National Water Policy, as a framework for future development, a number of development have taken place, minimizing the multiplicity of multiplicity of actors without a clear mandate (National Water Supply and Sanitation Council, 2018). This, however, has not changed because the institutional set-up remains complex except that now for clearly defined mandate to key players in the sector. The main objective of these reforms were aimed at achieving better ways of managing water supply and sanitation in Zambia. The old framework was based

on 1994 Water Policy and new institutional arrangement is been necessitated by Water Resources Management Act of 2011.

A look at the old and new institutional arrangements reveals that the major difference is the creation of the new Ministry of Water Development, Sanitation and Environmental Protection (MWDSEP). In addition, those regulators such as WARMA, ZEMA and NWASCO now fall under one ministry unlike previously where they were under different ministries thereby maximizing multiplicity of actors without clear mandates in the water sector. Though the sector has made some milestones in water reforms a lot needs to be done to build capacity in water resources management and minimize institutional gaps (Government of the Republic of Zambia - Republic of Denmark, 2007; Nyambe, 2008).

Water resources management has been a challenge particularly for groundwater, this is owing to responsibilities for regulators not clearly defined, changes in policy and legislation framework coupled with low investment in the water sector (Government of the Republic of Zambia - Republic of Denmark, 2007; Nyambe, 2008; Chitonge, 2011; Uhlendahl et al., 2011). Chomba and Nkhata (2016) also observed that there is not much clarity in the roles and responsibilities by institutions in the water management. Zambia has sufficient acts, regulations, and institutional set-up to mitigate and monitor water pollution but lacks capacity in implementation and enforcement because of financial and manpower constraints (Republic of Zambia, 2014; Schuler & Lokanc, 2015).

4.4 Challenges in the water sector

In order to appreciate and understand operations and challenges in the water sector, semi-structured interviews were conducted with key institutions in the water sector and pollution control. These institutions were NWASCO, WARMA and ZEMA; the responses from each institution are summarized below:

a) NWASCO:

- pH, turbidity, colour and free chlorine (residual). For the commercial utilities downstream of the copper mines (Copperbelt province), copper, cobalt,

manganese, Iron, and alkalinity. These tests are done because they have a bearing on the cost of water treatment.

- Microbiological tests for E-coli, fecal coliforms and total coliforms are done because of their immediate impact on the health of consumers.
- Iron sulfate and aluminium sulfate (preferred) and chlorine (gas and granular) are the major chemical used in water treatment.
- NWASCO attributes the high chemical cost, particularly on the Copperbelt province, to growth of algae in the Kafubu River (Kafubu water and Sewerage Company), arising from sewer discharge. The algae ultimately raises the chlorine demand due to pretreatment requirements. In the case of commercial utilities servicing mine townships (Nkana and Mulonga), the cost is attributed to the presence of heavy metals in the water thereby using more chemicals (e.g. coagulants) in water treatment in order to meet potable water standards. The other factor that also contributed to the rising cost of water treatment was depreciation of the local currency (Kwacha) against the US dollar, since a number of chemicals (coagulants) used in water treatment are imported.
- Low investment in the water sector led to low water production but there has been an increased investment in the infrastructure since 2011. Most of the infrastructure are more than 50 years old.
- In order to improve efficiency in the sector in terms of reporting, NWASCO as a regulator has now added a leakage index (leakage/m). This parameter is been captured in the “2017 Urban and Peri-Urban Water Supply and Sanitation Sector Report”. The council’s mandate on sanitation has also been extended to “own-septic-designs” in order to promote sustainable sanitation practices.
- The greatest challenge for the regulator has been compliance monitoring, especially for those utilities whose infrastructure have not been upgraded to meet the current needs. For example, most plants were not designed for removal of heavy metals.

- NWASCO coordinates with different government agencies and other institutions. These include;
 - i. Zambia Bureau of Standards (ZABS) for development of standards for potable water and water quality monitoring.
 - ii. WARMA for the development of standards for example, the council is currently coordinating with the authority ambient water quality standards.
 - iii. ZEMA for the regulation of what is discharged into the environment.
 - iv. Local Authorities for regulation of sanitation (pit latrines, septic tanks) designs.
 - v. Ministry of Education for the development of rural water quality monitoring standards.
 - vi. Ministry of Health for education, sensitization, and prevention of water borne diseases.

b) WARMA:

- Water quality (surface) monitoring is done quarterly but this is dependent on availability of financial resources. Regulation for groundwater monitoring (dewatering) are underway.
- Onsite water quality tests are done for pH, EC, TDS, DO since they are unstable. The other parameters include heavy metals (Pb, Zn, Mn, Fe, Cd), total hardness, Ca, K, Mg, Na, alkalinity, nitrates, HCO_3^- which are measured at WARMA lab. The choice of these parameters is on the basis of the underlying geology, agricultural and anthropogenic activities on the Copperbelt province. The other determining factor in the case of heavy metals is the availability of Atomic Absorption Spectrometry (ASS) equipment. Bacteriological tests (fecal coliforms, total coliforms).

- Water permits data are not available to the public except on written request. The data collected for a catchment is used to assess water demand before issuance of the permits.
- River flow data (real time) is collected daily via the Integrated Water Resources Management Information System (IWRMIS) and manually by gauge readers. The system was implemented in 2014/2015 after the installation of telemetric stations; the data is then transmitted to the headquarters in Lusaka. Prior to the implementation of the IWRMIS, and institutional reforms in the early 90s contributed to the inconsistency in the data collection.
- The greatest challenge faced is that reports or data are not received on time from the catchment. The monthly reports capture data on environmental flows and hydrology.
- WARMA collaborates with:
 - ZEMA: On effluent monitoring and conditions for EIAs before approval.
 - Ministry of Agriculture: Collaborate on catchment management plans.
 - Universities (UNZA, CBU): Collaborate on research.
 - Disaster Management and Mitigation unit: Collaborate on emergency response (e.g. floods).
 - Meteorological department: Collaborate on climate (weather forecasts).
 - NWASCO: Collaborate on the development of catchment management plan and water users associations and general advice on water management.

c) ZEMA:

- Water quality monitoring of effluents is done at least once a year. The parameters monitored are heavy metals, TSS, TDS, Sulphur, biological oxygen demand (BOD), chemical oxygen demand (COD). These parameters are critical for mining areas.

- Mining companies submit reports on water/effluent discharge into the environment and this is captured.
- Compliance monitoring is not systematic and sometimes it is done once a year or not done at all.
- Onsite tests are done for some parameters while others are done at Alfred Knight, a commercial lab.
- The challenges in water quality monitoring are inadequate work force and financial resources.
- Most of the data collected have been the same in the last 10 years. This is in order to compare and establish trends.
- ZEMA collaborates with WARMA, Mine Safety Department (MSD), and NAWASCO. These institutions are also regulators in the sector and as such, the collaboration is in the pieces of legislation that ZEMA enforces.

