FACTORS AFFECTING EFFICIENCY OF INDUSTRIAL WASTEWATER TREATMENT: CASE STUDY OF NJORO INDUSTRIAL SEWAGE WORKS, NAKURU COUNTY, KENYA

BANCY GATHONI CHEGE

A Thesis Submitted to Graduate School in Partial Fulfillment for the Requirements of the Award of the Degree of Master of Science in Environmental Science of Egerton University

EGERTON UNIVERSITY

AUGUST, 2019

DECLARATION AND RECOMMENDATIONS

Declaration

This thesis is my original work and has not been presented for any other award in any other university.

Signature ....Date ....

Bancy Gathoni Chege

NM12/51513/14

Recommendations

This thesis has been approved for the examination with our approval as the supervisors.

Signature ....Date ....

Prof. Wilkister N. Moturi, PhD

Department of Environmental Science

Egerton University

Signature ....Date ....

Dr. Stanley M. Makindi, PhD

Department of Environmental Science

Machakos University

COPYRIGHT

DEDICATION

I dedicate my work to the Almighty God for keeping me healthy throughout my studies. I would also dedicate to my beloved sons Garry and Byron for encouragement and understanding to see that l attained my goals.

ACKNOWLEDGEMENT

First, I would like to thank almighty God for the good health and divine protection throughout my studies. I also like to thank Egerton University for giving me the opportunity to study in the institution. . I also like to thank my supervisors, Prof. Moturi and Dr. Makindi, for the advices, patience and guidance during my thesis write up. Thanks to the Rift valley Water Services Board and the County Government of Nakuru, Ministry of Water, Environment, Energy and Natural Resource department for providing conducive environment to enable to undertake my studies. I also want to thank my family for their support and encouragement. Finally, special thanks to my colleagues and friends.

ABSTRACT

The efficiency of the sewage works depends on the quality and quantity of the influent and the design of the sewage works. Inefficiency of the sewage work has adverse health impact to the aquatic ecosystem. Pollutants can bio-accumulate and bio-magnify in the food chain causing health impact to both human being and wildlife. The main objective of this study was to assess the effectiveness of wastewater management system of Njoro industrial sewage works. This study used descriptive research design while purposive sampling was used to select the major industries. Data collection was done using questionnaire and laboratory experiment. Data was analysed using descriptive statistics and Analysis of Variance (ANOVA) and student t-test. Major pollutants discharged into Njoro sewage works were organic, inorganic and heavy metals. Three industries (Bidco Company, Tanners and Menengai oil refinery) pre-treated their wastewater before being discharged into the sewer line. The management systems used to pre-treat wastewater include; interceptor, stabilization ponds and wetland. There was no significant difference at the inlet and outlet for the concentration of pH (0.14), Conductivity (0.4), Total Dissolved Solids (TDS) (0.35), Lead (0.34), Copper (0.64), Zinc (0.35), Total alkalinity (0.66) and Chromium (0.11) at the influent and effluent of Njoro sewage works. There was a significant difference of the concentration of Chemical Oxygen Demand (COD) (0.05, Biological Oxygen Demand (BOD) (0.01), Dissolved Oxygen (DO) (0.000) and Total Suspended Solids (TSS) (0.01) at the influent and effluent of Njoro sewage works. Njoro sewage works was not effective in the reduction of heavy metals, TDS, conductivity and pH. It was effective in the reduction of COD, BOD, DO and TSS in the wastewater. The study therefore recommends that the pollutants be determined at the source of wastewater. The National Environment Management Authority (NEMA) and the Department of Water and Environment should intensify enforcement of wastewater standards of all industries and establish a forum with the industries.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PLATES

ACRONYMS AND ABBREVIATIONS

APHA: American Public Health Association

BOD: Biological Oxygen Demand

COD: Chemical Oxygen Demand

DO: Dissolved Oxygen

EMCA: Environmental Management and Co-ordination Act

FAO: Food and Agriculture Organization

JICA: Japanese International Co-operation Agency

MCN: Municipal Council of Nakuru

NAWASSCO: Nakuru Water Services and Sewerage Company

NEMA: National Environment Management Authority

NWQMS: National Water Quality Management Strategy

NWRMS: National Water Resources Management Strategy

NWSS: National Water Services Strategy

RVWSB: Rift Valley Water Services Board

RVWWDA: Rift Valley Water Works Development Agency

TA: Total Alkalinity

TDS: Total Dissolved Solids

TFS: Total Fixed Solids

TSS: Total Suspended Solids

TVS: Total Volatile Solids

UNEP: United Nations Environment Programme

WAB: Water Appeal Board

WASREB: Water Services Regulatory Board

WHO: World Health Organization

WRA: Water Resources Authority

WRM: Water Resources Management

WRMA: Water Resources Management Authority

WSB: Water Services Board

WSTF: Water Services Trust Fund

CHAPTER ONE

INTRODUCTION

1.1 Background information

Water comprises over 70% of the Earth's surface making it undoubtedly the most valuable natural resource that exists on the planet, without which life would be non-existent. It is vital for everything to grow and thrive (Akali *et al.*, 2011). The global benchmark of fresh water was 1000m^3per capita (National Water Resources Management Strategy (NWRMS) 2005 – 2007). Despite this, anthropogenic activities worldwide pollute water bodies leading to decrease in fresh water sources. It is estimated that nearly 1.5 billion people lack safe drinking water globally and that at least five million deaths per year can be attributed to waterborne diseases (Onsdorff, 1996). Water bodies have long been considered boundless dumping ground for wastes such as industrial effluents, raw sewage, garbage and oil spills (Tripathi *et al.,* 2007). With the rapid development of various industries, a high amount of fresh water is used as a raw material, as a means of production (process water) and for cooling purposes. Many kinds of raw material, intermediate products and wastes are brought into the water bodies when water passes through the industrial process (Akali *et al.*, 2011; Odjegba and Bamgbose, 2012). The amount of wastewater and pollution levels depends on the technical level of process in each industry sector and will be gradually reduced with the improvement of industrial technologies (Dlamini and Joubert, 1996). Today, most of the rivers receive millions of litre sewage, domestic waste and industrial effluents varying in characteristics from simple nutrient to highly toxic substances. In recent years, increasing industrialization, urbanization and developmental activities with the explosion of human population leads to generation of large amount of wastewater from domestic, commercial, industrial and other sources (Majid, 2010).

Various devastating ecological and human disasters associate industries as a major contributor to environmental degradation and pollution (Kiran *et al.*, 2012). Environmental pollution due to increase of industrial activities are one of the most substantial problems of the century today. Pollution in water is related to human activities such as industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their waste disposal (Dlamini and Joubert, 1996; Pruvot *et al.*, 2006). Poorly treated effluent with high level of pollutants caused by poor design, operation creates major environmental problems when discharged to the surface land and water bodies. Untreated (raw) wastewater is characterized by high levels of organic matter, nutrients, numerous pathogenic microorganisms and toxic compounds making it a significant source of non-point source pollution (Ngigi and Macharia, 2006). The principal objective of physicochemical and microbiological characterization of effluent in the maturation ponds is generally to allow human and industrial effluents to be disposed without danger to human health or unacceptable damage to the natural environment (Suleiman, 2010). Sewage is treated so as to reduce undesirable characteristics. Usually BOD and suspended solids concentration are checked to the degree necessary to ensure it does not pollute or contaminate to unacceptable degree, any water resource into which it is discharged or so that it can be re-used.

Kenya being a developing country, population is on the increase resulting in urbanization and associated population increase challenges, water quality being one of them. Kenya with a population of over 35 million is faced with challenges of water supply and sewerage system (National Water Resources Management Strategy (NWRMS) 2005 – 2007). It is projected that Kenya will be a middle income and prosperous nation coupled with increase in industrialization which leads to increase of industrial pollution which affect the performance of sewage works (Kenya Vision, 2030). It was also classified as a water scarce country with only 650m^3/ year per capita of renewable fresh water which could drop to about 350m^3/ year by the year 2020 (National Water Resources Management Strategy (NWRMS) 2005 – 2007). The current water per capita for Kenya is at 447m^3/year (FAO, 2015). Kenya is going through a water crisis and is likely to continue during the next years (Ngigi and Macharia, 2006). If sewage is improperly treated, discharging it into existing water bodies will exacerbate this situation. This calls for good performing sewage works. The performance of any sewage works depends mainly on the quality of wastewater, quantity and the design (Kumar and Pumnia, 2008). Nakuru town has two sewage works, the Old town sewage work and the Njoro sewage works. They were constructed in 1960s and 1970s respectively. The old town sewage work discharges into Lake Nakuru directly while the Njoro sewage works discharge to river Njoro which drains into Lake Nakuru. In the early 1990s there was increase of water capacity in Nakuru town. The then existing sewage works could not hold the volume of wastewater from both domestic and industrial wastewater. This called for the demand of expansion and rehabilitation of Njoro and Town sewage works by Japanese International Co-operation Agency (JICA) (Greater Nakuru Water Supply Project, 1990). The main objective of treating wastewater is to make it harmless to public health, environment, and both surface and ground water sources. This study focused on the non-performance of a sewage treatment plant receiving the industrial effluent.

1.2 Statement of the problem

The Njoro sewage works is the main sewage work for Nakuru urban town that receives about 90% of industrial wastewater and 10 % domestic wastewater. In the year 1995 the sewage works was rehabilitated due to increased wastewater capacity in Nakuru Town. The Water Resources Management Authority (WRMA) raised complaint in the year 2014 to Rift Valley Water Services Board (RVWSB) about the Njoro Sewage works which was developing pink coloration in the maturation ponds. The pink colour was assumed that the sewage works was not performing due to the non- compliance with water and wastewater quality standards. In normal circumstances, maturation ponds should have grey water. Despite the complaints raised by the concerned bodies, there was little documentation on any study having been carried out to establish the cause of the complaint. In-sufficient pre-treatment of industrial wastewater, may affect the normal functioning of sewage works and the aquatic life (flora and fauna) of the receiving water body. The underground water aquifer may also be contaminated by both chemical elements and microbial organism through percolation. Proper wastewater treatment is necessary for promoting public health and ecosystem survival. The purpose of this study was therefore to assess the efficiency of Njoro industrial sewage works

1.3 Objectives of the study

1.3.1 Broad objective

To assess the efficiency of Njoro industrial sewage works by checking on the historical trends of the physical and chemical parameters from year 2005 to 2016.

1.3.2 Specific Objectives

i. To assess the pollutant discharges of major industries that discharge into Njoro industrial sewage works from year 2005 to 2016.
ii. To document the wastewater management system used by the major industries before discharge into Njoro industrial sewage works.
iii. To establish the trends for physical and chemical wastewater parameters of the Njoro industrial sewage works from year 2005 to 2016.
iv. To determine the concentration level of the wastewater quality parameters at the inlet and outlet of Njoro industrial sewage works and its efficiency.

1.4 Research questions

i. What are the pollutants discharged from major industries that discharge into Njoro industrial sewage works from year 2005 to 2016?
ii. What are the wastewater management systems used by the major industries before discharge into Njoro industrial sewage works?
iii. What is the trend for physical and chemical wastewater parameters of the Njoro industrial sewage works from year 2005 to 2016?
iv. What is the concentration of wastewater quality parameters of the influent and effluent discharge of Njoro sewage works and its efficiency?

1.5 Justification of the study

The wastewater from all industries has to meet the required standards for discharge to the sewage works (EMCA 1999 amended 2015, Kenya Bureau of Standards 2007, WASREB water and wastewater guidelines, 2008, the Kenya Water Act 2002 and WRMA regulations, 2007). The Kenya Water Act 2016 is an Act of parliament that provides for the management, construction, use and control of water resources protection and conservation of the water catchment. The design of any industrial sewage works is related to the quality of the wastewater generated from the industries.

Analysis of physical and chemical characteristics of effluent in stabilization ponds of Njoro sewage works is in line with the environmental policy goals that states 'to achieve a better quality of life for present and future generations through sustainable management of the environment and natural resources' (Environmental Policy, 2012).

This study was also in line with overall goal for the Kenya Vision 2030 for environment, water and sanitation which aims 'to attain clean, secure and sustainable environment' (Kenya Vision 2030; 2013-2017). The study captured the weakness in not achieving the proper management of the generated wastewater which failed to conform to the provided regulations for a better environment for now and future generations. Clean, accessible water for all, is essential part of the world we want to live in. Also on Sustainable Development Goals of 2015, goal 6 on clean water and sanitation states that 'ensure availability and sustainable management of water and sanitation for all'. There is sufficient fresh water on the planet to achieve this, but due to bad economics or poor infrastructure such as the sewage works, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene. Studies done by Kairu

(1996) and Motelin *et al.* (1995) indicate that, lesser flamingos in the lake Nakuru had heavy metal poisoning. This study is of great significance in mitigating the negative impact of sewage water into Lake Nakuru which is a Ramsar site situated in the heart of Nakuru town. The wastewater from the sewage work joins River Njoro and then ends up to Lake Nakuru. Flamingoes and other aquatic habitats may be affected negatively or otherwise killed by the toxic substances with the resultant disruption of the aquatic ecosystem and its food chain.

1.6 Scope of the study

The study was conducted within the Nakuru western zone of Nakuru town. It involved assessment of effluent discharges of industries into the Njoro sewage works, documentation of the wastewater management system used by the major industries and establishment of the historical trends of analytical parameter data of wastewater of Njoro sewage works from 2005-2016. It also determined one point physical and chemical parameters (pH, total alkalinity, dissolved oxygen, conductivity, total dissolved solids, BOD, COD, chromium, copper, lead and zinc) at the influent of the sewage works, outlet of facultative and maturation ponds, and the final wastewater before it joins the River Njoro. The pH, conductivity, TDS and dissolved oxygen was analysed on site. The data obtained was used to assess the variation of the physical and chemical concentration of the trends for Njoro sewage works from 2005 and the one point sampling for physical and chemical parameters of seasonality and growth of effluent discharging industries.

1.7 Limitation of study and Assumptions

1.7.1 Limitation

The data for heavy metals was not consistent.

1.7.2 Assumptions

The pollutants that were determined from the industries were the ones likely to be found in the effluent in the wastewater treatment plant.

1.8 Definition and operationalization of terms

Composite sampling: Corrected samples at the selected sampling point at interval of 6 hours and this was mixed to form one representative sample.

Domestic sewage: Waste from residential, lavatory basins urinals in the western zone of Nakuru town, office buildings and institutions, it contained human excreta and urine.

Effluent: This was Liquid discharged as wastewater from the industrial or sewage works.

Efficiency: The performance of the sewage works and pre-treatment unit in the removal of pollutants in wastewater.

Grab sampling: This was samples collected at a site over a short period.

Industrial sewage: Wastewater that was obtained from the industrial production and the commercial establishment of the western zone in Nakuru town.

Influent: Wastewater that was entering the Njoro sewage work.

In-let: The point at which the wastewater from the factories entered the Njoro sewage works

In-situ test: Tests that were done on-site during sampling. They represented the actual environment condition on the ground.

Major industries: Industries that used large quantity of water for production and the raw materials used in the production contains ingredient that is detrimental to health and the environment.

Njoro sewage works: It was one of the sewage works for Nakuru urban town that receive industrial wastewater from the western zone in Nakuru town.

Out-let: This is the point at which the wastewater discharged into a sewer- line from the industries and from the ponds.

Pre-treatment: Components that was available for the removal or reduce most of the contaminants from the wastewater to prepare the effluent for further treatment before it is discharged into the environment. The level of treatment is selected to match the receiving environment and the intended use.

Sewage: It was also referred as wastewater discharged from the industries and being treated at the Njoro sewage works.

Sewage works or Sewage treatment plant: Facility consisting of system of sewers for carrying off liquid and solid sewage. A place where sewage is treated so that it can be safely got rid -off. In this case it will be the Njoro sewage works in Nakuru town.

Sewage wastewater: Wastewater that was generated from the industrial process for further treatment and from the sewage works.

Sewer-line: It is the carriage system for wastewater to the Njoro sewage works in western zone of Nakuru town.

Sewerage: System that conveys sewage or storm water. It can be pipes, chambers or manholes that take wastewater for treatment in the Njoro sewage works.

Sewerage wastewater design: Design for the Njoro sewerage treatments works that included the compliance condition for its construction so that it could achieve efficiency. This included depth of ponds, capacity, retention period and expected BOD concentrations

Town sewage works: It was one of the sewage works that received only domestic wastewater for the eastern zone in Nakuru town

Wastewater: It includes both organic and mineral matter in liquid media from the industries.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Globally wastewater treatment is given less attention as compared to water supply and treatment and therefore water scarcity and water pollution are issues due to increased urbanization in developing countries. Industrialization is also increasingly affecting the environment globally if wastewater released is not checked for compliance with the set standards. There was a rising sense of global urgency concerning the environmental pollution by chemicals arrangement used in various activities (Palaniappan *et al.*, 2009). For developed countries, industrial effluent receives at least pretreatment at factory level while for developing countries some wastewater may end up to sewer line or to the receiving water bodies untreated. The industrial pollutant may contain pollutant which cannot be removed by biological treatment. The aim of treatment is to get harmless wastewater to the environment (Kartal, 2010). For instance, the Fukushima water treatment plant in Japan had poor performance due to petrochemicals and therefore had to find ways of improving the quality of effluent by means of nitrification inhibitors (Aoyama *et al*., 2008). This is an indication how industrial wastewater can affect the performance of sewage works. The design of facultative ponds can have different performance in terms of reducing odour and the quality of effluent (Pearson *et al*., 2005).

The industrial effluents generally consist of organic compounds, inorganic complexes and other non-biodegradable substances (Huguet *et al*., 2009). Pollution of the environment by toxic metals has accelerated dramatically by 2008 due to increasing industrialization, leading to highly contaminated biosphere and atmosphere (Tiwari *et al*., 2008). The untreated industrial and domestic wastes disposal into environment affects quality of soil and ground water and is considered as undesirable soil use (Quazilbash *et al*., 2006). Rapid industrial development plays an important role in polluting environment and causes severe degradation in ecosystem. Water used in industries carry a potential hazard waste such as heavy metals into the soil and our environment (Azumi and Bichi, 2010). The accumulation of metals in an aquatic environment has direct impact to man and ecosystem (Alam and Mahbub, 2007). The release of pollutants differs from industry to industry. The waste from the pulp industry mainly contain carbohydrates, textile industry contain dyes, plating industry contain nickel and leather tanning wastes contains mainly chromium, zinc, copper, sulphides, carbonates, sodium and many other toxic organic compounds and inorganic compounds (Nouri *et al*., 2009).

2.2 Industrial wastewater

Industrial wastewater is the waste from industrial processes operation. Industrial wastewater is discharged directly into the receiving water body if treated to the required standards. The quantity and quality depend on lifestyle standard of living, technical and legal framework surrounding the area (Henze *et al*., 2001). The wastewater is discharged into municipal sewer if it is partially treated for further treatment to ensure the performance of the sewage works is achieved. Sewage contains industrial effluents, toxic contamination by persistent organic pollutants and heavy metals also occur. These problems result not only in the impairment of human use values of lakes but also degradation of the entire lake ecosystem (Karlsson *et al.*, 2011). The many substances found in wastewater have different characteristics which affect the public health and environment. These characteristics vary from location to location depending on population and activities of the generating establishment (residential, municipal, commercial, industrial and agricultural). Wastewater has typically physical, biological and chemical characteristics (Spring, 2007).

Physical characteristics of wastewater include odour, grey colour, turbidity and solid content of almost 0.1%. Biologically, wastewater contains various micro-organisms, protista (bacteria, fungi, protozoa and algae), plants and animals. Toxic compounds generated by the protista are found in wastewater (Punmia and Jain, 1998). Chemically, wastewater is composed of both inorganic and organic compounds as well as various gases. Inorganic compounds include heavy metals, nitrogen, sulphur, phosphorus, chlorides among others. Organic compounds may constitute carbohydrates, proteins, fats, greases, oils, pesticides, phenols among others. Wastewater contains a higher portion of dissolved solids than suspended, about 85-90% of the total inorganic component is dissolved. About 55-60% of the total organic component is dissolved. Gases dissolved in wastewater are hydrogen sulphide, methane, ammonia, oxygen, carbon IV oxide and Nitrogen (Jhanis and Mishra, 2013). Inorganic industrial wastewater is produced mainly in the coal and steel industry, non-metallic minerals industry, commercial enterprises and industries for the surface processing of metals (iron picking works and electroplating plants) as indicated in table 2.2. These wastewaters contain a large proportion of suspended matter which can be eliminated by sedimentation, often together with chemical flocculation through the addition of iron or Aluminium salts, flocculation agents and some kind of organic Polymers (Henze, 1992).

Industrial wastewater contains organic industrial waste flow from the chemical industries and large scale chemical works which mainly use organic substances for chemical reactions. Most organic industries wastewaters are produced by factories manufacturing pharmaceuticals, cosmetics, glue and adhesives, tanneries and leather factories, textile factories, cellulose and paper manufacturing plants, oil refining factories, brewery and fermentation factories and metal processing industries (Lefebrne and Molelta, 2006). There are many types of industrial wastewater based on the different industries and the contaminants with each sector producing its own particular combination of pollutants. These wastes affect the normal functioning of sewage works or life of the receiving water body if they are not treated well from the source point (Henze *et al*., 2001). The wastewater discharged into the receiving river without treatment has discoloration, foul smell and kill aquatic life (flora and fauna). The wastewater changes the chemical characteristic thus it becomes unfit for various purposes. In Nakuru town there are wet and dry industries (Table 2.1). Wet industries are those that use water in the production process and thereby generating wastewater as one of the final product. Dry industries do not use water in their processes but generate solid waste (Benard and Omondi, 2012).

Table 0.1: Factories connected to the public sewer within Nakuru town

Factory	Products	Industrial sector	Effluent type
Bidco Ltd	Edible Oil	Food	Organic
Palmac Oil Refiners	Edible Oil	Food	Organic
Manengai Oil Refiners Ltd	Edible Oil	Food	Organic
United Millers	Edible Oil	Food	Organic
Happy Cow Ltd	Milk Processing	Food	Organic
Valley Bakery Ltd	Bread baking	Food	Organic
Spin Knit Dairy	Milk Processing	Food	Organic
New Kenya Cooperative Creameries	Milk Processing	Food	Organic
Palmac Soap Factory	Soap	Chemical	Organic
Menengai Soap factory	Soap, oil	Food and textile	Organic
Pyrethrum Board of Kenya	Insecticides	Chemical	Organic
Nakuru Tanners	Chrome tanning	Tannery	Organic and heavy metal
Londra Ltd	Materials, yarn		Organic and heavy metal
Spin Knit Textile Ltd	Brankets, material, yarn	Textile	Organic and heavy metal

Source: MCN and NAWASSCO, 2009

The above factories were connected to sewer-line and were expected to ensure that wastewater released from their premises met the NEMA standards so that they do not affect the operation of sewage system.

Table 0.2: Toxic Pollutants from industrial waste

Industry	Total pollutant
Fertilizer	Ammonia, arsenic
Coke ovens	Phenols, cyanides, thiocyanate, ammonia
Metallurgical	Heavy metals (copper, cadmium, zinc)
Iron and Steel and	BOD, COD, oil, metals, acids, phenols and cyanide
Electroplating	Chromium, copper, cadmium ,zinc
Synthetic wool	Acrylonitrite, acetonitrite, HCN
Petrochemicals and refineries	Phenols, heavy metals, cyanides BOD, COD, mineral oils, phenols and chromium
Textile and leather	BOD, solids, sulfates and chromium
Pulp and paper	BOD, COD, solids, chlorinated organic compounds
Chemicals	COD, organic chemicals, heavy metals, SS and cyanide
Non- ferrous metals	Fluoride and Suspended Solid
Microelectronics	COD and organic chemicals
Mining	Suspended Solids, metals, acids and salts

Source: Kumar and Pumnia, 2008

The above industries were specific of their production and quality of wastewater from the industries was related to the raw materials used.

