

ASSESSMENT OF WATER QUALITY FOR IRRIGATION USE IN NKHWIBVI RIVER THAT RECEIVES SEWAGE WASTE IN MWANZA DISTRICT, SOUTHERN MALAWI.

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JULY, 2021

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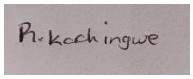
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DEDICATION

I dedicate my work in a special way to my father, MR K. Dzinyodo, and mother, MRS S. Dzinyodo, who have been the backbone of my existence, invaluably supporting me in all aspects of my life. My God Almighty grant you a long life so that you can one day reap the rewards of the vital role you have played in my life since childhood.

ABSTRACT

Water is essential to life and its availability is a crucial factor in human wellbeing, but despite having these vital roles, a variety of waste is being discharged into water sources. This study aimed to assess water quality for irrigation use in the Nkhwibvi river that receives sewage waste in the Mwanza district. A small survey to collect water samples was carried out, and water samples from the river were collected at three different locations, which were upstream of the river before the sewage waste discharge point (point 1), the middle stream which is along the market side, and just after the sewage waste discharge (point 2) and lastly downstream of the Nkhwibvi river after the market and residents area (point 3) for analysis of a set of Physico-chemical water quality parameters. Parameters including temperature, pH, dissolved oxygen, iron, salinity, calcium, and magnesium, electric conductivity, and nitrate-nitrogen were analyzed in the laboratory using American public health association (APHA) standard methods. Results were analyzed using Microsoft Excel 2013 for descriptive statistics, correlation and ANOVA statistics for p values and, graphs, and tables and also using irrigation water quality index. It was found that most parameters including temperature (20.770C to 22.40C), pH (7.62 to 8.10), dissolved oxygen (4.07 to 4.5mg/l), iron (0.13 to 0.35 mg/l), salinity (0.33 to 0.7 ppt), calcium (40 to 48.87 mg/l), and magnesium (19 to 29 mg/l) were within the guidelines for water quality for irrigation use set up by the WHO, although electric conductivity (1864µS/cm to 3391µS/cm) and nitrate-nitrogen (40.34mg/l to 70.3mg/l) showed elevated levels. In conclusion, this study showed that at the moment, water quality in the Nkhwibvi river was not badly impaired by toxic amounts of minerals and ions from the sewage discharge as the value of irrigation water quality index was found to be 51.27 which indicate that water is safe to use for irrigation (refer to appendix 4), and also because the values of the parameters that exceeded the recommended limits are not very far from the WHO standards hence water in Nkhwibvi river can be safely used for irrigation purposes as far as the scope of this study is concerned. Therefore, the Mwanza district council needs to nevertheless work to ensure minimization of waste disposal into the river and improve on sensitizing communities on best waste management practices.

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ABBREVIATIONS

AAS	Atomic absorption spectrophotometric
WHO	World Health Organization
UV/VIS	Ultraviolet spectrophotometric
APHA	American public health association
IWRM	Integrated water resources management
IWQI	Irrigation water quality index
DO	Dissolved oxygen
STDs	Standards
Max	Maximum
Min	Minimum
^{0}C	degrees celsius
PPT	parts per trillion
Mg/l	Milligrams per litter
uS/cm	Microsiemens per centimeter
L	Liter
Nitrate-N	Nitrate-Nitrogen

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Malawi is located in the southeast of the African continent and is about 900 km long and 80-161 km wide, with a total area of 118,484 km2 (11.8 million ha), of which 9.4 million ha is land and the remaining 2.4 million ha, about 20%, is covered by water, mainly Lake Malawi (Technology communication & Technology science, 2019) and human waste disposal and management is generally very poor in Malawi (Barré, 2014). Malawi is divided into 28 districts, one of which being Mwanza, the location of this study. Mwanza district is in Malawi's southern area, bounded to the north-east by the district of Neno, to the south by Chikwawa, and to the north-west by the Peoples' Republic of Mozambique. The district covers an area of 826 square kilometers and is about 100 kilometers from the capital. (Hudak & Wessman, 2000).

The population of Mwanza District is 92,947 people, with an intercensal annual growth rate of 4%.1% (*Preliminary Report*, 2018). Mwanza Boma which is entirely in T/A Kanduku has the highest population (Nation statistical, 2019). In the Mwanza boma, the Nkhwibvi River is the source of water for domestic purposes and irrigation (refer to appendix 2 and 3). Despite having these vital roles, a variety of wastes are being discharged. This is because, the residents of the informal settlements do not have access to wastes collection at regular intervals, have no wastewater treatment plants and the bulk of the wastes ends up in rubbish pits, in and around the river(FUM, 2018).

Irrigation is the artificial process of applying water to the soil primarily to meet the water needs of growing plants. Water from rivers, reservoirs, or lakes is pumped or flows by gravity through pipes, canals, ditches, or even streams. poor water quality used for irrigation caused by wastewater is currently a serious environmental issue all over the world (Millennium Ecosystem Assessment, 2005). Poor water quality used for irrigation harms soil quality and crop output. The chemical contents of water used for irrigation can have a direct or indirect effect on plant growth, either through toxicity or inadequacy or

by modifying nutrient availability. Assessing water quality used for irrigation is crucial to the sustainability of crop production and productivity (Kadyampakeni et al., 2017). Therefore due to lack of information on water quality of Nkhwibvi River for irrigation use in Mwanza, this study was conducted to assess the water quality for irrigation use in Nkhwibvi river that receives sewage waste as most public and private institutions in Mwanza such as Mwanza hospital, Mwanza hotel, and Mwanza Boma market are located along this river, by comparing the water quality in Nkhwibvi river with WHO standards of water quality used for irrigation.

1.2. PROBLEM STATEMENT

More than half of the world's rivers are seriously polluted, degrading and poisoning the surrounding ecosystems and threatening the health and livelihood of people who depend on them (Cosgrove & Rijsberman, 2000). Even in Malawi human waste disposal and management are generally very poor (Barré, 2014), where wastewater management plans are lacking or inappropriate and sewerage urban effluent enters river systems that are also sources of water for irrigation. Nkhwibvi River runs along Mwanza Boma and the catchment area of this river experiences different anthropogenic activities like the dumping of domestic waste containing both organic and inorganic pollutants from the residents and market that are located along the river but most of all receives the sewage waste at the middle stage of the river from the public and private institutions like hotels and the hospital as many people close to the discharge sites complain about the issue. This is because they do not have access to waste collection at regular intervals and have no wastewater treatment plants (FUM, 2018).

Hence this wastewater heavily impacts the quality of the river water used for irrigation (Mayhem and Chapman, 1999). Previous studies for example carried out by Hettiarachchi & Ardakanian, in 2016 found out that salt accumulation and salt balance is a crucial topic and problem in Egypt as the salinity of the drainage water was increasing and also there was an increase in biological contamination in different watercourses that were used for irrigation due to wastewater discharge. Anther studies carried out by Mvuma (1999) and

Lakudzala et al. (1999) in Mudi River in Blantyre found that the industrial activities were contributing to the pollution and degradation of water ecosystems in the city and beyond a similar study of the impact of wastewater effluent on the water quality of Alaro River in Ibadan, Nigeria showed that the physical and chemical parameters studied were above the allowable limits and also tended to accumulate downstream (Fakayode, 2005). Furthermore study done in South Lunzu in Blantyre (Malawi) showed that water resources were mainly degraded by poor sanitation practices as people lacked adequate sanitation facilities (Palamuleni, 2002).

In Malawi, several studies have been conducted to assess the water quality for different uses like for drinking and irrigation in different rivers around the country but there is a lack of information about water quality for irrigation use in Mwanza mostly for the Nkhwibvi river. People around using water from the Nkhwimbvi river for irrigation among other purposes hence sewage effluent entering the Nkhwibvi river is a common occurrence that requires investigation. Therefore this study intends to assess the water quality for irrigation use in the Nkhwibvi River that receives sewage waste in the Mwanza district. This study will help to fill some of the information gaps and other information will be added and recorded with regards to the water quality of the Nkhwibvi River and the effect of sewage waste discharge into the rivers.

1.3. RESEARCH OBJECTIVES

1.3.1. Main objective

This study aimed to assess the water quality in the Nkhwibvi River that receives sewage waste in the Mwanza district if they are in accord with the recommended standards for the world health organization (WHO) for irrigation use.