Water quality monitoring is critical in water resource management; this is because water should be considered in terms of quality and not just quantity. Much as it is important to monitor water quality, it should not just be done for the sake of it but is supposed to meet regulatory requirements for testing frequencies (Peletz et al., 2018). The results for flow rates (stream discharge) and water quality particularly on the Copperbelt province show that the regulators do not meet the required frequencies and the number of gaps in the data that was collected evidences this. A study by Arah (2015) in Ghana, noted that although water quality monitoring is done by many interest groups to ensure sustainability and coexistence with the mine and communities, there are still some mining activities that are difficult to monitor and control. This is particularly common in developing countries.

In view of the challenges of groundwater abstraction (through boreholes) which was not controlled, the Government of the Republic of Zambia (GRZ) signed a Statutory Instrument (SI) No. 20 of 2018 on 7th March 2018. The Water Resources Management (groundwater and boreholes) Regulations, 2018 under this SI, is now in effect. It is aimed at enhancing sustainable groundwater (quality and quantity) management. In its seventh

national development plan (7NDP), the government of Zambia (GoZ) acknowledges that water resources infrastructure is critical for sustainable water resources management and services (Government of the Republic of Zambia, 2017). Water plays a critical role as engine and catalyst for development. However, the linkages between sustainable development and water are many, complex and often too difficult to analyze (WWAP (United Nations World Water Assessment Programme), 2015b).

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

This study assessed cumulative impacts associated with copper mining on water quality and quantity in the upper Kafue River of the Copperbelt province from 2000 to 2020. Water quality and quantity data covered the period 2000 to 2017 while population data covered the projected growth in 2020, as well. The main objective of the study was to assess the cumulative impacts on water quality and quantity associated with copper mining in the Copperbelt province of Zambia.

Much as mining has been cited as a major source of pollution for both surface and groundwater resources on the Copperbelt province, particular attention needs also to be paid to disposal and management of agricultural chemicals. Agriculture, and wastes from sawmills also impact water systems. This is because the northern part of Zambia, where the Copperbelt lies, has seen increased land use in the recent past as opposed to the traditional southern half of the country that is predominantly agriculture – the rainfall in the southern part of the country has drastically reduced due to climate change. This has led to the shift in agriculture activities in the northern half of the country thus increased use of pesticides and fertilizers. Most river catchment in Zambia are in the north and as such, indigenous forests lie within the catchment of most river system. For example, the Kafue River, which is economically important to the nation, the copper mines are in the north while agriculture and hydropower stations are more developed in the south. In terms of the positive impact of mining on water quantity, dewatering from the mines discharges over 630 000 m³/day directly to the Kafue River, which increases flows in the river especially in the dry season.

Despite increase in population and economic growth in the Copperbelt, there is generally a downward trend in water production and consumption. This can be attributed to rising cost of water and reduction in non-accounted for water as NWASCO alluded to during the interviews.

Water contamination on the Kafue River and its tributaries; mainly from mining activities have raised water treatment costs for utility companies on the Copperbelt province.

Additionally, old and dilapidated infrastructure have not coped with the increasing population and mushrooming of informal settlements concerning water and sanitation services. In most cases, raw or poorly treated sewage is directly discharged into rivers thereby leading to nutrient loading, which leads to negative impacts on biota or aquatic life arising from high biochemical oxygen demand (BOD). The sewage contamination increases the chances of bacteriological pollution posing a health risk (e.g. cholera outbreaks and other waterborne diseases).

The regulators such as NWASCO, WARMA and ZEMA face challenges that include lack of adequate financing, and technical support to effectively enforce the regulations governing water resources management. There is also lack of coordination in terms of which water quality parameters to test for and why those parameters, and where that should be done. The budget or financial constraints should be able to help regulators give informed decisions on the relevance of testing for such parameters from both surface and groundwater.

Water quality monitoring also remains a challenge and consequently the extent of the impact of mining on quality of water is not clear. Water quality issues in the mining industry is still a sensitive issue and often times the regulators rely on data collected by the mines. The water quality in the Kafue River is still an issue of concern from the public and the government. The impact of acid mine drainage remains low in the Copperbelt because of high neutralization capacity of the underlying geology (carbonate rocks) and dambos. However, the neutralization capacity needs further studies especially in the light of increased population growth and changes in land use. Despite some successes that have been scored in the water sector reforms, sustainable water use has not improved as expected. This is largely due to inadequate capacity by regulators in enforcement and compliance of environmental regulations.

The following recommendations are made for water resources management in Zambia:

1. Regulators such as ZEMA, WARMA and NWASCO should invest in remote monitoring of water quality and quantity in view of constrained resources.
2. The regulators should collect data more frequently.

3. There is a need for more collaboration among regulators on the parameters to test for and a consolidated database or report such that it is to know that this data was collected in the drying season and from particular sampling points of significance and scenario of random sampling.
4. The government, through regulating agencies, should find a way of making data on water from mining companies accessible, especially to researchers so that they can inform policy on water resources management.
5. Particular attention needs to be paid to chemicals from households and agricultural activities that end up in water bodies especially with increased urbanization and population growth. This can be done through awareness campaigns and engagement with manufactures on hazardous waste disposal.
6. Groundwater quality should be monitored as most data available are skewed to surface water sources.
7. Regulators need to be funded adequately for them to monitor and enforce regulations for water quality and quantity.
8. Integrated water resources management in the Copperbelt and at national level needs much more attention especially with regard to the formation of the new Ministry Water Development, Sanitation and Environmental Protection.

REFERENCES

(Central Statistical Office. 2012. *2010 Census of Population and Housing:Population Summary Report*. Available: <http://www.nscb.gov.ph/activestats/psgc/municipality.asp?muncode=042109000®code=04&provcode=21>.

Abughlelesha, S.M. & Lateh, H.B. 2013. A Review and Analysis of the Impact of Population Growth on Water Resources in Libya. 23(7):965–971. DOI: 10.5829/idosi.wasj.2013.23.07.13102.

Acuña, A.P. & Peñailillo, R. 2014. Water resources industry in Chile management at the mining. In *Impact Assessment for Social and Economic Development 34th Annual Conference of the International Association for Impact Assessment*.

Admiraal, R., Rita, A., Mchenry, M.P. & Doepel, D. 2017. The Extractive Industries and Society Maximizing the impact of mining investment in water infrastructure for local communities. *The Extractive Industries and Society*. 4(2):240–250. DOI: 10.1016/j.exis.2017.01.014.

Arah, I. 2015. Monitoring Water Quality in River Bodies of Mining Communities in Ghana. *Asian Journal of Mining and Social Sciences*. 3(1).

Ashton, P., Love, D., Mahachi, H. & Dirks, P. 2001. An overview of the impact of mining and mineral processing operations on water resources and water quality in the Zambezi, Limpopo and Olifants Catchments in Southern Africa. *Mining, Minerals and Sustainable Development Project (MMSD)*. (August 2001):362. DOI: ENV-P-C 2001-042.

Bebbington, A.A. & Williams, M. 2008. Water and Mining Conflicts in Peru Water and Mining Conflicts in Peru. *Mountain Research and Development*. 28(3):190–195. DOI: 10.1659/mrd.1039.

