

EVALUATION OF THE TREATMENT EFFICIENCY OF MUST WASTEWATER TREATMENT PLANT: A CASE STUDY ON MUST CAMPUS

JOHN MGEMEZULU

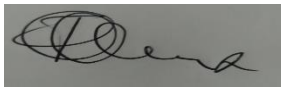
Thyolo, Malawi

Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the Bachelor of Science degree in water quality and management

12 July, 2021

DISSERTATION APPROVED BY:

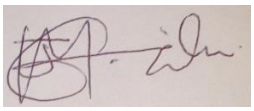
SUPERVISOR:

Mr F. Chauluka signature : 

ASSESSOR:_____ Signature: _____

Declaration

I John Mgemezulu declare that "EVALUATION OF TREATMENT EFFICIENCY OF MUST WASTEWATER TREATMENT PLANT" is my own work and that the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

Signature : 

Date : 19/07/21

Disclaimer

This document describes work undertaken as part of a programme of study at Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology. All views and opinions expressed therein remain the sole responsibility of the author(s), and do not necessarily represent those of the School.

copyright statement:

This copy of the dissertation has been supplied on condition that anyone who consults it is understood to recognize that its copyright rests with its author and that no quotation from the dissertation and no information derived from it may be published without acknowledgement.

abstract

Malawi is water scarce country in terms of quality with maximum rainfall received in the summer season which lasts for only three months (November, December and January); hence the water resources have to be protected. The municipal wastewater effluents are considered one of the environmental threats that impact the water quality of the streams. This study was conducted to evaluate the treatment efficiency of the MUST wastewater treatment plant. The study focused mainly on primary data which was collected and analyzed using the standard methods of laboratory analysis. The standard methods used include colorimetric method for measuring COD, Photometric method which measures TSS, turbidity and ammonia and the aqua multimeter probe which was used to take in-situ measurement of parameters including temperature, pH, ORP, EC and Salinity. The data set using ten water quality parameter (ammonia, BOD, TSS, COD, ORP, EC, turbidity, pH, temperature, salinity) was measured from influent and effluent of the MUST wastewater treatment plant using grab sampling technique

Physical, chemical and microbiological efficiency of MUST Sewage/Wastewater Treatment Plant was determined. This was done by studying the applied technology and comparing analyzed results of its influent and effluent with that of regulatory set limits of the Malawi Bureau of standards and World Health Organization (WHO). The result obtained from the samples collected from the influent of the MUST Sewage/wastewater Treatment Plant, showed that the Sewage/Wastewater quality was contaminated and the result of its Effluent showed that the sewage treatment Plant was not very effective and efficient, because it was not able to bring all the stated parameters to be within tolerance limits for industrial effluents. The Total Suspended Solid (TSS), ammonia, five-day Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Turbidity, Conductivity and in the influent were far above the regulatory set limits so as the effluents. This shows that the treatment plant is not able to satisfactorily reduce the highly polluted influent within the regulatory limits after treatment thus making the effluent not environmentally friendly. It is advised that combined sewage treatment technology as used by the MUST Sewage treatment Plant should be improved for efficient treatment. Performance appraisal has been carried out by comparing the concentrations of pollutants at the inlet and outlet of the treatment unit. The

grab samples were collected at the inlet and outlet of all the treatment units and analyzed as outlined in the standard methods for the examination of water and wastewater. The samples were analyzed for various parameters like pH, BOD, COD, TSS and TDS, ORP, ammonia depending on the results, performance of the plant was evaluated. The study highlighted that the MUST Wastewater Treatment Works (WWTW) is somehow not effectively treating the wastewater up to the required standards before discharging them into the downstream rivers. This study concludes that the MUST WWTW may contribute significant loads of pollutants into these rivers including Ndelerani stream that drains into Chimvu which commonly used by the surrounding communities

acknowledgements

Firstly, I would like to thank the God almighty for the keeping me health throughout the work. I would also like to express my deepest thanks to my supervisor, Mr. Francis Chauluka who was always available when needed and provided necessary comments that improved my work.

Many thanks go to Mr Harold Yapuwa as well for giving an open arm to the MUST laboratory and proper directions for conducting the tests

I would like to also thank Mr Mhamba who technically works at treatment plant for the cooperation he showed towards me during sample collection and briefing on the plant operations

I also thank My fellow student Gomezgani Msuku who we worked hand in hand in the sample collection and measurements both on the in-situ and in the laboratory without whom the measurements would be difficult

I would also want to extend my heartfelt appreciation to my family and everyone that offered their support. Without their support and encouragement, I would have not completed this dissertation.

ACCRONYMS / ABBREVIATIONS

MUST	Malawi University of Science and Technology
WHO	World Health Organization
WWTP	Wastewater treatment Plant
UNICEF	United Nations international Children Fund
DO	Dissolved Oxygen
SS	Suspended Solids
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
TDS	Total Dissolved Solids
ORP	Oxygen Reduction Potential
EC	Electrical Conductivity

Table of Contents

Declaration iii

Disclaimer iv

copyright statement: v

abstract vi

acknowledgements viii

List of figures xii

CHAPTER 1: INTRODUCTION 1

1.1 BACKGROUND 1

1.2 PROBLEM STATEMENT 4

SIGNIFICANCE OF THE RESEARCH 5

MAIN OBJECTIVE 5

SPECIFIC OBJECTIVE 5

RESEARCH QUESTIONS 5

SCIENTIFIC SIGNIFICANCE 5

CHAPTER 2: LITERATURE REVIEW 6

2.1 TREATMENT TECHNOLOGIES USED BY MUST WASTEWATER TREATMENT PLANT 8

PRIMARY TREATMENT 8

SECONDARY TREATMENT 8

TERTIARY TREATMENT 8

BIOLOGICAL PROCESSES IN MUST WASTEWATER TREATMENT PLANT 10

THE IMPORTANCE OF WASTEWATER TREATMENT PROCESSES 10

IMPORTANT PARAMETERS USED FRO EVALUATION 11

pH 11

BOD 11

TSS 12

Ammonia 12

TDS 12

CHAPTER 3 METHODOLOGIES 14

3.1 Research design 14

3.2 Materials and methods 15

LABORATORY / EXPERIMENTAL ANALYSIS FOR PRIMARY DATA 15

Study limitations 16

3.3 STUDY AREA 16
3.4 SAMPLING POINTS 18
Diagram 1 showing the influent point where influent sample was collected 18
Diagram 2 showing the effluent point where effluent sample was collected 18
3.5 SAMPLING AND ANALYSIS 19
CHPTER 4 RESULTS AND DISCUSION 20
Table 1 shows measurements for day 1 20
Table 2 show measurements for day 2 21
Table 3 showing a table of measurements for day 3 21
Table 4 shows the average values of the parameters of 3 days and the Tolerance limits for industrial effluents for Malawi 22
EC 27
Turbidity 27
DO 28
ORP 28
DISCUSSION 28
CHAPTER 5 CONCLUSION AND RECOMENDATION 30
ETHICAL CONSIDERATIONS 31
REFFERENCE 32
APPENDIX 34

List of figures

Figure 1; diagram showing categories of the wastewater 1

Figure 2 shows the flow of the research design undertaken 14

Figure 3; a map showing MUST campus in TA chimaliro, extracted from Thyolo within Malawi.....17

Figure 4; showing aerial view of the MUST campus locating MUST wwtp.....18

Figure 5 shows the graph of effluent discharge and Tolerance limits for industrial effluents for pH 23

Figure 6 shows the graph of effluent discharge and Tolerance limits for industrial effluents for temperature..... 24

Figure 7 shows the graph of effluent discharge and Tolerance limits for industrial effluents for suspended solids 24

Figure 8 shows the graph of effluent discharge and Tolerance limits for industrial effluents for ammonia..... 25

Figure 10 shows the graph of effluent discharge and Tolerance limits for industrial effluents for BOD 26

Figure 11 shows the graph of effluent discharge and Tolerance limits for industrial effluents for TDS..... 27

EC..... 27

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Wastewater is the water whose physical, chemical or biological properties have been changed as a result of the introduction of certain substances which render it unsafe for some purposes (Lundgren, S., 2013). It is categorized based on the source that led for it to generated according to the flow diagram below;

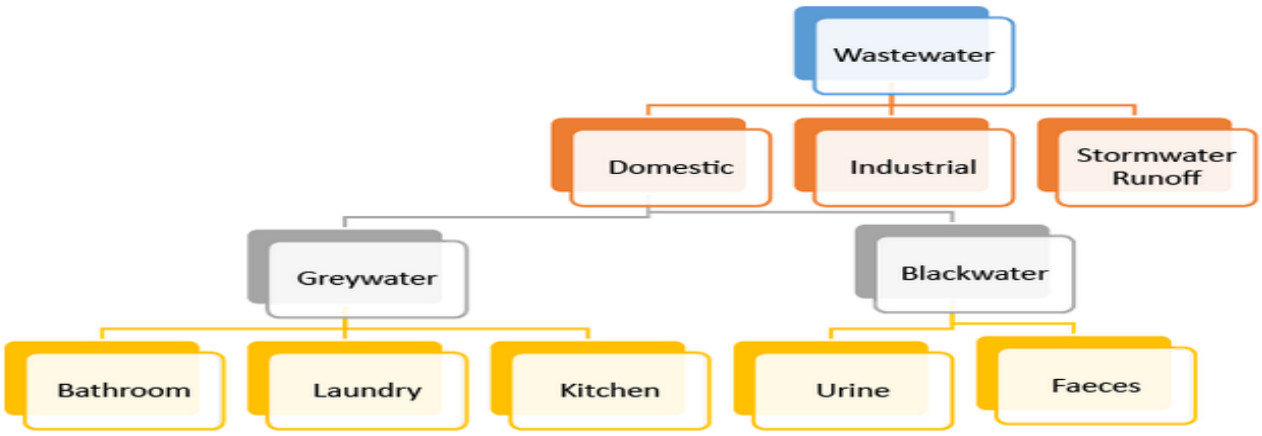


Figure 1; diagram showing categories of the wastewater

Wastewater contributes to nutrient loading leading to algae blooms and growth of plants in the aquatic ecosystem and also transmit pathogenic bacteria's e.g. E. coli, shigellosis, typhoid fever, salmonella, and cholera (Naido et al. 2013)

Malawi as a developing country, accessibility of quality water is a major problem, despite that it receives high amount of rains. For southern Malawi the rainy season normally lasts from November to February with between 150mm and 300m in rainfall per month (Vincent et al., 2014). There are a lot of activities that contribute to pollution of water sources which include industrial effluent discharge, sand mining, agricultural practices, livestock keeping that suggest that the pollution of the surrounding areas and consequent deterioration of public health also escalate. The shortage of potable water is an environmental concern all over the world (Ghisi et al., 2006). According to Fatta et al., (2005) the world is faced with the problems related to management of wastewater. The improperly treated wastewater effluents contains large amount of organic matter and nutrients which have detrimental impact on the receiving environment (Naidoo & Olaniran, 2013). This problem could deteriorate the receiving

environment through the excessive amount or poor quality of wastewater effluents. Most of the water sources are subjected to frequent drastic changes in microbial and chemical qualities as a result of the variety of the activities on the watershed. As a result, regulatory measures should be enforced for wastewater effluents discharge to protect the receiving environment. According to Davis and Masten, (2009) defined wastewater as water that contains parameters that exceed the permissible limits that makes it impure and hazardous to environment. It is the water discharged from homes, institutions and industries that contains dissolved, suspended and particulate organic and inorganic materials.