2.2.1 Effect of industrial wastewater

Environmental pollution is a wide reaching problem (Khan and Ghouri, 2011) and its potential to influence the health of human population is great (Fereidoun *et al.*, 2007). However, pollution from industrial and domestic sources and related public health problems is becoming a real menace. Water and air pollution, domestic and industrial wastes are some of the critical diseconomies that have resulted from the process of industrial expansion and social transformation in the country (Kimani, 2007). Water pollution from industrial sources has become a fairly serious problem and is severe by the fact that it is a source that causes severe public health calamities. This is due to the population's high dependency on natural sources for its drinking water. These problems result not only in the impairment of human use values of lakes but also degradation of the entire lake ecosystem (Karlsson *et al.*, 2011).

Pollutants in industrial wastewater are raw materials, processes chemical, final products and impurities in raw materials and process intermediates process bi-products. A study done at Amol's industrial treatment plant in America indicated that chemical shock affected the performance of the system which was affected by the organic load (Medesh *et* *al.*, 2009). Another study done in Pakistan on Kotlukh put industrial estate concluded that industrial pollutant caused more harm to both human and the environment (Sa'dia, 2003). Industrial pollutants changes water characteristics such as temperature, acidity, salinity or turbidity of receiving waters leading to altered ecosystems and higher incidence of water borne diseases. Impacts can be heightened by the synergistic combinations of contaminants affecting species communities and structures, wildlife, habitats, biodiversity, degradation of other environmental services and in decreased productivity (Karlsson *et al.*, 2011).

Metals are released to the environment through natural and anthropogenic activities (Daruibe, 2007). A study done by Henze *et al.* (2001), indicates that heavy metals block the enzymes of microorganisms or interfere with the cellular metabolite of bacteria and protozoa. Toxicity in the activated sludge depends on metal and the concentration, and only those that are soluble are toxic which can cause serious upset to a wastewater treatment plant. The presence of the heavy metal at the right concentration is good for growth of bacteria but at higher concentration it will interfere with many uses of water since they bio-accumulate in the food chain. Lead at even low levels affects microorganisms. Lead poisoning is most prevalent on public health problems in many parts of the world. Heavy metal concentrations affect also the BOD values due to decrease of Oxygen concentration hence reducing the microorganism in wastewater (Sa'id, 2010). Chromium is dominant in most wastewater streams compared to other metal ions due to its availability in the many industrial processes, and there is still the scope of the cost-effectiveness of the removal of chromium and the efficiency in the treatment. Chromium is required for carbohydrate and lipid metabolism and the utilization of amino acids. Its biological function is also closely associated with that of insulin and most Cr-stimulated reactions depends on insulin. However, excessive amount can cause toxicity and the toxic levels are common in soils applied with sewage sludge. Chromium can lead to liver damage, pulmonary congestion, oedema, and causes skin cancer (Smith and Steinmaus, 2009).

Table 0.3: Effects of industrial waste Source

Pollutants	**Effects**
Organic substances	The increase of organic matter in the sewage works deplete DO of the streams and impose great load on the secondary treatment units hence affecting the performance of the sewage work. The organic load is dependent on the DO in the wastewater.
Inorganic substances	The inorganic matter at high levels affect the design capacity of the sewage work and it results to undesirable for micro-plants of the receiving body and this render the water body unfit for further use e.g. Carbonates, chlorides, nitrogen, phosphorous.
Acids and alkalis	The pH of the wastewater is dependent of the presence of the level of acids and alkali in the waste which can affect the aquatic life and hence the operation of the treatment plant. This can affect the microorganisms in the wastewater.
Toxic substances	They are cyanides, sulphides, acetylene, alcohol etc. the flora and fauna of the receiving water body is greatly affected. Life of workers in the treatment units is also affected.
Colour producing substances	The impact objectionable colour in the receiving water body. The colour may not be conclusive of the root cause which is likely to be assumed of the non- performance of the system.
Oil	The oils floatation principle hinder self-purification process of a stream and affect operational in the treatment plant.

Source: Kumar and Pumnia, 2008

2.3 Wastewater management system (pre-treatment)

Wastewater pre-treatment is a process that removes heavy metals and phosphates from water utilized from the industries. Pre-treatment can be referred to as the process of treating wastewater that does not include domestic wastewater. It helps in the removal of non-domestic pollutants to achieve the NEMA water and wastewater regulations. The chemical used is expected to meet all The Municipal Provincial Federal County and State regulations. Heavy metals, oils and greases and phosphates are the primary concern for general industry to remove from their process water (Kartal, 2010). Most facilities have in-house facilities (pre-treatment in place), the neutralizer tank with the capability, and flash tank for flocculation clarifier and an assortment of transfer tanks (Henze *et al*., 2001). Water from metal finishes requires pH adjustment and charge adjustment with the coagulant. Coagulant is a chemical that has a charge that neutralizes dissolved metals like Zinc, Nickel, Chromium and Phosphates which transform them into suspended state. The effluent contains organic substances which can be removed by special pretreatment of the wastewater followed by biological treatment. Many of the contaminants in wastewater are highly stabilized organic compounds that are not destroyed by biological or chemical treatment of wastes (Azumi and Bichi, 2010).

The organic contaminants are not easily removed by steps of coagulation, chlorination and filtration employed in water purification plants. Some organic pollutants are more absorbable than others. Organic solvents are absorbable due to their low solubility in water. Higher molecular weight compounds are also effectively absorbed. Compounds such as alcohols are poorly absorbed (Stenzel, 1993). A study done in Ramadan city in Egypt by Kulkarni *et al*. (2013) showed that wastewater from organic chemical and waste from food industries can be removed by coagulation –flocculation process. Haydar *et al*. (2009) on tannery wastewater treatment showed that coagulation followed by flocculation and sedimentation was achieved by use of Alum (Aluminium sulphate) with anionic and cationic polymers as a coagulant aid. COD removal was indicated to be at 60-70% and this reduced the strength of wastewater. Hydar *et al. (*2009) also found that Waste Activated Sludge can be used as a coagulation aid in the coagulation –flocculation process using ferric chloride or aluminium sulphate. Also according to Rubi *et al. (*2009) sedimentation and coagulation was found to be effective in the removal of wastewater from car washes and achieved 74% for COD removal. Ho *et al*. (2009) report that using Kaolin suspension (Aluminium silicate and peclin) as a flocculent helped reduce wastewater at 99%.

Paper industries are efficiently done by coagulations and the oil producing industries can remove oils by addition of chloride salt. Heavy metals can also be removed by precipitation by use of lime or caustic (NaOH) to minimum pH value and solubility vary with each specific metal. Treatment of industrial wastewater that contains metal pollutants will require pre-treating the sample to remove substances that may interfere with the precipitation of the metal being removed. Chromium Cr^{6+} should first be reduced to Cr^{3+} and then be precipitate with lime. Care must be taken for the presence of ammonia and cyanides which forms complexes. Copper can be hydroxide and sulphide precipitation while zinc can be precipitated by Hydroxide at pH 11 (Specht *et al*., 2005). Chemical industry can reduce production of waste by avoiding production of waste formation during production. Treatment system depends on the characteristics of wastewater. A study on chemical wastewater treatment was found to be effective in Cairo Egypt when using activated sludge and Rotating Biological Contractors (RBC) (Nasr *et al.*, 2007).

2.4 Legal framework for wastewater disposal

The Constitution of Kenya 2010 part 2 on rights and fundamental freedoms Article 42 on environment, states that, 'every person has a right to a protected environment, for the benefits of present and future generations through legislative and other measures. Part 2 Article 69 clause (1) g on environment and natural resources states that, 'the state should eliminate processes and activities that are likely to endanger the environment and natural resources for the benefit of Kenya'. It also stresses that every person has an obligation to cooperate with state organs and other persons to protect and conserve the environment and to ensure sustainable development and use of natural resources. Article 70 clause (2) b on the enforcement of environmental rights provides for the preventing, stopping or discontinuing any act or omission for that is harmful to the environment and in Article 72 of the constitution has provided for the legislation which is related to the environment.

The Environmental Management and Coordination Act, 1999 amended 2015 (EMCA) is an Act of Parliament to provide for the establishment of appropriate legal and institutional frame work for the management of the environment. Part 1V Article 42 clause (1) e, says that no one shall deposit any substance in a lake, river or wetland. This is on the protection and conservation of the environment article. Part 111 of industrial use and effluent discharge guidelines standards states that NEMA plays a role of supervisory and to coordinate the lead agencies on matters of environment. It provides water and wastewater quality guidelines. The license for discharge of wastewater to the environment is issued by NEMA (Regulation, 2006). Industries discharging wastewater are only required to discharge effluent into an existing sewerage system in a local authority with a prescribed fee. License holder is supposed to ensure the wastewater meet the water quality guidelines and the authority can provoke Environmental Impact Assessment (EIA) and demand for a new EIA study. For the industries that discharge without license are demanded to submit accurate information about the quality and quantity of effluent or pollutants to the authority. NEMA has established a standard enforcement committee which with the lead agencies advice the authority to carry out investigation of actual or suspected water pollution including collecting data. Also it provides for the measures necessary for the treatment of effluent before being discharged into the sewerage system, works necessary for the treatment of effluent before it is discharged into the environment. NEMA also recommends for the treatment of effluent before release into the water body. It also provides for water and wastewater analyses status and conditions necessary for discharging effluent into the environment.

The Water Act 2002 created two sectors the Water Resources Management Authority (WRMA) and the Water and Sewerage Services (WSS). The water sectors provide for the management, conservation, use and control of water resources and for the acquisition and regulations of rights to use water; to provide for the regulation and management of water supply and sewerage services. The Water Act formed; Water Services Regulatory Board (WASREB), Water Resources Management Authority (WRMA), Water Trust Fund (WTF), Water Appeal Board (WAB), Water Services Board (WSB). WASREB is in charge for the supply of water and sewerage services. WRA is responsible for the management of all water resources. According to the WRA rules discharge permit is issued according to the quantity and quality of the river discharge and that of the discharge from the industry or factory. In part V of the Water Resources Management Rules (WRMR) on control of pollution, all toxic and pollutants are required to be treated to permissible standards that the authority authorizes. Those who contravene are fined not more than fifty thousand or imprisoned for not more than three months or both. The effluent discharge into any water resource without a permit issued by the authority is an offence and liable to fine of not more than ten thousand shilling or imprisonment of not exceeding three months. The requirement for discharge permit are the effluent discharge control plan approved by the authority after which if the authority is convinced the organization or industry is issued with the authorization which has imposed necessary conditions which include volume and effluent discharge requirement. The permit is then issued when the authority is certified with the conditions after monitoring and also the permit has effluent monitoring frequency volume and quality of effluent discharge requirement. The permit holder is expected to keep records as in effluent discharge plan. The permit does not allow any spillages into the surface and ground water body or land which is likely to contaminate the water resource. The quality of the wastewater is taken into consideration (WRMR, 2007). The WRMA come up with effluent Discharge threshold of 2009 which contain effluent discharge quantity (EQC), Effluent Discharge Quality Classification (EQC), Effluent Facility Classification (EFC) and Effluent Discharge Classification (EDC). Also the WRA has pollution loading classification to guide in the monitoring. Water Services Boards were licensed by WASREB and they appoint Water Service Provider (WSP) as an agent to provide water and sanitation services on their behalf in its area of jurisdiction. Therefore, the WSP for Nakuru Water Services and Sanitation Company (NAWASSCO) is an agent of RVWSB. NAWASCO use drinking water and wastewater guidelines as provided by the WASREB to ensure that the effluent from the industries meets the guidelines for discharge into the sewer-line in terms of water quality which are referenced from EMCA 1999. The Water Act 2002 was reviewed to water Act 2016. This was to align the water Act 2002 with the constitution of Kenya. Water services were devolved to counties. Rift Valley Water Services was transformed to Rift Valley Water Works Development Agency (RVWWDA) and WRMA was changed to Water Resources Authority (WRA) (Water Act, 2016).

2.5 NEMA Wastewater quality standards

Table 2.4 shows wastewater quality standards are required to be complied with by all the industries within town and within the sewer-line service carrying out production and intending to discharge into the sewer-line as provided by the regulation.

Table 0.4: Standards for discharge into sewer line

Parameter	Units	Maximum Allowable limit
pH	pH	6-9
Total Dissolved Solids	mg/l	2000.0
Temperature	^{0}C	20-35
Total suspended Solid	mg/l	250.0
BOD	mgO/l	500.0
COD	mgO/l	1000 .0
Lead	mg/l	1.0
Chromium Vl	mg/l	0.05
Zinc	mg/l	5.0
Copper	mg/l	1.0

Source: Environmental Management and Co-ordination (Water Quality) regulation, 2006

The below guidelines are provided for by NEMA for use by the lead agencies for monitoring of water bodies pollution.

Table 0.5: Standards for discharge into the water surface body

Parameter	Units	Maximum Allowable limit
pH	pH	6.5-8.5
Conductivity	mg/l	-
Total Dissolved Solids	mg/l	1200.0
Temperature	mg/l	+/-2^0
Dissolved Oxygen	mg/l	More than 2.0
Total suspended Solid	mg/l	30.0
BOD	mgO/l	30.0
COD	mgO/l	50.0
Lead	mg/l	0.01
Chromium	mg/l	0.05
Zinc	mg/l	0.5
Copper	mg/l	1.0

Source: Environmental Management and Co-ordination (Water Quality) regulation, 2006)

2.6. Conceptual Frame work

Wastewater contains physical, chemical and heavy metals, which are dissolved in various concentrations depending on the production processes of industries. The growth of industries will determine the quality and quantity of the wastewater produced. The characteristics of the effluents from the industries depend on the production processes and this can be evidenced by the trend of analysed parameters in the Njoro sewage works. The effluents from industries must be pre-treated before discharge into the sewer-line for further treatment. The test parameter depended on the efficiency of wastewater management system in place. The concentration of the effluents from the industries should comply with the provision of environmental policies and regulations (NEMA standards). These policies and regulations are supposed to be enforced by relevant bodies. The design of sewage works is dependent on the population, quantity and quality of wastewater. The higher the volume of water used in the industries discharging into the sewer-line the higher the quantity of wastewater generated. The raw materials used are directly related to quality of effluent produced and therefore related to parameters likely to be found in the effluent. In case the industries do not have the pre-treatment unit as required by the EMCA, the related regulations, proper enforcement and lack of awareness by the industrial management it will affect the quality of effluent and the performance of the sewage works. The treatment method used in specific industry directly reflects the quality of the wastewater treated. This depends on the level of enforcement from the recommendation from the lead agencies on the requirement to achieve the concentration of the parameter in order to comply with the wastewater quality guidelines. The concentration of the test parameters are dependent of the raw materials used in the production process and the efficiency of the treatment method used in reducing or eliminating the pollutant that are in the generated wastewater. Lifestyle of the population served by the sewage system can affect the physical and chemical parameters in the wastewater. Land size and terrain can affect the design of the sewage work, which can in turn affect the physical and chemical parameters of the wastewater.

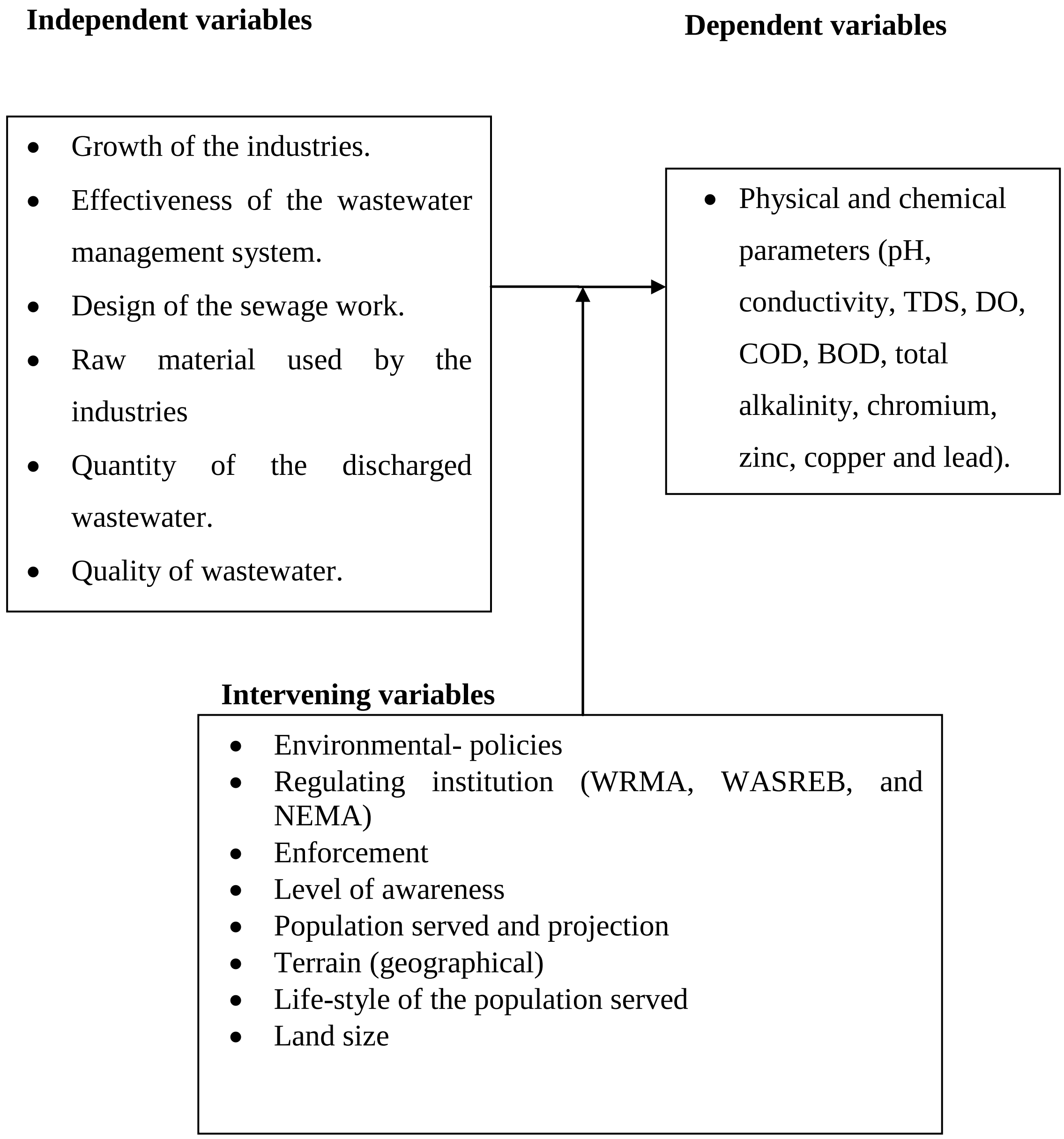


Figure 0.1: Conceptual framework

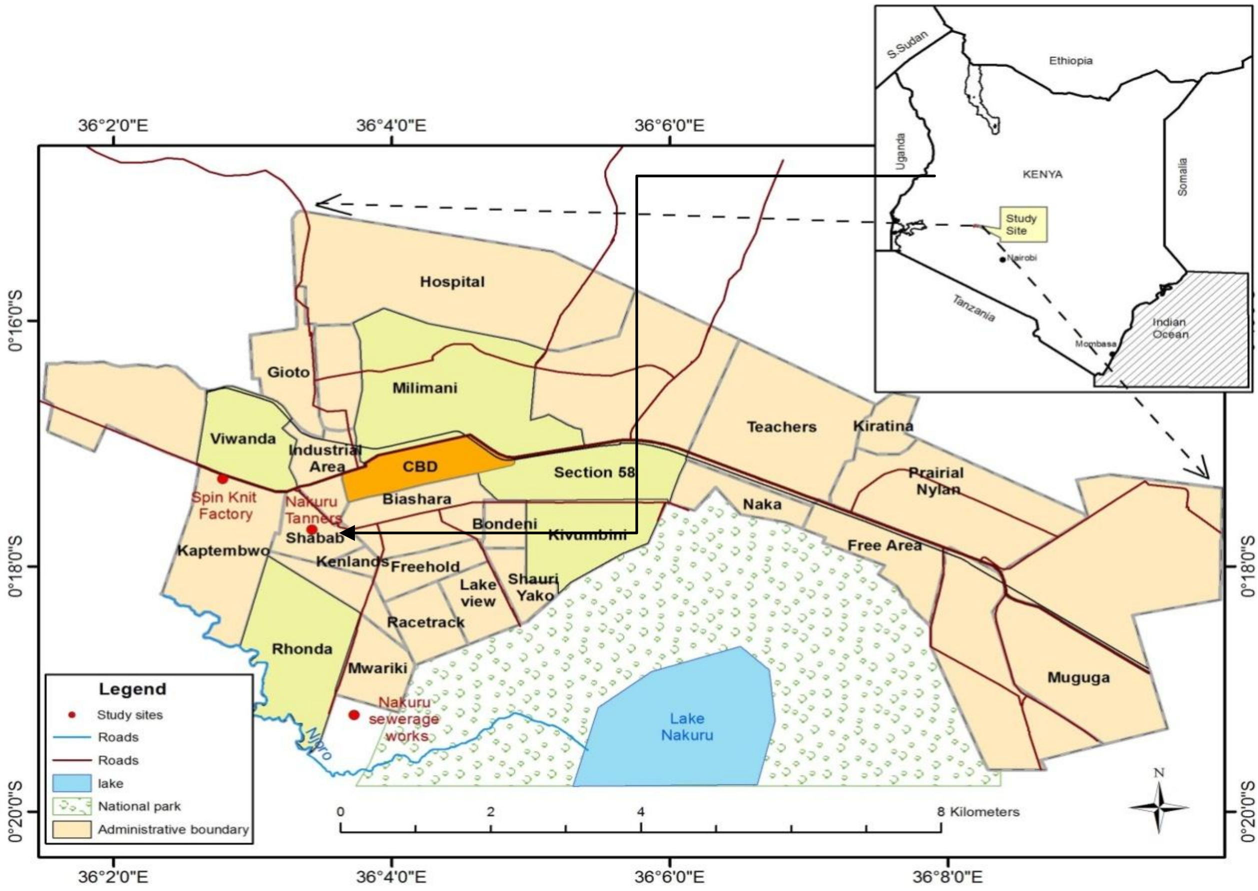
CHAPTER THREE

METHODOLOGY

3.1 Study area

3.1.1 Location

The study was conducted in Nakuru County, Kenya in the western zone (industrial area) and Njoro sewage works in Nakuru Town. The coordinates for the study area located at latitude $0^0$19’12’’, 83^0 S, longitude $36^0$3'43’’, 72^0E which is located south west of the Nakuru Town. The wastewater from the industries is discharged through sewer-line to the sewage works and storm drain concrete.



Source: Kenya National Bureau of Statistics, 2017

Figure 0.1: Map showing study area.

The target was the major industries that discharge effluent into the Njoro sewage works. The final wastewater joins River Njoro which eventually ends up to Lake Nakuru.

3.1.2 Demographic and social economic characteristics

Nakuru is situated 160 km North West of Nairobi at an altitude of 1859m above sea level. It derived its name from the Maasai speaking people of Kenya meaning (place for dust) due to its volcanic soil. It received township status in 1904 and became a municipality in 1952. Nakuru town has a population of approximately 307,990 (Kenya National Bureau of Statistics, 1999). It is the 4th largest and fast growing urban town in Kenya due to the population influx which occurred during 2007 post-election. According to a UN study released in 2011, Nakuru is Africa's fastest growing city and the fourth in the world. Nakuru is rapidly growing urban town and industrial activity, which provides employment but causes pollution, and was once the cleanest town in Eastern Africa and is home for the pink flamingoes (Wanjiru, 2001). The economic activities for Nakuru town are based on agriculture and tourism. There are also industries for both local and international export.