Behmel, S., Damour, M., Ludwig, R. & Rodriguez, M.J. 2016. Science of the Total Environment Water quality monitoring strategies — A review and future perspectives. *Science of the Total Environment*, The. 571:1312–1329. DOI:

10.1016/j.scitotenv.2016.06.235.

Central Statistical Office. 2013a. *2010 Census of Population and Housing: Migration and Urbanization Analytical Report*. Available: [https://psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Eastern Visayas.pdf](https://psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Eastern%20Visayas.pdf).

2013b. *2010 Census of Population and Housing - Population and Demographic Projections 2011 - 2035*. Available: [https://www.zamstats.gov.zm/phocadownload/Zambia Census Projection 2011 - 2035.pdf](https://www.zamstats.gov.zm/phocadownload/Zambia%20Census%20Projection%202011%20-%202035.pdf) [http://www.zamstats.gov.zm/phocadownload/Zambia Census Projection 2011 - 2035.pdf](http://www.zamstats.gov.zm/phocadownload/Zambia%20Census%20Projection%202011%20-%202035.pdf).

2014. *2010 Census of population and housing Copperbelt province analytical report*.

2017. *RESEARCH PAPER ON PROVINCIAL GROSS DOMESTIC PRODUCT*. Lusaka. Available: www.zamstats.gov.zm.

Chanda, S. & Wilson, M. 2017. The Effect of Mining on the Environment : A case Study of Kankoyo Township of Mufulira District of the Republic of Zambia THE EFFECTS OF MINING ON THE ENVIRONMENT : A CASE STUDY OF KANKOYO TOWNSHIP OF MUFULIRA DISTRICT OF THE REPUBLIC OF ZAMBIA MADENCİLİĞİ. (October).

Chitonge, H. 2011. A decade of implementing water services reform in Zambia: Review of outcomes, challenges and opportunities. *Water Alternatives*. 4(3):279–300.

Chomba, M.J. & Nkhata, B.A. 2016. *Water Security on the Kafue Flats of Zambia. Technical Report of the International Water Security Network, Water Research Node, Monash South Africa, Johannesburg*.

Cobbina, S.J., Duwiejuah, A.B., Quansah, R. & Obiri, S. 2015. Comparative Assessment of Heavy Metals in Drinking Water Sources in Two Small-Scale Mining Communities in. *International Journal of Environmental Research and Public Health*. 12(72):10620–10634. DOI: 10.3390/ijerph120910620.

Danoucaras, A.N., Woodley, A.P. & Moran, C.J. 2014. The robustness of mine water accounting over a range of operating contexts and commodities. *Journal of Cleaner Production*. 84:727–735. DOI: 10.1016/j.jclepro.2014.07.078.

Endo, A., Tsurita, I., Burnett, K. & Orenco, P.M. 2017. A review of the current state of research on the water, energy, and food nexus. *Journal of Hydrology: Regional Studies*. 11:20–30. DOI: 10.1016/j.ejrh.2015.11.010.

Foil Vedanta. 2016. How KCM is killing the Zambian Copperbelt. Part 1: water pollution. 2019. *Landmark jurisdiction case won by Zambian farmers at Supreme Court*. Available: <http://www.foilvedanta.org/uncategorized/landmark-jurisdiction-case-won-by-zambian-farmers-at-supreme-court/> [2019, April 11].

Foil Vendata. 2016. How KCM is Killing the Zambian Copperbelt: Water Pollution. (February). Available: <http://www.ipsnews.net/2007/08/environment-zambia-efforts-to-halt-the-strangulation-of-kafue/>.

Franks, D.M., Brereton, D. & Moran, C.J. 2010. Managing the cumulative impacts of coal mining on regional communities and environments in Australia. *Impact Assessment and Project Appraisal*. 28(4):299–312. DOI: 10.3152/146155110X12838715793129.

Gilberthorpe, E., Agol, D. & Gegg, T. 2016. ‘ Sustainable Mining ’ ? Corporate Social Responsibility , Migration and Livelihood Choices in Zambia. *The Journal of Development studies*. 52(11):1517–1532.

Government of the Republic of Zambia. 2017. *7 National Development Plan 2017 - 2021*.

Government of the Republic of Zambia - Republic of Denmark. 2007. *Sector Capacity Study Water and Sanitation Final Report*.

Grigg, N.S. 2019. Water – Health Nexus : Modeling the Pathways and Barriers to Water-Related Diseases. *Water Resources Management*. 33:319–335. Available: <https://doi.org/10.1007/s11269-018-2104-4>.

Gurria, A. 2017. *Putting water at the centre of the global agenda*. New York. Available: www.oecd.org/water.

High Court of Zambia. 2011.

Hughes-Jennett, J. 2019. Vedanta Resources PLC and Another (Appellants) v. Lungowe and Others (U.K. Sup. Ct.). *International Legal Materials*. 58(5):1114–1138. DOI:

10.1017/ilm.2019.44.

Ian H., Louis, G. n.d. *Practical aspects of watersealing at Konkola copper mine , Zambia.*

ICMM & Chamber of Mines of Zambia. 2014. *Enhancing mining ' s contribution to the Zambian economy and society Mining : Partnerships for Development.*

International Council of Mining & Metals. 2012. *Water management in mining : a selection of case studies.* London. DOI: 978-0-9559983-7-9.

Japanese International Agency (JICA) -Ministry of Energy and Water Development (MEWD). 1995. *Zambia National Water Resources Master Plan.*

JICA-MEWD. 1995. *THE STUDY ON THE NATIONAL WATER RESOURCES MASTER PLAN N THE REPUBLIC OF ZAMBIA.*

Juma, D.W., Wang, H. & Li, F. 2014. Impacts of population growth and economic development on water quality of a lake: Case study of Lake Victoria Kenya water. *Environmental Science and Pollution Research.* 21(8):5737–5746. DOI: 10.1007/s11356-014-2524-5.

Kangwa, P.K. 2008. *An Assessment of the Economic , Social and Environmental Impacts of the Mining Industry: A Case Study of the Copper Mining in Zambia.* LUND University.

Karen, M., El-fahem, T. & Museteka, L. 2015. *Groundwater Resources for Lusaka and selected Catchment Areas:HYDROGEOLOGY OF THE TOWN AREA OF SOLWEZI - BASELINE STUDY ON HYDROGEOLOGY AND HYDROCHEMISTRY.* Lusaka.

Kemp, D., Bond, C.J., Franks, D.M. & Cote, C. 2010. Mining , water and human rights : Making the Connection. *Journal of Cleaner Production.* 18(15):1553–1562. DOI: 10.1016/j.jclepro.2010.06.008.

Kunz, N.C. & Moran, C.J. 2014. Sharing the benefits from water as a new approach to regional water targets for mining companies. *Journal of Cleaner Production.* 84(1):469–474. DOI: 10.1016/j.jclepro.2014.02.053.

Kunz, N.C., Moran, C.J. & Kastle, T. 2013. Implementing an integrated approach to water management by matching problem complexity with management responses: A

case study of a mine site water committee. *Journal of Cleaner Production*. 52:362–373. DOI: 10.1016/j.jclepro.2013.03.018.

Lange, G.-M. & Hassan, R. 2006. The Economics of Water Management in Southern Africa. *Economic Policy*. DOI: 10.4337/9781847203021.