1.3.2. Specific objectives

1. To assess the selected physicochemical parameters (pH, EC, DO, salinity, and temperature) of water in the Nkhwibvi river.

2. To determine the levels of mineral nutrients, nitrogen in form of nitrate in the Nkhwibvi river.
3. To determine the levels of selected minerals and heavy metals (calcium, magnesium, and iron) in the Nkhwibvi river.

1.4. RESEARCH QUESTIONS

1. What other levels of selected minerals and heavy metals (calcium, magnesium, and iron) are in the Nkhwibvi River?
2. How is the quality of water for irrigation use in the Nkhwibvi River?
3. How are the selected physicochemical parameters (pH, EC, DO, salinity, and temperature) of water in the Nkhwibvi river
4. What levels of mineral nutrient nitrogen in form of nitrate are in the Nkhwibvi River?

1.5. SIGNIFICANCE OF THE STUDY

In Malawi number of studies have been conducted to assess the water quality of different uses like for drinking, irrigation in different rivers around the country. However, there are still challenges coming out due to waste. Therefore this study is relevant to fill some of the information gaps and other information will be added and recorded with regards to the water quality of the Nkhwibvi River for irrigation use. This work is also relevant to inform the Mwanza district council to work to ensure minimization of waste disposal into the river and improve on sensitizing communities on best waste management practices.

CHAPTER 2: LITERATURE REVIEW

2.1. SEWAGE WASTE DISCHARGE

Most aquatic ecosystems around the world, especially rivers have been polluted by untreated domestic sewage/wastewater among others. This is due to extensive industrialization, increasing population density, and high urbanized societies (Shevah, 2004). The research was conducted in Zimbabwe, where the effluent from the town of Chinhoyi was released into the middle Manyame River. The investigation discovered that all of the sampling sites had nitrate-nitrogen levels over the allowable limits, putting the whole Middle Manyame River stretch at risk (Norah et al., 2015).

The Huangpu River in China that flows through the heart of Shanghai also experiences serious waste discharge problems. Around the mid-1980s, nearly 70% of the 5.5 106 m3 of untreated or partially treated domestic sewage and industrial wastewater was deposited directly into the Huangpu River, or through urban sewers, into the Huangpu River and its branches. As the result, the Huangpu River has become extremely filthy. In the early 1980s, the Huangpu River's urban segment went dark and anoxic for around 100 days, and this escalated to more than 200 days in the 1990s (Zhang, 1997).

The Nile Valley and Delta are home to the majority of Egypt's population. Because sewage services were not available in most rural regions, sewage was collected and discharged directly into watercourses, drainage systems, and irrigation systems. Farmers appear to have no other viable options until new remedies are discovered and widely distributed among them but to use the same water to irrigate their plants (El-Gamal & Housian, 2016). Another 2012 research by Felizatto found that untreated wastewater is increasing due to increased urbanization of the watershed and inadequate wastewater treatment, untreated or poorly treated sewage from Sarah-Brasilia Hospital in Brazilian was discharged into surface water bodies which contributed to the development of a eutrophication process in Lake Paranoa. The presence of a huge amount of algae indicated that the lake was out of control, and the lake's trophic condition was assessed. (Felizatto et al., 2017)

Lilongwe City in Malawi, Urban Structure Plan estimated that the total sewerage generation is around 5,280 cubic meters per day which is less than the current treatment plant capacity. There are seven treatment plants but only 9% of the city is attached to the sewage system and there is no regulation on septic tank de-sludging and people remove sewage at their convenience. Therefore, household wastewater is discharged untreated and seeps underground (Malawi government, 2017). The study at Likangala River, Zomba, Malawi showed that the water in the outlet from the wastewater treatment plant into the river had a dark, blackish color and a distinct smell of sewage. On one section of the river, the houses are small and close together, with an indiscriminate mix of household rubbish strewn along the riverside and wastewater used directly to irrigate maize on the riverbank (Ullberg, 2015).

2.2. EFFECT OF SEWAGE WASTE ON WATER QUALITY USED FOR IRRIGATION

The rapid increase in the population leads to the unplanned growth of informal settlements that do not have urban services hence this situation generates the discharge of large volumes of sewage waste into surface water bodies used for agriculture (Hettiarachchi & Ardakanian, 2016). Therefore due to the same problem, studies carried out by Kretschmer et al. (2002), Reckson & Tawanda (2014), and Jiménez (2006) confirmed that water used for irrigation was strongly contaminated with parasites and fecal coliforms. The concentration of fecal coliforms was higher than the permitted limits for water used to irrigate vegetables. As a result, more than 30 percent of those vegetables were not fit for consumption. Hence, as a result, these have an impact on people's health and the environment, as people contract life-threatening infections such as diarrhea, cholera, hepatitis, and (Owili et al., 2003).

Sewage waste discharge into the river affects water quality used for irrigation, mainly on the content of dissolved salts. The problem arises when the total salts content of water is so high that the salts accumulate in the root zone then the plants draw water and nutrients from the saline soil with great difficulty which affects the plant's growth (*ASAWA*, 2005). Wastewater that has not been treated or is only partially treated is a negative externality

of urban water use, is widely used for irrigation in water-scarce regions in several countries including India. While the nutrients in the wastewater are beneficial to agriculture, the pollutants found in it are hazardous to the environment and human health (Ibrahim et al., 2017).

Contamination of soils and crops due to food crop irrigation with untreated sewage water is an increasingly common practice worldwide. A field study conducted in Pakistan to examine the phyto-availability of three heavy metals (cadmium (Cd), copper (Cu), and zinc (Zn)) in two cereal (wheat, maize) and legume (chickpea, mung bean) crops in response to the use of contaminated water with sewage waste found that the concentrations of Cd, Cu, Zn were determined in various plant parts (Murtaza et al., 2017). In China, has been reported that 45% of wastewater irrigated areas were contaminated with heavy metals at the most serious level in their crops. And not only in China, but this has also been a problem in several other countries like Germany, France and India as well (Srinivasan & Reddy, 2009). Consumption of heavy metal-contaminated food can deplete several essential nutrients in the body, leading to weakened immune responses and intrauterine pregnancy complications, growth retardation, reduced psychosocial capabilities, and problems linked to malnutrition, and a high prevalence of upper gastrointestinal cancer rates (Tabatabaei et al, 2020). Similarly, Kulkarni et al. (2015) and Sriadibhatla (2018) have also reported an increased accumulation of heavy elements and nutrients, salinity, organic matter content, and electric conductivity in water used for irrigation.

The studies were done by Jaramillo (2017), Qk et al. (2018), and Kulkarni et al. (2015) reported that the presence of pathogenic micro and macro-organisms is a source of threat, especially to those who are directly or indirectly exposed to wastewater. Key evidence for health risks associated with wastewater use includes hazards from bacteria, helminths, trematodes, protozoa, viruses which are mainly through contact as during irrigating plant people gets contact with the water and through consumption of these vegetables. There are also hazards due to skin irritants through contact (Siebe et al., 2016).

2.3. MWANZA DISTRIBUTION PATTERN AND IRRIGATION

Mwanza District is in the Republic of Malawi's Southern Region, bordered to the north-east by Neno, to the south by Chikwawa, and to the north-west by the People's Republic of Mozambique (Hudak & Wessman, 2000). Mwanza District has a total population of 92,947 people with an intercensal annual growth rate of 4.1% (*Preliminary Report*, 2018). Mwanza Boma which is entirely in T/A Kanduku has the highest population of 14,226 people than other areas in Mwanza (Nation statistical, 2019).

In the Mwanza district, Nkhwibvi, Nkulumadzi, and Mwanza Rivers are the main sources of water for drinking purposes, domestic and irrigation. Despite having these vital roles, a variety of wastes are being discharged mostly in Nkhwibvi River where sewage water is being discharged, residents of informal communities do not have access to regular waste collection, wastewater treatment facilities, or sanitation services and the bulk of the wastes ends up in rubbish pits, in and around the river, in traditional pit latrines and along the roadsides(FUM, 2018). Therefore water quality used for irrigation are seriously affected in the Nkhwibvi river because it is along Mwanza Boma which has the highest population in Mwanza as mentioned above and also most of the public and private institutions in Mwanza such as Mwanza hospital, Mwanza Prison, Mwanza hotel and Mwanza Boma market are located along that river.