3.1.3 Design capacity of Njoro sewage work

The target design average daily sewage discharge rate value for the Njoro Sewage Works is 9600 m^3/day comprising of the 3600 m^3/day line and 6000 m^3/day line. The corresponding design hourly peak rate value is 800m^3/hr comprising of 300m^3/hr and 500m^3/hr for the 3600m^3/day line and 6000m^3/day line respectively. The sewage works treats over 1,500m^3 per day of the wastewater. The sewerage covers 90% of industrial wastewater and 10 % of domestic wastewater. The design capacity for the sewage influent at the inlet is not supposed to exceed BOD of 800mg/l for better performance of the treatment plant. The depth of the anaerobic ponds are 3 metres, facultative ponds are 2 metres, rock filters are 1.6 metres while first, second and third maturation ponds are 1.5 metres each. The rehabilitation and expansion of the sewage works was as a result of increase of the water volume from the greater Nakuru water supply project in Gilgil that increased the capacity in the town. (Greater Nakuru Water Supply Project 1990).

Source: NAWASCO, 2009

Figure 0.2: Njoro sewage works sketch diagram AP-Anaerobic pond

RF-Rock filter

FP-Facultative pond

GP-Grass Pond

FMP-First Maturation pond

SDB-Sludge Drying Bed

SMP-Second Maturation pond

TMP-Third Maturation pond

⬤ - Sampling point inlet

⬤ - Sampling point outlet

Plate 3.1: In-let of sewage works

3.2 Research Design

The study used descriptive research design. The research design was descriptive including observation and historical records. The study involved test analysis of the physical and chemical parameters in the laboratory and in-situ test.

3.3 Sampling

The study used purposive sampling method for the selection of Water Service Provider since they had key information on the management of sewage works and the major industries that discharge wastewater into the sewerage system. The major industries selected included, Spin knit, Nakuru Tanners, Bidco, Kenya Seed Company, Bedi textile and Menengai oil refinery. These industries were chosen because they use chemicals containing heavy metals in their process which were likely to discharge them into the sewerage system. The assessment of the wastewater management system in the industries was based on the production activities of the industries. The quantity of water and raw materials used in the processes was considered to gauge the quality of wastewater discharged into the sewage work. Composite method of sampling was used to collect samples for physical-chemical and heavy metals tests. The sampling point was at the inlet of the sewage work, facultative pond, maturation pond and the outlet point to river Njoro. Samples were collected twice a day within a span of six hours (9:00am to 3:00pm) and mixed to come up with a homogenous sample as per the guidelines of APHA (2005). The parameters of concern determined included BOD, COD, total alkalinity, pH, temperature, DO, TSS, TDS and heavy metals (Chromium, copper, zinc, and lead). Sampling for in-situ test samples still used the composite sampling method. For qualitative analysis using clean sampling bottles. The in-situ tests were pH, DO, Conductivity, TDS and Temperature. The in-situ test analysis was measured using clean glassware and calibrated field equipment which were all rinsed well after every sampling. All samples for heavy metals were pre-treated (Acidified) according to APHA, 2005. The samples were marked properly and stored in a cool box and then taken to Rift Valley Water Services Board laboratory for analysis and in Nakuru water testing laboratory at NAWASSCO. Samples for BOD were analyzed immediately and the rest were refrigerated and analyzed within the recommended conditions.

There were five sampling points (inlet and outlet of one pond were counted as one sampling point) which are indicated in figure 3.2. Two samples for each site were collected making an average of 8 samples per day. Composite samples were collected from the inlet and outlet of each pond. The samples were collected during the dry season and wet season. This was done to check if the climatic conditions affected the efficacy of the sewage system

3.4 Data collection

3.4.1 Assessment of the efficiency of Njoro industrial sewage works

Information on the effluent discharge trends of the discharging major industries and Njoro sewage works was collected from 2005 to 2016. The questionnaire for the discharging industries (appendix I) gave information on effluent of the major industries that discharged into the sewage works and the wastewater management system used by the industries. Information on the effectiveness of the pre-treatment method for wastewater discharged by the industries was obtained from secondary sources (NAWASSCO records) from the tests of effluents discharged from these industries. The Technical Manager of Water Service Provider, (NAWASSCO) was interviewed using questionnaire (appendix II) to get information on sewage works and wastewater analysis trends for from 2005 – 2016. Data on the trends for physical and chemical concentration of the sewage works were collected from the historical data from the Water Service Provider in-charge of the sewage works for the years 2005 – 2016 (NAWASSCO records).

Conductivity, Total Dissolved Solids, Dissolved Oxygen and pH was done on site (in-situ test). The measurements were digitally read direct from the field equipment. The chemical and heavy metal sample analysis were conducted according to guidelines provided

(APHA, 2005) and the Atomic Absorption spectrophotometer (AAS) operating Manual. The method used was spectrophotometric of which every test was done at specific wavelength as provided by the equipment manual. The influent to the sewage work and effluent of the ponds wastewater characteristics was each determined through a series of standard tests according to (APHA, 2005). This also included the sample preparation for analysis, standards and storage of samples.

Biological Oxygen Demand was done using Oxitrop equipment. The equipment has got dilutions indicated on the machine. The volumes depend on pollution level and the sample were measured and put in the Oxitrop bottles. Then the tube was inserted to the bottle and 1 to 2 Sodium Hydroxide pellets was put in the tube. Analysis was done at 20^{o}c for 5 days. The equipment computes the reading daily at controlled temperature.

The analysis of COD followed the Hach method procedure manual (Hach, -2000). The reagents were supplied pre-prepared and analysed according to the organic load. The reagent range from low, medium and high ranges. Sample of 10mls was put in the specific range of reagent and digested for one hour in the heating block, then left to cool before subjecting to the COD reader which automatically indicates the reading digitally.

The Total alkalinity was done using titrimetric method (APHA, 2005). Stock solution of 0.1N was prepared concentrated sulphuric acid and the 0.02N standard was made from the stock and used as titrant. Methyl orange indicator was used in the titration. The pH was digitally done by use of a calibrated pH meter using buffers for accuracy. Measurements were read directly from the Meter. All pH parameter was done on site. The units for temperature were ^{0}C. Tests were done during sampling. The equipment displayed temperature for specific sample. The dissolved oxygen was tested using digitized equipment which has self-controlled temperatures. TSS was analysed by first filtering paper and then dried in the oven for 60min, later cooled for 30min. The filter paper was then weighed and the weight recorded. The weighed filter paper was then put in a membrane filtration unit and wetted with distilled water. Measured 100mls of sample and poured into the filter paper, suctioned the sample and completely rinsed the side of the filter holder. The filter paper was dried in the oven for 103^{0}C for 60 min, cooled for 30 min and then weighed. The weight of the TSS is got by subtracting the weight of the filter paper before filtration from the weight of filter after filtration.

Weight of TSS in sample (A) =weight of filter with dried sample - (Minus) weight of filter

mg /l TSS = A×1000 ÷volume of sample used (APHA, 2005)

Conductivity and Total Dissolved Solids (TDS) was done using automatic compensation temperatures equipment corrected to 25^{o}C.

The heavy metal (Cr, Pb, Cu and Zn) analyses were done using Atomic Absorption spectrophotometer. The samples were pre-treated immediately after sampling on site by adding 0.5 ml of conc. HNO_3. Samples were digested by adding 5ml HNO_3 to the 100ml sample of the treated sample. The sample was digested until it reduced to about 15-20ml. The digestion method was mild and this applied to all metal analysis. The equipment procedure followed the guidelines provided by the AAS manual and APHA, 2005 procedures. Standards for each metal were prepared from specific stock solution. The standards were of range 0.0 PPM, 2.0 PPM, 4.0 PPM, 8.0 PPM, 10.0 PPM. Analysis was done for each specific metal at the right wavelength. The concentrations were calculated by means of calibration curve which is displayed by the AAS. The specific element was determined by aspirating the sample in the flame of the Atomic Absorption spectrophotometer. The element is normally converted to atomic state by thermal dissociation. The absorption of the atoms was measured at the right beam path at wavelength of the specific element being analysed. Also the hollow cathode lamp for specific element was used.

3.5 Data Analysis

Microsoft software excel was used to analyse the data. Descriptive statistics was used in the analysis of the effluent discharge trends of industries that has been discharging to Njoro sewage works from 2005-2006. Analysis of the wastewater management system used in the selected industries and analysis of the historical analysis trends for the Njoro sewage works from 2005 to 2016. ANOVA was used to compare the variation of the concentrations for the trends of wastewater for Njoro sewage works with the effluent from the discharging industries. Student T-test for the relationship between the inlet and outlet of sewage works

Table 0.1: Summary of data analysis

Research Questions	Variables	Statistical Tool
1. What are the effluent discharges of major industries that discharge into Njoro industrial sewage works from year 2005 to 2016?	Growth in size of industries, range of products being produced, work force capital investment, volume trends of effluent and raw materials being used.	Descriptive statistic
2. What are the wastewater management systems used by the major industries before discharge into Njoro industrial sewage works?	Availability of pre-treatment unit, age of the pre-treatment unit, frequency of disludging, physical and chemical parameters.	Descriptive statistics
3. What are the trends for physical and chemical wastewater parameters of the Njoro industrial sewage works from year 2005 to 2016?	Historical analytical data for physical and chemical concentrations from year 2005 to 2016 and one point test samples data from the sewage works	ANOVA for trends
4. What is the relationship between wastewater quality paramet ers of the influent and effluent discharge of Njoro sewage works?	Physical and chemical parameters data from the inlet and outlet of Njoro sewage works	Student T-test

CHAPTER FOUR

RESULTS AND DISCUSSION

Njoro sewage works was constructed in 1971. The main source of wastewater is from industrial and domestic water. It was later rehabilitated from 1996 - 1997 to increase its capacity from 2500m^3/day to 6000m^3/day. The design capacity of the sewage works is 9600m^3/day. Since rehabilitation the efficiency of the sewage works improved both in quantity and quality. The quality of effluent from the final discharge from Njoro sewage works is within allowable limits. Water Service Providers monitors wastewater from the industries weekly and carry out tests on the physical and chemical parameters at the inlet of Njoro sewage works. Njoro sewage works has got a license for wastewater disposal from NEMA and WRMA.

4.1 Effluent discharge of major industries that discharge effluent into Njoro Sewage works.

Table 4.1 indicate the form of industry, volume of water used, products manufactured, materials used, major pollutants, duration of operation and the body that monitors the sewage works.

The major pollutants discharged by Bidco Company are TDS, oil and grease. It is mandatory that the company should pre-treat their wastewater to meet NEMA standards before being discharged to the sewer line. Oil and grease blocks the sewer system and may also affects the efficiency of the sewage works. Releasing these pollutants to the environment has got adverse impact to the environment particularly the aquatic ecosystem. Oil and grease blocks the respiratory system of the aquatic life causing death. It also reduces the light penetration in the ponds which affects the photosynthesis reaction process of algae in the maturation pond, eventually reducing oxygen concentration. Overload of TDS affects anaerobic ponds by reducing the breakdown of ions in wastewater, thus reducing the efficiency of the sewage works.

Table 0.1: Effluent Discharge of Major Industries

Industries	Form of Industry	Volume of water used per day	What they manufacture	Raw materials used	Major pollutant	Duration of Operation	Who monitors industry
BIDCO	Wet	135m^3	Edible oils Animal feeds	Maize germ Soya bean seeds Sunflower seeds	TDS Oil and grease	24 hrs	NEMA NAWASSCO
Kenya seed	Dry	1000m^3	Wheat seed	Wheat seed	Copper	8 hrs	NEMA OSHA
Bedi Textile	Wet	1500m^3	Textile apparels	Fibre Yarn Fabric	Dyes Cleaning detergents	24 hrs	NEMA KEBs Government
Spin Knit	Dry	42m^3	Textile products	Acrylic tops Pulled synthetic fibre Polyester	Fluoride Nitrates Chlorides Carbonates	24 hrs	NEMA NAWASSCO
Tanners	Wet	25m^3	Leather	Acrylic yarn Hides	Chromium Acids	24 hrs	Livestock ministry Ministry water of and Environment, NEMA
Menengai oil refinery	Wet	150 m^3	Detergents, cooking oil	Sodium bicarbonate	TDS Total alkalinity Oil and grease	24hrs	NEMA Ministry of Water and Environment

This study is in line with a study by Alade *et al. (*2011), done in Malaysia which revealed that high concentration of oil and grease in wastewater is as a result of increasing number of oil processing industries. Oils and grease affects the ecology of wastewater treatment plants. A study by Wang *et al. (*2005) in Beijing showed that TDS causes shock loading on the activated sludge therefore affecting the efficiency of wastewater treatment system.

Kenya Seed Company uses dry process in manufacturing of their products. The main pollutant produced is Copper. Copper residues may be contained in wash wastewater from their production premises, which is channelled to the sewer line. Copper is a heavy metal that bio-magnify and bio-accumulate in both aquatic life and human beings. Ruixue *et al. (*2013) revealed that copper loading concentration in wastewater inhibited removal efficiency and uptake of ammonia in wastewater treatment system. High copper concentration also affects the final removal of nitrates by inhibiting the specific nitrogen oxide uptake rate by 32.4%.

Major pollutants from Bedi textile industry were dyes and cleaning detergents. Dyes reflect and absorb sunlight in water. This reduces photosynthetic activity of algae and influences the food chain. Dyes are carcinogenic and toxic to life. Residues of dyes in water affect water quality of water bodies thus affecting the aquatic life. Wang *et al.* (2011) revealed that textile dyeing industry uses large volume of water and produces large quantities of wastewater. Wastewater from dying of textiles contains colour, which contains dyes and chemical residues having high BOD and COD concentration.

Detergents contain phosphates and nitrates which causes eutrophication in water bodies. Wastewater with high concentration of phosphates and nitrates increases the concentration of BOD and COD thus affecting the efficiency of wastewater treatment system. A study done in Nepal by Richards (2003) revealed that the efficiency of Guheshwori wastewater treatment plant was affected by foaming problems from use of detergents. The detergents in wastewater had anionic surfactants which were used in local laundry detergents which led to poor biodegradation properties. Partnership for Environment Education and Rural Health (2010) showed that high concentration of nitrates cause excess growth of plants and algae in stabilization ponds. Increase in algae growth prevents sunlight from reaching into deep depth in water causing algae to die and decay. The decaying matter will settle at the bottom of the ponds and the bacteria feeding on it will increase in number causing decrease in the level of oxygen. Oxygen will fall to levels that are too low for many aquatic insects and fish to survive.

Fluorides, nitrates, chlorides and carbonates were the main pollutants in Spin-knit textile industry. Wastewater from Spin-knit industry is discharged into Njoro sewage treatment plant. Njoro sewage works uses stabilization ponds to treat wastewater. Flourides, chlorides and carbonates cannot be naturally removed by the stabilization ponds. Fluorides, nitrates, chlorides and carbonates in pollutant in high concentration increase the alkalinity of the wastewater thus increasing the organic load affecting efficiency of the sewage works.

Ochoa-Herrera *et al. (*2009) revealed that fluoride is the common pollutant in many of the textile industries which is toxic to microorganisms in biological wastewater treatment plants. Fluoride is toxic to anaerobic microorganisms which are involved in metabolic steps of anaerobic digestion process. A study done in Thailand by Thongchai and Chandarut (1999) revealed that high concentration of chlorides increases the salt concentration in the wastewater. This affects the bacteria in anaerobic, anoxic and aerobic in the stabilization ponds, therefore affecting the efficiency of the wastewater treatment of the sewage works.

Carbonate is one of the main pollutants from Spin-knit industry. Effluents from industries should meet the pH value of NEMA standards (6-9). Wastewater released from industries containing carbonates affects the alkalinity of wastewater which impacts on the pH of wastewater in the sewage works. A study by Martin (2015) compares with this study and revealed that nitrogen converting bacteria in anaerobic pond in wastewater treatment are active at pH range of 7-8, where Ammonia is converted to Nitrates.

Chromium and acids were the main pollutants from Nakuru Tanners factory. Nakuru Tanners factory is a wet industry that uses Chromium and sulphuric acid among others in tanning of hides and skins. Tanners discharged its final effluent into the sewage works. According to Environmental Health and Safety guidelines (2007) the composite of untreated wastewater in tannery industry amounts to 20–80 cubic meters per metric ton (m^3/t) of skin or hide, is turbid, coloured, and foul smelling. It consists of alkaline and acidic liquors, with chromium levels of 100–400 mg/l. The NEMA standards for Chromium concentration for discharging industries is 0.05mg/l. A study by Alfonso *et al. (*2018) showed that the discharging of wastewater from tanneries without any treatment leads to accumulation of chromium traces which are toxic and cannot be eliminated naturally with slow disintegration. Chromium precipitate and mix in the mud and sediments of the receiving water bodies where it bio-accumulates and bio-magnifies in the trophic chain, causing toxicity to organisms.

4.2 Wastewater management system used by the major industries before discharge into Njoro industrial sewage works.

All the six major industries studied generated both solid waste and wastewater. The wastewater was discharged into the sewer line. Three industries (Bidco Company, Tanners and Menengai oil refinery) pre-treated the wastewater before being discharged into the sewer line. The waste management systems used to pre-treat wastewater include; interceptor, stabilization ponds and wetland. Bidco used interceptor, Tanners used stabilization ponds and Menengai oil refinery used both stabilization ponds and wetland (Table 4.2).

Table 0.2: Wastewater Management System

Industry	Interceptor	Stabilization Ponds	Wetland
BIDCO	√	X	X
Kenya seed	X	X	X
Bedi textile	X	X	X
Spin knit	X	X	X
Tanners	X	√	X
Menengai oil Refinery	X	√	√

Interceptor use removes oil and grease which are the main pollutants. If the interceptor is effective the wastewater discharged to the sewer line will meet the NEMA standards. If the pre-treatment unit is ineffective oil and grease will find their way into the sewage works forming films and blockages of sewer line. Oil and grease films will affect photosynthesis process of algae thus impacting on the efficiency of the stabilization ponds. El-Gawad (2014) reveals that conventional techniques remove grease and oils using oil and grease traps and skimming tanks in treatment plants. The main challenge with these methods is their low removal of grease and oil removal. The remaining oil in pre-treated wastewater causes blocking of pipes in treatment units that requires costs for replacement pipes and maintenance of sewage works.

Nakuru tanner's factory uses stabilization ponds to pre-treat wastewater. The main pollutant in Nakuru tanners is chromium and the stabilization ponds may not be effective in its removal. Chromium cannot be eliminated through natural process since its disintegration is slow. Chromium precipitate and mix with sediments in wastewater where it ends up in the trophic chain which results to chronic poisoning in organisms. Chromium can be absorbed by the lungs and gastrointestinal tract and extent by intact skin. The health effects of chromium include; respiratory effects, skin effects (dermatitis), carcinogenic, renal effects, severe liver effects, gastrointestinal effects, cardiovascular, hematological effects, reproductive and development effects, genotoxic and mutagenic effects (Agency for Toxicity Substance and Disease registry, 2013). This study is in line with a study done by Samae *et al. (*2016) which revealed that, the average amount of chromium from the influent, anaerobic and first and second facultative pond outlets were 0.0076 mg/l, 0.0065 mg/l, 0.0043 mg/l and 0.0056 mg/l respectively. The removal efficiency of chromium in stabilization ponds was low.

Kenya seed, Bedi textile and Spinknit factories are dry processing industries and have no pre-treatment unit. They channel their wash water to the sewer line. Copper from Kenya seed and dyes from Bedi textile and Spinknit factories may end up in sewage works increasing the organic load. This results to negative implications to the effectiveness of sewage works. Copper is a heavy metal which is carcinogenic to aquatic life and human beings. Long-term exposure to copper can cause, mouth and eyes irritation of the nose, headaches, stomach aches, dizziness, vomiting stomach aches, dizziness and diarrhoea. High uptake of copper may cause liver damage, kidney damage and death (Agency for Toxicity Substance and Disease and Registry, 2015). Textile dyes contain colourants which are bound with organic chlorine, a known carcinogenic. Chemical pollution of dyes can disturb the normal functioning of cells and alter biochemical and physiology mechanisms of animal impairing important functions like osmoregulation, respiration, reproduction and mortality. The heavy metals present in dyes are not biodegradable hence bio-accumulate in the food chain (Odjegba and Bamgbose, 2012).

Menengai oil refinery uses stabilization ponds and wetland to pre-treat wastewater. Use of wetland to treat wastewater can reduce organic and heavy metals concentration. It can also reduce the volume of wastewater discharged into the sewage works. If the wetlands are not effective it will negatively impact on the surrounding environment. A study by Kayombo *et al.* (2004) in Dar-es- salaam indicated that use of waste stabilization ponds and wetlands for pre-treatment of wastewater are effective in removal of organic and inorganic loads. Wetlands and stabilization ponds are also capable of removing high percentage of pathogenic organisms in wastewater.

4.3 Trends for physical and chemical wastewater parameters of the Njoro industrial sewage works from 2005 to 2016.

This study collected data for the physical chemical trends of wastewater at the inlet of Njoro sewage works from the year 2005 to 2016. The physical chemical trends of wastewater from Njoro sewage works in the year 1995 to 2004 were missing. The analysis of dissolved oxygen was also missing. The averages were done and organised into two seasons; wet season and dry season. Data on pH, temperature, conductivity, Total Dissolved Solids, Biological Oxygen Demand, Chemical Oxygen Demand and heavy metals were collected.

4.3.1 The pH trend of wastewater

The figure 4.1 below is a bar graph showing the pH levels of wastewater at the inlet of Njoro sewage works. The highest pH (8.3) in the dry season was observed in the year 2010, the lowest pH (6.9) was observed in the year 2012. In the wet season the highest pH (11) was observed in the year 2012 and the lowest pH (7.1) was observed in the year 2014.