Wastewater treatment is of high importance, mainly due to two reasons: to protect the environment and to prevent the contamination of water resources, which can lead to the spreading of diseases. It is especially important in urban and industrial areas where water often contains high concentrations of pathogens and substances such as heavy metals that may be harmful to people and organisms. Untreated wastewater let out in streams, rivers and on land without purification can be a danger to many kinds of life forms. For humans there is a high risk of transmission of water related diseases. On land it can damage and destroy crops and form ponds, which can function as breeding pools for insects and other organisms (Lundgren & Lundgren, 2013). An overload of nutrients can also lead to eutrophication of rivers, lakes and oceans. Some studies have been conducted to evaluate or asses the efficiency of the treatment plant. In the year 2010 a study was conducted and assess the efficiency of the two treatment plants that came up with poor results with respect to removal of total dissolved solids in contrast to the removal/reduction in other parameters like total suspended solids, BOD and COD (Kumar & Pinto, 2010). The performance of the aeration tank and secondary clarifier was nearly up to the mark in both the cases. In order to achieve better performance, fresh sludge with higher microorganism populations should be recycled and the aerators must be operated continuously. The treated effluent can be safely discharged into streams, rivers, bay, lagoon or wetland, or it can be reused for irrigation of a golf course, green way, park or for groundwater recharge as opined by (Fatta et al., 2005).

In Africa, the evaluation in performance efficiency of different wastewater treatment plants in El-Gharbia governorate in Egypt (Ramadan & Eltawab, 2018). The results show that, all collected samples from Tanta, and El Mehala El Kobra WWTPs were exceeding the Egyptian

Permissible limits (COD: 80 mg/l) while the samples collected from Mehalet Marhom, Mehalet Menof, Kotour, El Santa, Shernak and Zefta were complying the Egyptian regulations.

In year 2013 a study in zomba, Malawi was done to evaluate the efficiency of two wastewater treatment plants. Water samples were collected from different parts of the plants, in order to compare differences in concentrations at the inlet, during the purification process, and at the outlet. The results were compared with guideline values established by the WHO and the Malawian bureau of standards. The results of the study showed that both plants exhibit elevated levels of iron and manganese in effluents. No nutrients, except phosphate, exceeded the guideline values for drinking water, but for many nutrients there was also no significant reduction. The high phosphate levels in both plants are alarming given the increase in algae growth these levels can contribute to. Hence a conclusion were made that further studies are necessary at both plants to examine the content of the wastewater, especially pathogen levels (Lundgren & Lundgren, 2013). For most of treatment works in Malawi no data is available including for the Malawi university of science and technology.

Therefore, this study evaluates the treatment efficiency of MUST wastewater treatment plant to provide an overview of the level of concentration of the effluents. This will contribute to MUST community and Malawi as a country to assess the treatment efficiency of industrial treatment plants so as to provide protection to the ecosystem and the human health.

1.2 PROBLEM STATEMENT

Wastewater effluent is considered one of the environmental threats that impact water quality of the streams for example it contributes to eutrophication beside agricultural fertilizers, kills aquatic organisms, transmit waterborne disease. Wastewater discharged from MUST treatment plant into streams is used for commercial activities like watering crops sold to communities therefore knowledge of the wastewater quality is required to protect the human health. As the demand of water resource is growing as the economy expands and the population increases, wastewater and sewage treatment works increasingly operated under stress. The study by Mdolo (2017) at Kauma treatment works in Lilongwe showed that poorly were wastewater effluent were being discharged to the environment, result in the overflow of untreated wastewater to the river system due to equipment failure to handle the increased loads at the treatment works. The studies conducted by Odjadjare et al. (2010)also concluded that majority of municipal wastewater treatment works in South Africa are ineffective in removing pollutants. This could pose a threat to the receiving environment as well as the public health of the people who depend on the river system for their consumption as the effluents are discharged into water bodies. The discharge of wastewater poses a great burden in terms of wastewater management which will not only increase the treatment cost, but also introduce a wide range of chemical and microbial contaminants to the water. The contamination of the river system will also have health effects on the aquatic species and the downstream communities which uses the river water without prior treatment. The inadequately treated effluents are discharged into the local water systems, which affects the downstream ecosystem and rural communities and also degrading the environment. Environmental pollution has become the global concern and attracts a lot of attention. The demand of water resource is growing as the economy expands and the population increases, wastewater and sewage treatment works increasingly operated under stress. Since there is no data about the quality of effluent from the MUST treatment plant therefore, to prevent negative outcomes of the effluent from MUST treatment works to the surrounding community effluent data must be analyzed to determine the quality of the effluent. This study focuses on the evaluation of the treatment plant of MUST treatment plant to ensure the quality of the ecosystem environment and health of the community.

SIGNIFICANCE OF THE RESEARCH

Through the findings; The institution will be able to improve treatment plant to be better in the efficiency, it will also be help in reduction of negative impacts of wastewater in the environment and public health. This paper will add knowledge to scientific community since the studies about the treatment efficiency of wastewater treatment facilities are very rare locally.

MAIN OBJECTIVE

- To evaluate the treatment efficiency of MUST wastewater treatment plant through evaluating its discharge effluent

SPECIFIC OBJECTIVE

- Examine the physical, chemical, biological parameters of wastewater of MUST wastewater treatment plant
- Comparing the effluent of the MUST wastewater treatment plant to the Malawi beaureu of standards

RESEARCH QUESTIONS

- Has the water quality of the Ndelerani stream deteriorated with time due to the discharge of effluent from the MUST wastewater treatment plant?
- Do the discharge effluents from the MUST wastewater treatment plant meet the discharge limits of the Malawi standard?

SCIENTIFIC SIGNIFICANCE

Since MUST has existed since the year 2014 and it run its own treatment plant and dispose the effluent direct to the environment. The study was worth undertaking since it will enable the institution to understand the treatment efficiency so that proper improvement on the treatment are achieved to protect the aquatic system and downstream users in case of its low efficiency.

CHAPTER 2: LITERATURE REVIEW

The chapter presents the views of other researchers on related studies. Further to outlining the importance of treatment processes effectively treating the effluent, the chapter also provides the impact of discharging partial or untreated wastewater into the water resources.

Industrial effluent is collected in septic tanks or discharged into the sewerage systems. The City assemblies do clear septic tanks but very little waste water is treated in any way before being discharged to rivers or open quarries (Msilimba & Wanda, 2007). Cities produce large amounts and very diverse types of waste including wastewater. The quality of these wastes depends on their source, the way in which they are collected and the treatment they receive. The final fate of these wastes is also very diverse (Mena et al., 2017). A Sewage Treatment Plant may treat some industrial effluent but their main function is the treatment of domestic effluent (sewage). Responsibility for the treatment of sewage is generally undertaken by the Local Authority or Water Company. Local legislation exists in most parts of the world to oblige operators of these treatment plants to conform to local legislation on final sewage discharge quality; others may be governed by those standards recommended by the World Health Organization (WHO) guidelines.

Some studies have been conducted to evaluate or asses the efficiency of the treatment plant. In the year 2010 a study was conducted and assess the efficiency of the two treatment plants that came up with poor results with respect to removal of total dissolved solids in contrast to the removal/reduction in other parameters like total suspended solids, BOD and COD(Kumar & Pinto, 2010). The performance of the aeration tank and secondary clarifier was nearly up to the mark in both the cases. In order to achieve better performance, fresh sludge with higher microorganism populations should be recycled and the aerators must be operated continuously. The treated effluent can be safely discharged into streams, rivers, bay, lagoon or wetland, or it can be reused for irrigation of a golf course, green way, park or for groundwater recharge as opined by (Fatta et al., 2005).

In Africa, the evaluation in performance efficiency of different wastewater treatment plants in El-Gharbia governorate in Egypt(Ramadan & Eltawa, 2018). The results show that, all collected

samples from Tanta, and El Mehala El Kobra WWTPs were exceeding the Egyptian Permissible limits (COD: 80 mg/l) while the samples collected from Mehalet Marhom, Mehalet Menof, Kotour, El Santa, Shernak and Zefta were complying the Egyptian regulations.

In year 2013 a study in zomba, Malawi was done to evaluate the efficiency of two wastewater treatment plants. Water samples were collected from different parts of the plants, in order to compare differences in concentrations at the inlet, during the purification process, and at the outlet. The results were compared with guideline values established by the WHO and the Malawian bureau of standards. The results of the study showed that both plants exhibit elevated levels of iron and manganese in effluents. No nutrients, except phosphate, exceeded the guideline values for drinking water, but for many nutrients there was also no significant reduction. The high phosphate levels in both plants are alarming given the increase in algae growth these levels can contribute to. Hence a conclusion were made that further studies are necessary at both plants to examine the content of the wastewater, especially pathogen levels (Lundgren & Lundgren, 2013).

Davis and Masten (2009) defined wastewater as water that contains parameters that exceed the permissible limits that makes it impure and hazardous to environment. It is the water discharged from homes, institutions and industries that contains dissolved, suspended and particulate organic and inorganic materials. Wastewater (including sewage water) management is a challenge faced by many cities and institution authorities in Malawi (Mdolo, 2017). Malawi University of science and technology was establish on 17 December 2012 and became operational in March 2014 and it has its own wastewater treatment plant which came into operational in 2014 as well. It receives all kinds of wastewater including black water, grey water, rain water. MUST wastewater treatment plant uses different processes of waste water treatment which include preliminary treatment process, primary treatment process, secondary treatment process and also different mechanisms are involved which are physical, chemical and the biological under different level in the treatment process. In the start of the treatment system there is an underground septic tank in which the wastewater with excess fecal matter, urine, washing and bathing soaps and other waste from hostels, classrooms and any other sources within the campus are collected. In the septic tank it is where the primary sedimentation takes place, the solids settle out from the wastewater and the remaining liquid waste with some suspended solids are directed into the bio tower system.

2.1 TREATMENT TECHNOLOGIES USED BY MUST WASTEWATER TREATMENT PLANT

Malawi University of science and technology was established on 17 December 2012 and became operational in March 2014 and it has its own wastewater treatment plant which came into operational in 2014 as well. It receives all kinds of wastewater including black water, grey water, rain water. MUST wastewater treatment plant uses different processes of waste water treatment which include preliminary treatment process, primary treatment process, secondary treatment process and also different mechanisms are involved which are physical, chemical and the biological under different level in the treatment process. In the start of the treatment system there is an underground septic tank in which the wastewater with excess fecal matter, urine, washing and bathing soaps and other waste from hostels, classrooms and any other sources within the campus are collected. In the septic tank it is where the primary sedimentation takes place, the solids settle out from the wastewater and the remaining liquid waste with some suspended solids are directed into the bio tower system.