2.4. METHODS OF WATER QUALITY ANALYSIS

Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are under the recommended standards (Roy, 2019). Heavy metals (calcium, sodium, potassium, magnesium, manganese, iron, aluminum, copper, and zinc) in wastewater can be analyzed using Atomic Absorption spectroscopy methods. Sriadibhatla (2018) and Kulkarni et al. (2015) used the flame atomic absorption technique while Şahin et al.,(2005) and Nassef et al. (2006) used flameless atomic absorption using the Heated Graphite Furnace. The water samples were analyzed by first digest sample with strong acid. Organic matter is destroyed during digestion, interfering ions are removed, and metallic compounds in suspension are brought to the solution. Then

finally analysis of minerals and heavy metals (calcium, sodium, potassium, magnesium, manganese, iron, aluminum, copper, and zinc) was done by using the above two types of Atomic absorption spectroscopy (AAS) and then the obtained values were calibrated against the standard values. The atomic absorption spectroscopy technique was used because it is relatively simple, versatile, accurate, and free from interferences (Sriadibhatla, 2018). But flameless atomic absorption method because of the high salt content suffers from substantial interferences if seawater is being used and if water is more turbid (Paus, 1973).

A Multi-parameter Analyzer (multi-probe aqua meter) was used to examine the physicochemical parameters of water samples, including pH, electric conductivity, salinity, dissolved oxygen, turbidity, and total dissolved solids by using a Multi-parameter analyzer by dipping the meter directly into the water, and then readings were recorded in a study done by Radulescu and others in 2014. This method is simple to use and it saves time (Radulescu et al., 2014).

Nephelometric method and turbidity meter was used to analyze turbidity, Electrical Conductivity Method and salinity meter were used to analyze salinity, the temperature was measured using an electronic thermometer with an analog or digital readout and pH meter was used to analyze PH in a study done by Thomas in 2017 and *Ballance* in 1996. These methods are difficult to use and they are time-consuming compared to the multi-parameter analyzer (Thomas, 2017).

Nitrogen concentration can be measured using two different methods, which are the colorimetric method as done by Sheikh et al. in 2016 and Charles et al. in 2011 and the Ultraviolet spectrophotometric screening method as done by Narayana & Sunil (2009) and Kurniawati et al. (2017). The calorimetric method was done using the following steps in brief; suspended solids in the sample were removed, color was then developed, photometric was measured and finally, they prepared standard curve by plotting absorbance of standards against nitrate-nitrogen concentration then computing sample

concentration directly from the curve. While the ultraviolet spectrophotometric screening method, nitrogen concentration was determined in form of nitrate where absorbance was measured using ultraviolet spectrophotometric at 220nm wavelength, and the absorbance was proportional to the nitrate concentrations in the samples. The ultraviolet spectrophotometric screening method was used because it is a precise and sensitive method, low cost, and fairly easy to operate (Baezzat et al., 2011) but it is suitable only for samples with low organic matter content (Kurniawan et al., 2017). Both methods (calorimetric method and ultraviolet spectrophotometric screening method) cannot be applied to samples with high turbidity hence all more turbid samples have to be filtered before analysis.

CHAPTER 3: MATERIALS AND METHODS

3.1. STUDY AREA

This study took place at Nkhwibvi River, Mwanza district. Mwanza district is located in the southern region of Malawi. This river is perennial, and it discharges its water into the Mwanza River. Water samples were collected during June, which is in the wet season.

MAP OF MALAWI SOUTHERN REGION



MAP OF NKHWIBVI RIVER

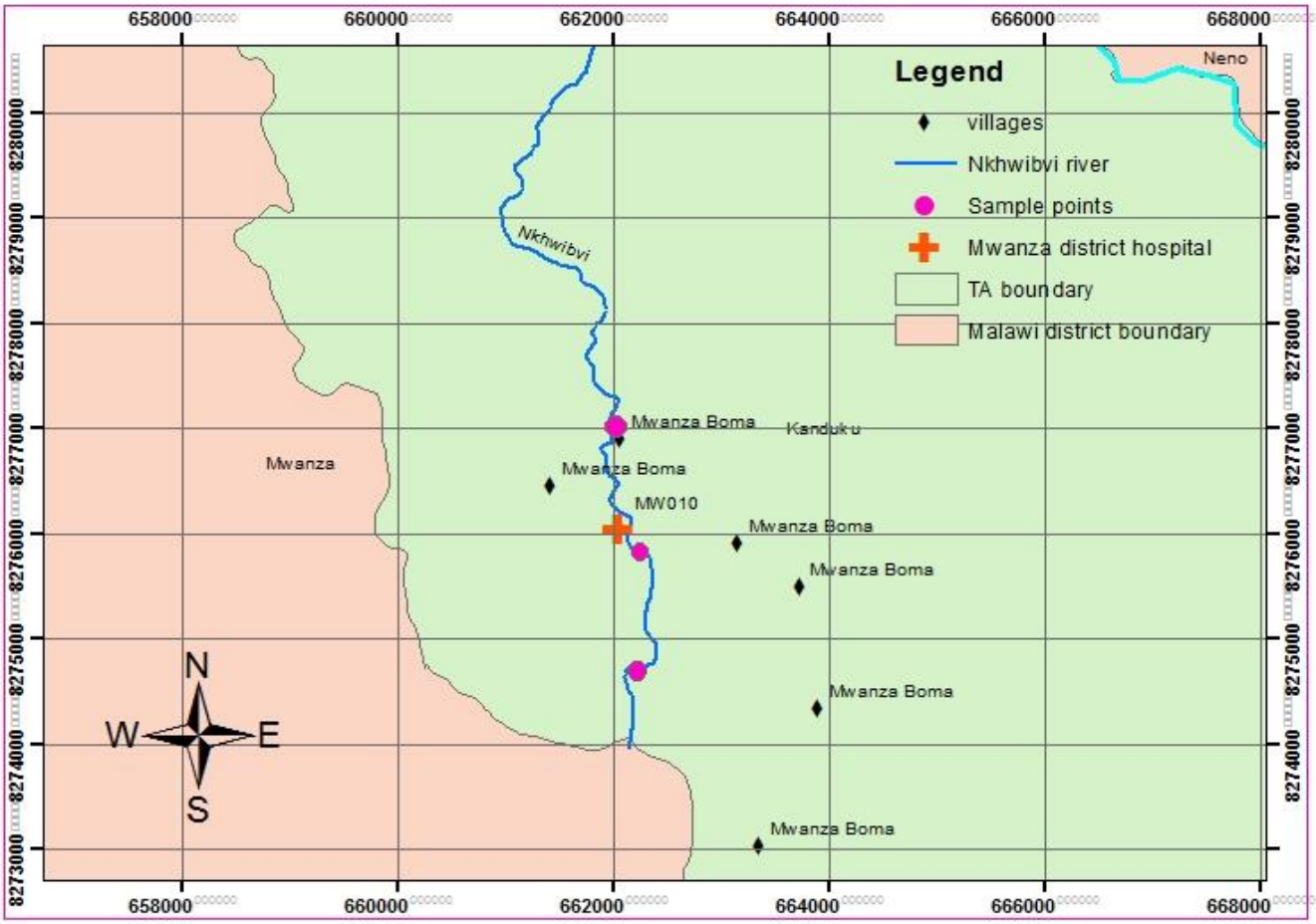


Figure 1: Map of southern Malawi (top) and Nkhwibvi River (bottom) (Made by Rose Kachingwe using ArcMap)

3.2. RESEARCH DESIGN AND SETUP

This study was descriptive as done by Nandwana and Chhipa in 2014 (Nandwana & Chhipa, 2014) and is as well combined with the aspect of quantitative research. Water samples were collected at each sampling site as grab samples and in triplicates. Water samples from the river were collected at three different locations along the study area, which were upstream of the river before the sewage waste discharge point (point 1) on the coordinate of -15.6053168, 34.4787240 (15^0 36'19.0" S $34^0$28'43.4" E), the middle stream which is along the market side, and just after the sewage waste discharge (point 2) has the coordinates of -15.6053170, 34.4787240 (15^0 36'19.1" S $34^0$28'43.4" E) and lastly downstream of the Nkhwibvi river after the market and residents area (point 3) and it has the coordinates of -15.6053790, 34.4787240 (15^0 36'19.4" S $34^0$28'43.4" E). Three bottles on each sample point were used to collect water samples of which one bottle on each point were acidified with 1ml hydrochloric acid, for later analysis of metal concentrations for calcium, sodium, potassium, magnesium, iron and the other bottle remain constant for the analysis of electric conductivity and salinity. The acidified samples were kept at room temperature while the unacidified samples were immediately chilled in a cooler bag and later transferred to the fridge (4°C). The samples were analyzed within 24 hours of collection at the water laboratory, southern religion irrigation and water development (Blantyre), and the Malawi University of science and technology water quality laboratory. Sample analysis was done according to the protocols provided by APHA in the Standard Methods for the Examination of Water and Waste Water 1992, 18th Edition. Physiochemical parameters; pH, salinity, dissolved oxygen, electric conductivity, and temperature were measured onsite using pH meter for pH, dissolved oxygen (DO) meter for dissolved oxygen, and multi-probe aqua meter for electric conductivity and salinity as done by postolache, Girão, and Pereira in 2016 (Postolache et al., 2016).