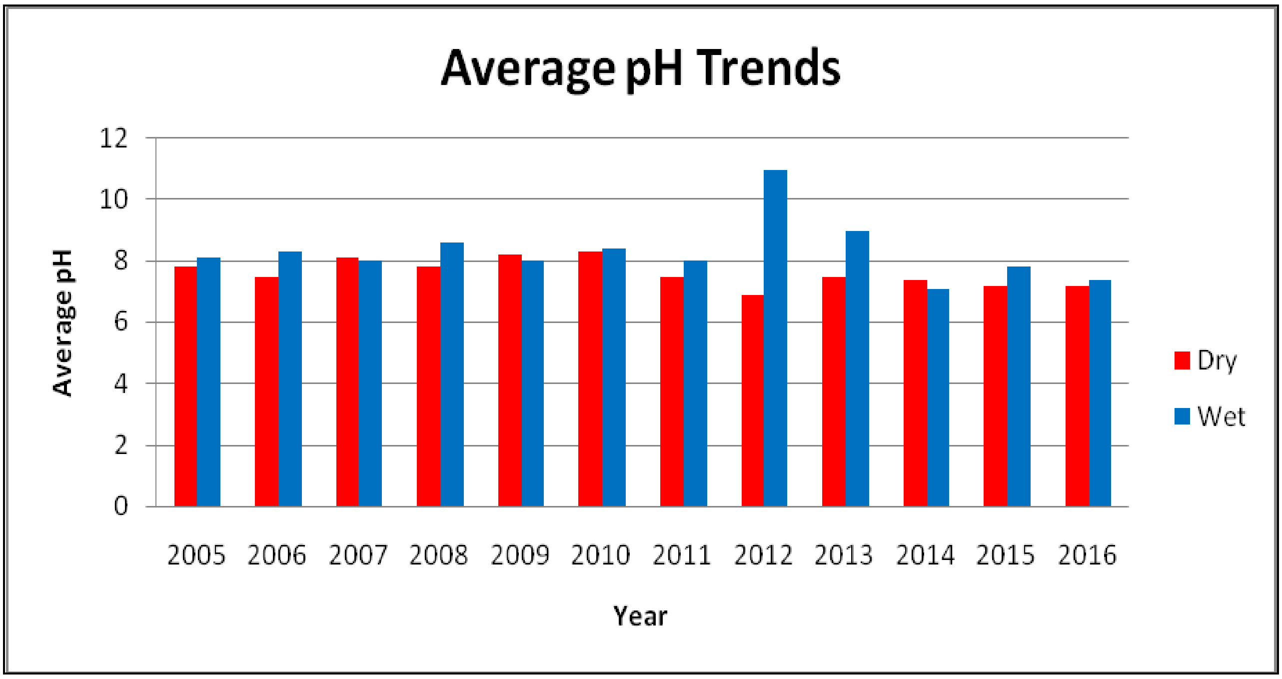


Figure 0.1: pH Trends

High pH has got an effect on the microorganisms in the wastewater treatment plants, thus impacting the performance of the wastewater treatment plant. A study by Environmental Business Specialists (EBS), (2018), indicates that the pH of wastewater has an adverse effect of the growth rate of microbial organisms. High pH affects the metabolic functions of enzymes. Majority of microbes thrives well at pH of 6.5 to 8.5. However, at extreme pH some enzymes can do well and thrive in basic or acidic wastewater. For example fungi tolerates in acidic wastewater. However, bacteria and protozoa thrive well at pH of 7. Irregular pH in wastewater treatment plants can reduce removal of organic load in wastewater thus affecting biological oxygen demand (BOD). The effluents from the point and non-point sources during the wet season could have ended up to the sewer line of the sewage works. The effluent may have contained a lot of dissolved solids, hence affecting the pH of the influent at the sewage works.

4.3.2 The Conductivity Trends of Wastewater of Njoro Sewage Works

The P-value is greater than the selected alpha level (0.05) therefore there was no significant difference between conductivity means of the inlet and outlet. This implies that the conductivity means within and between the inlet and outlet are the same. This is as shown in table 4.3.

Table 0.3: ANOVA Test for Conductivity

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	264810	1	264810	0.380818	0.543501	4.30095
Within Groups	15298187	22	695372.1			
Total	15562997	23				

Figure 4.2 indicates conductivity trends of wastewater of Njoro sewage works. The highest conductivity (4622.0 µS/cm) in the dry season was observed in the year 2016, and the lowest conductivity (1530.0 µS/cm) was observed in the year 2012. In the wet season the highest conductivity (4268.0 µS/cm) was observed in the year 2014 and the lowest conductivity (1970.0 µS/cm) was observed in 2016.

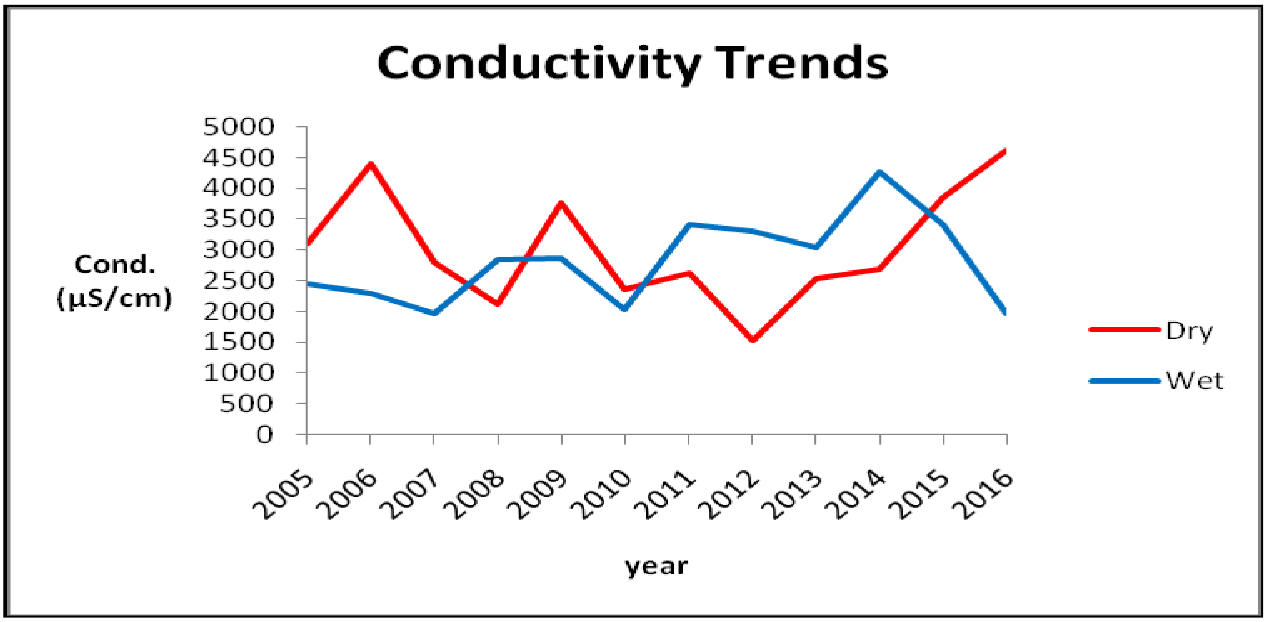


Figure 0.2: Conductivity Trends

Highest conductivity was observed during the dry season in the year 2016. This is far above the maximum allowable limits of conductivity in the effluent discharged into the public sewers (3000 µS/cm). This indicates that discharge from industries were likely to have high concentrations of dissolved salts. During the wet season in the year 2014, the conductivity recorded was highest probably due to discharge of untreated wastewater from some industries and surface run-off from non-point sources. The salts in the wastewater were likely to be high during this period. This study is in line with a study that was done by Mkunde *et al.* (2014) in Dodoma Tanzania which revealed that the conductivity level of wastewater from an annual average of conductivity was 1768.17µS/cm. The waste stabilization ponds managed to reduce the conductivity of wastewater by 13% to

1538.83µS/cm. This indicates that higher conductivity level of wastewater has got an impact on the effectiveness of waste stabilization ponds.

4.3.3 Total Suspended Solids Trends of Wastewater in Njoro Sewage Works

The P-value is greater than the selected alpha level (0.05) therefore there was no significant difference between total suspended solids in the inlet and outlet. This implies that the total suspended solids means within and between the inlet and outlet are the equal. This is as shown in table 4.4.

Table 0.4: ANOVA Test for Total Suspended Solids

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1072813	1	1072813	1.410497	0.247639	4.30095
Within Groups	16733022	22	760591.9			
Total	17805835	23				

The highest Total Suspended Solids (TSS) 1488mg/l in the wet season were observed in the year 2012, whereas the lowest TSS (208 mg/l) was observed in the year 2006. In the dry season the highest TSS (4010 mg/l) was observed in the year 2013 and the lowest TSS (247 mg/l) was observed in the year 2007. This is as shown in figure 4.3.

As the Total Suspended Solids in wastewater increase the absorption level of sunlight increases thus increases in the temperature in wastewater reduces the oxygen level in hence affecting the growth of microorganisms in wastewater. During the wet season the total suspended solids tends to increase due to surface runoff from the roads, storm drains and overflows from septic tanks, inspection chambers and pit latrines. This may have affected the quality of wastewater discharged to the sewage works. A study by Chemtech International (2017) indicates that a high concentration of TSS reduces the efficiency of wastewater treatment operation by disrupting the water balance due to increase of wastewater temperature and reducing the dissolved oxygen.

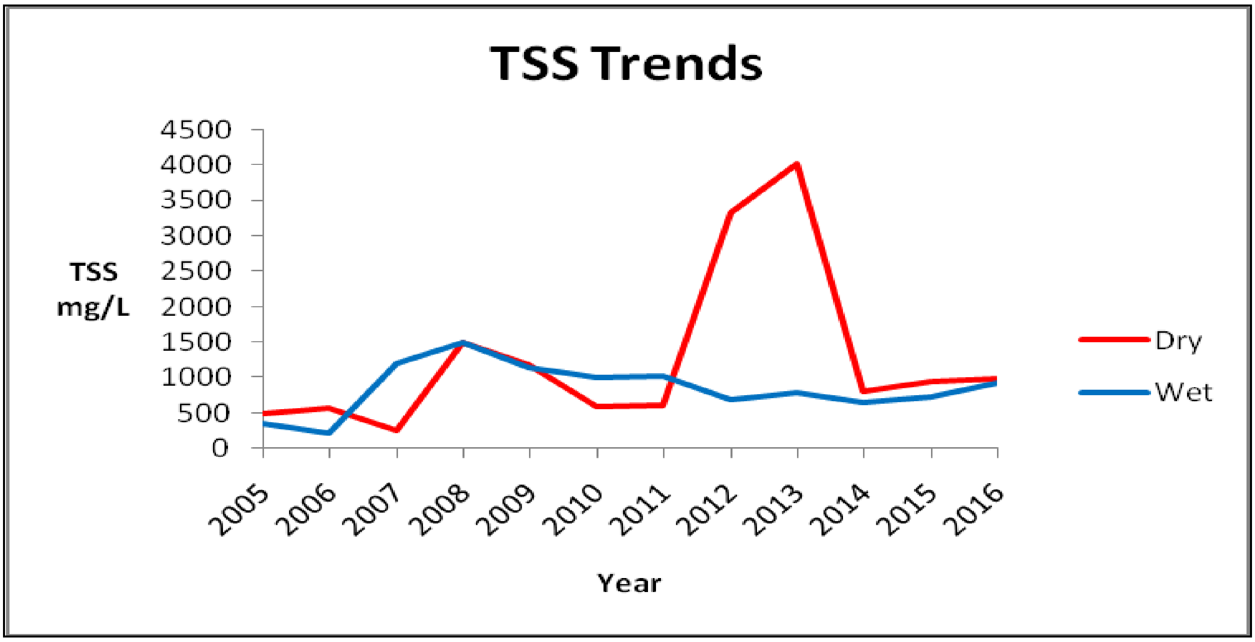


Figure 0.3: Total Suspended Solids Trends

4.3.4 Biological Oxygen Demand Trends of Wastewater of Njoro Sewage works

The p - value is greater than the selected alpha level (0.05) therefore there was no significant difference between BOD in the inlet and outlet. this implies that the BOD means within and between the inlet and outlet are equal. This is as shown in table 4.5.

Table 0.5: ANOVA Test for Biological Oxygen Demand

Source of Variation	SS	df	MS	F	p-value	F crit
Between Groups	3.33015	1	3.33015	1.92E-05	0.996547	4.30095
Within Groups	3823899	22	173813.6			
Total	3823902	23				

The highest BOD (1460 mgO_2/l) in the wet season was observed in the year 2011, whereas the lowest BOD (430 mgO_2/l) was observed in the year 2005. In the dry season the highest BOD (2122 mgO_2/l) was observed in the year 2008 and the lowest BOD (387mgO_2/l) was observed in the year 2005 (Figure 4.4).

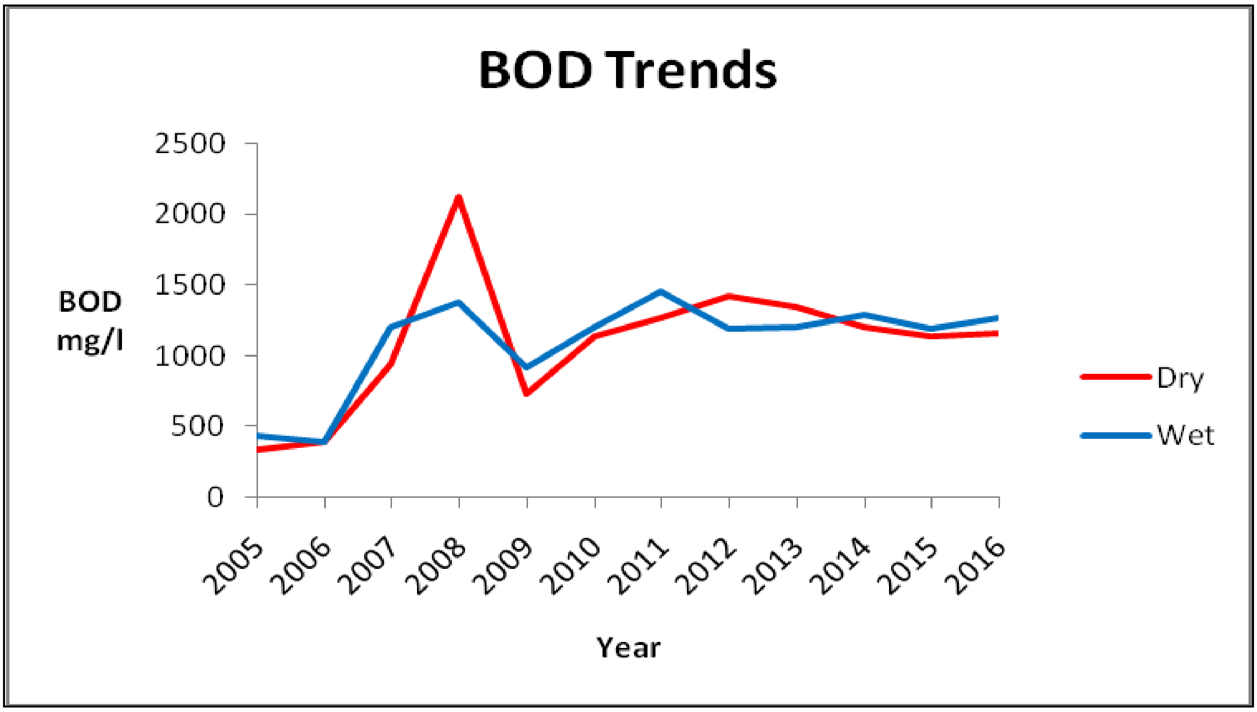


Figure 0.4: Biological Oxygen Demand Trends

During the dry season in the year 2008 the BOD concentration was recorded highest. This indicates that there was a likelihood of release of untreated wastewater from some industries with high organic load. In wastewater treatment plant bacteria are useful in the breakdown of organic load in wastewater. During wet season the BOD concentration tended to fluctuate far much above the recommended allowable concentration for the effluent discharged to the sewer line. In both wet and dry seasons the BOD concentration steadily rose every year. This implies that the results were likely not evaluated. However, higher levels of BOD in wastewater can result to unwanted amounts of bacteria. These bacteria can drain oxygen in the waste stabilization ponds which can eventually harm the aquatic life. Therefore it is significant for the industries to control the BOD of their effluent to the sewage works. This study is in line with a study done by Morrison (2017) in Canada, which indicted that higher concentrations of inorganic solids in wastewater take longer time to breakdown and hence can cause clogging and siltation of the system thus affecting the performance of sewage works.

4.3.5 Chemical Oxygen Demand Trends of wastewater in Njoro sewage works

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between COD in the inlet and outlet. This implies that the COD means within and between the inlet and outlet were equal. This is as shown in table 4.6.

Table 0.6: ANOVA Test for Chemical Oxygen Demand

Source of Variation	SS	df	MS	F	p-value	F crit
Between Groups	127604.2	1	127604.2	0.147039	0.705061	4.30095
Within Groups	19092099	22	867822.7			
Total	19219703	23				

Highest COD (3520.0 mgO_2/l) in the wet season was observed in the year 2011, whereas the lowest COD (1100 mgO_2/l) was observed in the year 2005. In the dry season the highest COD (3540.0 mgO_2/l) was observed in the year 2013 and the lowest COD (686 mgO_2/l) was observed in the year 2007. This is shown in figure 4.5.

The concentration of COD during the wet and dry seasons fluctuated with steady rise and fall; this could be due to the release of wastewater with high chemical oxidising compounds with high oxygen affinity from different industries. From the data it shows that that the industries were releasing untreated wastewater to the main sewer line. The trends of COD levels for the wastewater in Njoro sewage works range from 947 mgO_2/l to 3540 mgO_2/l.

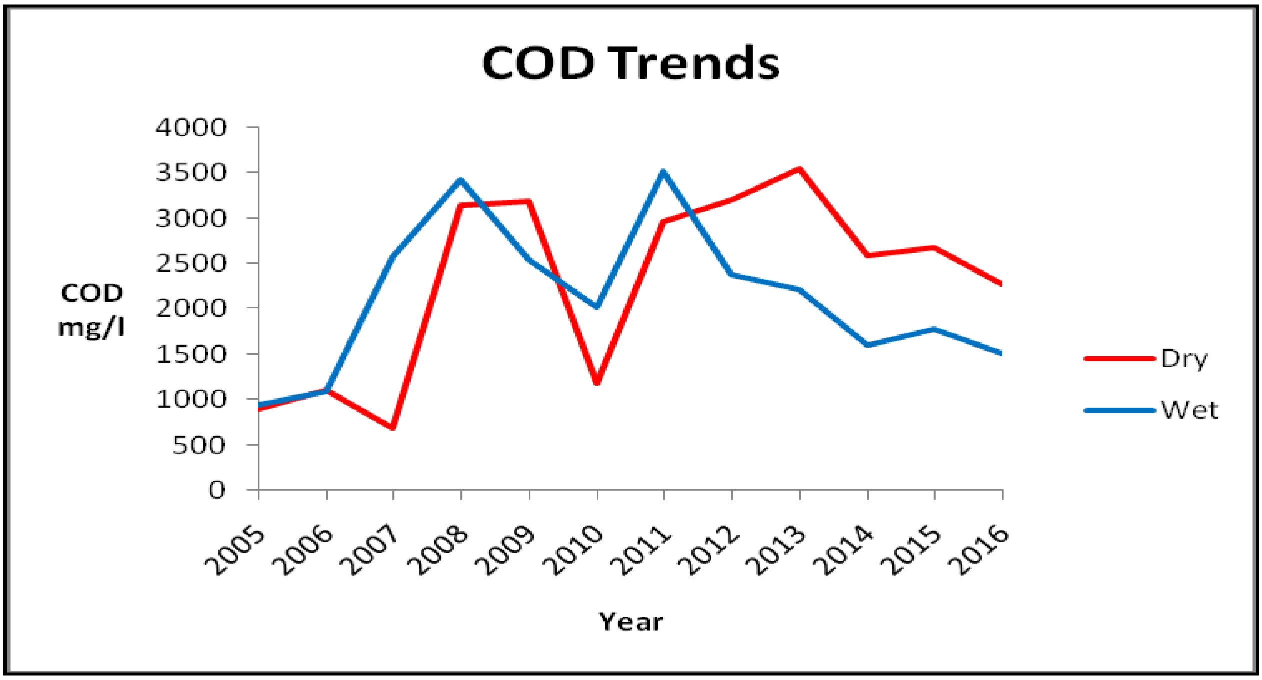


Figure 0.5: Chemical Oxygen Demand Trends

According to Hegazy and Gewad (2016), the effectiveness of the waste stabilization ponds depends on the growth of microorganisms in the treatment unit and maintenance of the environment conditions for the system to remove the excess sludge. If the influent wastewater has got higher level of COD it will deplete the dissolved oxygen affecting the performance of the treatment plant.

4.3.6 Weekly variation of Physical chemical parameters of the inlet and outlet of Njoro sewage works.

4.3.6.1 Weekly variation of pH of the inlet and outlet of Njoro sewage Works

The pH level of influent from the industries was higher (8.5) in the second week and lower (7.0) on the first week. The pH level of the effluent was higher (8.5) in the second week and the fourth week. This is as shown in figure 4.6. There was a pH variation at the inlet and the outlet of wastewater in the sewage works, possibly due to cationic magnification in the entire sewerage operation treatment system, which could not be removed by natural processes. Change in the pH level in the sewerage works affects the growth of microorganisms, thus affecting the performance of the sewerage treatment.

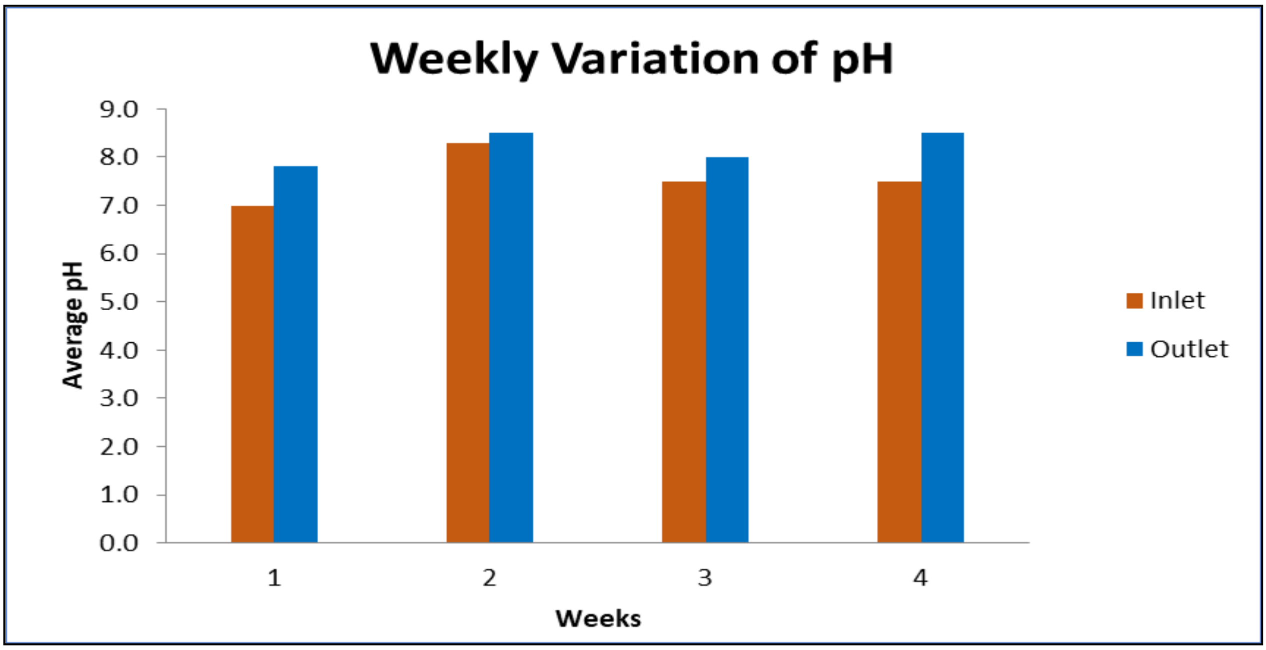


Figure 0.6: Weekly Variation of pH

4.3.6.2 Weekly variation of conductivity of the inlet and outlet of Njoro sewage Works

The p - value is greater than the selected alpha level (0.05) therefore there was no significant difference between conductivity of the inlet and outlet; the conductivity means within and between the inlet and outlet are the same. This is as shown in table 4.7.

Table 0.7: Student T-test for Conductivity

	Inlet	Outlet
Mean	1968.75	8.195
Variance	20672.92	0.132966667
Observations	4	4
Pearson Correlation	-0.23285	
Hypothesized Mean Difference	0	
Df	3	
t Stat	27.25527	
P(T<=t) one-tail	5.42E-05	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.000108	
t Critical two-tail	3.182446	

The conductivity level of the influent was higher (620 µS/cm) in the second week and lower at the fourth week (363 µS/cm). The conductivity level of the effluent was higher (120 µS/cm) at the third week and the lower conductivity level at the first week. This is as shown in figure 4.7. The conductivity levels between the inlet and the outlet of the sewerage system show that there was a chemical reduction. This shows that the sewerage system was effective in reduction of some chemical.