Lindahl, J. 2014. *Towards better environmental management and sustainable exploitation of mineral resources*. Uppsala. Available: www.sgu.se.

Liyanage, C.P. & Yamada, K. 2017. Impact of Population Growth on the Water Quality of Natural Water Bodies. DOI: 10.3390/su9081405.

Loucks, D.P. 2017. Managing Water as a Critical Component of a Changing World. *Water Resources Management*. 31:2905–2916. DOI: 10.1007/s11269-017-1705-7.

M'Kandawire, E. 2010. DETECTION OF BIOLOGICAL EFFECTS OF ENVIRONMENTAL POLLUTANTS OF THE KAFUE RIVER ON THE KAFUE LECHWE (KOBUS LECHE KAFUENSIS) BY CHARACTERIZATION OF SELECTED BIOMARKERS. University of Zambia.

Makondo, C.C., Sichilima, S., Silondwa, M., Sikazwe, R., Maiba, L., Longwe, C. & Chiliboyi, Y. 2015. Environmental Management Compliance, Law and Policy Regimes in Developing Countries: A Review of the Zambian Case. *International Journal of Environmental Protection and Policy*. 3(4):79. DOI: 10.11648/j.ijep.20150304.11.

Mbula, M. 2016. IMPACTS OF WATER HYACINTH ON SOCIO-ECONOMIC ACTIVITIES ON KAFUBU RIVER IN THE COPPERBELT PROVINCE: A Case Study of Ndola District, Zambia.

Mcgrane, S.J. 2016. Impacts of urbanisation on hydrological and water quality dynamics , and urban water management : a review water management : a review. *Hydrological Sciences Journal*. 61(13):2295–2311. DOI: 10.1080/02626667.2015.1128084.

McIntyre, N., Bulovic, N., Cane, I. & McKenna, P. 2016. A multi-disciplinary approach to understanding the impacts of mines on traditional uses of water in Northern Mongolia. *Science of the Total Environment*. 557–558:404–414. DOI: 10.1016/j.scitotenv.2016.03.092.

Mhlongo, S., Mativenga, P.T. & Marnewick, A. 2018. Water quality in a mining and water-stressed region. *Journal of Cleaner Production*. 171:446–456. DOI: 10.1016/j.jclepro.2017.10.030.

Ministry of Local Government and Housing (MLGH). 2015. *National Urban and Peri-Urban Sanitation Strategy (2015-2030)*. Available: https://www.washwatch.org/uploads/filer_public/eb/8b/eb8b5d5c-c067-4fcd-9ed5-7d57e8eeb1b1/national_urban_and_peri-urban_sanitation_strategy_2015-2030_ministry_of_local_government_and_housing_2015.pdf.

Ministry of Mines and Minerals Development. 2016. *Zambia Mining Environment Remediation and Improvement Project: Environmental and Social Framework*.

Mwansa, C.C. 2016. A Political Ecology of Copper Production and Environmental Degradation In Zambia.

National Water Supply and Sanitation Council. 2008. *Urban and Peri-Urban Water Supply and Sanitation Sector Report 2007/2008*.

2018. *Urban and Peri-Urban Water Supply and Sanitation Sector Report 2017*.

Nkhuwa, D.C.W., Mweemba, C. & Kabika, J. 2013. *Zambia: Country Water Resource Profile*. Available: <http://nepadwatercoe.org/wp-content/uploads/CountryWaterResourceReport-MalawiFinal1.pdf>.

Norrgrén, L., Örn, S., Bergqvist, P. & Ab, E. 2000. Environmental Monitoring of the Kafue River, Located in the Copperbelt, Zambia. *Archives of Environmental Contamination and Toxicology*. 38(May). DOI: 10.1007/s002449910044.

Northey, S.A., Mudd, G.M., Saarivuori, E., Wessman-Jääskeläinen, H. & Haque, N. 2016. Water footprinting and mining: Where are the limitations and opportunities? *Journal of Cleaner Production*. 135:1098–1116. DOI: 10.1016/j.jclepro.2016.07.024.

Ntengwe, F.W. 2006. Pollutant loads and water quality in streams of heavily populated and industrialised towns. 31:832–839. DOI: 10.1016/j.pce.2006.08.025.

NWASCO. 2015. *STRATEGIC PLAN 2016 - 2020*. Lusaka.

Nyambe, I.A. 2008. Institutional implications, issues and necessities for effective Water Demand Management in Zambia. 1–16. Available: <https://webcache.googleusercontent.com/search?q=cache:kMG1c5f7hJwJ:https://www.riob.org/en/file/264429/download%3Ftoken%3DeJ190Klu+&cd=38&hl=en&ct=clnk&gl=us&client=safari>.

Nyambe, I.A. & Feilberg, M. 2009. *Zambia – National Water Resources Report for WWDR3 (Theme -Water in a Changing World)*. Lusaka.

Ochieng, G.M., Seanego, E.S. & Nkwonta, O.I. 2010. Impacts of mining on water resources in South Africa : A review Impacts of mining on water resources in South Africa : A review. *Scientific Research and Essays*. 5(22):3351–3357. Available: www.academicjournals.org/SRE.

Okello, C., Tomasello, B., Greggio, N., Wambiji, N. & Antonellini, M. 2015. Impact of Population Growth and Climate Change on the Freshwater Resources of Lamu Island, Kenya. *Water*. 7:1264–1290. DOI: 10.3390/w7031264.

Pegasys and WWF. 2016. *Exploring shared risks and opportunities in the Kafue Flats*. Available: http://d2ouvy59p0dg6k.cloudfront.net/downloads/water_in_the_zambian_economy_final_2nd_edition.pdf.

Peletz, R., Kisiangani, J., Bonham, M., Ronoh, P., Delaire, C., Kumpel, E., Marks, S. & Khush, R. 2018. Why do water quality monitoring programs succeed or fail? A qualitative comparative analysis of regulated testing systems in sub-Saharan Africa. *International Journal of Hygiene and Environmental Health*. (February):1–14. DOI: 10.1016/j.ijheh.2018.05.010.

Pettersson, U. 2002. A Geochemical Study of the Kafue River , Zambia. Lulea Universty of Technology.

Pettersson, U.T. & Ingri, J. 2001. The geochemistry of Co and Cu in the Kafue River as it drains the Copperbelt mining area , Zambia. *Chemical Geology*. 177:399–414.

Population Action International. 2011. *Why Population Matters to WATER RESOURCES*.

Ren, L., Cui, E. & Sun, H. 2014. Temporal and spatial variations in the relationship between urbanization and water quality. *Environmental Science and Pollution Research*. 21(23):13646–13655. DOI: 10.1007/s11356-014-3242-8.

Republic of Zambia. 2006. *Vision 2030 : A Prosperous Middle Income-Nation By 230*.

2010. *National Water Policy (2010)*. Lusaka.

2014. *Report of the Auditor General on the Management of Environmental Degradation Caused by Mining Activities in Zambia*. Lusaka.

SADC. 2010. *Economic Accounting of Water Use*.