3.3. EXPERIMENTAL WORK AND CHEMICAL ANALYSIS

This research uses a quantitative method where numerical data were collected as done by Nandwana and Chhipa in 2014 (Nandwana & Chhipa, 2014) using experimental data collection method, by conducting experiments. Ultraviolet-visible spectrophotometry (UV/VIS) was used to measure nitrogen and iron, finally, calcium and magnesium were measured using the titration method (Kulkarni et al, 2015).

Electric conductivity and salinity readings were measured by dipping a multi-probe aqua meter directly into the River and after the same minutes (about 5-10 minutes), the readings were recorded. Temperature, pH, and dissolved oxygen were measured by dipping the pH meter and dissolved oxygen (DO) meter respectively into the river and after the same minutes (about 5-10 minutes), the readings were also recorded.

The concentration of nitrogen was measured in form of nitrate in filtered samples using ultraviolet-visible spectrophotometry (Thomas, 2017), where first, all samples were filtrated by gravity through filter paper especially those of more turbid. Then the following steps were done; the first 5ml of the acidified sample was transferred into a 100ml Pyrex beaker and 2ml of sodium salicylate solution was added into the beaker of a sample, then mix them well and evaporated in a water bath until it dried. After that, the beaker was removed from the water bath and 1ml of sulphuric acid was added to the beaker and shaken for the solids to dissolved and wait for 10 minutes, thereafter 50ml of distilled water was added into the beaker for dilution then 10ml of sodium hydroxide (NaOH) solution was measured using measuring cylinder and added into each beaker then mix them well. After that, the color changed to yellow, which indicates the presence of nitrate. The solution was then transferred into a 100ml volumetric flask and distilled water was added up to the mark and mix them. Finally, 100% transmittance with distilled water was set on the UV spectrophotometer and then the readings of transmittance at 220nm using UV/VIS spectrophotometer were read. The readings were recorded.

The concentration of iron was measured using Ultraviolet-visible spectrophotometry using the following procedures (APHA, 2002). The first 25ml of the thoroughly mixed sample

was pipetted into a 50ml volumetric flask. Then 1ml of hydrochloric acid was added using a pipette and mix them well. Thereafter 5ml of hydroxyl ammonium chloride solution was added and mixed well and then acetate buffer was also added using a pipette and mixed. Phenanthroline solution (3ml) was also added into the beaker using a pipette again and mix them well. After that distilled water was added into the flask to the mark of the flask to dilute the solution and mix them well. Then the solution was allowed to stand for 15minutes for color (pink) to develop. Finally, 100% transmittance with distilled water was set (measured) on the UV spectrophotometer and then the readings of transmittance at 508nm using UV/VIS spectrophotometer were read. The readings were then recorded. The standard iron (stock) was used as control solutions where 0.6ml, 10ml, and 0ml of standard iron were pipetted into three 50ml volumetric flasks each respectively and the steps were repeated but at the same time as samples as shown below.



Figure 2: Experimental setup of samples and standard iron solution for iron analysis.

Calcium concentration and magnesium concentration were measured using the EDTA titration method. For calcium; the first 50ml of non-acidified samples was pipetted into a

250ml volumetric flask and also 50ml of distilled water was pipetted into another 250ml volumetric flask to act as a control solution. 1ml of total hardness was added into the sample flask and distilled flask each and each flask was mixed well. Then a little monochrome black tea was added into each flask and each flask was mixed well until the purple color was developed. Finally, the solutions were titrated using EDTA solution, drop by drop while shaking until the color turns blue, and the starting and ending volumes of EDTA were recorded for later calculation of calcium concentration. While for magnesium; the first 50ml of non-acidified samples was pipetted into a 250ml volumetric flask and 1ml of calcium buffer was added into the flask and mix them. Then a little murexide was added into the flask and mix then well until the pink color was developed. Finally, the solution was titrated using EDTA solution, drop by drop while shaking until the color turns purple and the starting and ending volumes of EDTA were recorded for later calculation of magnesium concentration. Distilled water was used as the control solution, where 50ml of distilled water was pipetted into a 250ml volumetric flask and finally the steps were repeated. The concentration of calcium and magnesium was then finally calculated using the formulas below (Gilcreas, 1967):

Total hardness= ((end volume – start volume)*1000)/ (sample volume)

Calcium hardness= ((total volume - end volume)*1000)/ (sample volume)

Calcium concentration=calcium hardness * 0.4

Magnesium concentration= (total hardness - calcium hardness) * 0.24

Finally, all the procedures for all parameters were repeated for all sample points and sample bottles.

3.4. DATA ANALYSIS

Results were analyzed using Microsoft Excel 2013 for descriptive statistics and ANOVA statistics for p values and by using irrigation water quality index. Any chosen correlation between specific parameters was computed using Microsoft Excel to find the relationship between them. The mean values were compared with WHO Guidelines for irrigation

water purposes. The results were demonstrated using tables and graphs (bar graphs) to show patterns and trends of the parameters.

3.5. QUALITY ASSURANCE AND QUALITY CONTROL

Both in the field and the laboratory, quality assurance, and quality control plans were implemented. All sampling vials were pre-labeled as part of the quality assurance and quality control plan to avoid mixing the samples. Triplicate samples were obtained to verify the accuracy of the results. Measuring equipment was calibrated at the laboratory before measurements. The mean values of all the data sets for each sampling location were used to get the final results of a parameter. While samples were taken to a respectable laboratory, standard analytical methods and references were employed (water laboratory, southern religion irrigation and water development (Blantyre), and the Malawi University of science and technology water quality laboratory) for analysis.

3.6. ETHICS AND PROFESSIONALISM

Ethical consideration is of paramount importance in research therefore it was required and necessary as it was done to get permission from the district commission (DC) and the village head to be approved to conduct the project in their community. “Water is life so it is good to take good take of our water around us always,” said the village head Ntchotseni. The results obtained in this study are relevant and beneficial to the community and the project was designed to minimize risks to the participants of this research. All information that was taken from any source was cited accordingly to prevent plagiarism.

CHAPTER 4: RESULTS

The results of measured water quality parameters of the surface water samples of the Nkhwibvi river are summarized and shown in tables 1 to 5. The data were analyzed at a 95% confidence interval with a test probability of 0.05. This study found the probability of EC between points to be 0.000127, temperature to be 0.0029, salinity was 0.83, DO was 0.37, pH to be 0.065, nitrate-nitrogen was $6.12x10^{-12}$, iron was $3.12x10^{-5}$, calcium to be $6.23x10^{-7}$, and finally, magnesium to be $1.83x10^{-7}$. The irrigation water quality index value was found to be 51.27.

Table 1: Results for physicochemical parameters

sample points	Ph	DO (mg/L)	EC (uS/cm)	SALINITY (ppt)	TEMP (°C)
point 1	7.56	5.07	1944	0.06	22
	7.84	4.08	1874	0.06	22.4
	7.48	4.35	1774	0.87	22.8
point 2	7.92	4.54	2193	1.11	21.9
	7.98	4.32	2197	0.07	22.1
	8.41	4.13	2202	0.06	21.5
point 3	7.75	3.96	3223	0.07	20.7
	7.89	3.93	3747	1.97	20.5
	7.65	4.33	3203	0.06	21.1

Table 2: Mean value of sample points

sample points	pH	DO (mg/L)	EC (uS/cm)	TEMP (°C)	SALINITY (ppt)
Point 1	7.62	4.5	1864	22.4	0.33
point 2	8.10	4.33	2197.33	21.83	0.41
point 3	7.76	4.07	3391	20.77	0.7

The results of nitrate-nitrogen, iron, magnesium, and calcium analysis of the surface water samples of the Nkhwibvi river are shown in Tables 3 and 4 below.