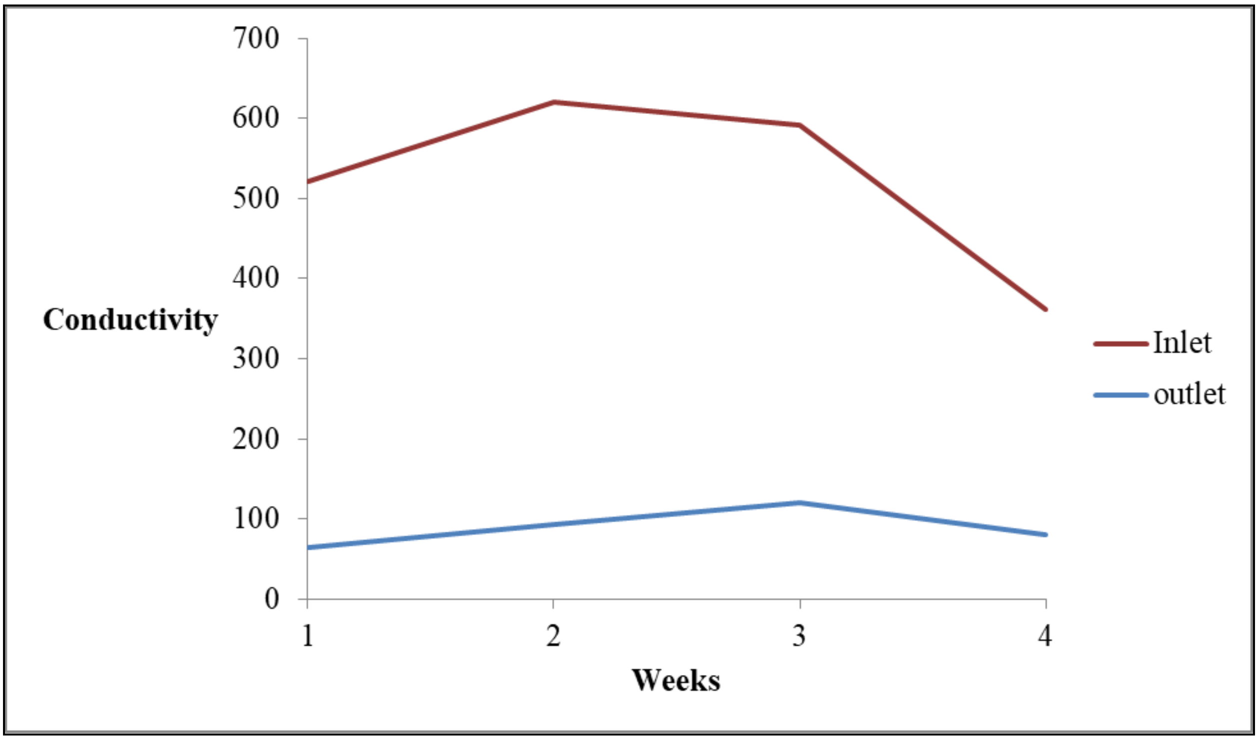


Figure 0.7: Weekly Variation of Conductivity

4.3.6.3 Weekly variation of Total Dissolved Solids of the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between TDS of the inlet and outlet; the TDS means within and between the inlet and outlet are the same. This is as shown in table 4.8.

Table 0.8: Student T-test for Total Dissolved Solids

	Inlet	Outlet
Mean	842.5	1010
Variance	18825	8066.666667
Observations	4	4
Pearson Correlation	-0.5437	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.66893	
P(T<=t) one-tail	0.096862	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.193724	
t Critical two-tail	3.182446	

The TDS concentration of the influent was higher (1030 mg/l) on the third week and lower on the fourth week (740mg/l). TDS concentration of the effluent was higher (1110 mg/l) on the first week and lower (750mg/l) on the fourth week. This is as shown in figure 4.8. The concentration of TDS was higher outlet than in the inlet in week 1, 2 and 4. At the inlet the released wastewater from the industries could be having low chemical concentration, whereas at the outlet there was accumulation of chemicals. There could be a possibility of high evaporation rates taking place in the sewerage system at that time before discharge. All this could cause high concentration of Total Dissolved Solids.

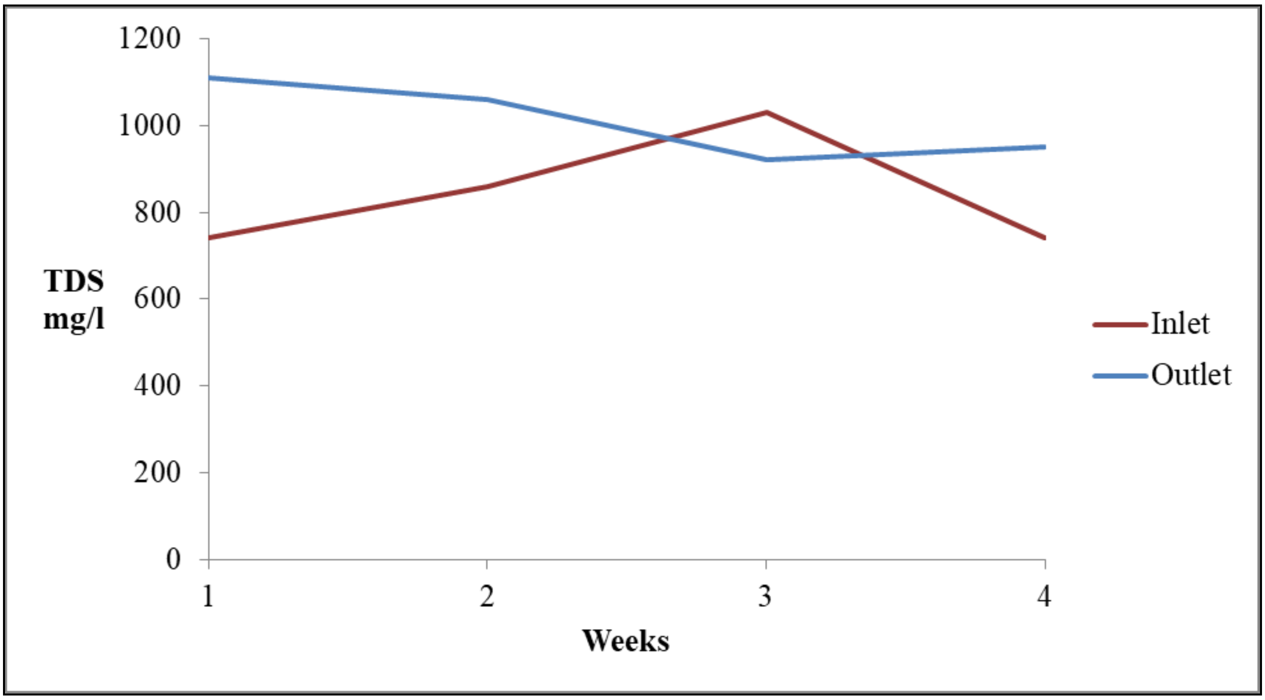


Figure 0.8: Weekly Variation of Total Dissolved Solids

4.3.6.4 Weekly variation of Total Suspended Solids of the inlet and outlet of Njoro sewage Works

The p - value is less than the selected alpha level (0.05) therefore there was a significant difference between TSS of the inlet and outlet; the TSS means within and between the inlet and outlet are not the same. This is as shown in table 4.9.

Table 0.9: Student T-test Total Suspended Solids

	Inlet	**Outlet**
Mean	524	89.5
Variance	13362.67	544.3333333
Observations	4	4
Pearson Correlation	0.494131	
Hypothesized Mean Difference	0	
Df	3	
t Stat	8.196047	
P(T<=t) one-tail	0.0019	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.003801	
t Critical two-tail	3.182446	

Total Suspended Solids concentration of the influent was higher (620 mg/l) on the second week and lower on the fourth week (362 mg/l). TSS concentration of the effluent was higher (120mg/l) on the third week and lower (93 mg/l) on the first week. This is as shown in figure 4.9. On the fourth week there was release of wastewater with low concentration in Total Suspended solids. The maximum allowable limit for release of wastewater to the surface water is 50 mg/l. This indicates that there was reduced retention time in ponds.

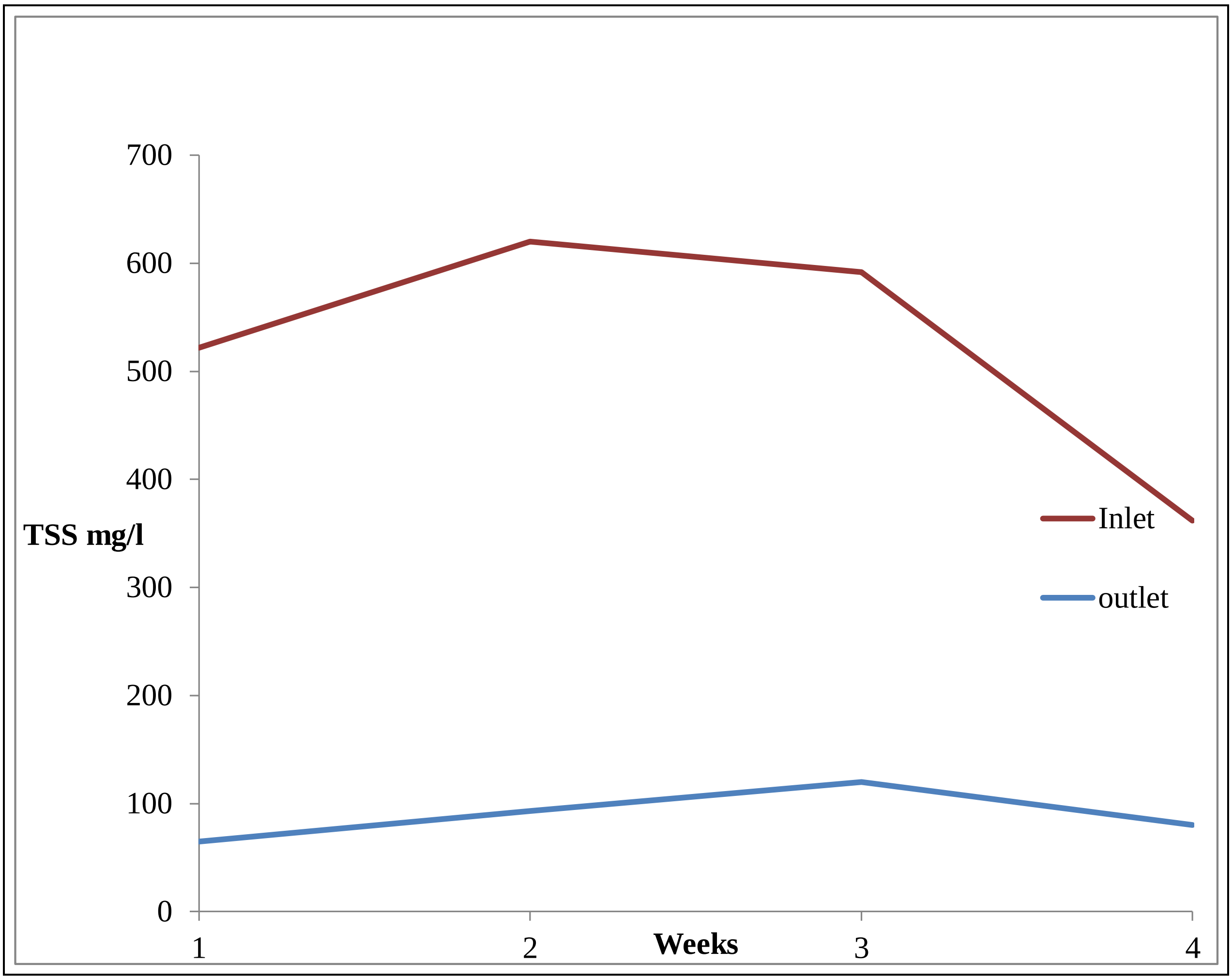


Figure 0.9: Weekly Variation of Dissolved Oxygen

4.3.6.5 Weekly variation of Dissolved Oxygen of the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore we accept the null hypothesis; the DO means within and between the inlet and outlet are the same. This is as shown in table 4.10.

Table 0.10: Student T-test for Dissolved Oxygen

	Inlet	Outlet
Mean	0.07	0.12
Variance	0.000267	0.002867
Observations	4	4
Pearson Correlation	-0.07625	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.74964	
P(T<=t) one-tail	0.089246	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.178491	
t Critical two-tail	3.182446	

P value (0.178491) > Alpha value (0.05). There is no statistical significant difference between the means of Dissolved Oxygen.

DO concentration of the influent was higher (0.09mg/l) on the fourth week and lower on the second week (0.05mg/l). DO concentration of the effluent was higher (0.18 mg/l) on the third week and lower (0.13 mg/l) on the first week.

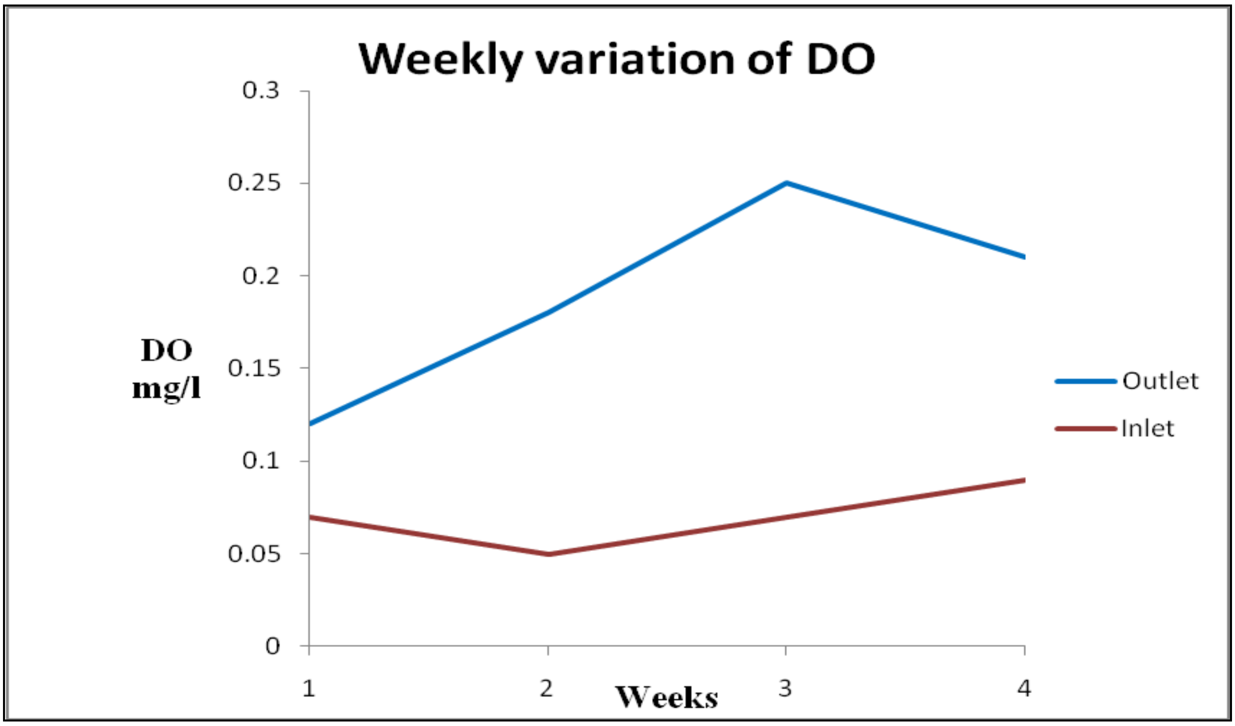


Figure 0.10: Weekly Variation of Dissolved Oxygen

This is as shown in figure 4.10. The concentration of DO at the outlet was higher than at the inlet. This shows that the microbes in the wastewater had reduced the organic load and the aquatic plants started thriving well in the sewage works thus releasing oxygen to the wastewater.

4.3.6.6 Weekly variation of Total Alkalinity of the inlet and outlet of Njoro sewage Works

The p - value is greater than the selected alpha level (0.05) therefore there was significant difference between TA in the inlet and outlet. The TA means within and between the inlet and outlet is equal. This is as shown in table 4.11

Table 0.11: Student T-test for Total Alkalinity

	Inlet	**Outlet**
Mean	1212.5	983.25
Variance	89297	156842.25
Observations	4	4
Pearson Correlation	0.827821	
Hypothesized Mean Difference	0	
Df	3	
t Stat	2.04634	
P(T<=t) one-tail	0.066616	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.133232	
t Critical two-tail	3.182446	

The TA concentration of the influent was higher (1568 mg/l) on the second week and lower on the third week (888 mg/l). TA concentration of the effluent was higher (1568 mg/l) on the second week and lower (690 mg/l) on the fourth week. This is as shown in figure 11. In the second week there was release of wastewater with high concentration of carbonates. Indicating that there was likely release of wastewater from industries with high carbonate concentration to the sewage works. There was conformity in the relationship of the concentration of carbonates of influent and effluent in all weeks. This is associated with the level of pH at both the inlet and outlet of the sewage works.

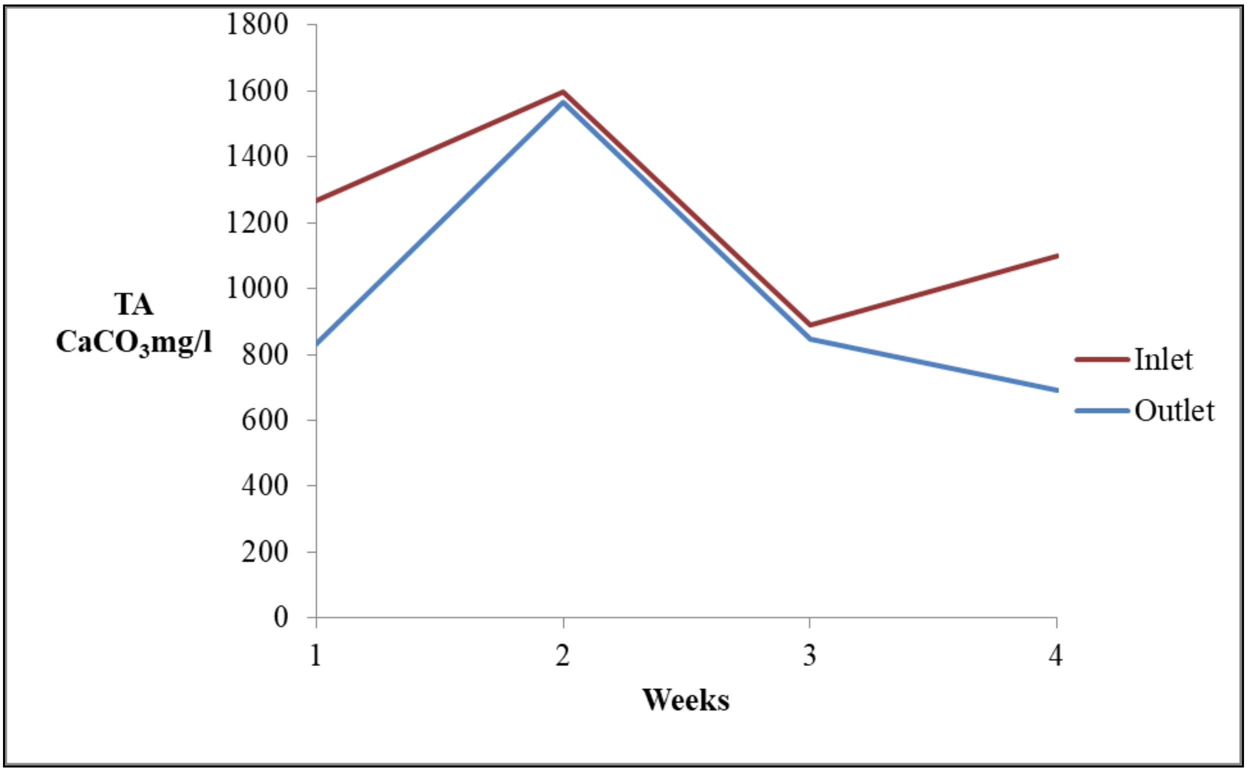


Figure 0.11: Weekly Variation of Total Alkalinity

4.3.6.7 Weekly variation of Biological Oxygen Demand in the inlet and outlet of Njoro sewage Works

The p - value is less than the selected alpha level (0.05) therefore there was significant difference between BOD in the inlet and outlet; the BOD means within and between the inlet and outlet are not equal. This is as shown in table 4.12.

Table 0.12: Student T-test for Biological Oxygen Demand

	Inlet	Outlet
Mean	337.5	108.25
Variance	5625	792.25
Observations	4	4
Pearson Correlation	0.673055	
Hypothesized Mean Difference	0	
Df	3	
t Stat	7.667714	
P(T<=t) one-tail	0.002304	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.004608	
t Critical two-tail	3.182446	

BOD concentration of the influent was higher (400mg/l) on the first and fourth week and lower on the second week (250mg/l). BOD concentration of the effluent was higher (150 mg/l) on the fourth week and lower (90 mg/l) on the second week. This is as shown in figure 4.12. The maximum allowable limits of BOD concentration of wastewater to sewage works is 500 mg/l. This shows that the quality of influents to the sewage works achieved the standards. The maximum allowable limits of BOD concentration of wastewater for release to the surface water is 50mg/l. This shows that the sewage work was not efficient in removal of BOD. This could be due to reduced retention time of the sewage works. Thus the wastewater did not get efficient contact time to breakdown the organic load. It is a requirement to do desiltation of the sewage ponds to achieve maximum efficiency.

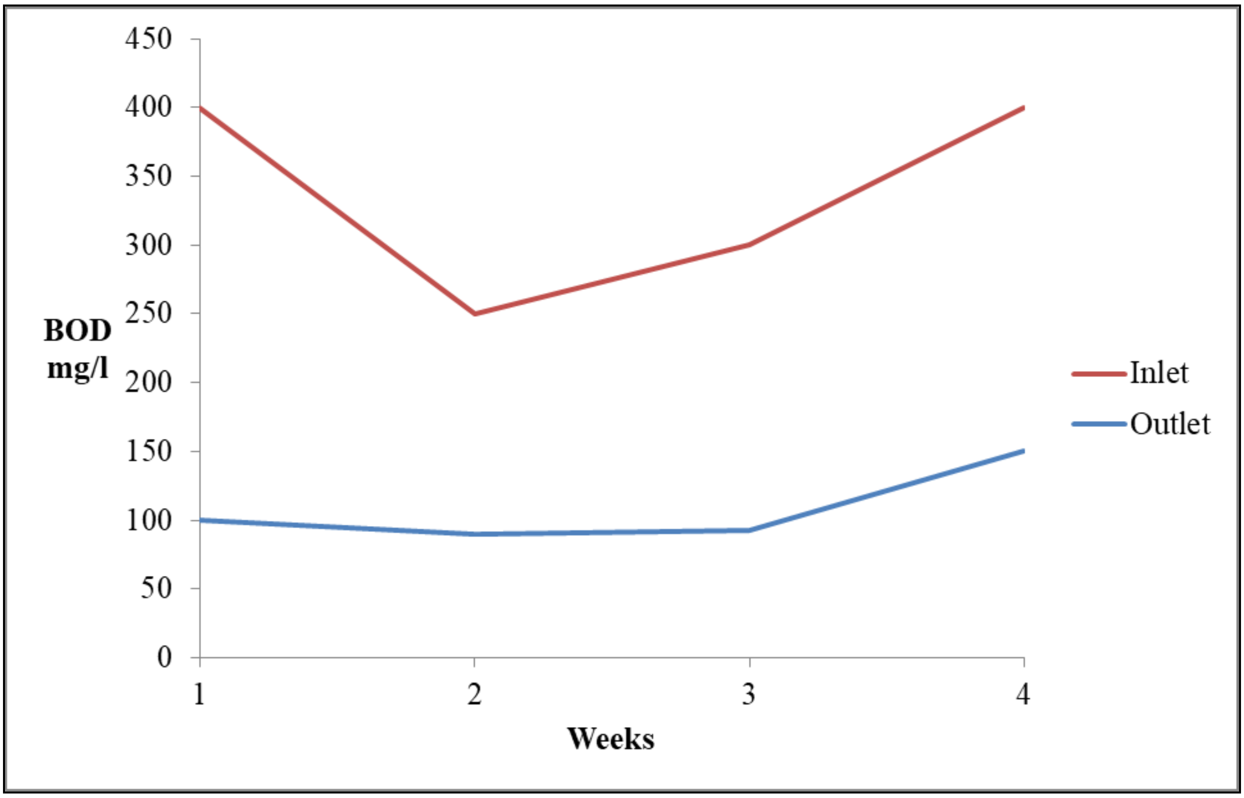


Figure 0.12: Weekly Variation of Biological Oxygen Demand

4.3.6.8 Weekly variation of Chemical Oxygen Demand in the inlet and outlet of Njoro sewage Works

The p-value is less than the selected alpha level (0.05) therefore there was significant difference between COD of the inlet and outlet; the COD means within and between the inlet and outlet are not equal. This is as shown in table 4.13.