Sambo, P.T. 2019. Konkola Copper Mines PLC v Nyasulu and 2000 Others Appeal No. 1/2012. *SAIPAR Case Review*. 2(2):4.

Dos Santos, S., Adams, E.A., Neville, G., Wada, Y., de Sherbinin, A., Mullin Bernhardt, E. & Adamo, S.B. 2017. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. *Science of the Total Environment*. 607–608:497–508. DOI: 10.1016/j.scitotenv.2017.06.157.

Schuler, P.M. & Lokanc, M. 2015. Making Mining Work for Zambia: The Economic, Health, and Environmental Nexus of Zambia’s Copper Mining Economy. (5).

SGAB-SWECO-THMRO-UNZA. 2005. *PREPARATION OF PHASE 2 OF A CONSOLIDATED ENVIRONMENTAL MANAGEMENT PLAN: Surface Water Resources and Water Quality in the Upper Kafue River*.

SGAB-THOMRO-SWECO-UNZA. 2005. *Future secure domestic water supply in the Copperbelt*.

Sibanda, N. 2007. *ENVIRONMENT-ZAMBIA: Efforts to Halt the Strangulation of Kafue*. Lusaka. Available: <http://www.ipsnews.net/2007/08/environment-zambia-efforts-to-halt-the-strangulation-of-kafue/%0D> [2018, December 20].

Sichilima, S., Makondo, C. & Lungu, C. 2015. Impact Assessment of Increasing Population in Suburban Areas on Water Quality — A Case Study in Kitwe Township-Zambia. *International Journal of Environmental Science and Development*. 6(1):34–39.

DOI: 10.7763/IJESD.2015.V6.557.

Sikamo, J., Mwanza, A. & Mweemba, C. 2016. Copper mining in Zambia - History and future. *Journal of the Southern African Institute of Mining and Metallurgy*. 116(6):491–496.

Sikosana, M.K.L.N., Randall, D.G. & von Blottnitz, H. 2017. A technological and economic exploration of phosphate recovery from centralised sewage treatment in a transitioning economy context. *Water SA*. 43(2):343–353. DOI: 10.4314/wsa.v43i2.17.

Siwila, S. 2015. A Mini-Review on Zambia ' s Water Governance in a Changing Climate. *EC Agriculture*. 2.2:285–299.

Sracek, O., Mihaljević, M., Kr̃ibekMajer, V. & Veselovsky, F. 2010. Geochemistry and mineralogy of Cu and Co in mine tailings at the Copperbelt , Zambia. *Journal of African Earth Sciences*. 57:14–30. DOI: 10.1016/j.jafrearsci.2009.07.008.

Sracek, O., Kribek, B., Mihaljevic, M., Majer, V., Veselovsky, F., Vencelides, Z. & Nyambe, I. 2012. Mining-related contamination of surface water and sediments of the Kafue River drainage system in the Copperbelt district, Zambia: An example of a high neutralization capacity system. *Journal of Geochemical Exploration*. 112:174–188. DOI: 10.1016/j.gexplo.2011.08.007.

The Lusaka Times. 2018. Make Pollution Political -1826 Zambian claimants Demand Justice in Supreme Court, London. *The Lusaka Times* (Lusaka). 31 December.

The World Bank. 2009. *Zambia Managing Water for Sustainable Growth and Poverty Reduction: A Country Water Resource Assistance Strategy for Zambia*. Washington DC. Available: www.worldbank.org.

Trottier, J. 2007. *Technical Report : Second Order Water Scarcity in Southern Africa*.

Tychsen, J., Mukofu, C., Msimuko, J., Zimba, K., Chadukwa, C., Chibonga, M., Phiri, C., Simukali, M., et al. 2018. “ASM Handbook for Zambia” *Geological Survey of Denmark and Greenland (GEUS)*. Copenhagen.

Uhlendahl, T., Salian, P., Casarotto, C. & Doetsch, J. 2011. Good water governance and

IWRM in Zambia: Challenges and chances. *Water Policy*. 13(6):845–862. DOI: 10.2166/wp.2011.155.

UNEP. 2016a. *Options for decoupling economic growth from water use and water pollution: A report of the Water Working Group*.

2016b. *A Snapshot of the World's Water Quality: Towards a global assessment*. Nairobi.

USGS. 2019. *2015 Minerals Yearbook: The Mineral Industry of Zambia*.

Voulvoulis, N., Skolout, J.W.F., Oates, C.J. & Plant, J.A. 2013. From chemical risk assessment to environmental resources management : the challenge for mining. *Environ Sci Pollut Res*. 20:7815–7826. DOI: 10.1007/s11356-013-1785-8.

WARMA. 2020. *WARMA Home - Zambia Water Resources Management Website*. Available: <http://www.warma.org.zm/> [2020, November 24].

Wessman, H., Salmi, O., Kohl, J., Kinnunen, P., Saarivuori, E. & Mroueh, U. 2014. Water and society : mutual challenges for eco-efficient and socially acceptable mining in Finland. *Journal of Cleaner Production*. 84:289–298. DOI: 10.1016/j.jclepro.2014.04.026.

Woodley, A., Danoucaras, A., McCombe, C., Kunz, N. & Collins, N. 2013. A Robust Methodological Approach for Mine Site Water Accounting. In *Water in Mining 2013 Proceedings*. Brisbane: The Australasian Institute of Mining and Metallurgy. 335–342.

World Bank. 2009. *Zambia - Managing Water for Sustainable Growth and Poverty Reduction: A country Water Resource Assistance Strategy for Zambia*. Washington DC. Available: www.worldbank.org.

2015. *Zambia Economic Brief: Making Mining Work for Zambia: The Economic, Health, and Environmental Nexus of Zambia's Copper Mining Economy*. Washington.

2016a. *Zambia Mining Investment and Governance Review*. (April).

2016b. *THE MINING INVESTMENT AND GOVERNANCE REVIEW (MInGov) ZAMBIA MINING INVESTMENT AND GOVERNANCE REVIEW - FINAL REPORT APRIL 2016*.

WWAP (United Nations World Water Assessment Programme)/UN-Water. 2018. *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water*.

Paris. Available: www.unwater.org.

WWAP (United Nations World Water Assessment Programme). 2015a. *The United Nations World Water Development Report 2015 WATER FOR A SUSTAINABLE WORLD FACTS AND FIGURES*.

2015b. *The United Nations World Water Development Report 2015: Water for a Sustainable World*. Paris. Available: <http://www.unwater.org>.

WWF. 2017. *Kafue Flats Status Report: Monitoring the pulse of the blue*. Lusaka.

2018. *Water Situational Analysis of the Lower Kafue Basin: SOCIO-ECONOMIC DEVELOPMENT AND CLIMATE CHANGE: RISKS AND OPPORTUNITIES*.

Zambia Chamber of Mines. 2019. *Downloads – Page 2 – Zambia Chamber of Mines*. Available: <http://mines.org.zm/downloads/page/2/> [2019, November 26].

Zambia Extractive Industries Transparency Initiative (EITI). 2019. *10th Zambia EITI Report*.