PRIMARY TREATMENT

The target for primary wastewater treatment is the removal of settleable suspended solids and floating solids. In primary treatment, wastewater passes through a sedimentation tank at such low velocity that the fine solids settle out of suspension via gravity and form sludge at the tank base.

SECONDARY TREATMENT

The main objective of secondary treatment is the removal of organic matter. Organic matter is present in the following forms: dissolved organic matter (soluble or filtered BOD) that is not removed by merely physical operations, such as the sedimentation that occurs in primary treatment and organic matter in suspension (suspended or particulate BOD), which is largely removed in the occasionally existing primary treatment, but whose solids with slower settleability (finer solids) remain in the liquid mass.

TERTIARY TREATMENT

Tertiary treatment includes treatment processes used after the secondary, for example granular media filtration used for removal of residual suspended solids, and disinfection for pathogen reduction. Additional treatment for nutrient removal is also included in tertiary treatment.

The components of wastewater treatment plant are pumping sewage, primary treatment, secondary treatment and tertiary treatment, The different treatment methods used in wastewater treatment plant are classified in three different categories as; Primary Treatment: Refers to physical unit operations, Secondary Treatment: Refers to chemical and biological unit processes and Tertiary Treatment: Refers to any one or combination of two or all three i.e., physical unit operations and chemical or biological unit processes, used after secondary treatment(Choksi et al., 2015). The MUST wastewater treatment plant works under a redundant system where there are two systems that operate, the bio tower (that uses bio filters) system and the stabilization lagoons that operates in case of the bio filter system failure. The primary effluent then undergoes screening to remove solids that have capacity to cause blockage of the pipe systems and also there is grit chamber that collects the grit particle which include sand and other small particles after which the effluent is directed into an underground water holding tank in the underground of the control chamber which also some of percentage of settling of remaining particles occur after some specified time the effluent are directed to the tank outside the tank control chamber. Outside control room the wastewater goes through tank and directed to where the disinfectant (chlorine in form sodium chloride) where chlorine act as disinfectant (Mackeown et al., 2020). is applied to the wastewater after which it is the directed back into the control where they undergo bio filtration in which the MUST sewer system has too tanks. In the bio filter is where the microorganisms are cultured and a full biological treatment occurs and there is also a continuous supply of the oxygen from air blower machine within the control room. From this process the effluent is discharged to the environment. The degree of treatment provided to the waste water will largely be based on the effluent standards prescribed by regulatory agencies when the treated effluent is to be discharged into a watercourse or land near the institution. The complete treatment of waste water is brought by a sequential combination of various physical unit operations that include the primary sedimentation in the septic tank, and chemical and biological unit processes in the bio filters (Ghawi, 2018).

BIOLOGICAL PROCESSES IN MUST WASTEWATER TREATMENT PLANT

In a bio filtration system like the one MUST uses; the pollutants are removed due to biological degradation rather than physical straining as is the case in normal filter. With the progression of filtration process, microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) are gradually developed on the surface of the filter media and form a biological film or slime layer known as biofilm. There are three main biological processes that occur in a bio filter which are attachment of microorganism, growth of microorganism and decay and detachment of microorganisms (Chaudhary et al., 2003).

THE IMPORTANCE OF WASTEWATER TREATMENT PROCESSES

The importance of the wastewater treatment process using different influent treatment stages (involving pre – treatment, primary, secondary and tertiary) is to reduce or remove organic matter, solids, nutrients, disease-causing organisms and other pollutants from the influent wastewater before the effluent is discharged to a water body. The properly treated wastewater discharged into the water bodies would reduce the risks for the downstream communities who rely on river water for consumption without pre –treating it. Municipal wastewater treatment is the process of removing contaminants from wastewater and household sewage, both runoff and domestic. Municipal wastewater treatment covers the physical, chemical, and biological processes of physical, chemical and biological contaminants removals. Majority of areas in Malawi including MUST surrounding communities use stream water for most of the domestic purposes. The health of the community is threatened by microbial and chemical pollution as a result of untreated or partially treated wastewater effluents from MUST wastewater treatment works and agricultural fields. It is therefore necessary to treat wastewater to protect human and environmental health. According to Manungufala et al. (2011), the wastewater treatment works that performs poorly have an impact on the water quality of the receiving stream (with metals, nutrients and disease carrying bacteria) as the effluents are discharged into it.

IMPORTANT PARAMETERS USED FRO EVALUATION

According to Arpor and Muchie (2011) the common physical and chemical quality variables of concern in wastewater include: pH, ammonia, chemical oxygen demand (COD), biological oxygen demand (BOD) conductivity, dissolved oxygen (DO), ORP,

pH

pH measures the degree of acidity of water. The degree of acidity or alkalinity is determined by the relative amounts of acids and bases in the water. If both are present in equal proportion (as in pure water), the pH is neutral or 7. If there are more acids than bases, the water is acid (pH below 7). If bases predominate, the water is alkaline or basic (pH above 7). Water with pH of less than 4.8 or greater than 9 can be harmful to the aquatic environment. The pH is a useful indicator of chemical balances in water. High (greater than 9) or low (less than 5) pH will adversely affect the availability of certain chemicals or nutrients in the water to be used by the plants (Powell et al., 2008; Jensen, 2010). The fluctuation of pH of water affects the solubility of chemicals which could also distress the availability of toxic and nutritive chemicals to the aquatic organisms. According to Mosley et al, (2004), most metals become more water soluble and more toxic with increase in acidity. pH has also an effect on the performance of the wastewater treatment plant. The study by Hodgson and Larmee (1998) reported that an increase in pH (above 10.7) of the final could also results in the reduction of the coliforms in the final effluent. The elevated pH also causes phosphates to precipitate the metal ions such as calcium, magnesium, and iron present in the wastewater causing a reduction in phosphorus concentrations (Powell et al., 2008).

BOD

Biochemical Oxygen Demand (BOD) referred to the quantity of dissolved oxygen in the aquatic environment that is used to break down organic materials in a given water sample at certain temperature over a specific time (Chapman, 1996). It measures the number of organic compounds in water and is used as a gauge of effectiveness of wastewater treatment plants. According to Suthar et al. (2010), the presence of BOD in water indicates the organic contaminants in the aquatic system which adversely impacting the water quality and biodiversity of the river system. The more organic materials discharged into the aquatic system,

the more oxygen is required to break it down. Low aquatic oxygen levels (below 92% saturation) results in aquatic organisms to be more susceptible to diseases and hamper swimming abilities.

TSS

Total suspended solids (TSS) refer to all particles suspended in water which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater (CCME, 2008). High concentration of TSS impacts the aquatic environment by clouding (turbid) and increasing the temperature of the water body (Wilson, 2010). Wilson (2010) reiterated that as the levels of TSS increase, the water body begins to lose its ability to support the diversity of aquatic life.

Ammonia

Ammonia is a pungent colorless gaseous compound of nitrogen and hydrogen that is soluble in water and can also be condensed into a liquid by cold and pressure (Durgapersad, 2005). Most of the domestic wastewater contains ammonia and ammonium salts as are used as cleansing agents and as food additives at household level (WHO, 2003a). According to Durgapersad (2005) the presence of ammonia in surface water is usually due to domestic and agricultural wastes. On dissolution in water, ammonia forms the ammonium cation; hydroxyl ions are formed at the same time. The ammonium cation is less mobile in soil and water than ammonia and is involved in the biological processes of nitrogen fixation, mineralization, and nitrification (WHO, 2003a). Ammonia gas is toxic to fish and other aquatic organisms. If dissolved oxygen is present, ammonia can be broken down by nitrifying bacteria to form nitrites and nitrates (WHO, 2003a)

TDS

Total dissolved solids (TDS) refers to the inorganic salts (primarily calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter present in solution in water which originate from natural sources, sewage, urban and agricultural run-off, and industrial wastewater (Elamassi, 2009). Majed (2006) highlighted that TDS of wastewater increases when passing through the treatment process due to evaporation.

Nadia (2006) as well as Igbinosa and Okoh (2009), state that the discharge of wastewater effluents with a high TDS level (above 470 mg/l) would have adverse impact on the aquatic

life, rendering the receiving water unfit for drinking and domestic purposes, as well as reducing crop yield

CHAPTER 3 METHODOLOGIES

The methods and material that were used in this study are discussed in depth in this chapter. These methods highlight on the current situation in the study area and also predicted what might happen in future if the current discharge patterns do not change. Standard ethical principles were followed in the process of data collection. In order to achieve the objectives of the research which aimed to conduct a full evaluation of the treatment plant. The steps below clearly indicate the processes and procedures followed to achieve the research objectives. Performance appraisal has been carried out by comparing the concentrations of pollutants at the inlet and outlet of the treatment unit. The grab samples were collected at the inlet and outlet of all the treatment units and analyzed as outlined in the standard methods for the examination of water and wastewater. The samples were analyzed for various parameters like pH, BOD, COD, TSS and TDS, ORP, ammonia depending on the results, performance of the plant was evaluated

3.1 Research design

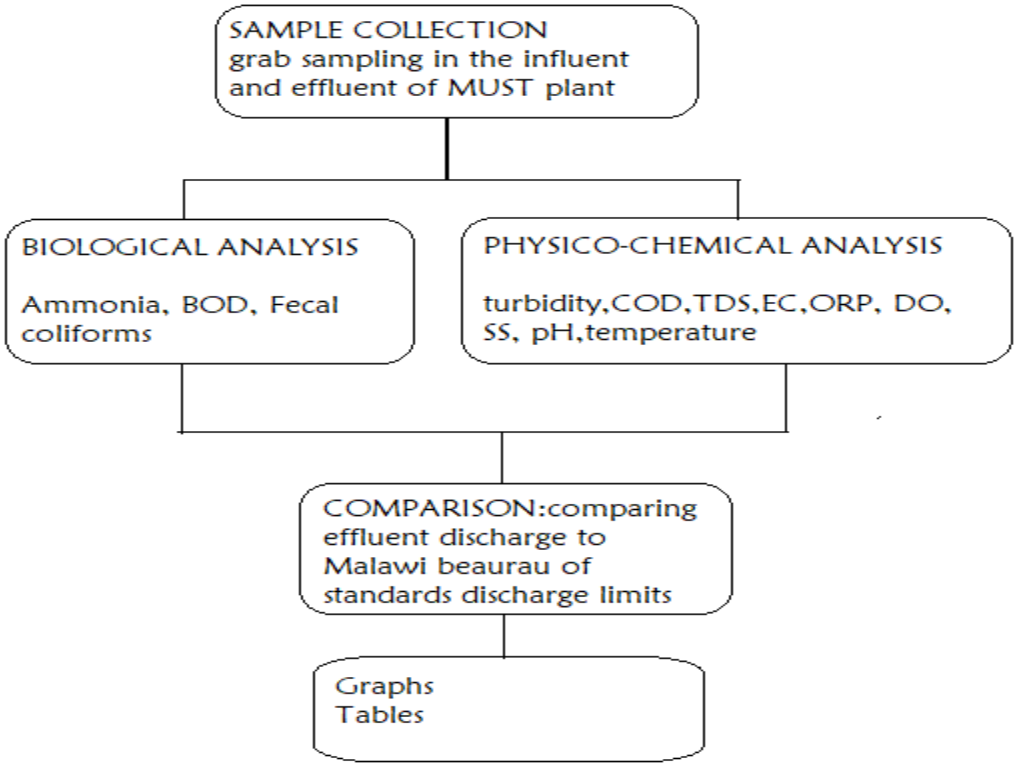


Figure 2 shows the flow of the research design undertaken

The research design solely involved the quantitative research which involved measurements of the parameters on the in-situ and in the laboratory and statistical valuation of the results.