Table 0.13: Student T-test for Chemical Oxygen Demand

	Inlet	Outlet
Mean	833.5	165.75
Variance	200345.7	1414.916667
Observations	4	4
Pearson Correlation	0.150792	
Hypothesized Mean Difference	0	
Df	3	
t Stat	3.011345	
P(T<=t) one-tail	0.028575	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.057151	
t Critical two-tail	3.182446	

COD concentration of the influent was higher (1399 mg/l) on the first week and lower on the fourth week (450 mg/l). COD concentration of the effluent was higher (222 mg/l) on the second week and lower (143 mg/l) on the first week. This is as shown in figure 4.13. In the first week the concentration of COD in the wastewater was high, this could be due to the release of wastewater with high level of chemical concentration. Influent with high chemical content causes reduced reactions in the wastewater. This results to reduced oxygen in wastewater affecting breakdown of the organic load.

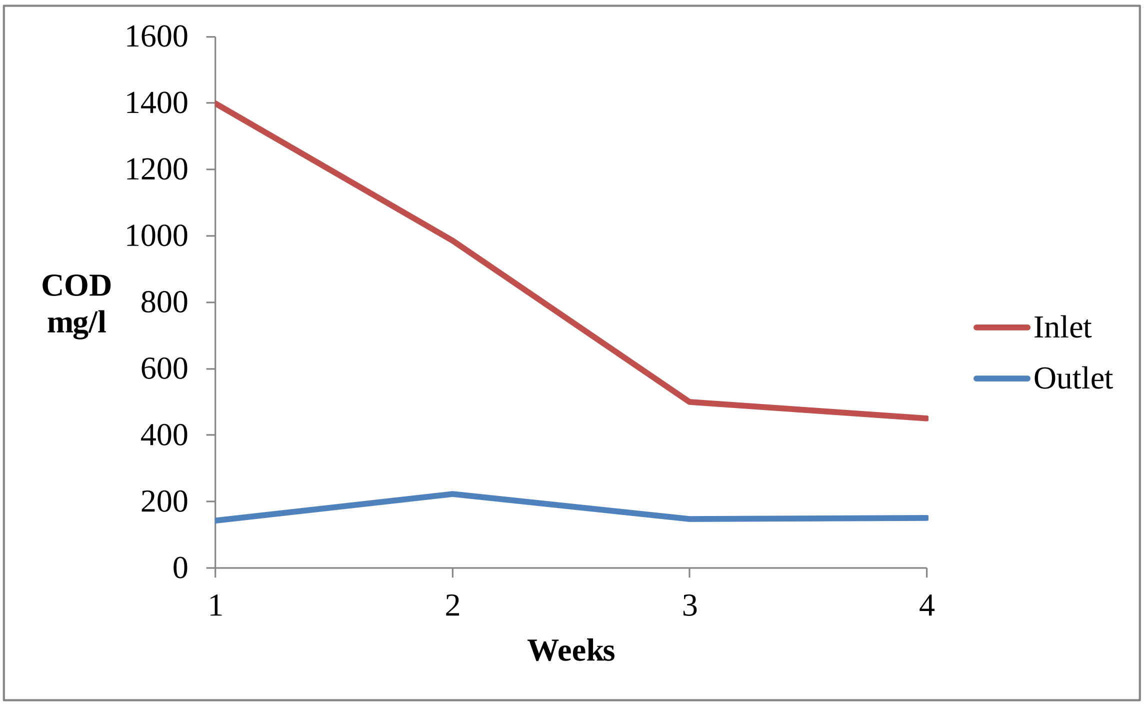


Figure 0.13: Weekly Variation of Chemical Oxygen Demand

4.3.6.9 Weekly variation of Lead in the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore we accept the null hypothesis; the Pb means within and between the inlet and outlet are the same. This is as shown in table 4.14.

Table 0.14: Student T-test for Lead

	Inlet	Outlet
Mean	0.132175	0.09315
Variance	0.012106	0.006417
Observations	4	4
Pearson Correlation	-0.65276	
Hypothesized Mean Difference	0	
Df	3	
t Stat	0.450403	
P(T<=t) one-tail	0.341489	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.682979	
t Critical two-tail	3.182446	

Lead concentration of the influent was higher (0.0783 mg/l) on the first and second weeks and lower on the third week (0.00 mg/l). Lead concentration of the effluent was higher (0.1621 mg/l) on the fourth week and lower (0.0 mg/l) on the third week. This is as shown in figure 4.14. In the second and fourth week, there was high level of lead in wastewater at the outlet. This could be due to the accumulation of lead in the ponds which were not removed through natural process.

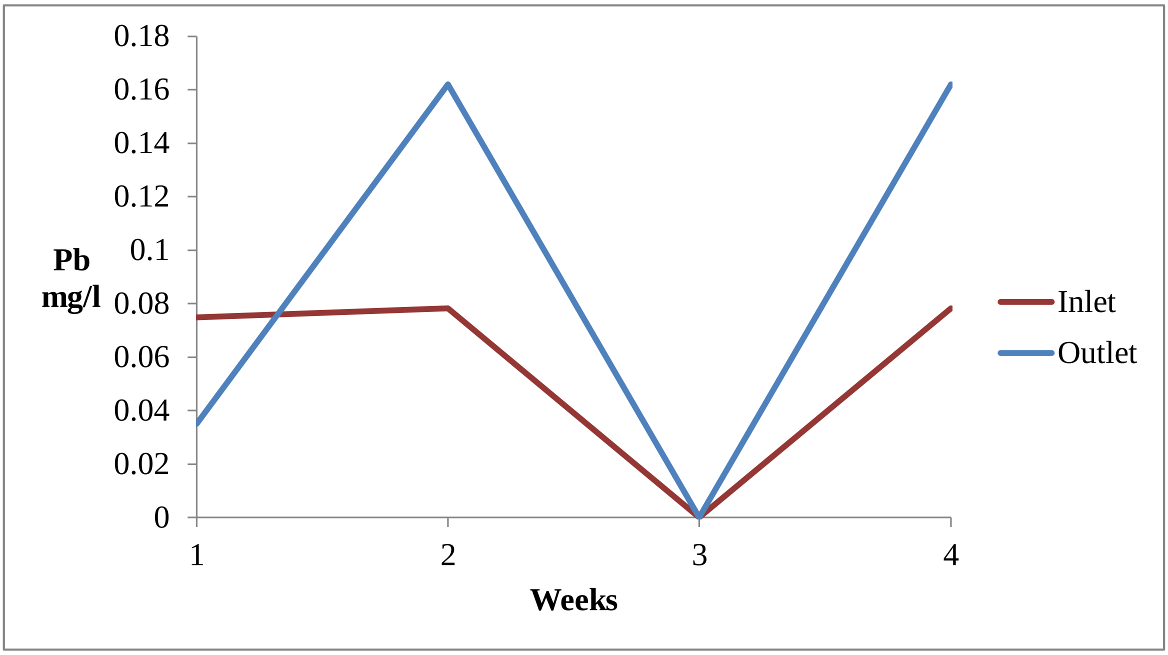


Figure 0.14: Weekly Variation of lead

4.3.6.10 Weekly variation of copper in the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between Cu in the inlet and outlet; the Cu means within and between the inlet and outlet are equal. This is as shown in table 4.15.

Table 0.15: Student T-test for Copper

	Inlet	Outlet
Mean	-0.14255	-0.031325
Variance	0.016073	0.002136223
Observations	4	4
Pearson Correlation	0.43802	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.94531	
P(T<=t) one-tail	0.073473	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.146946	
t Critical two-tail	3.182446	

Copper concentration of the influent was higher (0.000 mg/l) on the fourth week and lower on the third week (0.000 mg/l). Copper concentration of the effluent was higher (0.0238 mg/l) on the first week and lower (0.000 mg/l) on the second week. This is as shown in figure 4.15. The concentration of copper at the inlet was undetected but there were traces of copper at the outlet. This implies that there could be some releases of wastewater with copper from some industries. Copper cannot be removed by natural process in the ponds, thus finds its way at the outlet.

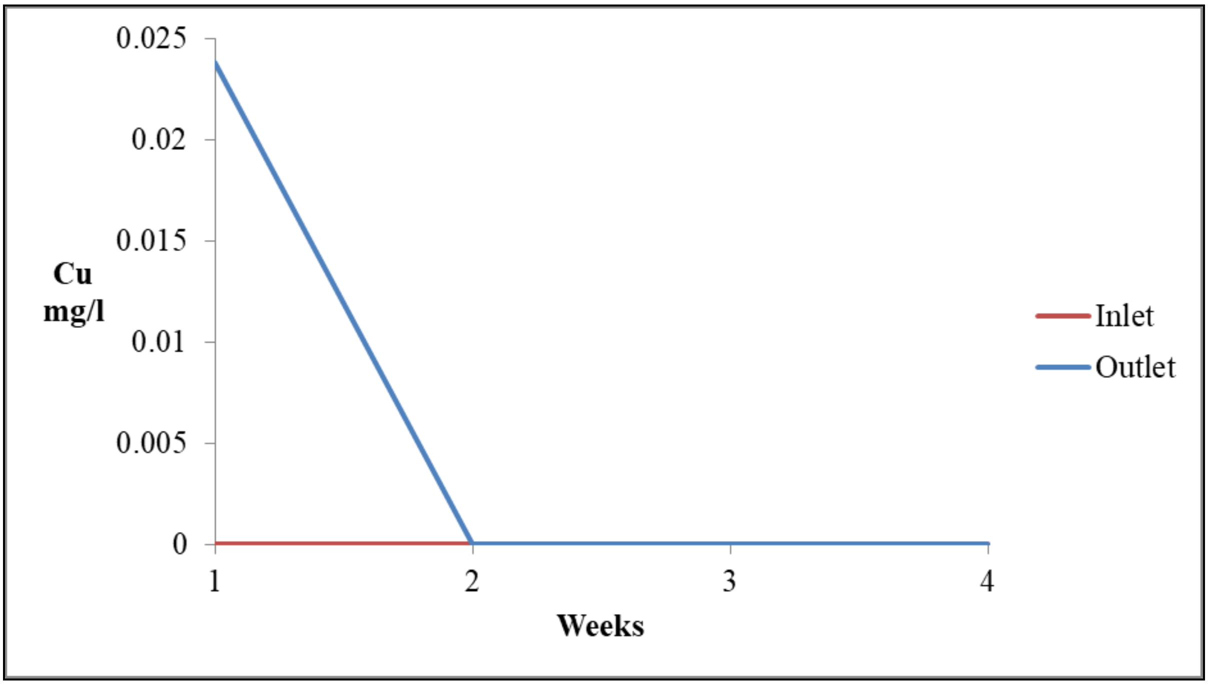


Figure 0.15: Weekly Variation of Copper

4.3.6.11 Weekly variation of Zinc of the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between Zn in the inlet and outlet; the Zn means within and between the inlet and outlet are equal. This is as shown in table 4.16.

Table 0.16: Student T-test for Zinc

	Inlet	**Outlet**
Mean	0.423225	0.19417
Variance	0.036434	0.134107001
Observations	4	4
Pearson Correlation	0.143191	
Hypothesized Mean Difference	0	
Df	3	
t Stat	1.18078	
P(T<=t) one-tail	0.16139	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.32278	
t Critical two-tail	3.182446	

Zinc concentration of the influent was higher (0.5961 mg/l) on the fourth week and lower on the first week (0.1505 mg/l). Zinc concentration of the effluent was higher (0.7434 mg/l) on the second week and lower (0.0042 mg/l) on the third week. This is as shown in figure 4.16. Zinc cannot be removed by the stabilization ponds of the sewage works. Zinc is inactive in wastewater, it cannot react in wastewater, and it can be either in sludge or in wastewater.

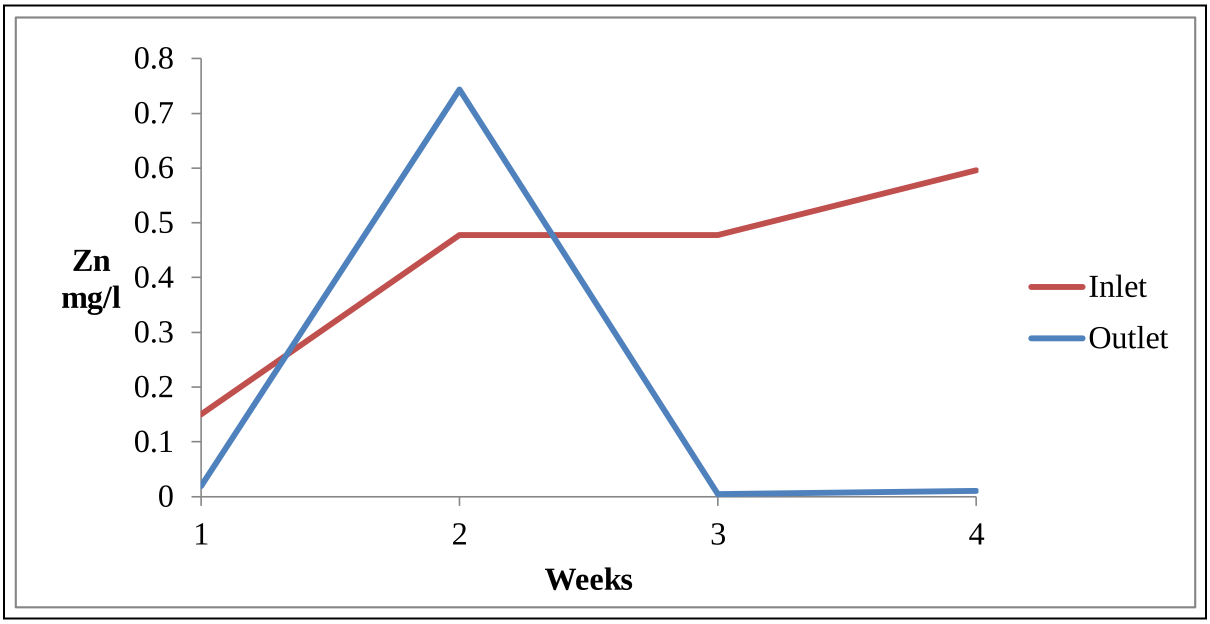


Figure 0.16: Weekly Variation of Zinc

Pink colouration was observed in the facultative and maturation ponds of Njoro sewage works. This pink coloration phenomenon is as a result of massive growth of Sulphur bacteria in the ponds. The pink coloration is a sign of inefficiency of the system of the Njoro sewage works. The pink coloration is caused by overload of the wastewater of the influent of Njoro sewage works, which emanates from the influent. It is as a result of chemical reaction, through reduction process of sulphate to sulphide in facultative and maturation ponds. It results to reduction in oxygen in facultative and maturation ponds, changing to anaerobic conditions which stimulate growth of Sulphur bacteria. In absence of oxygen, Sulphur compounds are reduced by anaerobes leading to formation of hydrogen sulfide. The purple Sulphur bacteria thrive in water containing hydrogen sulphide formed on reduction of Sulphur compounds. The Sulphur bacteria grow anaerobically in light and use hydrogen Sulphide as a hydrogen donor for photosynthesis. The sulphur bacteria are responsible for the purple colouration observed in facultative and maturation ponds. Study by Belila *et al. (*2013) in Tunisia showed that the organic load due to the reduced oxygen in the pond enhances the growth of Sulphur bacteria which enhances Sulphate cycle. The chemical test done in the laboratory indicated traces of heavy metals. They accumulated in the ponds due to reduced Oxygen in the ponds. The System tended to change from aerobic to anaerobic state.

4.3.6.13 Weekly variation of Chromium in the inlet and outlet of Njoro sewage Works

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between Cr in the inlet and outlet; the Cr means within and between the inlet and outlet are equal. This is as shown in table 4.17.

Table 0.17: Student T-test for of Chromium

	Inlet	Outlet
Mean	1.153875	0.11184
Variance	1.078662	0.052510342
Observations	4	4
Pearson Correlation	-0.48912	
Hypothesized Mean Difference	0	
Df	3	
t Stat	1.78446	
P(T<=t) one-tail	0.086172	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.172344	
t Critical two-tail	3.182446	

Chromium concentration of the influent was higher (2.0868 mg/l) on the second week and lower on the fourth week (0.023 mg/l). Chromium concentration of the effluent was higher (0.0223 mg/l) on the fourth week and lower (0.000 mg/l) on the first week. This is as shown in figure 4.17.

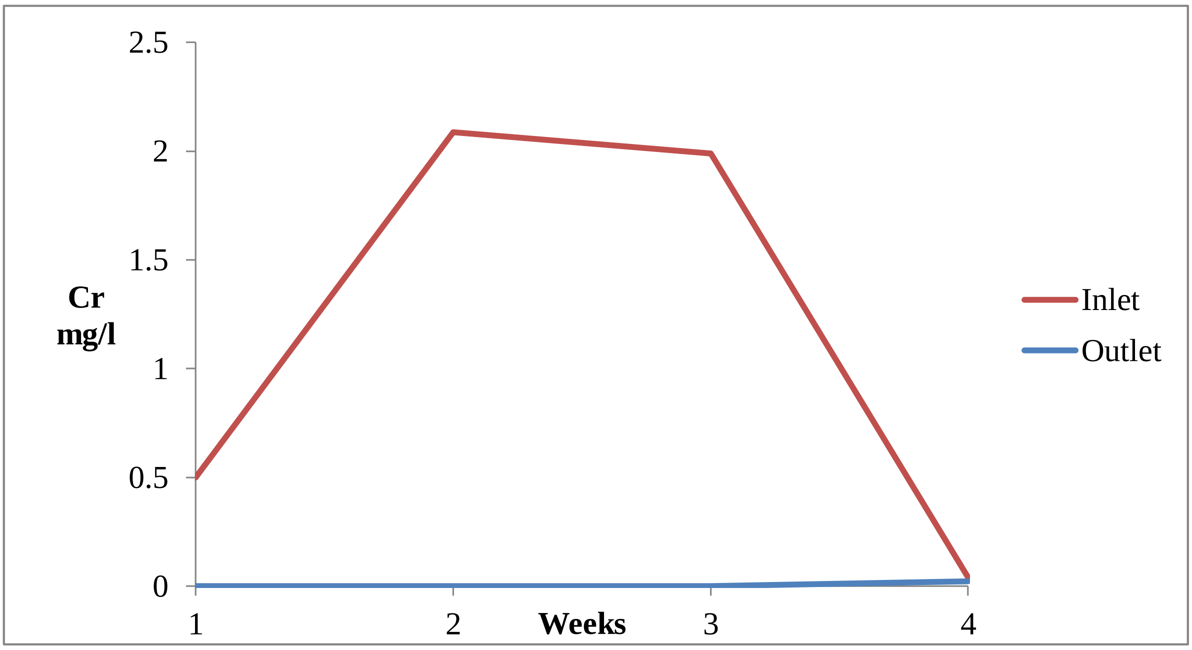


Figure 0.17: Weekly Variation of Chromium

There was presence of chromium of at the inlet in all the four weeks. The maximum allowable limit of chromium concentration in wastewater discharged to sewage works is 2.0 mg/l. The concentration of chromium at the inlet on the second week exceeded the recommended limit. Chromium in the sewage works in the presence of oxygen gets oxidized to hexavalent chromium which is toxic to human and aquatic life.

4.4 The concentration level of wastewater quality parameters at the inlet and outlet of Njoro industrial sewage works

Student T- test was done to determine the relationship between inlet and outlet of physical and chemical parameters of Njoro industrial sewage works wastewater for four consecutive week

4.4.1 pH

The p-value is greater than the selected alpha level (0.05) therefore there was no significant difference between pH of the inlet and outlet; the pH means within and between the inlet and outlet are equal.

Table 0.18: Student T-test of pH

	Inlet	Outlet
Mean	7.575	8.2
Variance	0.289166667	0.126666667
Observations	4	4
Pearson Correlation	0.766348191	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-3.571428571	
P(T<=t) one-tail	0.018756982	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.037513964	
t Critical two-tail	3.182446305	

The pH concentration between and within the inlet and outlet of wastewater were the same. Therefore was no effect on the pH concentration on the treatment of wastewater in Njoro sewage works. According to the study done in New York by Metcalf and Eddie (2003) indicates that, the pH concentration range conducive for the survival of most aquatic life is typically 6-9. This is in line with the NEMA standard which indicates the maximum allowable limits of pH of wastewater at the outlet as 6.5 to 9.2.

4.4.2 Conductivity

The p-value is greater than the selected alpha level (0.05); the conductivity means within and between the inlet and outlet are the same. P value (0.143631) > Alpha value (0.05). There is no statistical significant difference between the means of Conductivity.

Table 0.19: Student T-test for Conductivity

	Inlet	Outlet
Mean	1705	2003.25
Variance	96966.67	10602.25
Observations	4	4
Pearson Correlation	0.245815	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.96868	
p (T<=t) one-tail	0.071815	
t Critical one-tail	2.353363	
p (T<=t) two-tail	0.143631	
t Critical two-tail	3.182446	

The study results indicate that there was no relationship between the conductivity concentration of wastewater at the inlet and outlet of Njoro sewage works. The high conductivity in wastewater relates to the high mineral content and high salinity. It is also relates to the highest concentrations of the dominant ions which leads to solubility and ion exchange in the wastewater. It shows the strong positive relationship with the TDS, Calcium ions and bicarbonate ions in the inlet and the outlet (Gautam *et al*., 2013)

4.4.3 Total Dissolved Solids

The p-value is greater than the selected alpha level (0.05), the TDS means within and between the inlet and outlet are the same. p - value (0.193724) > Alpha value (0.05). Therefore there is no statistical significant difference between the means of Total Dissolved Solids.

The study results indicated that the removal of dissolved solids in the stabilization ponds were not effective. This shows that the inorganic and organic compounds present in wastewater were not biodegraded by microbes in the stabilization ponds. This study is in contrary with the study done by Chebor *et al*. (2017) in Uasin-Gishu, Kenya, which revealed that the TDS concentration reduced from one stabilization pond to another during the dry season but during the wet season it increased from one stabilization pond to the other.