Table 3: Concentrations of nitrate-nitrogen, iron, magnesium and calcium

sample points	IRON(mg/L)	MAGNESIUM (mg/L)	CALCIUM (mg/L)	NITRATE-N(mg/L)
point 1	0.338	18.96	41.6	40.1
	0.354	18.58	41.91	40.4
	0.364	19.54	41.49	40.53
point 2	0.107	20.91	48.8	70.3
	0.161	21.56	48.4	70.1
	0.109	21.1	49.4	70.53
point 3	0.106	28.69	40.8	50.5
	0.121	28.97	40.4	50.42
	0.152	29.4	41.3	50.125

Table 4: Mean values of sample points for calcium, iron, magnesium and nitrate-N

sample points	IRON (mg/L)	MAGNESIUM (mg/L)	CALCIUM (mg/L)	NITRATE (mg/L)
Point 1	0.35	19.03	41.67	40.34
point 2	0.13	29.19	48.87	70.3
point 3	0.13	21.02	40.83	50.348

Table 5: Summary of descriptive statistics of the physio-chemical parameters of water

PARAMETERS	MEAN	MIN	MAX	STD DEVIATION	VARIANCE	WHO STDs
PH	7.83	7.62	8.10	3.92	0.06	6.5-8.5
EC (μg/cm	2484.11		3391	802.88	644613.37	≤700
Temp (^{O}C)	21.67	20.77	22.4	0.83	0.68	10-22

DO (mg/l)	4.30	4.07	4.5	0.21	0.05	>4
Salinity (mg/L)	0.48	0.33	0.7	0.19	0.04	2.5
Calcium (mg/L)	43.79	40.83	48.87	4.41	19.51	≤100
Magnesium (mg/L)	23.08	19.03	29.19	5.25	27.64	≤60
Nitrate-N (mg/L)	53.67	40.34	70.3	15.25	232.64	≤50
Iron (mg/L)	0.20	0.13	0.35	0.13	0.02	≤5

The variance shows how far a set of numbers are spread out from their mean values. The more spread the data, the larger the variance is with the mean.

$S^2 = (\sum (x_i - \dot{x})^2)/n+1$ (Ayeni, 2014)

Where S^2 is the sample variance, x_i is the values of one observation, $\dot{x}$ is the mean value of all observation and n is the number of observations

Standard deviation is a measure of the amount of variation or dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean set, while a high standard deviation indicates that the values are spread out a wider range.

$\sigma = \sqrt{(\sum(\mathrm{xi} - \mu)2)/N}$ (Ayeni, 2014)

Where σ the sample standard deviation is μ is the population mean, N is the number of observations X_i is the values of one observation.

Table 6: showing the correlation of parameters

	pH	DO	EC	TEMP	SALINITY	IRON	MAGNESIUM	CALCIUM	NITRATE-N

pH	1								
DO	-0.15	1							
EC	-0.043	-0.982	1						
TEMP	-0.098	0.998	-0.989	1					
SALINITY	-0.042	-0.981	1	-0.989	1				
IRON	-0.713	0.799	-0.668	0.767	-0.667	1			
MAGNESIUM	-0.045	-0.981	1	-0.989	1	-0.667	1		
CALCIUM	0.933	0.214	-0.398	0.265	-0.4	-0.415	-0.4	1	
NITRATE-N	0.998	-0.212	0.0198	-0.161	0.0175	-0.756	0.017	0.909	1

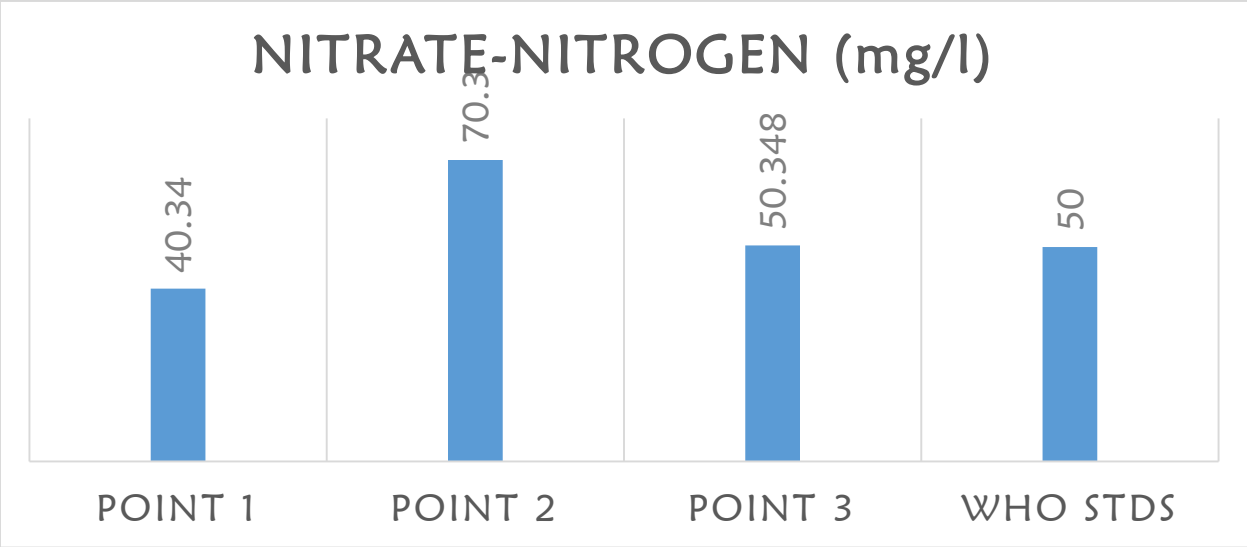


Figure 3: showing concentrations of water nitrate-nitrogen levels for Nkhwibvi river and WHO permissible limits for irrigation use.

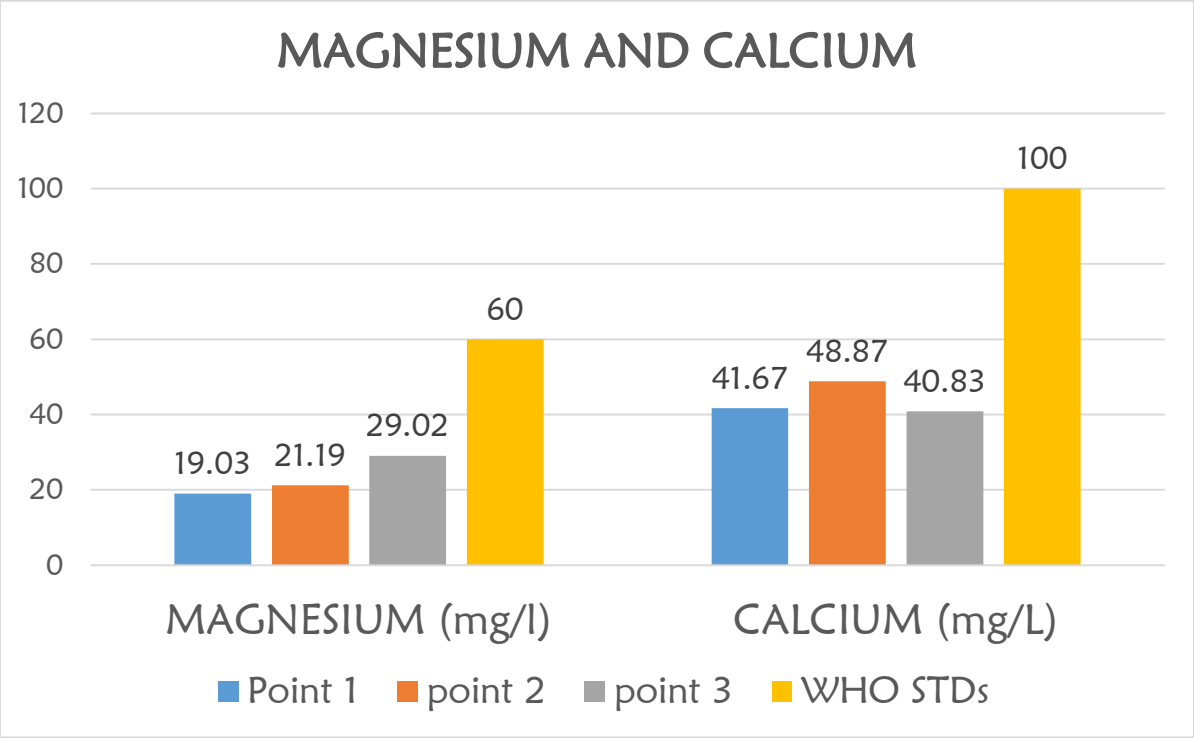


Figure 4: showing levels of magnesium, and calcium of water for Nkhwibvi river and WHO maximum permissible concentration for irrigation use.