3.2 Materials and methods

The study employed the following materials and chemicals in order to come up with the measured results, the samples were collected and measured for three days at random time and measurement involved both laboratory and in-situ. Photometer was used to measure TSS, Ammonia, turbidity. field sample collection was done using a beaker tied by a lope for gab sampling and reagents bottles was used for sample collection and transfer from the study site to the laboratory, multi-probe aqua meter for an in-situ measurement of EC, pH, ORP, salinity as well as the temperature.

LABORATORY / EXPERIMENTAL ANALYSIS FOR PRIMARY DATA

During the laboratory analysis of the water samples, the standard and accredited methods for water quality analysis were followed. No sample preservation was done as all the samples were analyzed immediately after sampling. Below are the specific methods for analyzing each parameter:

Multi-probe aqua meter

- The instrument was calibrated then carried on the in-situ
- Sample were grabbed and poured into a 20 liters plastic pail and then the probe was deepened into the pail on the in-situ
- And the parametric values were displayed on the meter and the recorded these parameters were; temperature, pH, salinity ORP, EC,

Three samples were measured using a photometer which were turbidity, TSS and ammonia

Photometric procedure

- When the blank sample is filled in the viral tube of 10ml and inserted into the meter, it is set in the mode 34, by pressing shift 34 when it is switched on
- Then on range of parameters then TSS is selected and then zeroing is set by pressing zero and then pressing test and the a viral filled with collected sample whilst shaked was inserted in the meter with no reagents were added to the sample and then test key was pressed
- After some few minutes a parametric concentration value of turbidity shows on the display and it were recorded in all the 3 days

Similar procedures were followed to test for turbidity and for the Ammonia before the sample was filled in the in the viral it was filtered and the 5ml was diluted in the tap water of 400ml and then poured into a viral tube of 10ml and then reagents were added to the sample which were ammonia 1 followed by ammonia 2 and then the viral tube was inserted into the meter and the time counted for 10 minutes to give a concentration value.

Digestion method for determining COD

- The water sample filtered using membrane filtration
- And the determined using digestion method at 150^0c. The water was used for blank determinations and preparation of control standards to show negligible interference and a pipette for transferring samples in mercury test tubes.
- The tubes will be swirled to mix the contents and closed in a digester, a heating source set at 150^0c for 2 hours.
- In order to determine the value of COD a spectrophotometer through spectrometric method which measures the interaction of light with the sample was used.

To determine the values for BOD the conversion factor was determine from a ratio of BOD/COD afterward the measured concentration value of COD was being multiplied by the factor to get the concentration of BOD.

Study limitations

- Due to system clean up and duration which was set for sample collection the plant was not function which led to number of days for sample collection to be reduced from 5 to three days.
- Since the instrument is used by so many of us also limited the number of days since the instrument was always busy
- Calibration was also problem with the multi-probe aqua meter as such so much errors could be available in the data.

3.3 STUDY AREA

Malawi is a country located in the southeast part of Africa. It covers area of 118 480 km2 and a population size of about 15 million makes Malawi one of the most densely populated countries in Africa (WHO, 2012, Internet). According to UNDP, Malawi is one of the world's poorest countries, ranking 171 out of the 182 countries studied in the Human Development Index (UN, 2011, Internet). Malawi is landlocked, which has made the country vulnerable and

dependent on its neighboring countries for export and import. Malawi has agriculture as its main industry. With 90% of the population depending on agriculture, both as income and food source, years with crop failure has struck hard on the population and at several times the country has suffered from mass starvation. According to UNICEF, one of the major causes of death amongst young children in Malawi is water-borne diseases. More than 25% of the population in Malawi does not have access to safe drinking water sources and UNICEF's monitoring showed, in 2008, that only 56% of the population have access to improved sanitation facilities UN 1, 2012, Internet; UNICEF, 2008, Internet. The rapid urbanization is putting pressure on the already existing wastewater treatment plants and the need for more treatment plants is growing as the cities grow and institutions.

Thyolo district is one of the districts in Malawi. The district covers an area of 1,715 km.² and has a population of 458,976. It is also has crossroads leading to Makwasa, Molere, Konzalendo, Thekerani into Muona and eventually Nsanje leading to another border with Mozambique. The type of climate in thyolo is tropical savanna wet. The driest month having precipitation less than 60 mm (2.4 in) and less than 4% of the total annual precipitation.

MUST is situated in Thyolo district which is located in the southern region of Malawi in TA Chimaliro

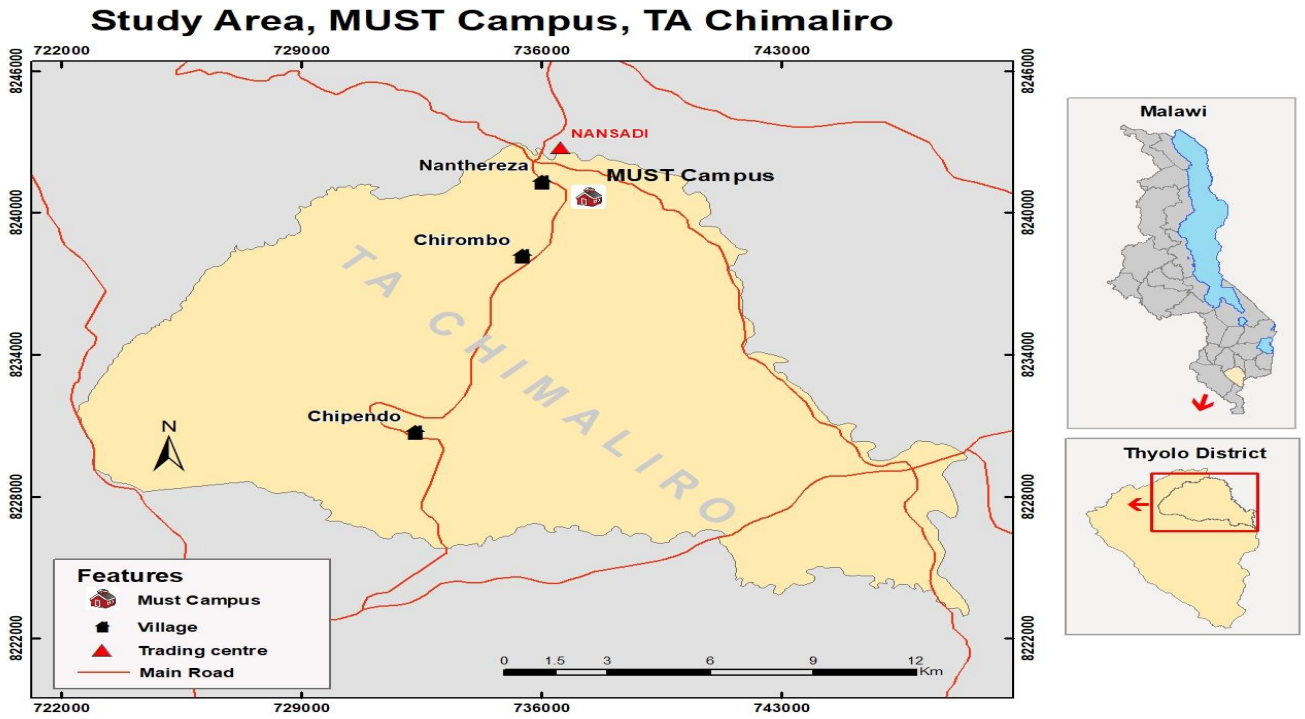


Figure 3; a map showing MUST campus in TA chimaliro, extracted from Thyolo within Malawi

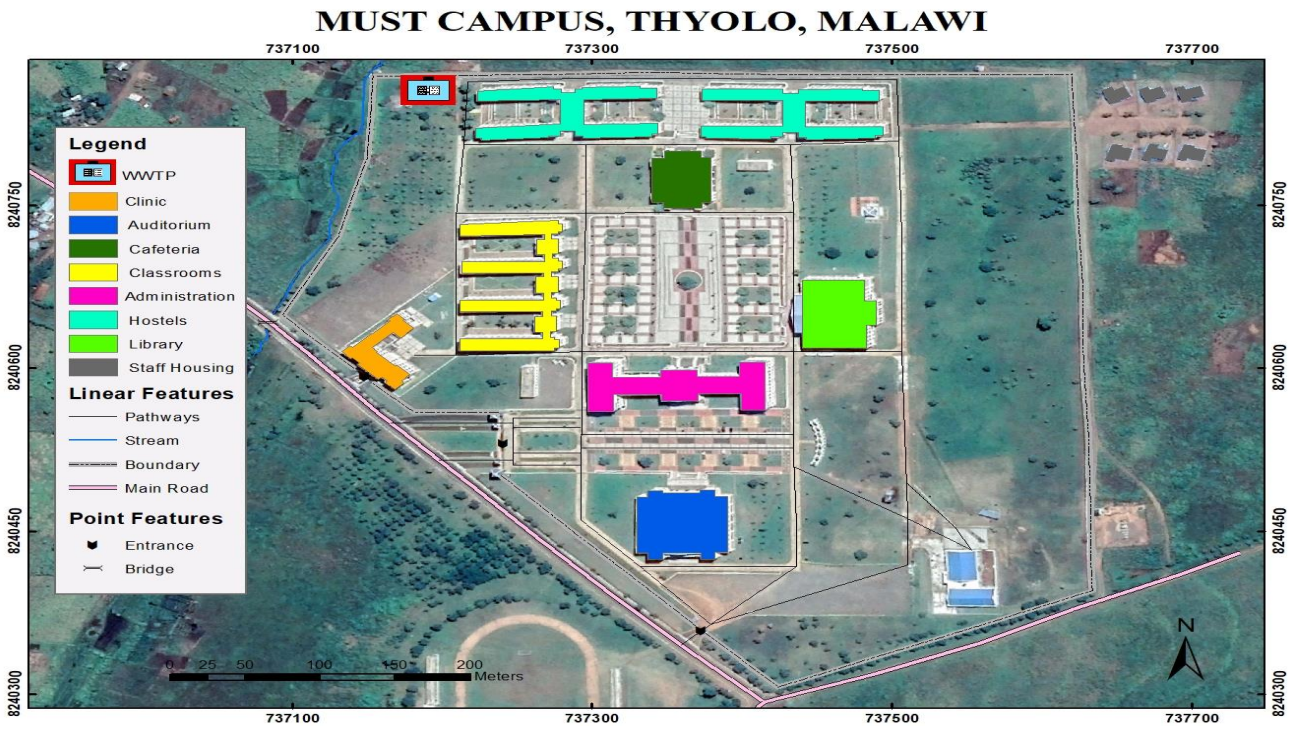


Figure 4; showing aerial view of the MUST campus locating MUST wwtp

3.4 SAMPLING POINTS

The sampling point for this project work was at the influent receiving tank and the effluent discharge line of the MUST Sewage Treatment Plant



Diagram 1 showing the influent point where influent sample was collected



Diagram 2 showing the effluent point where effluent sample was collected

3.5 SAMPLING AND ANALYSIS

Wastewater samples used in the study were obtained from treatment facility influent and effluent in month of June for three days chosen randomly within the month. The samples were collected by hand. A total of 6 samples (3 influents and 3 effluents) were procured for the study. pH, temperature, DO, EC, and TDS values were determined on the spot using multi-probe aqua meter. Chemical oxygen demand (COD) was conducted with digestion method using spectrophotometer. SS, turbidity and ammonia was determined by photometric procedure using the photometer.