Zambia Statistics Agency & Ministry of Labour and Social Security. 2020. *2019 Labour Force Survey Report*. Available: http://www.statistics.gov.my/portal/download_Labour/files/labour_force/Labour_Force_Survey_Report_Malaysia_2012.pdf.

Zambian Business Times. 2020. Copperbelt Surpasses Lusaka in National GDP Contribution. *Pressreader*. 11 December.

Zambian Ministry of Mines and Mineral Development & Trimble Land Administration. 2020. *Zambia Mining Cadastre Portal - Supported by Spatial Dimension - Developers of FlexiCadastre*. Available: <https://portals.landfolio.com/zambia/> [2020, November 27].

ZCCM-IH. 2002. *Environmental assessment of the Copperbelt and Kabwe area*.

Zientek, M.L., Bliss, J.D., Broughton, D.W., Christie, M., Denning, P.D., Hayes, T.S., Hitzman, M.W., Horton, J.D., et al. 2014. *Sediment-hosted stratabound copper assessment of the Neoproterozoic Roan Group, Central African Copperbelt, Katanga basin, Democratic Republic of the Congo and Zambia: U.S. Geological Survey Scientific*

Investigations Report 2010-5090-T. Available: <http://dx.doi.org/10.3133/sir20105090T>.

APPENDICES

APPENDIX A: Interview Questions and Response

1. Water Resources Management Authority (WARMA)

Sn	Questions	Response
i)	Do you monitor ground and surface water quality and how often do you conduct this?	Yes (surface water), on quarterly basis. However, this is dependent on availability of funds.
ii)	What water parameters do you test for and why?	PH, EC, TDS, DO; these are done on-site since they are unstable. Heavy metals (Pb,Zn,Mn,Fe,Cd,) are done at the lab dependent on the available Atomic Absorption Spectrometry (ASS);total hardness, Mg hardness,Ca,Mg,K,Na,alkalinity,chlorides,nitrates,HCO ₃ ⁻ ,these test are done owing to the underlying geology, agricultural and anthropogenic activities ;fecal coliforms, total coliforms.
iii)	Do you carry out water test on-site or at the laboratory also?	Yes
iv)	How many water permits have been issued to date? What are the amounts applied for and what is being actually abstracted?	Data provided (soft copy in Excel) for Kafue Catchment
v)	How often do you collect data on river flows?	River flow data is collected daily (real time data through Integrated Water Resources Management Information System (IWRMIS) and by gauge readers
vi)	There is more consistency on flows (Upper Kafue	Initially there were over 300 stations (previously managed by dept. of Water Affairs. Some stations are not operational and

	River) from 1969 to 2001, but from 2002 to date, there are gaps, any explanation for this?	no gauge readers due financial constraints. The other reason was also due to institutional reforms and that some gauge readers were not submitting reports on time - reasons that resulted in this inconsistency.
vii)	Do mining companies specifically report on how much water they abstract, and the quality of dewatering and effluent discharge?	Not yet started collecting data on groundwater (dewatering) but regulation for dewatering are underway.
viii)	How often do holders of permit submit reports, monthly or annually and is the data available to the public? How are these water data used? Which decisions do they influence?	Monthly submission but not available to the public. Inspectors install back flow meters for monitoring purposes. The water data is used for assessing water demand in the catchment. This information is also useful in the allocation of water permits.
ix)	Do you have a database for managing water-related information? Or is the data gathered in report format?	Data base is available (IWRMIS)
x)	What are the greatest challenges that you face in increasing the availability of water quantity or quality data?	Data/reports are not received on time. We receive monthly on environmental flows and hydrology
xi)	Have there been any changes in recent years (e.g. last 10 years) regarding the type of water data that you collect? If so, do you collect	In the past gauge, readers were using standard hard copy forms for data entry. More efficient (2014/2015) data collection from hydrometric station after the installation of telemetric instruments. In addition, this is transmitted to Lusaka (HQ) for storage.

	<p>more/less/different data? What have been the reasons for these changes?</p>	
xii)	<p>Do you coordinate with other government agencies? If so, which ones and why?</p>	<p>Yes;</p> <ul style="list-style-type: none"> ▪ ZEMA: On effluent monitoring and conditions for EIAs before approval ▪ Ministry of Agriculture: Collaborate on catchment management plans ▪ Universities (UNZA,CBU): Collaborate on research ▪ Disaster Management and Mitigation unit: Collaborate on emergency response (e.g. floods) ▪ Meteorological department: Collaborate on climate (weather forecasts) ▪ NWASCO: Collaborate on the development of catchment management plan and water users associations and general advice on water management

2. Questions and Responses for Zambia Environmental Management Agency

Sn	Questions	Response
i)	How often do you monitor water quality of effluents and what parameters do you test for and why?	at least one a year; Heavy metals, TSS, sulphur, BOP & COP; these are the critical ones for mining.
ii)	Do mining companies submit reports on environmental management and do the reports capture data on water quality and quantity of dewatering or effluent discharge into the environment?	yes, reports are submitted & data on water/effluent discharge into the environment is captured.
iii)	How often do you conduct compliance monitoring or environment audits?	not systematic; sometimes once a year & sometimes none.
iv)	Do you carry out water test on-site or at the laboratory also?	on site tests are done for some parameters while others are done at the lab.
v)	What are the greatest challenges that you face in improving water quality monitoring?	inadequate manpower & financial resources
vi)	Have there been any changes in recent years (e.g. last 10 years) regarding the type of water data that you collect? If so, do you collect more/less/different data? What have been the reasons for these changes?	No. most of the data collected is similar so that comparisons and trends are established.
vii)	Do you coordinate with other government agencies? If so, which ones and why?	yes. WARMA, MSD, NUASCO. They are regulators in the sector. The collaboration is also provided for in the pieces of legislation we enforce.

3. Questions and Responses for National Water Supply and Sanitation Council (NWASCO)

Sn	Questions	Response
i)	What parameters do you test for potable water and why?	<p>Physiochemical: PH, Turbidity, colour and free chlorine (residual).In the case of commercial utilities downstream of mining operations, tests for Cu,Co,Mn,Fe,alkalinity This is because the parameters have a bearing on the behavior of bacteria and treatment cost. For example, high turbidity helps bacteria to hibernate on the surface making chlorine ineffective. PH will also influence chemical reactions in terms of dissociation of chlorine. Since bacteria has a negative charge, coagulation is also affected. Low PH will lead to corrosion of GI pipes.PH of more than 8.5 becomes corrosive especially for metal industries. PH also influence the test of water. Colour of the water will affect customer perception and this why water should be “Clean and Safe”</p> <p>Microbiological: E-coli, feacal coliforms and total coliforms. These have an immediate impact on the health of consumers and as such, there water should be free of these parameters.</p>
ii)	What chemicals do commercial utilities (CUs) use in water treatment?	<p>i. Iron sulphate and aluminium sulphate. However, aluminium sulphate is preferred.</p>