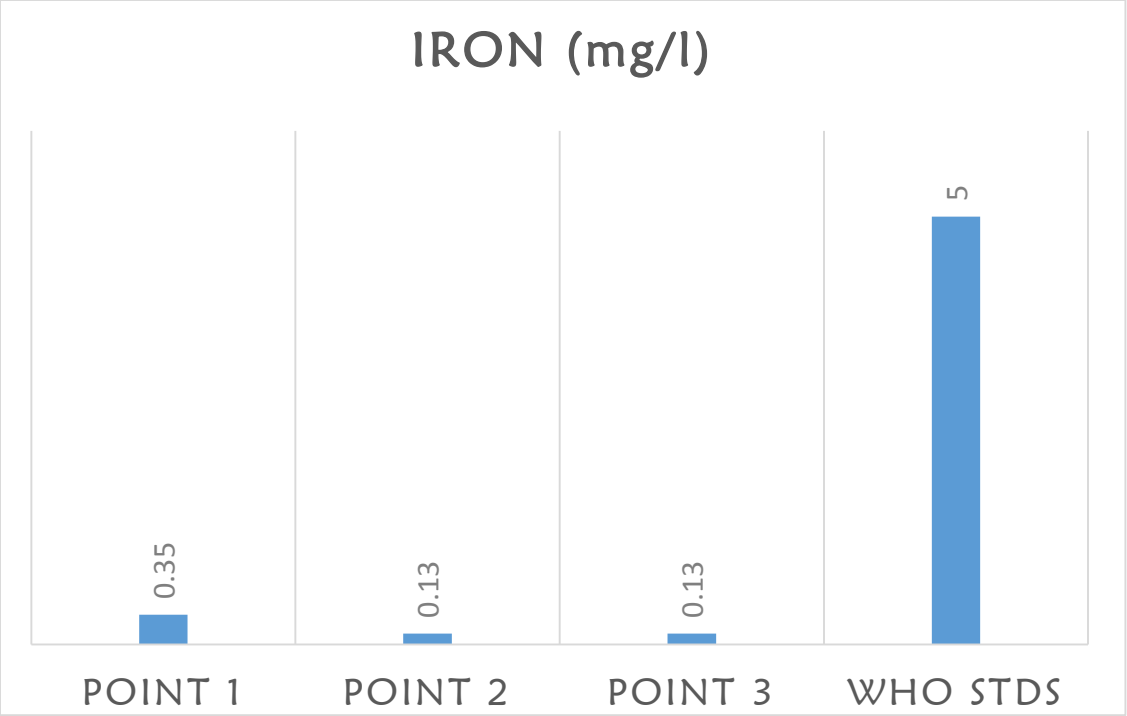


Figure 5: showing levels of iron for Nkhwibvi river and WHO maximum permissible concentration for irrigation use.

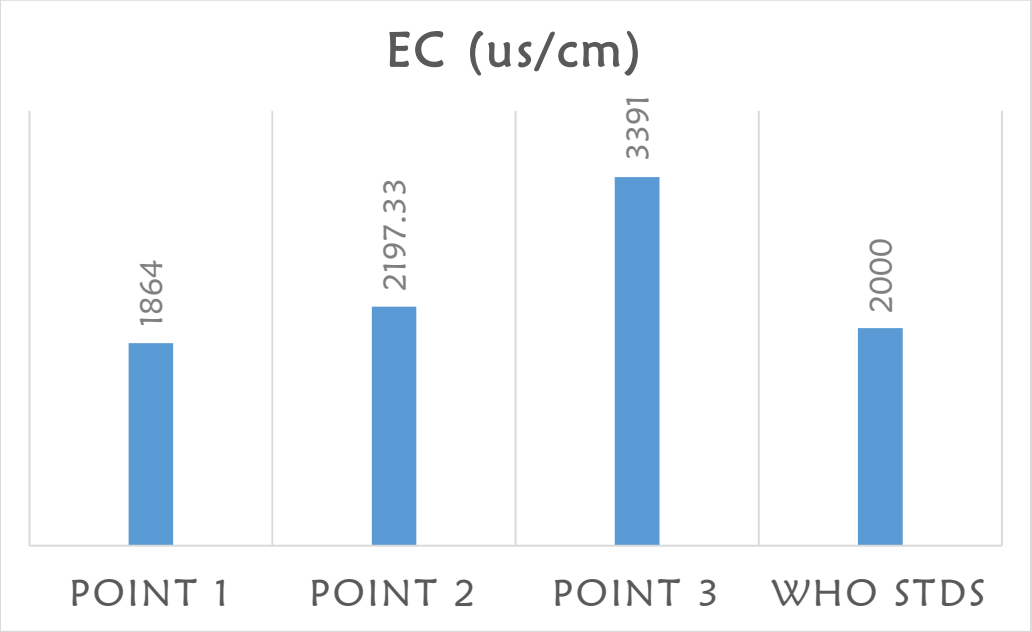


Figure 6: showing concentrations of Electric conductivity of water for the Nkhwibvi river and shows WHO maximum permissible concentration for irrigation use.

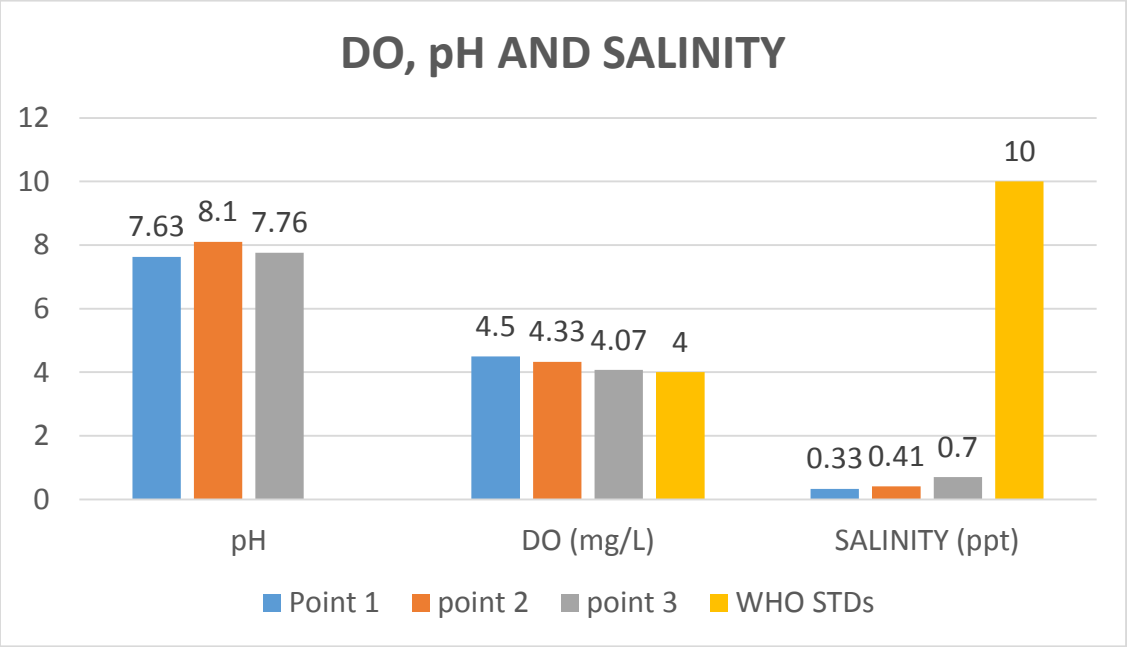


Figure 7: showing levels of dissolved oxygen, pH, and salinity of water for the Nkhwibvi river and WHO maximum permissible concentration for irrigation use.