Statistical analysis

Excel sheet was using to come with influent and effluent averages and graphs of comparison between the effluents and the effluent discharge limits for the Malawi government and trend line graphs of the influent and effluent.

CHPTER 4 RESULTS AND DISCUSION

The chapter describes the results from the various methods described in the previous chapter. Of note was that the samples collected from the influent and effluent points were aimed on evaluating the effectiveness of the wastewater plant in removing wastes before discharge.

The trend time graphs for the collected data below is shown in the APPENDIX for effluent and influent

Table 1 shows measurements for day 1

DAY 1		
PARAMETER	PRE-TREATMENT	POST-TREATMENT
pH	7.75	7.79
Temperature	14.4	14.9
DO	2.42	2.3
suspended solids	130	76
ammonia	32	29.6
COD	280	72
BOD	173.6	17.28
TDS	1226	1154
ORP	-20.3	-33.4
EC	1889	1780
Turbidity	114	71

Table 2 show measurements for day 2

DAY2		
PARAMETER	PRE-TREATMENT	POST-TREATMENT
pH	7.7	8.13
Temperature	15.2	15.3
DO	0.55	3.33
suspended solids	123	67
ammonia	50.4	36
COD	280	72
BOD	173.6	17.28
TDS	1337	1155
ORP	-35	-36
EC	2054	1784
Turbidity	113	65

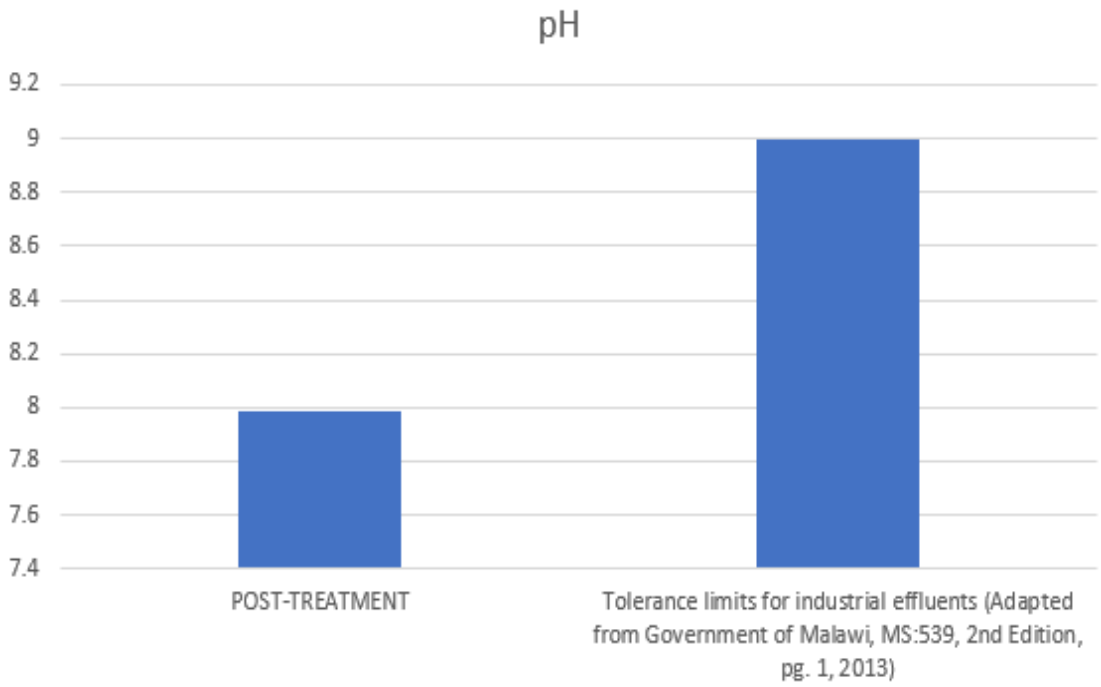
Table 3 showing a table of measurements for day 3

DAY 3		
PARAMETER	PRE-TREATMENT	POST-TREATMENT
pH	7.71	8.05
Temperature	14.18	14.24
DO	1.35	3.34
suspended solids	293	59
ammonia	43	41.6
COD	280	72
BOD	173.6	17.28
TDS	1348	1225
ORP	-35	-36
Turbidity	255	65
EC	2086	1784

Table 4 shows the average values of the parameters of 3 days and the Tolerance limits for industrial effluents for Malawi

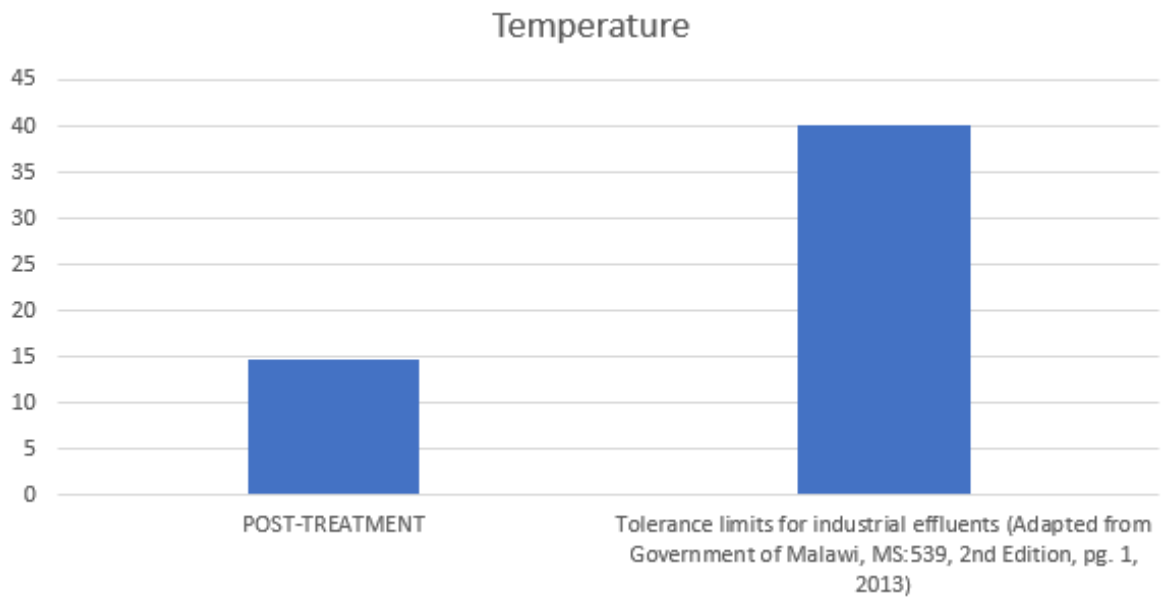
PARAMETER	PRE-TREATMENT	POST-TREATMENT	Tolerance limits for industrial effluents(MBSMS:539, 2nd Edition, pg. 1, 2013)
pH	7.72	7.99	9
Temperature	14.59333333	14.81333333	40
DO	1.44	2.99	4
SS	182	67.33333333	30
ammonia	41.8	35.73333333	10
COD	280	72	60
BOD	173.6	17.28	20
TDS	1303.666667	1178	500
ORP	-30.1	-35.13333333	NA
Turbidity	160.6666667	67	NA
EC	2009.666667	1782.666667	NA

Figure 5 shows the graph of effluent discharge and Tolerance limits for industrial effluents for pH



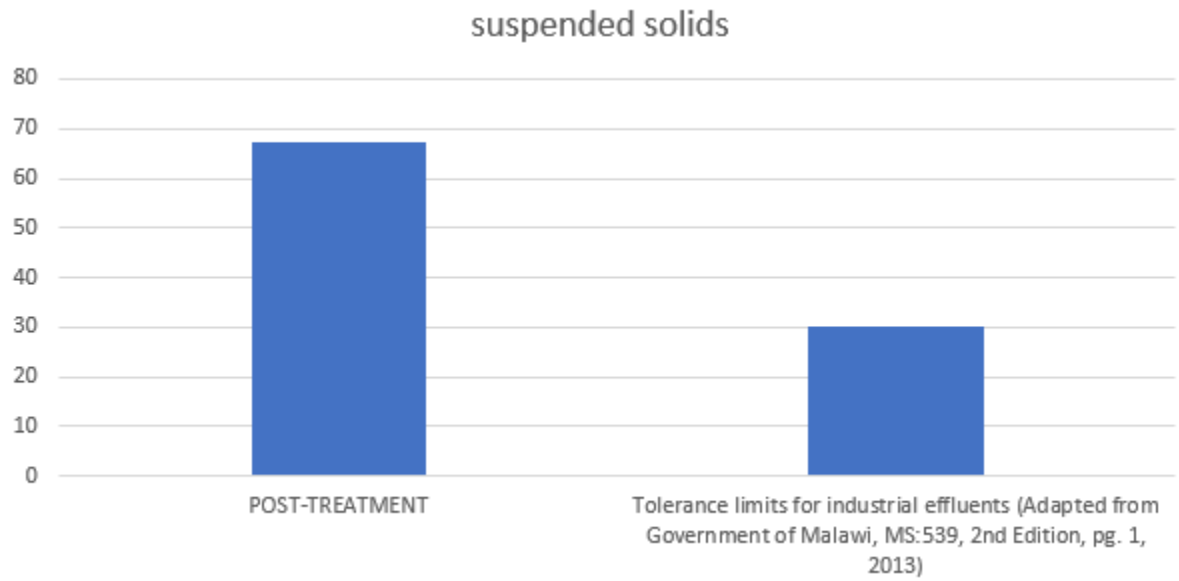
All the influent wastewater samples were analyzed. The mean pH value was 7.72 and was in the range of 7.7 to 7.75. The mean pH value of the effluent wastewater was 7.99 and they ranged from 7.79 to 8.01 and were all within Malawi standards range of 6.5 to 9. The results show not significant change in terms of the pH of the treatment of the influent and effluent of the wastewater.