Table 0.20: Student T-test for Total Dissolved Solids

	Inlet	Outlet
Mean	842.5	1010
Variance	18825	8066.667
Observations	4	4
Pearson Correlation	-0.5437	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.66893	
p(T<=t) one-tail	0.096862	
t Critical one-tail	2.353363	
p(T<=t) two-tail	0.193724	
t Critical two-tail	3.182446	

4.4.4 Total Suspended Solids

The p - value is less than the selected alpha level (0.05), the TSS means within and between the inlet and outlet are not the same. p value (0.003801) < Alpha value (0.05). There is a statistical significant difference between the means of Total Suspended Solids.

Table 0.21: Student T-test for Total Suspended Solids

	Inlet	Outlet
Mean	524	89.5
Variance	13362.67	544.3333
Observations	4	4
Pearson Correlation	0.494131	
Hypothesized Mean Difference	0	
Df	3	
t Stat	8.196047	
p(T<=t) one-tail	0.0019	
t Critical one-tail	2.353363	
p(T<=t) two-tail	0.003801	
t Critical two-tail	3.182446	

The study showed that the waste stabilization ponds were effective in the removal of TSS in the wastewater. This shows that the grit removal section had effective retention time for removal of settle-able and suspended sediments.

4.4.5 Dissolved Oxygen

The p-value is greater than the selected alpha level (0.05), the DO means within and between the inlet and outlet are the same. p value (0.178491) > Alpha value (0.05). There is no statistical significant difference between the means of Dissolved Oxygen.

Table 0.22: Student T-test for Dissolved Oxygen

	Inlet	Outlet
Mean	0.07	0.12
Variance	0.000267	0.002867
Observations	4	4
Pearson Correlation	-0.07625	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.74964	
p (T<=t) one-tail	0.089246	
t Critical one-tail	2.353363	
p (T<=t) two-tail	0.178491	
t Critical two-tail	3.182446	

DO is an indicator of the activity of an aerobic zone of a facultative waste pond. DO is required by aerobic bacteria in order to breakdown the organic matter in the wastewater. The typical DO range required of a waste pond is 4-12 mg/L. The presence of oxygen in wastewater helps in the growth of algae. This increases in the photosynthesis action in the ponds there by increasing the oxygen concentration.

4.4.6 Total Alkalinity

The p-value is greater than the selected alpha level (0.05), the TA means within and between the inlet and outlet are the same. p value (0.133232) > Alpha value (0.05). There is no statistical significant difference between the means of Total Alkalinity. The total alkalinity is the measure of all acids neutralizing bases in water. In the industrial wastewater, presence of inorganic and organic compounds contributes to the level of alkalinity in wastewater. Total alkalinity is related to the amount of total dissolved solids in wastewater (Environmental Business Specialist (EBS), (2018).

Table 0.23: Student T-test for Total Alkalinity

	Inlet	Outlet
Mean	1212.5	983.25
Variance	89297	156842.3
Observations	4	4
Pearson Correlation	0.827821	
Hypothesized Mean Difference	0	
Df	3	
t Stat	2.04634	
p (T<=t) one-tail	0.066616	
t Critical one-tail	2.353363	
P (T<=t) two-tail	0.133232	
t Critical two-tail	3.182446	

4.4.7 Biological Oxygen Dissolved

The p - value is greater than the selected alpha level (0.05), the BOD means within and between the inlet and outlet are not the same. p value (0.178491) > Alpha value (0.05). There is no statistical significant difference between the means of Biological Oxygen Demand.

Table 0.24: Student T-test for Biological Oxygen Dissolved

	Inlet	**Outlet**
Mean	0.07	0.12
Variance	0.000267	0.002867
Observations	4	4
Pearson Correlation	-0.07625	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-1.74964	
p (T<=t) one-tail	0.089246	
t Critical one-tail	2.353363	
p (T<=t) two-tail	0.178491	
t Critical two-tail	3.182446	

BOD concentration indicates the presence of microorganism activities and the dead organic matter on which the microorganisms feed. BOD is linked directly with the decomposition of organic matter which is present in the wastewater and therefore higher levels of BOD can be directly linked to pollution status of the wastewater. Higher concentration of BOD means presence of more biodegradable organic matter (Fatoki *et al.*, 2003).

4.4.8 Chemical Oxygen Demand

The p-value is greater than the selected alpha level (0.05), the COD means within and between the inlet and outlet are the same. p value (0.057151) > Alpha value (0.05). There is no statistical significant difference between the means of Chemical Oxygen Demand**.**

Table 0.25: Student T-test for Chemical Oxygen Demand

	Inlet	**Outlet**
Mean	833.5	165.75
Variance	200345.7	1414.917
Observations	4	4
Pearson Correlation	0.150792	
Hypothesized Mean Difference	0	
Df	3	
t Stat	3.011345	
p (T<=t) one-tail	0.028575	
t Critical one-tail	2.353363	
p (T<=t) two-tail	0.057151	
t Critical two-tail	3.182446	

Chemical Oxygen Demand reduction uses the same principle as in the reduction of BOD in wastewater. COD in wastewater reduces the amount of oxygen used by microorganisms to break down organic and inorganic matter. Study done by Ramesh (2004) shows that COD can only be reduced effectively by a chemical oxidant which reduces organic matter in the wastewater. The organic compounds measured by COD may not be degraded by microorganism in the wastewater stabilization processes.

4.4.9 Lead

The p-value is greater than the selected alpha level (0.05), the Pb means within and between the inlet and outlet are the same. p value (0.682979) > Alpha value (0.05). There is no statistical significant difference between the means of lead.

Table 0.26: Student T-test for Lead

	Inlet	Outlet
Mean	0.132175	0.09315
Variance	0.012106	0.006417
Observations	4	4
Pearson Correlation	-0.65276	
Hypothesized Mean Difference	0	
Df	3	
t Stat	0.450403	
P(T<=t) one-tail	0.341489	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.682979	
t Critical two-tail	3.182446	

The study indicates that there is no significant difference between the mean of lead in wastewater at the inlet and the outlet in the Njoro sewage works. Lead is a dangerous chemical since it can accumulate in the food chains of individual organisms. High concentration of lead has got adverse health impacts from lead poisoning. Even in low concentrations of lead present in water bodies, it has got health effects to the shellfish. Lead also interferes with the body functions of the phytoplankton. Lead can cause several health effects, such as: disruption of the biosynthesis of anaemia and haemoglobin, a rise in blood pressure, kidney damage, miscarriages and subtle abortions, disruption of nervous systems, brain damage, declined fertility of men through sperm damage, diminished learning abilities of children (Philip *et al.,* 2002).Behavioral disruptions of children such as aggression, impulsive behavior and hyperactivity (Pichery *et al.,* 2011). Lead can enter a foetus through the placenta of the mother thereby causing serious damage to the nervous system and the brains of unborn children (Tong *et al.,* 2000).

4.4.10 Copper

The p-value is greater than the selected alpha level (0.05), the Cu means within and between the inlet and outlet are the same. p value (0.73454) > Alpha value (0.05). There is no statistical significant difference between the means of copper**.**

Table 0.27: Student T-test for Copper

	Inlet	**Outlet**
Mean	0.142525	0.21805
Variance	0.016082	0.13928073
Observations	4	4
Pearson Correlation	-0.09945	
Hypothesized Mean Difference	0	
Df	3	
t Stat	-0.37211	
P(T<=t) one-tail	0.36727	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.73454	
t Critical two-tail	3.182446	

Copper is micronutrient element and plays an important role in the bone formation together with certain proteins and enzymes, but it produces severe toxic effects at higher concentrations. The excessive intake of copper ions by the human beings leads to the severe mucosal irritation and corrosion, hepatic and renal damage, widespread capillary damage, severe gastro intestinal irritation, irritation of the central nervous system, and possible necrotic changes in the liver and kidney could occur. The excessive amounts of Cu (II) ions in fresh water resources and aquatic ecosystem damage the osmo-regulatory mechanism of the aquatic life (Mohsen and Nazila, 2016).

4.4.11 Zinc

The p - value is greater than the selected alpha level (0.05), the Zn means within and between the inlet and outlet are the same. p value (0.313802) > Alpha value (0.05). There is no statistical significant difference between the means of Zinc.

Table 0.28: Student T-test for Zinc

	Inlet	Outlet
Mean	0.42575	0.194175
Variance	0.036761	0.134105
Observations	4	4
Pearson Correlation	0.168861	
Hypothesized Mean Difference	0	
Df	3	
t Stat	1.207359	
p (T<=t) one-tail	0.156901	
t Critical one-tail	2.353363	
p (T<=t) two-tail	0.313802	
t Critical two-tail	3.182446	

The results indicate that there was no statistically difference between the means of Zinc in the wastewater at the inlet and outlet of Njoro sewage works. Zinc is an essential and beneficial element in human growth. Zinc can be toxic when exposures exceed physiological needs. Zinc is necessary for various metabolic processes like embryonic development, cellular differentiation and cell proliferation. It also provides the substrates for expression of the genetic potential of the individual (Prasad, 2008). Zinc on the other hand is harmful to human beings if it exceeds the required limit.

4.4.12 Chromium

The p-value is greater than the selected alpha level (0.05) therefore we accept the null hypothesis; the Cr means within and between the inlet and outlet are the same. p value (0.172017) > Alpha value (0.05). There is no statistical significant difference between the means of Chromium.

Table 0.29: Student T-test for Chromium

	Inlet	Outlet
Mean	1.153875	0.126425
Variance	1.078662	0.047877116
Observations	4	4
Pearson Correlation	-0.43283	
Hypothesized Mean Difference	0	
Df	3	
t Stat	1.786354	
P(T<=t) one-tail	0.086008	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.172017	
t Critical two-tail	3.182446	

Chromium may exist in the water in both the hexavalent and the trivalent states. In larger concentration of chromium and in different forms, chromium can be toxic and carcinogenic to human health. Hexavalent chromium in water is a proven carcinogen to different internal and external organs of the living organisms. Hexavalent chromium is a danger to human health and it includes, skin rashes, upset stomachs, ulcers, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer, ulcerations, dermatitis, irritation, edema and death (Dababrata *et al*., 2017).

The efficiency of the sewage treatment work in reducing the parameters measured was calculated as follows;

$$\text{Efficiency } (\%) = \frac{\text{Inlet} - \text{Outlet}}{\text{Inlet}} X100$$

The results of the sewage's efficiency were as shown in table 4.28. the results indicated that the treatment work was able to reduce chromium (89.04), Total Suspended Solutes (82.92%) and Chemical Oxygen Demand (82.84%). It was able to reduce Total Dissolved solutes by 19.88% and improved conductivity by 17.49%. The average efficiency of the treatment works was 53.52%. This means that the efficiency of the treatment works is average (Table 4.30).

Table 0.30: Efficiency of the sewage works

Parameters	Inlet	Maximum allowable limits for discharge to sewer line	Outlet	Maximum allowable limits for surface water	Efficiency%
Conductivity	1705 mg/l	-	2003.25 mg/l	-	17.49%
TDS	842.5 mg/l	2000.0 mg/l	1010 mg/l	1200.0mg/l	19.88%
TSS	524 mg/l	250.0mg/l	89.5 mg/l	30.0mg/l	82.92%
TA	1212.5 mg/l	-	983.25 mg/l	-	18.90%
DO	0.07 mg/l	-	0.12 mg/l	>2.omg/l	71.42%
BOD	337.5 mgO_2/l	500.0 mgO_2/l	105.25 mgO_2/l	30.0 mgO_2/l	68.81%
COD	961.33 mgO_2/l	1000.0 mgO_2/l	165.75 mgO2/l	50.0 mgO_2/l	82.84%
Pb	0.132175 mg/l	1.0mg/l	0.09315 mg/l	0.01mg/l	29.53%
Zn	0.42575	5.0mg/l	0.194175 mg/l	0.5mg/l	54.39%
Cr	1.153875 mg/l	0.05	0.126425 mg/l	0.05mg/l	89.04%
Cu	0.142525mg/l	1.0mg/l	0.21805mg/l	1.0mg/l	-21.66%

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Major industries that discharge into Njoro sewage works include; Nakuru tanners, Menengai oil refinery, Spinknit, Bedi textile, Bidco and Kenya seed. Major pollutants discharged into Njoro sewage works included; Total Dissolved Solids, grease, oils, copper, fluorides, nitrates, chlorides, carbonates, dyes, detergents, chromium, acids and total alkalinity.

Three industries (Bidco Company, Nakuru Tanners and Menengai oil refinery) pre-treated their wastewater before being discharged into the sewer line. The waste management systems used to pre-treat wastewater include; interceptor, stabilization ponds and wetland. Interceptors are effective in removal of oil and grease and suspended solids. Stabilization ponds are affective in removing Total Dissolved Solids, Total Suspended Solids, Biological Oxygen Demand, Chemical Oxygen Demand, and Total Alkalinity. Wetland is effective in removal of heavy metals such as; Lead Chromium, Zinc, Copper and Chromium. Three industries (Kenya seed, Spinknit and Bedi textile) did not pre-treat their wastewater. The likely pollutants being discharged to the sewage works include; Copper, dyes, detergents, Fluorides, Chlorides, Nitrates and Carbonates.

Seasonal trends observed yearly indicates high concentration of conductivity; TSS, BOD and COD during the dry season. High pH concentration was also observed during the wet season. Laboratory results showed that pH and DO concentration of the effluent were higher. Lead concentration of the effluent was higher in week 2 while Zinc concentration of the effluent was higher in week 1, 3 and 4. The concentration of TDS was higher for the effluent than for the influent in week 1, 2 and 4. Conductivity, Total Suspended Solids, TA, BOD, COD and Chromium concentrations were higher for the influent. The concentration of copper for the influent was undetected but there were traces of copper at the effluent. Pink coloration was observed in the facultative and maturation ponds of Njoro sewage works.

Heavy metals that were found in the effluent of Njoro sewerage works were; Lead, Copper, Zinc and Chromium. High concentration of Chromium (2.0868 mg/l), Zinc (0.7434 mg/l), lead (0.1621 mg/l) and copper in traces. There was statistical significant difference between the means of Total Suspended Solids ($0.003801 < 0.05$) for the influent and effluent of Njoro Sewage works. There was no statistical significant difference between the means of conductivity ($0.143631>0.05$), Total Dissolved solids ($0.193724>0.05$), Dissolved Oxygen

(0.178491.0.05), Total Alkalinity (0.133232>0.05), Biological Oxygen Demand (0.17849> 0.05) and Chemical Oxygen Demand (0.057151>0.05) for the influent and effluent of Njoro Sewage works.

5.2 Recommendation

i. All pollutants from industries discharging into Njoro sewage works in Nakuru County should be determined in order to establish the type of pre-treatment required for wastewater.

ii. All industries should be required to pre-treat their wastewater before discharging into the sewer line in respective of the type of production process. The enforcement bodies should also come up with the strategy of ensuring that all the requirements are met. The enforcement bodies should intensify enforcement of wastewater standards of all industries and establish forum with the industrial management.

iii. Use of wetlands should be enforced in both the industries and in the sewage works processes for efficient removal of heavy metals. Water Service Provider (NAWASSCO) should monitor the influent of Njoro sewage works to ensure its effectiveness by acting on remedial measures to eliminate the presence of pink coloration in both the facultative and maturation ponds.

iv. The sewage works should be rehabilitated to achieve the desired effectiveness.The aim of the study research was to assess the effectiveness of the Njoro industrial sewage work. It did not focus on the specific waste generated from each industry. Therefore further research can be focused from the source. This can give an indication of the source of the specific pollutant.

REFERENCES

Agency for Toxicity substance and Disease Registry (2013). *Chromium Toxicity: What are the physiologic effects of Chromium exposures?* 4770 Buford Hwy NE, Atlanta, GA, 30341.

Agency for Toxicity substance and Disease Registry (2015). *Public Health Statement for copper,* 1600 Cliffton NE, Atlanta, GA, 30333.

Akali, N. M., Nyongesa, N.D., Neyole, E.M., and Miima, J.B. (2011). Effluent discharge by Mumias sugar Company in Kenya: An empirical investigation of the pollution of River Nzoia. *Sacha journal of environmental studies* 1 (1) 1-30.

Alade, A. O., Ahmad, T., Jameel, S., Muyubi, M. and Zahangir, A. (2011). Removal of Oil and Grease as Emerging Pollutants of Concern (EPC) in Wastewater Stream. *ILLUM Engineering Journal*, 12:(4).

Alam, S. S and Mahbub, M. N. (2007). Karyotype comparison in two varieties of *Vignamungo* after staining with Orcein and CMA, Bangladesh. *Journal of Botany*, 36(2): 167-170

Alfonso, V., Bonilla, E., Pinilla, L. and Serrezuela, R. (2018). Removal of Chromium in Wastewater from tanneries applying bioremediation with Algae, Orange peels and Citrus pectin. *Contemporary Engineering Science*, 11(9), 433-499.

American Public Health Association (2005). *Standard Methods for Examination of water and wastewater analysis*, 21st Edition. Washington, DC.

Aoyama, M., Hirose, K., Nemoto, K., Takatsuki, Y., and Tsumune, D. (2008). Water masses labeled with global fallout 137Cs formed by subduction in the North Pacific. *Geophysical Research Letters*, *35*(1).

Azumi, D. S and Bichi M.H. (2010). Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. *Journal of Applied Science in Environmental Sanitation*, 5(1): 23-29.

Belila, A., Abbas, B., Fazaa, I, Saidi, N., Snoussi, M., Hassen, A., and Muyzer, G. (2013). Sulphur bacteria in wastewater stabilisation ponds periodically affected by the red-water phenomenon. *Application of microbial biotechnology 97 (1),* 379-394, Tunisia.

Benard, O., and Omondi, G. (2012). Wastewater Production, Treatment, and Use in Kenya. In *Third regional workshop'safe use of wastewater in agriculture, Johannesburg*.

Chebor, J., Ezekiel, K. and Mwamburi, A. (2017). Effect of seasonal Variation on Performance of Conventional Wastewater Treatment System. *Journal of Applied and Microbiology*. 5(1), 1-7.

Chemtech International (2017). *How 7 companies manage their Total Suspended Solids (TSS) Problems*. USA.

Dababrata, P., Lala, B., Matthew, S., and Pattanathu, K. (2017). Recent Bio reduction of Hexavalent Chromium in Wastewater Treatment: A review. *Journal of Industrial and Engineering Chemistry*, 55, 1-20.

Dlamini, K.D. and Joubert, P.N. (1996). Industrial development, pollution and disease: The case of Swaziland. *Botswana journal of African studies* 10(1) 71-82.

Duruibe, J. O., Ogwuegbu, M. O. C., and Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. *International Journal of physical sciences*, *2*(5), 112-118.

El-Gawad, S. (2014). Oil and Grease Removal from Industrial Wastewater Using New Utility Approach, *Advances in Environmental Chemistry*, 24, 1-6.

EMCA (1999). National Environment Management Authority. Retrieved from: 2018 https://www.nema.go.ke/images/Docs/Legislation%20and%20Policies/Environmental Act(EMCA1999).pdf

Environmental Business Specialist (EBS) (2018). *pH Testing in Wastewater Treatment*. Wastewater training and Consulting. United States.

Environmental Health and Safety Guidelines (2007). Tanning and Leather Finishing. Pollution Prevention and Abatement Handbook. Retrieved from: 2018 http://www.Ifc.org//fcex/enviro.nst/content/Environmentalguideline

FAO (2015). Aqua stat. Global Water Information System. Retrieved from http://www.fao.org/nr/water/aquastat/projects/index.stm

Fatoki, S., Gogwana, P. and Ogunfowokan, A. (2003). Pollution Assessment in the Keiskamma River and in the Impoundment Downstream. *Water SA*, 29(3), 183-187.

Fereidoun, H., Nourddin, M.S., Rreza, N.A., Mohsen, A., Ahmad, R. and Pouria, H. (2007). The effects of long term exposure to particulate pollution on the lung function of Teheranian and Zanjanian students. *Pakistan journal of physicology*3(2)1-5.

Gautam, K., Kumar, J., and Sign, K. (2013). A study of the effectiveness of Sewage treatment Plants in Delhi Region. *Applied Water Science*, 3(1), 57-65.

Greater Nakuru Water Supply Project (1990). *Project document. Nakuru Water and Sewarage Services Company.*

Hach, D. R. (2010). Spectrophotometer procedures manual. *HACH Company, USA (1996, 1997)*.

Haydar, S., and Aziz, J. A. (2009). Coagulation–flocculation studies of tannery wastewater using combination of alum with cationic and anionic polymers. *Journal of Hazardous Materials*, *168*(2-3), 1035-1040.

Hegazy, M. H., & Gawad, M. A. (2016). Measuring and Evaluating the Performance of a Wastewater Treatment Plant. In *Proceedings of the World Congress on Civil, Structural, and Environmental Engineering, Paper No. AWSPT* (Vol. 111).

Henze, M. (1992). Characterization of waste water for modeling of activated sludge processes. *Water Science Technology*, 25(6), 1-15.

Henze, M., Harremoes, P., la Cour Jansen, J., and Arvin, E. (2001). Wastewater treatment: biological and chemical processes. *Springer Science and Business Media*.

Ho, Y. C., Norli, I., Alkarkhi, A. F., and Morad, N. (2010). Characterization of biopolymeric flocculant (pectin) and organic synthetic flocculant (PAM): A comparative study on treatment and optimization in kaolin suspension. *Bioresource technology*, *101*(4), 1166-1174. Retrieved from: *http://www.chemeng.lth.se/vvan01/Arkiv/Report*TreatmentPond.pdf

Huguet, N. F., Bosch, C. and Lourencetti, C. (2009). Human health risk assessment of environmental exposure to organochlorine compounds in the Catalan Stretea of the Ebro River, Spain. *Bulletin of Environmental Contamination and Toxicology*, 83: 662-667.

Jhansi, S. C., and Mishra, S. K. (2013). Wastewater treatment and reuse: Sustainability options. *Consilience: The Journal of Sustainable Development*, *10*(1), 1-15.

Kairu, J. K. (1996). Heavy metal residues in the birds of Lake Nakuru, Kenya. *African Journal of Ecology*, 34: 397 - 400.

Karlsson, L., Liu, X. and Jewitt, N. (2011). *Waste Stabilization/Treatment Ponds*.

Kartal, B., Kuenen, J. V., and Van Loosdrecht, M. C. M. (2010). Sewage treatment with anammox. *Science*, *328*(5979), 702-703.

Kayombo, S. T. S. A., Mbwette, T. S. A., Katima, J. H. Y., Ladegaard, N., and Jrgensen, S. E. (2004). *Waste stabilization ponds and constructed wetlands*: design manual.

Kenya Bureau of Standards (KEBS) (2007). Kenya Standards for Effluent discharge into surface waters -KS 1966-1 and Effluence discharged into public sewer KS 1966-2: 2007. Retrieved from: https://www.kebs.org

Kenya National Bureau of Statistics (2017). Data for Kenya and its constituencies. Retrieved from: www.knbs.org

Khan, A. M. and Ghouri, M. A. (2011). Environmental pollution: Its effects on life and remedies. *Journal of arts, science and commerce* 11(2) 276-285.

Kimani, N. G. (2007). Environmental pollution and impacts on public health: Implications of the Dandora Dumping Site Municipal in Nairobi, Kenya: *United Nations Environmental Programme*.

Kiran, D. L., Krishna, D. L., Vivek, S. M. and Dilip S. R. (2012). Impact of industrial effluent discharge on physicochemical characteristics of agricultural soil. *International research journal of environmental sciences* 1(3) 32-36.

Kulkarni, S. J., and Kaware, J. P. (2013). Review on research for removal of phenol from wastewater. *International Journal of Scientific and Research Publications*, *3*(4), 1-5.