		ii. Chlorine (granular and gas)
iii)	What can you attribute the rising cost for chemicals, particularly for Copperbelt based CUs, to?	<p>The rising cost of chemicals is attributed to growth of algae (Kafubu River) where there is discharge of sewer effluents. This raises the chlorine demand due to pretreatment (stop microbiology growth) and dose chlorine.</p> <p>In the case of commercial utilities in the mining areas (Mulonga & Nkana), the pollution (relative) from the mines raises the chlorine demand due to presence of heavy metals in the water.</p> <p>The rising cost can also be attributed to economic factors (depreciation of the local currency- Kwacha)</p>
iv)	The water production in the Copperbelt region has been almost constant since 2001, what could be the reason behind this trend?	<p>The water production has been almost constant due to low funding and investment in the sector and made the operation unsustainable. However, from 2011 there has been an increased investment in the sector.</p> <p>The other factor is that most the infrastructures are very old (45-55 years) with the same design capacity</p>
v)	In which ways do you think that mining might have influenced potable water quality?	In the case of commercial utilities in the mining areas (Mulonga & Nkana), the pollution (relative) from the mines raises the chlorine demand due to presence of heavy

		metals (Co,Cu,Mg,Mn) and turbidity in the water
vi)	Have there been any changes in recent years (e.g. last 10 years) regarding the type of water data that you collect? If so, do you collect more/less/different data? What have been the reasons for these changes?	Yes, the Council has now added leakage index (leakages/m), plant utilization (water treatment and sewage). The 2017 sector report highlights this aspect. The council has been also delegated to look at own septic tanks designs in conjunction with local authorities. This is to improve efficiency in the sector in a sustainable way
vii)	What are the greatest challenges that you face in improving potable water quality monitoring?	No greater challenges in water quality monitoring since the council employs temporal inspectors in most parts of the country. Moreover, this has improved efficiency. The challenge that we have is in terms of compliance monitoring due to the fact most water treatment facilities were not designed to remove heavy metals and are very old as such quality of water may be compromised.
viii)	Do you coordinate with other government agencies? If so, which ones and why?	Yes and it at different levels. The coordination is with all the stakeholders in the water sector. These are ZEMA, Zambia Bureau of standards (ZABS), WARMA, Ministry of health, Ministry of water dept., ministry of local government, higher learning institutions. For example, WARMA is currently developing ambient water quality standards and we are collaborating on that aspect. In our strategic plan, goal 3, more cooperation is highlighted with WARMA.

		<p>The ministry of health collaborates with us especially when it comes waterborne disease. The ministry of education owns boreholes in schools (especially in rural areas) and we have cooperated well in the development of rural water quality monitoring standards and for education campaigns in the sector. ZABS has been engaged by the council to evaluate the water quality monitoring standards to be launched next year. ZEMA regulates what we discharge into the environment and NWASCO mandate is up to discharge points. The local authority have now delegated the regulation of sanitation facility (pit latrines ,septic tanks) designs for private owned to NWASCO</p>
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4. Introductory Letter for Data Collection



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Master of Philosophy programme
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30 November 2017

To whom it may concern,

Re: Data for Copperbelt Province and Access to Water Information

Mr Bright Mwamba, a hydrogeologist based in Zambia, is one of our students registered for his Master of Philosophy specialising in Sustainable Mineral Resource Development.

For completion of his thesis focussing on water resources management we would like to request permission for data for the Copperbelt province and any water information from your organisation that might be helpful for his project.

Please could you let us know if this is possible, and whether you have any questions or queries.

With many thanks and best wishes,

Signature Removed

Dyllon

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Appendix B: Kafue River Flow Measurements

Kafue River Flow Rates @ Raglan Station (m³/s)														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Stdev
2000	91.6	177	200	171	76	29	20.2	13.8	7.85	1.21	1.5	15.39	67.05	75.3589
2001	18.5	69.7	66	42	23	10.4	6.51	4.13	2.1	3.42	2.76	7.672	21.32333	24.51395
2002	56.1	313	-	-	-	-	-	-	-	1.2	1.61	1.9	74.831	135.3863
2003	23.6	54.9	85	78.4	-	15	9.31	6.27	-	-	-	-	38.98414	33.49247
2004	57.9	80.9	34	25.3	12	4.87	3.15	2.05	1.26	-	1.86	11.38	21.31636	26.43062
2005	2.7	-	100	-	-	-	-	-	-	-	0.74	2.33	26.3595	48.88101
2006	121	132	115	57.6	19	10.3	6.76	4.61	2.36	1.07	1.49	6.334	39.77981	52.38129
2007	39.5	115	129	100	27	12.8	8.63	6.13	3.15	1.31	1.37	10.99	37.97892	48.02511
2008	87.6	-	-	74.9	52	-	-	-	-	1.51	3.53	31.63	41.785	35.99511
2009	91.1	156	186	198	151	62.3	13.8	-	-	226	114	17.1	121.447	74.45133
2010	16.6	81.7	113	131	79	24.1	19.2	15.9	-	-	-	11.04	54.51889	46.76999
2011	28.9	63.9	117	129	49	-	12.1	-	4.94	-	-	-	57.86157	49.01936
2012	54.7	-	-	73.4	-	-	-	-	-	3.38	1.7	19.22	30.4702	32.07267

Kafue River Flow Rates @ Smith Bridge Station (m³/s)														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Stdev
2000	238.8	-	-	250.5	160	92.3	83.65	83.6	83.5	-	-	50.1	130.2563	77.0022
2001	119.2	195	164.5	112.3	64.6	38.4	27.74	21.2	16	83.3	83.1	60.5	82.12917	56.80899
2002	90.5	154	185.8	219.2	109	48.4	33.64	25	17.8	-	-	45.2	92.83	71.94617
2003	132.9	161	207.4	164.6	120	19.3	-	-	-	-	19.6	33.8	107.3313	73.53218
2004	148.8	159	105.7	68.51	44.9	19.3	17.02	-	-	12	12.9	40.1	62.822	56.19269
2005	-	-	-	-	-	-	-	-	11.8	-	-	-	11.78	
2006	166.5	244	299.1	-	-	-	-	-	-	8.77	9.9	31.3	126.5843	127.8169
2007	-	-	-	-	-	-	-	-	-	-	-	-		
2008	-	-	-	-	-	-	-	-	19.1	-	-	-	19.14	
2009	167.6	220	-	220.8	137	-	-	-	23	14	17	-	114.2614	94.68074
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Kafue River Flow Rates @ Wusakile Station (m ³ /s)														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Stdev
2000	-	-	-	-	-	-	-	54.2	47.8	-	-	-	51.015	4.532554
2001	-	-	-	-	-	-	-	54.1	47.8	-	-	-	50.925	4.475986
2002	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	139	137.6	102.1	68.3	36.16	19.81	-	-	-	-	19.9	42.65	70.71625	49.72612
2005	-	48.06	42.51	42.44	42.39	42.41	53.18	56.1	42.4	-	-	65.58	48.34111	8.331531
2006	143	237.7	233.8	119.7	56.08	35.43	28.32	22.8	18.4	39.6	39.5	39.72	84.5075	80.34661
2007	-	-	-	-	69.91	-	-	-	-	17.6	19	-	35.51667	29.79326
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2011	115	-	-	207.2	95.63	-	-	-	-	-	-	-	139.21	59.65612
2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Kafue River Flow Rates @ Mpatamato Station (m ³ /s)														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Stdev
2000	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	96	155	155	-	-	-	-	-	-	-	12	19	87.234	69.90034
2005	24	119	227	111	59.4	35.3	33.1	33	35	5.70	4.21	3.06	57.47533	65.47178
2006	41	41	41.1	43.2	36.7	31.3	31.2	31	20	39	41	41	36.53417	6.795381
2007	130	279	240	128	63	45.7	33.6	26	16	8.69	12	22	83.70542	92.28352
2008	178	367	327	193	116	75.8	75.8	76	76	10	8.6	70	130.9792	115.0608
2009	162	215	388	215	106	-	-	-	-	76	76	79	164.5713	107.817
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Kafue River Flow Rates @ Machiya Station (m³/s)														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVERAGE	STDEV
2000	-	-	-	-	-	-	135	108	16.7	12.8	-	-	68.1875	62.722
2001	-	-	-	-	-	-	-	-	-	12.7	-	-	12.7	-
2002	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	157	251	159	100	49	33.57	-	-	-	18.6	22.65	49.38	93.3467	80.006
2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2015	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Water Resources Management Authority (WARMA)