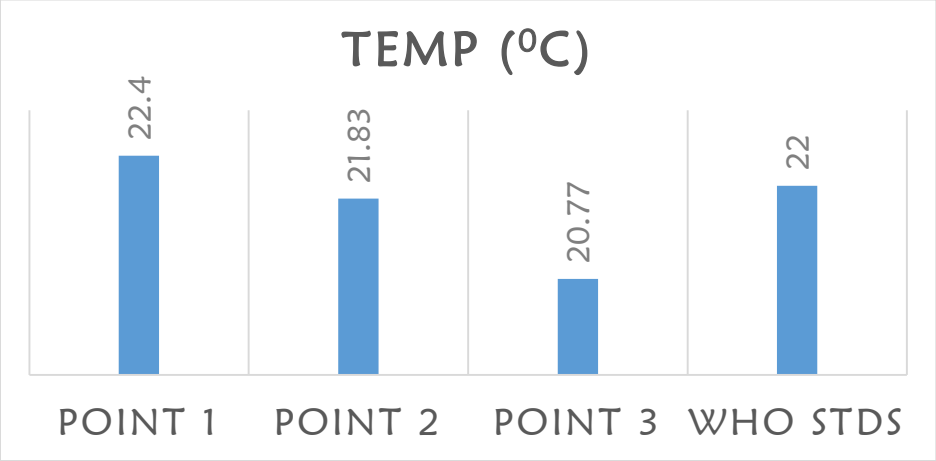


Figure 8: showing the temperature of water for the Nkhwibvi river and WHO maximum permissible concentration for irrigation use.

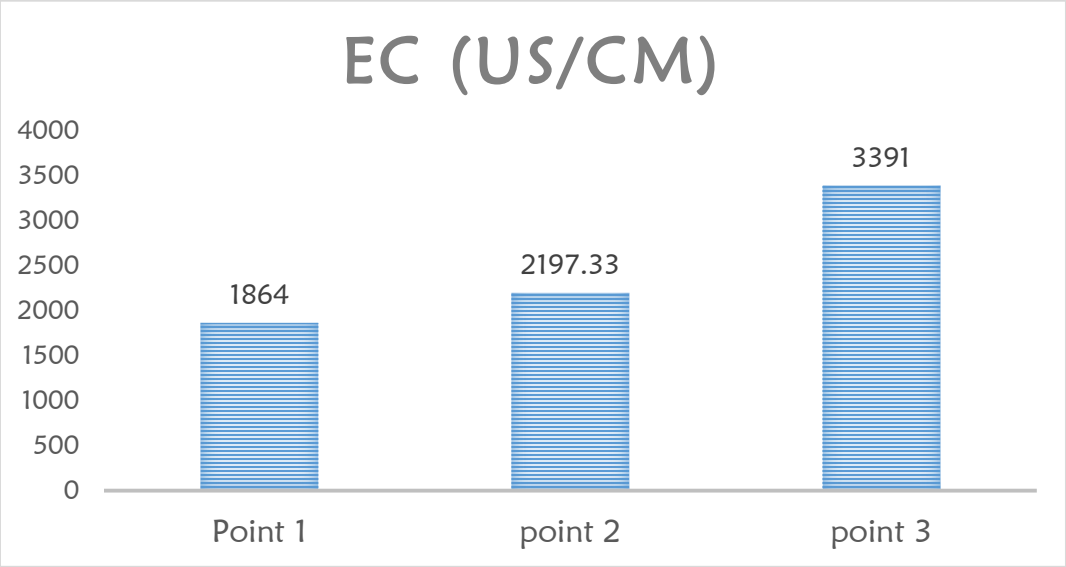


Figure 9: Showing Electrical conductivity increasing trends with distance and sampling points.

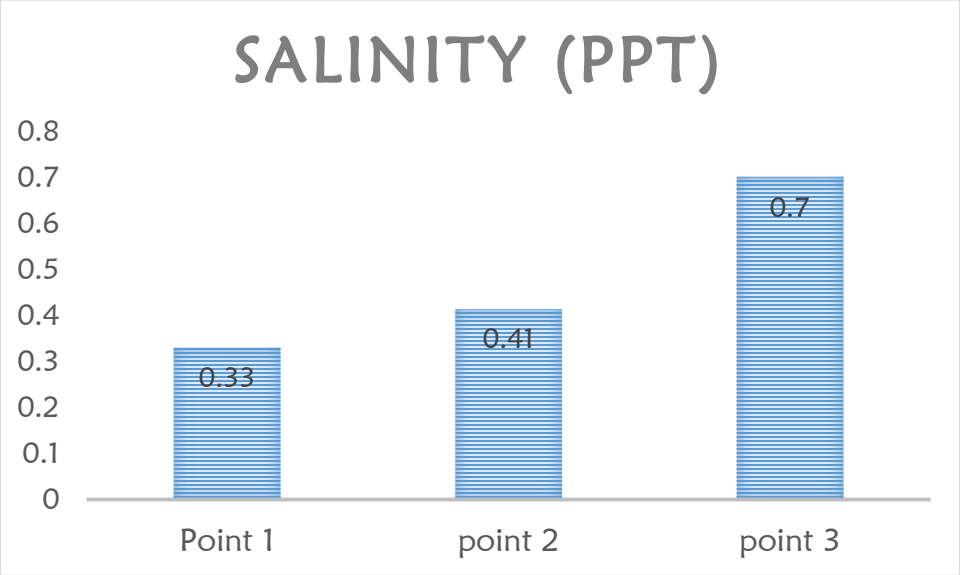


Figure 10: Salinity showing increasing trends with distance and sampling points.

CHAPTER 5: DISCUSSIONS

5.1. Temperature and dissolved oxygen concentration of water

The temperature of all water samples varies from 20. 8 °C to 25.80 °C with a mean value of 21.67. Dissolved oxygen is one of the most important markers of water quality (DO). It was found at all water sample points ranges from 4.08mg/l to 5.0mg/l with the mean value of 4.30 which were all (dissolved oxygen and temperature) in the recommended limits as shown in Figures 7 and 8 above.

5.2. Water pH

The pH of water determines whether it is acidic or basic. The range is 0 to 14, with 7 representing neutrality. A pH less than 7 implies acidity, while a pH greater than 7 suggests a base. The solubility (the amount that can be dissolved in water) and biological availability (the amount that can be utilized by aquatic life) of chemical components including nutrients (phosphorus, nitrogen, and carbon) and heavy metals are determined by the pH of water (lead, copper, cadmium). Because metals are more soluble at lower pH values, they become more hazardous. Metals and other compounds corrode or dissolve in low-pH water. (Kuyeli et al., 2009). The pH of all water sample points in the Nkhwibvi river was about neutral as shown in figure 7, the range being 7.6 to 7.8 with a mean value of 7.83. Hence, values in all water samples were found within the limits of WHO (refer to the appendix). This concurred with the pH values in the range of 7.0 to 8.1 found by Ogbonna (2014) in Rivers of Port Harcourt Metropolis in Nigeria. Water used for irrigation with pH outside the limits may cause a nutritional imbalance or may contain toxic ions and also it has the greatest direct hazard on irrigation equipment.

5.3. Electrical Conductivity and salinity of water

The Electrical Conductivity (EC) of water is its ability to conduct an electric current. When salts or other compounds are dissolved in water, they can produce positively and negatively charged ions. These free ions in the water conduct electricity, so the water's electrical conductivity depends on the concentration of ions present in it. The reason that

the conductivity of water is important is that it tells how many dissolved substances (salinity), chemicals, and minerals are present in the water. Higher concentrations of these contaminants will result in increased conductivity (Kuyeli et al., 2009). Significant changes in the conductivity of water indicate that a pollutant has entered the water, for example, a sewage leak. Electric conductivity and salinity of all water samples measured vary from 1864µS/cm to 3391 µS/cm and from 0.33 to 0.7 respectively. The values of electrical conductivity were high above the limits of WHO for water used for irrigation as presented in figure 6. While salinity was below the recommended limits which are; for highly tolerate crops is 10g/L; moderately tolerate crops is 5g/L and for sensitive tolerate crops is 2.5g/L (refer to the appendix). A study by Kuyeli and others in Blantyre urban streams also found high EC levels that range from 4000µS/cm to 2000µS/cm in the dry season and 2800µS/cm to 6200µS/cm in the rainy season (Kuyeli et al., 2009). The high value of EC and salinity of water used for irrigation affect the plant growth as when high salts accumulate in the root zone then the plants draw water and nutrients from the saline soil with great difficulty which affects the plants' growth and also salinity reduces water infiltration.