Figure 6 shows the graph of effluent discharge and Tolerance limits for industrial effluents for temperature



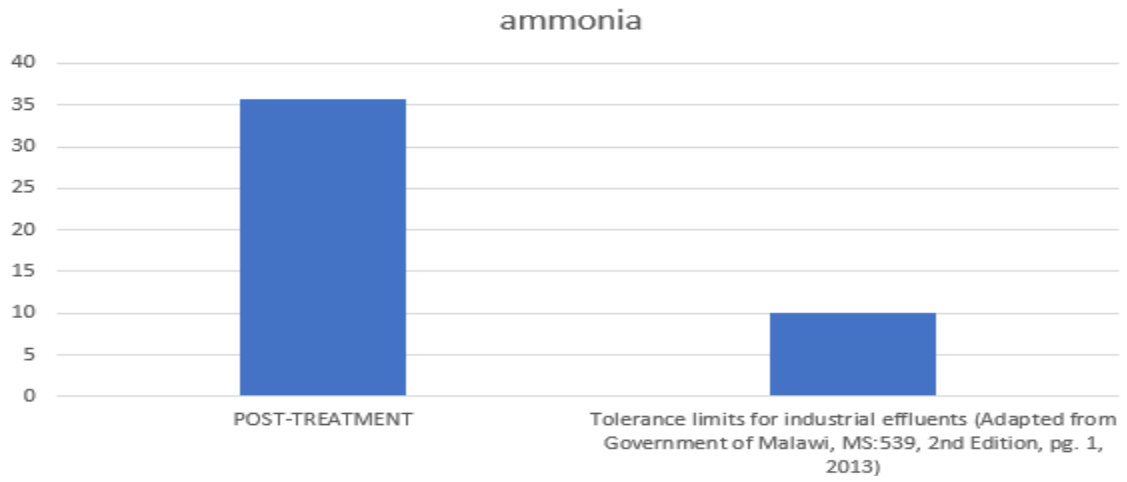
The temperature of the influent wastewater to the treatment plant ranged from 14.4 to 15.2 The effluent temperature ranged from 14.9 to 15.3. The results show no significance difference in the temperature of the influent and the influent, the slight increase in temperature may be energy produced by the activities of the microorganisms. The results gave the mean effluent temperature of 14.81°C which is below the Malawi standards for the effluent discharge of 40°C. This could be due to environmental climatic conditions of the area.

Figure 7 shows the graph of effluent discharge and Tolerance limits for industrial effluents for suspended solids



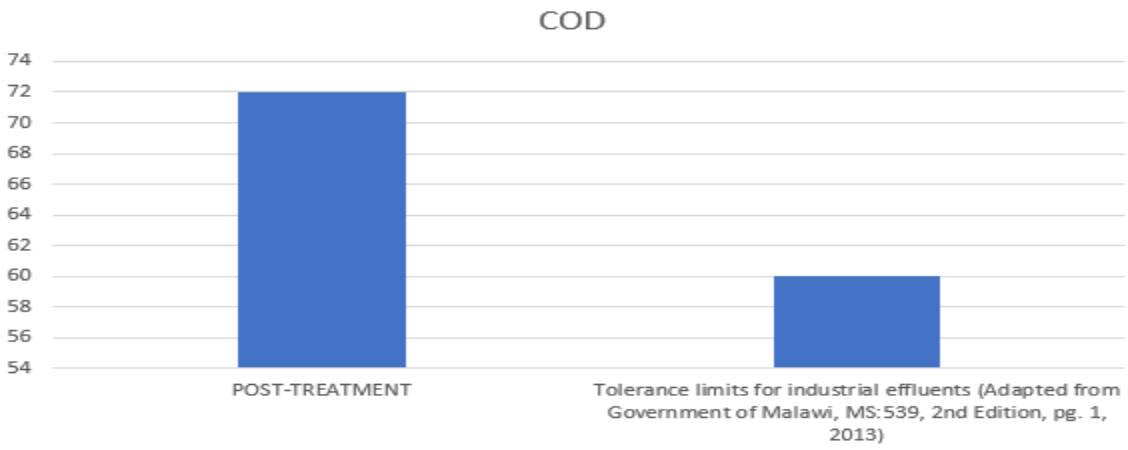
The mean influent SS value ranged from 123 to 293 mg/l and was 182 mg/l. The mean effluent SS value ranged from 59 to 76 mg/l and was 67 mg/l. The mean effluent value of 67 mg/l was more than the Malawi standard guideline value of 30 mg/l. The high mean effluent SS value could be attributed to incomplete sludge settlement during the sedimentation stage.

Figure 8 shows the graph of effluent discharge and Tolerance limits for industrial effluents for ammonia



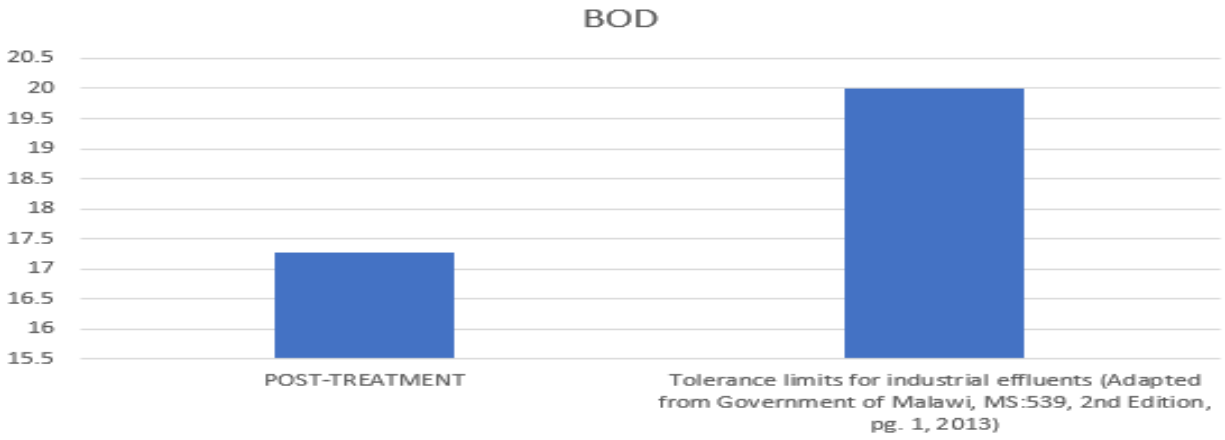
The mean influent ammonia value ranged from 32 mg/l to 50.4 mg/l and was 41.8 mg/l. The mean effluent value was 35.7 mg/l and ranged from 29.6 mg/l to 41.6 mg/l. The initial rise in ammonia of the influent quality could be due to the presence of ammonia is a by-product of anaerobic digestion whilst the fall in the effluent values could be due to nitrification and de-nitrification processes. The average effluent result was above Malawi standard set guideline of 10 mg/l.

Figure 9 shows the graph of effluent discharge and Tolerance limits for industrial effluents for COD



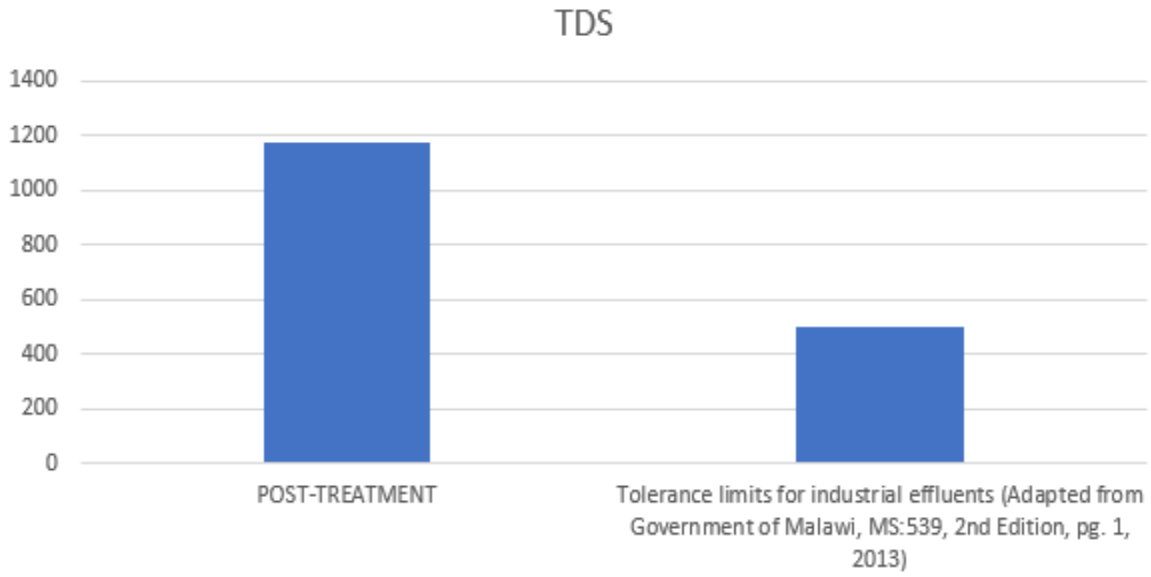
The mean influent COD value was 280 mg/l. The mean effluent COD was 72 mg/l. Even though all the effluent COD values were low as compared to the influent values none met the Malawi standard guideline value of 60 mg/l. The effluent values could be attributed to the presence of sulphides, sulphites, thiosulphate and chlorides that cause interferences to COD.

Figure 10 shows the graph of effluent discharge and Tolerance limits for industrial effluents for BOD



The influent BOD concentration of the treatment plant had a mean of 173mg/l. The high values of BOD in the influent wastewater may be attributed to the high concentration of the organic matter content in the wastewater. The mean effluent BOD concentration was 17 mg/l. the results shows that the effluent value were below the discharge value of Malawi standard of 20mg/l, The average plot of effluent BOD results and the Malawi standard guideline. The result of the average effluent signifies that the biological method is able to treat the wastewater by means of biodegradation of organic matter. It is noted that the release of excess amounts of organic matter into receiving waters could result in a significant depletion of oxygen and subsequent mortality of fishes and another oxygen dependent aquatic or marine organism.

Figure 11 shows the graph of effluent discharge and Tolerance limits for industrial effluents for TDS



Total dissolved solids consist of both the organic and inorganic molecules and ions present in the true solution of the water. Mean influent TDS value ranged from 1226 to 1348 mg/l and was 1303 mg/l. Mean effluent TDS value was 1178 mg/l and ranged from 1154 to 1225 mg/l. It was noted that both average influent and effluent TDS results were above the Malawi discharge limits of effluent of 500mg/l into water body.