APPENDIX C: Water Production and Consumption

Year	Water Consumption (million m ³)	Water Production by Utilities (million m ³)
2000	-	-
2001	90.13	191.4
2002	84.24	185.1
2003	91.84	198.4
2004	101.33	198.4
2005	103.8	186.8
2006	103.9	187.9
2007	104.1	184.8
2008	103.3	181
2009	98.7	172.7
2010	97.52	171.4
2011	91.7	171.6
2012	93.62	161.65
2013	74.2	156.86
2014	77.7	175.6
2015	74.5	176.4
2016	75.2	163.2
2017	76.79	157

Year	Water Production (Million m ³)	Population Served	Water Production per Capita (l/c/d)
2001	191.4	1,213,325	432.19
2002	185.1	1,188,175	426.81
2003	198.4	1,129,398	481.28
2004	198.4	1,382,030	393.31
2005	186.8	1,453,437	352.12
2006	187.9	1,470,844	350.00
2007	184.8	1,442,376	351.02
2008	181	1,477,031	335.73
2009	172.7	1,531,309	308.98
2010	171.4	1,601,150	293.28
2011	171.6	1,633,801	287.76
2012	161.65	1,661,977	266.48
2013	156.86	1,709,227	251.43
2014	175.6	1,758,618	273.56
2015	176.4	1,801,350	268.29
2016	163.2	1,804,289	247.81
2017	157	1,847,977	232.76

Source: National Water Supply and Sanitation Council (NWASCO)

APPENDIX D: Population and Economic Growth

Copperbelt Province								
	Census Year		Projected Population					
Year	2000	2010	2011	2012	2013	2014	2015	2020
Population	1,581,221	1,972,317	2,143,413	2,195,878	2,249,824	2,305,258	2,362,207	2,669,635

Year	GDP (K' Million)	Population
2000	47,404.85	1,581,221
2001	49952.31	-
2002	52,174.95	-
2003	55798.48	-
2004	59722.45	-
2005	64043.73	-
2006	69105.55	-
2007	74877.55	-
2008	80699.45	-
2009	88134.13	-
2010	97215.88	1,972,317
2011	103377.9	2,143,413
2012	110335.8	2,195,878
2013	117743.1	2,249,824
2014	124335	2,305,258
2015	125003.5	2,362,207
2016	129699.9	-
2017	134987.5	-

Source: Central Statistical Office reports (2000-2017)

APPENDIX F: Copper Production

Year	National Copper Production (Metric tonnes '000)	Copper Production on the Copperbelt (Metric tonnes '000)	GDP (K' Million)
2000	227	226.805	47,404.85
2001	300	297.292	49,952.31
2002	330	335.023	52,174.95
2003	340	372.212	55,798.48
2004	400	424.499	59,722.45
2005	410	388.523	64,043.73
2006	490	388.302	69,105.55
2007	561	399.556	74,877.55
2008	575	358.182	80,699.45
2009	699	276.387	88,134.13
2010	767	294.756	97,215.88
2011	740	304.927	103,377.86
2012	721	345.615	110,335.78
2013	764	359.038	117,743.12
2014	708	348.491	124,335.00
2015	711	320.871	125,003.50
*2016	771	242.698	129,699.90
*2017	797	236.637	134,987.50

Source: Central Statistical Office (CSO) reports; 2016 and 2017 data is from Chamber of Mines annual reports.

APPENDIX G: Water and Sanitation Coverage

Year	Total Population in serviced Areas	Population Served with Water Supply	Population Served with Sanitation	Copperbelt Water Supply Coverage (%)	Copperbelt Sanitation Coverage (%)
2001	1,504,747	1,213,325	690,889	80.6	45.9
2002	1,308,553	1,188,175	657,609	90.8	50.3
2003	1,292,653	1,129,398	997,977	87.4	77.2
2004	1,604,196	1,382,030	1,081,139	86.2	67.4
2005	1,658,806	1,453,437	1,191,432	87.6	71.8
2006	1,725,158	1,470,844	1,173,776	85.3	68.0
2007	1,728,561	1,442,376	882,917	83.4	51.1
2008	1,742,390	1,477,031	920,578	84.8	52.8
2009	1,755,325	1,531,309	1,045,279	87.2	59.5
2010	1,801,888	1,601,150	1,158,117	88.9	64.3
2011	1,797,873	1,633,801	1,180,776	90.9	65.7
2012	1,821,714	1,661,977	1,220,392	91.2	67.0
2013	1,860,508	1,709,227	1,279,587	91.9	68.8
2014	1,898,126	1,758,618	1,334,182	92.7	70.3
2015	1,933,472	1,801,350	1,415,032	93.2	73.2
2016	1,996,755	1,804,289	1,447,438	90.4	72.5
2017	2,026,239	1,847,977	1,521,036	91.2	75.1

APPENDIX F: Ethics Clearance

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:

Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: <http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf>

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant	Mwamba Bright	
Department	Chemical Engineering	
Preferred email address of applicant:	Brightmwamba08@gmail.com	
If a Student	Your Degree: e.g., MSc, PhD, etc.,	MPhil in Sustainable Mineral Resource Development
	Name of Supervisor (if supervised):	Dr. Dyllon Randall
If this is a research contract, indicate the source of funding/sponsorship	Click here to enter text.	
Project Title	WATER RESOURCES MANAGEMENT IN ZAMBIA: A CASE OF CUMMULATIVE IMPACTS ASSOCIATED WITH COPPER MINING IN THE UPPER KAFUE CATCHMENT, COPPERBELT PROVINCE, ZAMBIA	

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Bright Mwamba	Signature Removed	15 Aug 2018
APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Dyllon Randall	Signature Removed	15 Aug 2018
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section 1; and for all Undergraduate research (Including Honours).	ADENIYI J ISAFIADE Click here to enter text.	Digitally signed by Adeniyi J Isafiade Date: 2018.10.03 18:22:39 +02'00' Signature Removed	Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	Click here to enter text.		Click here to enter a date.

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