5.4. Calcium and magnesium levels of water

Hardness is a metric that measures the amount of calcium and magnesium in water. Calcium and magnesium are two minerals that plants need to flourish. However, substantial amounts of exchangeable magnesium in soils are generally considered to cause infiltration problems. Calcium and magnesium concentrations in water samples in the Nkhwibvi river ranged from 40.8mg/l to 48.9 mg/l and from 19mg/l to 29mg/l respectively. The concentration of calcium and magnesium in all water samples was within the limits of WHO which are 100mg/L and 60mg/L respectively as displayed in figure 4. A study by Ospanov and 3 others (Ospanov et al., 2020) also found high Calcium and magnesium levels that range from 25.6mg/ to 40.9 mg/l and from 17.3mg/l to 22mg/l respectively which were also within the permissible limits by WHO. Magnesium salts are cathartic and diuretic and high concentration may cause a laxative effect, while deficiency may cause structural and functional changes.

5.5. Iron levels in water

In water, iron is mostly found in two forms: soluble ferrous iron and insoluble ferric iron. Because the iron is dissolved, water containing ferrous iron is clear and colorless. High amounts of iron in irrigation water can contribute to soil acidity and a loss of essential phosphorus and molybdenum availability (Yasir, 2016). The concentration of iron, which is characterized as undesirable metal in water quality used for irrigation in the Nkhwibvi river was found to be below the limit of WHO which is 5mg/L as demonstrated in figure 5. The concentrations ranged from 0.13mg/l to 0.35mg/l. A study on determining heavy metal levels in water by Radulescu and others found iron levels above the recommended limits by WHO (Radulescu et al., 2014).

5.6. Nitrate-nitrogen levels in water

Nitrate-N is a plant nutrient and stimulates crop growth. The concentration of nitrate-N in all water samples in the Nkhwibvi river ranges from 40mg/l to 70mg/l with a mean value of 53.67. The mean value and the point immediately after sewage disposal were higher above the limits of WHO for water used for irrigation which is 50mg/L as shown in figure 3 above. A past study by Norah and others in Zimbabwe has documented different nitrate-N levels ranged from 6.42 mg/L to 15.86mg/l with higher levels at the point immediately after sewage disposal (Norah et al., 2015). This is because the study by Norah and others took place during the rainy season hence due to dilution factors the nitrate-N levels decrease. Excess nitrogen in water used for irrigation causes problems. Because of over-stimulation of growth, delayed maturity, or poor quality, the production of some regularly produced crops may be disrupted if excessive levels are present. Nitrogen concentrations greater than 5 mg/l may harm sensitive crops. Until nitrogen levels approach 30 mg/l, most other crops are relatively unaffected. Sugarbeets, for example, a sensitive crop, grow in size as a result of excessive nitrogen fertilizer, but their sugar content and purity diminish, reducing the total amount of recoverable sugar produced per hectare.

5.7. The correlation of parameters

The poor correlation between the different parameters measured in the results is an indication that the minerals and ions input to the river is likely due to sewage discharge into the river (refer to table 6 above).

5.8. Irrigation water quality index

The IWQ index was then calculated as:

$$\text{WQI Index} = \sum_{i=1}^{9} \left(_{Gi}\right) \qquad \text{(Spandana et al., 2013)}$$

Where „i" is an incremental index and G represents the contribution of each one of the 9 parameters that were used to assess the quality of water for irrigation use.

5.9. Dissemination of the results

The results obtained in this study will be reported to the audience through presentation especially to the supervisors and examiners, while to the communities, they will know by reading the articles and journals that will be published after the project is done. The results will be reported to the policymakers and the Malawi Bureau of standards MBS.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Water samples from the river were collected at three different locations along the study area, which are upstream of the river before the sewage waste discharge point (point 1), on the coordinate of -15.6053168, 34.4787240 (15^0 36'19.0" S $34^0$28'43.4" E), the middle stream which is along the market side, and just after the sewage waste discharge (point 2) has the coordinates of -15.6053170, 34.4787240 (15^0 36'19.1" S $34^0$28'43.4" E) and lastly downstream of the Nkhwibvi river after the market and residents area (point 3) and it has the coordinates of -15.6053790, 34.4787240 (15^0 36'19.4" S $34^0$28'43.4" E). Water samples were collected for analysis of a set of Physico-chemical water quality parameters. Parameters including temperature, pH, dissolved oxygen, iron, salinity, calcium, and magnesium, electric conductivity, and nitrate-nitrogen were analyzed in the laboratory using American public health association (APHA) standard methods. The concentrations of nitrate-N and iron were measured using ultraviolet spectrophotometry, and concentrations of calcium and magnesium were measured using the EDTA titration method, temperature and pH were measured using a pH meter, DO was measured using DO meter and finally, electric conductivity and salinity were measured using multi-probe aqua meter. Results were analyzed using Microsoft Excel 2013 for descriptive statistics, correlation and ANOVA statistics for p values and, graphs, and tables and by using irrigation water quality index.

It was found that most parameters including temperature (20.770C to 22.40C), pH (7.62 to 8.10), dissolved oxygen (4.07 to 4.5mg/l), iron (0.13 to 0.35 mg/l), salinity (0.33 to 0.7 ppt), calcium (40 to 48.87 mg/l), and magnesium (19 to 29 mg/l) were within the guidelines for water quality for irrigation use set up by the WHO, although electric conductivity (1864µS/cm to 3391µS/cm) and nitrate-N (40.34mg/l to 70.3mg/l) showed elevated levels. Some of the parameters include EC and nitrate-N showed clear trends with distance and sampling points as the river flows through Mwanza Boma, with generally poor water quality downstream than upstream of the studied area as shown in Figures 9 and 10.

In conclusion, this study showed that at the moment, water quality in the Nkhwibvi river was not badly impaired by toxic amounts of minerals and ions from the sewage discharge as the value of irrigation water quality index was found to be 51.27 which indicate that water is safe to use for irrigation (refer to appendix 4), and also because the values of the parameters that exceeded the recommended limits are not very far from the WHO standards hence water in Nkhwibvi river can be safely used for irrigation purposes as far as the scope of this study is concerned. Therefore, the Mwanza district council needs to nevertheless work to ensure minimization of waste disposal into the river and improve on sensitizing communities on best waste management practices. An IWRM approach should also be incorporated into the process. The study was concluded only on the state of the water quality within the wet season due to time limit constraints leaving out the dry season and rainy season water quality situation.

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APPENDICES

APPENDIX 1: Same of the world health organization (WHO) standards for water quality used for irrigation (WHO, 2006), (Gabr, 2019).

Recommended limits for water quality used for irrigation	
parameters	WHO
PH	6.5-8.5
EC (μg/cm	for food crop ≤700, for processed food ≤ 2000
Temp (°C)	10-22
DO (mg/l)	>4
Salinity (mg/L)	Highly tolerate crops =10g/L; Moderately tolerate crops =5g/L; Sensitive tolerate crop = 2.5g/L
Calcium (mg/L)	≤100
Magnesium (mg/L)	≤60
Nitrate-N (mg/L)	≤50
Potassium (mg/L)	≤0.005
Aluminium (mg/L)	≤5
Zinc (mg/L)	≤2
Lead (mg/L)	≤0.2
Copper (mg/L)	≤0.2
Manganese (mg/L)	≤0.2
Iron (mg/L)	≤5

APPENDIX 2: Vegetable irrigation agriculture happening alongside Nkhwibvi river



APPENDIX 3: showing sugarcane irrigation agriculture happening alongside Nkhwibvi river



APPENDIX 4: Irrigation Water Quality Index (IWQI) (Spandana et al., 2013)

IWQI	WQI, %	Suitability of water for irrigation
<22	>48%	LOW
22-37	48 – 82%	MEDIUM
>37	>82%	HIGH