EC

Generally, conductivity of water is determined to ascertain the ability of the waters to conduct electrical current. The mean influent conductivity value ranged between 1889 and 2086 μS/cm and was 2009 μS/cm. The high influent conductivity values may be attributed to the high concentration of dissolved ions present in the wastewater during the bottles washing stage of the bottle preparation process. Mean effluent conductivity was 1782 μS/cm in a range from 1780 to 1784 μS/cm. Even though the drop in conductivity shows some amount of ion removal, the conductivity levels of the effluents wastewater were unsatisfactory compared to Malawi standards of 1000 μS/cm.

Turbidity

Turbidity, a measure of the light transmitting properties of wastewater, is a test used to indicate the quality of wastewater discharges with respect to colloidal and residual suspended matter. High levels of turbidity in industrial effluents contribute large amounts of suspended solids to receiving waters. The mean influent turbidity value was in the range of 113 to 225 NTU and

was 160 NTU. The final effluent turbidity value was in the range of 65 to 71 NTU. The mean effluent turbidity value of 67 NTU was above the Malawi standard guideline value of 65 NTU. The mean effluent turbidity value could be attributed to incomplete sludge settlement during the stage.

DO

Dissolved oxygen is required for the respiration of aerobic microorganism as well as all other aerobic life forms. Mean influent DO ranged from 0.55 to 2.42 mg/l and was 1.4 mg/l. Mean effluent DO was 2.99 mg/l and ranged from 2.3 to 3.34 mg/l. The increase in the effluent DO may be attributed to the infusion of air by blowers during the wastewater treatment period. Both the influent and effluent DO values were consistent and above the Malawi standards guideline value of 1 mg/l.

ORP

Oxidation-reduction potential (ORP) measures the ability of a lake or river to cleanse itself or break down waste products, such as contaminants and dead plants and animals. When the ORP value is high, there is lots of oxygen present in the water. Positive value reading indicates the environment is an oxidizing environment and negative results indicate a reducing environment. Hence the results show that the environment is reducing environment in the wastewater

DISCUSSION

After comparing the results of the effluent discharge of MUST treatment with the Malawi bureau of standards effluent discharge limit, the result obtained from the samples collected from the influent of the MUST Sewage Treatment Plant, shows that the Sewage/Wastewater quality is contaminated and the result of its Effluent shows that the Plant is not effective and efficient, because it was not able to bring all the stated parameters to be within regulatory limits of the Malawi standards. The comparison of the results of analysis with the Tolerance limits for industrial effluents (MBS MS:539, 2013) at which wastewater is allowed for discharge into the environment, showed that the influent was polluted with contaminants and the effluent was also not within regulatory set limits. Though most of the physical effluent parameters met the set guidelines, the biological parameters were unacceptable.

There is need to improve the treatment plant so that most or all parameters meet the discharge limit of the Malawi. The process of treatment employed did not remove all the pollutant.

From the data obtained, the pH was almost in the same range as with that f the effluent and influent implying no significant change. The Result also shows that both influents and the effluent are approximately neutral. Comparison of the results from analysis of the parameters in the sewage / waste water samples with the Malawi tolerance for industrial discharge set limits revealed that the values of pH (7.22) and Dissolve Oxygen (DO)(1.44) were below the regulatory limits in the influent as well as in the effluent after treatment, they had values of 7.99 and 2.99 mg/L respectively, which were no within the regulatory limits for the DO. The result also revealed that the Total Suspended Solid (TSS), Nitrate, Phosphate, five-day Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Turbidity in the influent had values were far above the regulatory set limits. From the result, the influent pH and DO were lower than regulatory minimum limits while BOD5, COD, TSS, and some other parameters were all higher than regulatory maximum limits hence the effluent was not environmentally friendly.

CHAPTER 5 CONCLUSION AND RECOMENDATION

After evaluating the treatment plant, the result from the influent and effluent analysis, we can say that the MUST Sewage/Wastewater Treatment Plant technology is not that much efficient in treating sewage to an environmentally friendly state. And when we consider the effect of untreated waste water discharge into receiving water bodies, we can rightly say the treatment plant may contribute to the problems arising from the improper management of sewage/Wastewater which include detrimental effects to health of human beings, aquatic lives, floras and fauna. Comparison between the results from the effluent and the results from the Malawi regulatory set standards shows it is not that environmentally friendly and safe for discharge to receiving water bodies. For effective protection of our environment from the detrimental effect associated with untreated wastewater, its treatment is essential. Hence for Quality Assurance and Quality Control pre and posted treatment analysis should always be carried out on sewage and waste water effluent before discharge.

The result of the effluent analysis shows it is not environmentally friendly, which is a clear indication that the MUST Sewage/Wastewater Treatment Plant is not efficient. The purpose of analyzing and treating wastewater is to be able to detect and eliminate the characteristic pollutants in it to avoid pollution of receiving water bodies or land. The treatment and analysis of wastewater is of great importance. The results gotten from most parameter analyzed before and after the treatment are above regulatory limit. This result obtained may be different for other classes of wastewater; this is because natural changes and sources of Sewage/ Wastewater can alter the values gotten from other places / Sources. Analysis of wastewater helps to ascertain the quality of the water, because that will enable the analyst to select the appropriate treatment process to curtail and avert the negative effect the pollutants in the water may have on the environment, flora and fauna.

However, based on the experiments on this research work, it can be stated that all sewage/waste water should be treated and their influent and effluent be analyzed to make sure that they meet regulatory limits before discharge to the environment to prevent the contaminants present in sewage/waste water from polluting the environment, thereby causing biological and health hazards to living things in the environment.

The study and understanding of the sewage treatment plants may help in reducing the impacts of wastewater on the health and the aquatic system. And also care for treatment plant is

necessary by reducing amount of loading to the plant may help in the plant treatment efficiency by lowering the demand for on-site or municipal wastewater treatment solutions these include: don't flush your toilets to dispose of items which should be treated as solid waste and thrown into the garbage, prevent unnecessary water consumption by turning off faucets when they are not being used and fixing plumbing leaks, make upgrades to your home to lower water consumption. Switching to low-flow toilets and shower heads can drastically reduce the amount of water used, maximize utilization of water-consuming appliances by only washing full loads in washing machines and dishwashers.

As the system improvement, MUST has to opt for the use of slow sand filtration which mostly deals with the biological treatment. Slow sand filtration can be used due to its low-cost water treatment process which can be operated and maintained by a trained member of the local community. No other available water treatment technology, excluding disinfection, can produce as safe a drinking water and provide as great a protection of public health. Pretreatment processes for highly turbid surface waters are available and allow wider application of slow sand filtration in tropical areas. Other minor disadvantages are generally outweighed by the advantages and some developing countries have already taken advantage of the technology in their water supply programs. There is still a lack of awareness of the benefits to be gained from increasing application of slow sand filtration in many developing countries and the objective of this booklet is to draw attention to facts about this appropriate technology and encourage more countries to take advantage of its simplicity and low cost.

ETHICAL CONSIDERATIONS

Malawi university of science and technology as an institution, I asked for consent from the Estates officer that looks over any development within the campus which was done in accordance with research ethics. And also consulted the team working at the plant to create an environment easy for the sampling to take place.

REFFERENCE

Chaudhary, D. S., Vigneswaran, S., & Ngo, H. (2003). *Biofilter in Water and Wastewater Treatment Biofilter in Water and Wastewater Treatment*. *June 2015*. https://doi.org/10.1007/BF02706936

Chavez, M. (2008). *SOP 206-BOD.pdf*.

Choksi, K. N., Sheth, M. A., & Mehta, D. (2015). *To evaluate the performance of Sewage Treatment Plant : A Case study*. 1076–1080.

David, M. K. (2017). *(PDF) A Review Paper on Industrial Waste Water Treatment Processes*. *April 2016*. https://www.researchgate.net/publication/305827717_A_Review_Paper_on_Industrial_Waste_Water_Treatment_Processes

Depat. (2016). *Wastewater Operator Certification Training Module 1 : Introduction to Wastewater Treatment*.

Fatta, D., Arslan Alaton, I., Gokcay, C., Rusan, M., Assobhei, O., Mountadar, M., & Papadopoulos, A. (2005). Wastewater Reuse: Problems and Challenges in Cyprus, Turkey, Jordan, and Morocco. *European Water*, *11*(12), 63–69.

Government of Malawi, MS:539, 2nd Edition, pg. 1, 2013)

Ghawi, A. H. (2018). *Design of Biofilter Odor Removal System for Conventional Wastewater Treatment Plant*. *19*(4), 7–15.

Ghisi, E., Montibeller, A., & Schmidt, R. W. (2006). Potential for potable water savings by using rainwater: An analysis over 62 cities in southern Brazil. *Building and Environment*, *41*(2), 204–210. https://doi.org/10.1016/j.buildenv.2005.01.014

jirka, A.M & M.J, C. (1997). *5220 CHEMICAL OXYGEN DEMAND (COD)* 5220 B . Open Reflux Method*. *5000*, 14–19.

Lundgren, S., & Lundgren, S. (2013). *Efficiency of wastewater treatment plants situated in Zomba , Malawi situated in Zomba , Malawi*.

Mackeown, H., Gyamfi, J., Vital, K., Marnix, K., Dumoulin, D., Verdickt, L., Ouddane, B., Criquet, J., Mackeown, H., Gyamfi, J., Vital, K., Marnix, K., & Dumoulin, D. (2020). *Formation and removal of disinfection by-products in a full scale drinking water treatment plant To cite this version : HAL Id : hal-02399687*.

Mdolo, P. (2017). *TREATMENT EFFICACY OF KAUMA WASTEWATER TREATMENT WORKS IN LILONGWE , MALAWI FOR POLLUTION CONTROL AND WASTEWATER REUSE Principal Mdolo (NRC). October*.

Mohanty, B., Beran, M. G., Keval, K. P., Dhruvit, K. T., & Vimal, G. S. (2017). Design and Construction of a Modified Rapid Sand Filter for Treatment of Raw Water. *Journal for Research*, *3*(May), 8–13.

Naidoo, S., & Olaniran, A. O. (2013). Treated wastewater effluent as a source of microbial pollution of surface water resources. *International Journal of Environmental Research and Public Health*, *11*(1), 249–270. https://doi.org/10.3390/ijerph110100249

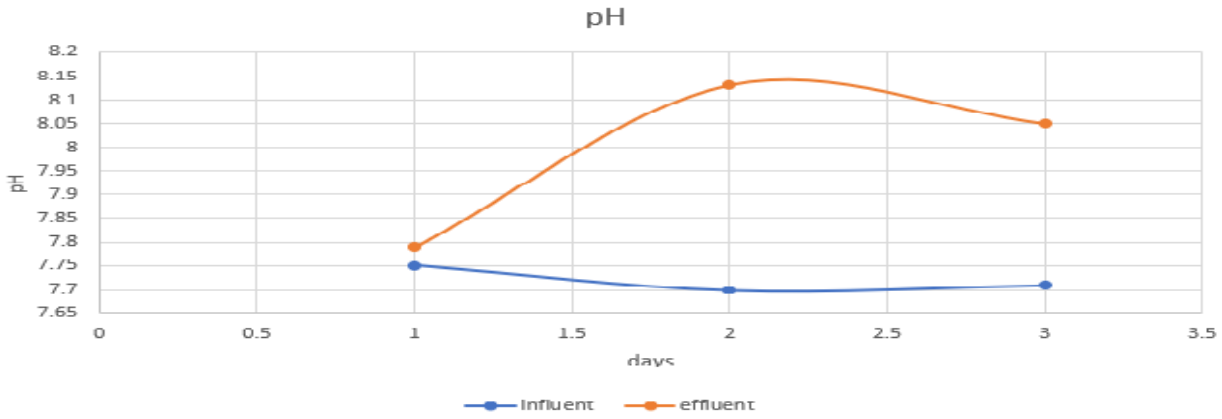
Standard Operating Procedure for : Total Suspended Solids. (n.d.).

Yapuwa, H. (2020). *Ndata School of Climate and Earth Sciences Wastewater Management and Utilization (WAMU - 420) Module Writer Date July 2020 Copy right*. *July*.

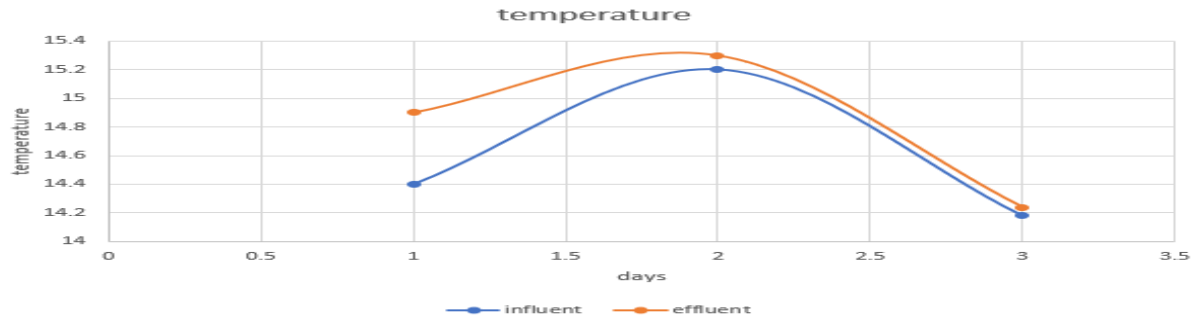
Vincent, K., Dougill, A. J., Mkwambisi, D. D., Cull, T., & Stringer, L. C. (2014). Analysis of Existing Weather and Climate Information for Malawi. *University of Leeds*, *April*, 1–18.

APPENDIX

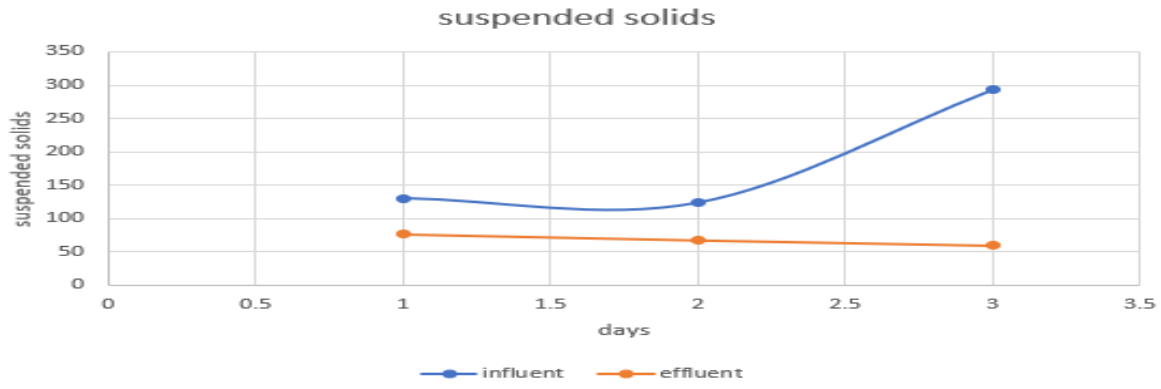
Shows the trend graph of pH of effluent values and influent values for 3 days



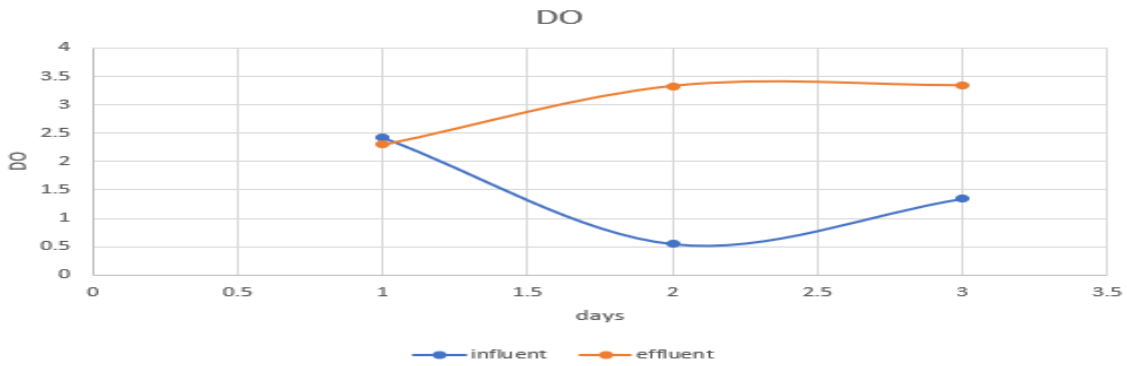
shows the trend graph of temperature of effluent values and influent values for 3 days



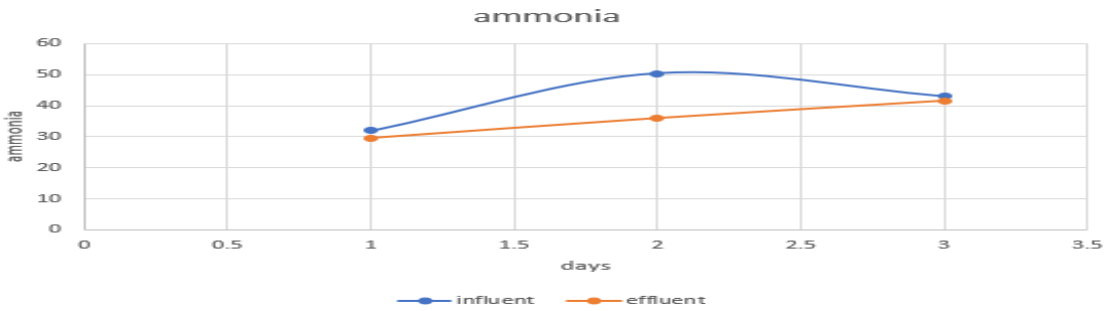
shows the graph of suspended solids of effluent values and influent values for 3 days



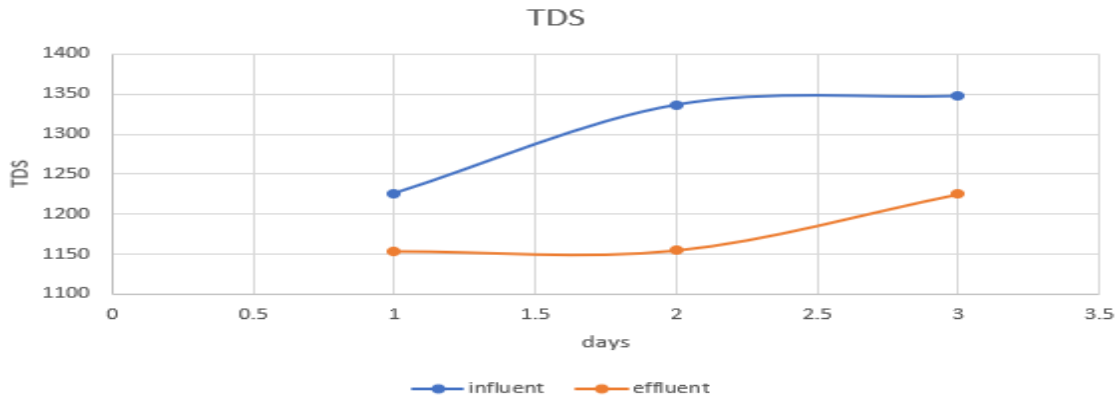
Shows the trend graph of DO of effluent values and influent values for 3 days



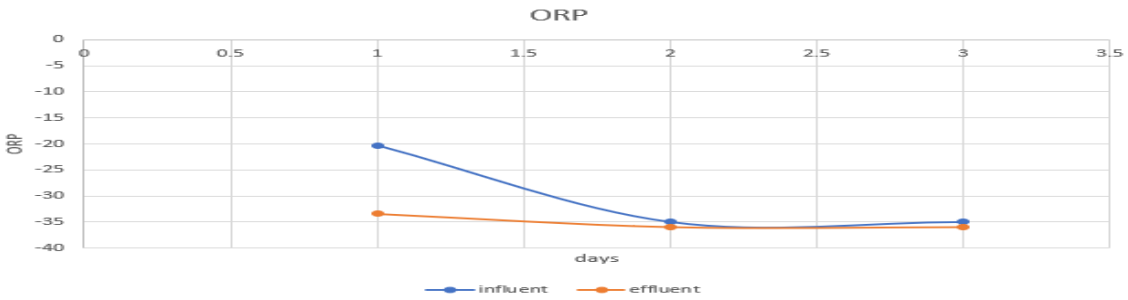
Shows the trend graph of ammonia of effluent values and influent values for 3 days



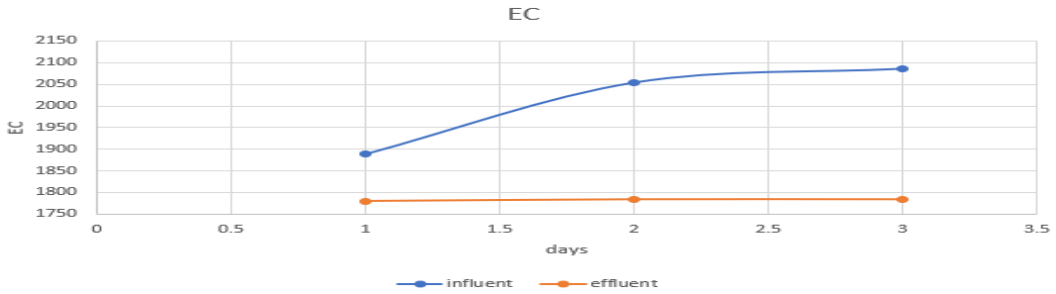
shows the trend graph of TDS of effluent values and influent values for 3 days



shows the trend graph of ORP of effluent values and influent values for 3 days



shows the graph of EC of effluent values and influent values for 3 days



shows the graph of turbidity of effluent values and influent values for 3 days