Kumar, A. and Pumnia, B. (2008). *Wastewater Engineering*. Luxmi publications, Boston, U.S.A.

Lefebvre, O. and Moletta, R. (2006). Treatment of organic pollution in industrial saline wastewater: a literature review. *Water research*, *40*(20), 3671-3682.

Majid (2010). Common effects of heavy metals on various plants: Toxicity and waste management using bioremediation. *Advances in environmental engineering and green technology,* pg 11.

Martin, M. (2015). *The role of Alkalinity in Anaerobic Wastewater Treatment Plants: Magnesium Hydroxide Vs Caustic Soda*. 8140 Corporate Drive Suite 220, Baltimore, Maryland 21236 USA.

Medesh, S., Ghaem, D. N. and Bahaar, H. (2009). Chemical shock (strong acidic influent) and organic load. A Study on Amoi Industrial treatment works in Iran.

Metcalf, L. (2003). *Wastewater engineering: treatment and reuse.* McGraw-Hill.

Mkude, I. T., & Saria, J. (2014). Assessment of waste stabilization ponds (WSP) efficiency on wastewater treatment for agriculture reuse and other activities a case of Dodoma municipality, Tanzania. *Ethiopian Journal of Environmental Studies and Management*, *7*(3), 298-304.

Mohsen, A and Nazila, G. (2016). Removal of Copper (II) from Industrial Wastewater: A Review of Removal Methods. *International Journal of Epidemiological Research*, 3(3), 283-293.

Morrison, J. (2017). Efficiency and Removal of BOD from Wastewater. Flow point Environmental System. Canada.

Motelin, G. K.,Thampy, R. J., and Ndeti, R. (1995). The mysterious lesser flamingo death in Lake Nakuru: a cross-sectional ecotoxicology study of the potential roles of algae toxins and heavy metals and pesticides. *Report by World Wildlife Fund, Nakuru: Kenya*.

Municipal Council of Nakuru and NAWASSCO (2009). *Factories connected to the public sewer within Nakuru town.*

Nasr, F. A., Doma, H. S., Abdel-Halim, H. S., and El-Shafai, S. A. (2007). Chemical industry wastewater treatment. *The Environmentalist*, *27*(2), 275-286.

NAWASSCO (2009). *Design Capacity of Njoro Sewage Work. Wastewater manual.*

Ngigi, A. and Macharia, D. (2006). Kenya water sector policy overview paper. *Intelligent Energy, Europe*.

Nouri, J., Khorasani, N., Lorestani, B., Karami, M., Hassani, A. H. and Yousefi, N. (2009). Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. *Environmental Earth Science*, 59: 315-323.

NWRMS (2007). National Water Resources Management Strategy. Retrieved from: https://waterfund.go.ke/watersource/Downloads/006.%20Water%20Resources%20Management%20Strategy.pdf

Ochoa-Herrera, V., Banihani, Q., León, G., Khatri, C., Field, J. A., & Sierra-Alvarez, R. (2009).Toxicity of fluoride to microorganisms in biological wastewater treatment systems. *Water research*, 43. 3177-3186.

Odjegba, V. J., and Bamgbose, N. M. (2012). Toxicity assessment of treated effluents from a textile industry in Lagos, Nigeria. *African journal of environmental sciences and technology* 6(11) 438-445.

Onsdorff, K. A. (1996). Pollution: Water environment. *Law practical journal* 4: 1-14.

Palaniappan P. L, Krishnakumar, N. and Vadivelu, M. (2009). Bioaccumulation of lead and the influence of chelating agents in *Catlacatlafingerlings. Environmental Chemistry Letters*, 7: 51-54.

Partnership for Environmental Education and Rural Health (2010). *Nitrates and their Effects on Water Quality*. Wheatley River Improvement Group, North Central Queens County in Prince Edward Island, Canada.

Pearson, H. W., Athayde, S. T., Athayde, G. B., and Silva, S. A. (2005). Implications for physical design: the effect of depth on the performance of waste stabilization ponds. *Water Science and Technology*, *51*(12), 69-74.

Philip, L., Clyde, S., Jeffrey, M., Marianne, F., and Joel, S. (2002). Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities. *Environmental Health Perspectives*, 110 (7): 4-16.

Pichery, C., Bellanger, M., Zmirou-Navier, D., Glorennec, P., Hartemann, P, and Grandjean, P. (2011). Childhood lead exposure in France: benefit estimation and partial cost-benefit analysis of lead hazard control, *Environmental Health*, 10 (1)**:** 1-12.

Prasad, S. (2008). Zinc in Human Health: Effect of Zinc on Immune Cells. *Mol. Med.* 14 (5–6): 353–357. *Proceedings from the fourteenth international water technology conference*, IWTC 14, 2010 Cairo, Egypt.

Pruvot, C., Douay, F., Hervé, F. and Waterlot, C. (2006). Heavy metals in soil, crops and grass as a source of human exposure in the former mining areas (6 pp). *Journal of soils and sediments*, *6*(4), 215-220.

Punmia, B. C. and Jain, K.S.A (1998). Characteristics of industrial wastewater. *Wastewater Engineering.***7** 180-217.

Quazilbash, A. A, Farayal R. and Naqui, K. B. (2006). Efficacy of indigenous Bacillus species in the removal of chromium from industrial effluent. *Biotechnology*, 5(1): 12-20.

Ramesh, K. J. (2004). Environmental microbiology. Chania MJP publishers

Republic of Kenya (1999). Environmental Management Co-ordination Act (EMCA) 1999. Retrieved from: https://www.law.org

Republic of Kenya (2002). Water Act 2002. Retrieved from: https://www.law.org

Republic of Kenya (2005). The National Water Resources Management Strategy (NWRMS) 2005 – 2007. Ministry of Water and Irrigation. First Edition. Retrieved from: https://waterfund.go.ke/watersource/Downloads/006.%20Water%20Resources%20Management%20Strategy.pdf

Republic of Kenya (2007). Kenya Vision 2030. Retrieve from http://www.vison2030.go.ke

Republic of Kenya (2007). Water Resources Management Rules. Retrieved from http://*www.wrma.org*.ke

Republic of Kenya (2012). National Environmental Policy 2012. Retrieved from: http://www.environment.go.ke

Richards, A. (2003). *Effects of detergent use on water quality in Kathmandu, Nepal* (Doctoral dissertation, Massachusetts Institute of Technology).

Rubi, H., Fall, C., and Ortega, R. E. (2009). Pollutant removal from oily wastewater discharged from car washes through sedimentation–coagulation. *Water Science and Technology*, *59*(12), 2359-2369.

Ruixue, J., Shujuam, S., Khai, W., Zhaoum, H and Xioch, L. (2013). Impacts of Cu (ll) on Kinetics of Nitrogen Removal during the Wastewater treatment Process. *Ecoxitology and Environmental Safety*. 98: 54-58.

Sa'idi, M. (2010). Experimental studies on effect of heavy metals presence in industrial wastewater on biological treatment. *International journal of environmental sciences*, *1*(4), 666.

Samae, M., Maleknia, H., Elhamiyan, Z., Shahsavani, E., & Ebrahimi, A. (2016). Removal of Chromium and Cadmium from Wastewater Stabilization Ponds, Yazd-Iran. *Journal of Health Sciences and Surveillance System*, 4(2), 83-88.

Smith, A. H., and Steinmaus, C. M. (2009). Health effects of arsenic and chromium in drinking water: recent human findings. *Annual review of public health*, *30*, 107-122.

Specht, J., Schubach, P., Rein, R., and Claude, P. (2005). *U.S. Patent Application No. 10/519,006*.

Spring, M.V. (2007). *Waste water characteristics treatment and disposal*, WA publishing Alliance House, U.K.

Stenzel, M. H. (1993). Remove organics by activated carbon adsorption. *Chemical Engineering Progress; (United States)*, *89*(4).

Sulieman, A. M. E. H., Yousif, A. W. M., and Mustafa, A. M. (2010). Chemical, physicochemical and physical properties of wastewater from the Sudanese fermentation industry (SFI). In *Fourteenth International Water Technology Conference* (Vol. 14, pp. 305-315).

Thongchai, P. and Chandarut, A. (1999). Impact of high chloride wastewater on an anaerobic/anoxic/aerobic process with and without inoculation of chloride acclimated seeds. *Water Research,* 33(5), 1165-1172.

Tiwari, S., Srivastava, A. K., Bisht, D. S., Bano, T., Singh, S., Behura, S., ... and Padmanabhamurty, B. (2008). Black carbon and chemical characteristics of PM 10 and PM 2.5 at an urban site of North India. *Journal of Atmospheric Chemistry*, *62*(3), 193-209.

Tong, S., Schirnding Y. and Tippawan P. (2000): Environmental lead exposure: A public health problem of global dimensions. *Environment and Health:* 1074-1075.

Tripathi A. K, Sudhir N. and Harsh K. (2007). Fungal treatment of industrial effluents: a mini review. *Life Science Journal*, 4(2).

Wang, J., Zhan, X., Feng, Y. and Qian, Y. (2005). Effect of Salinity Variation on the Performance of Activated Sludge System. *Biomedical and Environmental Science*, 18; 5-8.

Wang, Z., Xue, M., Huang, K. and Liu, Z. (2011). Textile dyeing wastewater treatment. *Advances in treating textile effluent*, *5,* 91-116.

Wanjiru, J. (2001). *Kenya's pink flamingos weighted down by heavy metals*. Environment News Service, July 16, 2001.

Water Resource Management Authority (2007). WARMA Regulations 2007. Retrieved from: https://www.wra.go.ke

Water Service Regulatory Board (WASREB) (2008). Water and wastewater guidelines, 2008. Retrieved from: https://wasreb.go.ke

APPENDICES

APPENDIX 1: Questionnaire for industries

Introduction

I am a post graduate student for a Master Degree in Environmental Science in the Department of Environmental Science. I am conducting a study on the topic: **Factors affecting efficiency of industrial wastewater works, Njoro Sewage works Nakuru town, Kenya**. All information provided will be treated with the highest confidentiality and will be used for academic purpose only.

Thanking you in advance for your time and cooperation.

Bancy G. Chege

Section A: Background Information

(a) Respondent background information

b) Business title of the respondent: Owner [ ] Manager [ ] Owner /Manager [ ] other specify [ ]

Gender: male [ ] female [ ]

(c) What is your highest level of formal education?

No formal education [ ]

Primary level [ ]

Secondary level [ ]

A-level [ ]

College/university [ ]

(d)Have you undergone any technical training related to wastewater management?

Yes [ ] No [ ]

If yes, which one? ....

Section B: Effluent discharging industry trends

1. Identification of industries

a. Form of industry ownership; Sole proprietorship [ ] partnership [ ] company [ ]

b. For how long it been operation in years? ……………………………...........................

c. What form of industry? Dry [ ] wet [ ]

If, wet, what is your source of water? Public supply [ ] private water supply [ ]

d. How much of water in m^3/day do you use? ....

2. **Pollutant characterization**

a. Do you test the water source? Yes [ ] No [ ]

If yes, what are the major pollutants in the water used for production?

i……………………………………………………………………………………….

ii………………………………………………………………………………………

iii……………………………………………………………………………………..

iv…………………………………………………………………………………….

v……………………………………………………………………………………..

b. list the raw material used in your industry

i……………………………………………………………………………………….

ii………………………………………………………………………………………

iii……………………………………………………………………………………..

iv…………………………………………………………………………………….

v……………………………………………………………………………………..

c. What do you manufacture?

……………..

d. For how long does the operation take? 24 hrs [ ] 12 hrs [ ] 8 hrs [ ] others [ ]

e. Has the industry increased in production since 1995? Yes [ ] No [ ]

If yes, by what %? Specify…………………………………………………………………

f. Monitoring of industry

Who monitors your industry? ....

Specify ……………………...

Section C: Wastewater management systems for industry

1. Pre-treatment units

a. What type of waste do you generate? Solid Waste [ ] wastewater [ ] both [ ]

If wastewater, how much in m^3/day…………………………………………………......

b. Where do you dispose your wastewater? Sewer-line [ ] water body [ ] storm drain [ ] Soak pit [ ] others, specify [ ]

c. Do you pre-treat your wastewater? Yes [ ] No [ ]

d. if Yes ,Why do you treat your wastewater? Compliance [ ] self-monitoring [ ] other specify………………………………………………………………………………

If No, give reason for not treating? Quality of wastewater meet standards [ ] lack of awareness

[ ] nobody monitors [ ] others specify………………………………………

e. What pre-treatment method is used in your industry? Coagulation [ ] Stabilization [ ] Interceptor [ ] others………………………………………

d. Do you reuse wastewater? Yes [ ] No [ ]

If, yes why? ....

e. For what purpose? ………………………………………………………………………

If, No why? ……………………………………………………………...

f. Do you disludge the pre-treatment unit? Yes [ ] No [ ]

g. After how long do you disludge your pre-treatment unit? Quarterly [ ] twice a year [ ] yearly [ ] others specify……………………………………………………………………….

Section D. legal compliance

1. Disposal compliance

a. Do you have a licence for disposal? Yes [ ] No [ ]

If, yes, from which organization? NEMA [ ] WRMA [ ] WSP [ ] others [ ]

b. What is the duration of the licence?

c. Does it have conditions? Yes [ ] No [ ]

If yes, Specify condition…………………………………………………...............................

d. Do they monitor your process? Yes [ ] No [ ]

e. If yes, how frequent? Monthly [ ] quarterly [ ] yearly [ ] others specify………………

f. Do you get feedback? Yes [ ] No [ ]

If yes, which one?

g. Do you implement the recommendation therein? Yes [ ] No [ ]

If yes, do they do follow-up of the recommendation Yes [ ] No [ ]

h. Do you have report? Yes [ ] No [ ]

i. Does your industry have EIA certificate? Yes [ ] No [ ]

j. Do you carry out audit for the production process? Yes [ ] No [ ]

If yes, which audit? Environmental compliance [ ] Environmental risks [ ] environmental management [ ] functional environmental [ ]

k. Of what benefit is audit to your industry? List

i………………………………………………………………………………………

ii………………………………………………………………………………………

iii………………………………………………………………………………………

iv………………………………………………………………………………………

Do you report on status of environment to NEMA Yes [ ] No [ ]

3. Observational Checklist

Name of industry	Wastewater treatment pond	soak pit	Solid bed	wetlands	Oil-trap (interceptors)	Septic tank

APPENDIX 1I: Questionnaire for Water Service Provider

Introduction

I am a post graduate student for a Master Degree in Environmental Science in the Department of Environmental Science. I am conducting a study on the topic: **Factors affecting efficiency of industrial wastewater works, Njoro Sewage Nakuru town, Kenya**. All information provided will be treated with the highest confidentiality and will be used for academic purpose only.

Thanking you in advance for your time and cooperation.

Bancy G. Chege

Section A: Background Information

(a) Respondent background information

b) Business title of the respondent: Owner [ ] Manager [ ] Owner /Manager [ ] other specify [ ]

Gender: male [ ] female [ ]

(c) What is your highest level of formal education?

No formal education [ ]

Primary level [ ]

Secondary level [ ]

A-level [ ]

College/university [ ]

(d)Have you undergone any technical training related to wastewater management?

Yes [ ] No [ ]

If yes, which one? ....

Section B: Sewage works

i. When was the sewage works constructed?

....

ii. What is the Source of wastewater?

Specify……………………………………………

iii. What was the design capacity?

....

iv. When was it rehabilitated?

…………………………………………………………………

v. When?

....

vi. Why?

....

vii. What is the design capacity after rehabilitation?

....

viii. What is the volume of the influent?

....

ix. Has it changed the efficiency from 1995?

Specify………………………………………

x. Where is the effluent discharged to?

……………………………………………………..

xi. What is the quality of effluent of the final discharge from the sewage works? above limit [ ] below allowable limit [ ] within allowable limit [ ]

xii. What has been the trend of the quality of influent and effluent for the sewage works from rehabilitation (1995) to date? ....

Section C: Wastewater Analysis trends

a. Do you carry out test on wastewater? Yes [ ] No [ ]

If yes, after how long? Daily [ ] once a week [ ] monthly [ ] quarterly [ ] yearly [ ] other specify…………………………………………………………………………………….

b. What parameters do you test for the wastewater?

Specify a………….b…………….c…………...d…………..... e.....………….f.....…………

c. How frequent do you test wastewater in the sewage works? Monthly [ ] quarterly [ ] yearly [ ]

Other

specify……………………………………………………………………………………..

Section D: Legal compliance

1. Disposal compliance

a. Do you have a license for disposal? Yes [ ] No [ ]

If, yes, from which organization?

NEMA [ ] WRMA [ ] WASREB [ ] WSB [ ] others [ ]

b. What is the duration of the license?

c. Does it have conditions? Yes [ ] No [ ]

If yes, Specify condition…………………………………………………………......................

d. Do they monitor your process? Yes [ ] No [ ]

e. If yes, how frequent? Monthly [ ] quarterly [ ] yearly [ ] others specify………………

f. Do you get feedback? Yes [ ] No [ ]

If yes, which one?

g. Do you implement the recommendation therein? Yes [ ] No [ ]

If yes, do they do follow-up of the recommendation Yes [ ] No [ ]

h. Do you have reports for recommendation? Yes [ ] No [ ]

i. Does your industry have EIA certificate? Yes [ ] No [ ]

j. Do you carry out audit for the production process? Yes [ ] No [ ]

If yes, which audit? Environmental compliance [ ] Environmental risks [ ] environmental management [ ] functional environmental [ ]

k. Of what benefit is audit to your industry? List

i…………………………………………………………………………………

ii…………………………………………………………………………………

iii…………………………………………………………………………………

iv…………………………………………………………………………………

2. Do you report on status of environment to NEMA Yes [ ] No [ ]

3. Observational Checklist

Sewage work

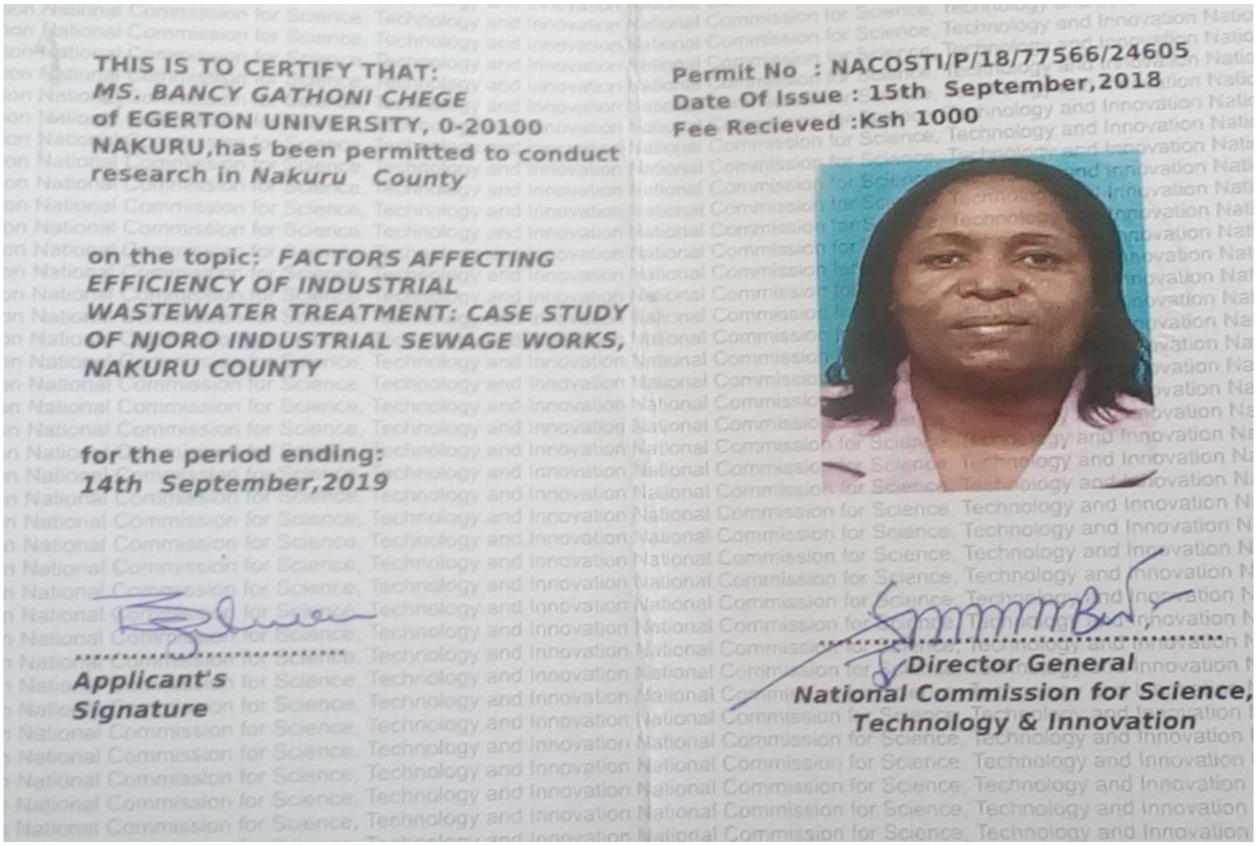
	Pond1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6
Wastewater colour						
Availability of algae						

APPENDIX III: Rainfall Data from 2005 to 2016

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
2005	19.3	47	82.1	87.6	175.9	103.7	67	105.3	154.4	65.1	24	19.5	**950.9**
2006	8.7	13	85.7	113.9	131.9	66.8	73	89.9	11.7	57	188	106.6	**946.2**
2007	57.7	128.6	28.3	157	134.8	104.3	163.2	145	148.7	92.1	46.2	9.6	**1215.5**
2008	15.7	6.5	86.1	48.7	43.2	36.5	72.4	99.3	106.1	175.7	120	15.3	**825.5**
2009	15.7	7.3	11.6	191.4	184.3	15.3	19	37.4	47	62.3	67.3	137.8	**796.4**
2010	15.7	151.4	225.4	157.2	200.1	36.4	111.8	169.4	161.1	147.4	45.6	13.9	**1435.4**
2011	1.1	0.1	104.5	58.4	111.4	109	177.8	123.9	146.4	114.1	126.7	37.7	**1111.1**
2012	0	34.8	8	274.3	170.4	79.4	110	102.7	116.3	116.1	68.4	65.1	**1145.5**
2013	27	0.8	74.8	251.3	59.3	165.7	174.3	112.7	144.1	57.8	66.4	84.9	**1219.1**
2014	9.1	32.9	60.2	92.8	105.7	79	63.8	92	57.6	92.9	82.2	157.5	**925.7**
2015	0	3.8	11.8	149.6	108.3	63.2	41.8	20.3	102.5	62.7	132	120.4	**816.4**

Source: Meteorological Report, 2016

APPENDIX IV: Research permit



THIS IS TO CERTIFY THAT:
MS. BANCY GATHONI CHEGE
of EGERTON UNIVERSITY, 0-20100
NAKURU,has been permitted to conduct
research in *Nakuru County*

on the topic: *FACTORS AFFECTING EFFICIENCY OF INDUSTRIAL WASTEWATER TREATMENT: CASE STUDY OF NJORO INDUSTRIAL SEWAGE WORKS, NAKURU COUNTY*

for the period ending:
14th September,2019

Permit No : NACOSTI/P/18/77566/24605
Date Of Issue : 15th September,2018
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

APPENDIX IV: Letter from Ministry of Water, Environment and Natural Resource Nakuru County

REPUBLIC OF KENYA
COUNTY GOVERNMENT OF NAKURU
DEPARTMENT OF WATER, ENVIRONMENT, ENERGY AND NATURAL RESOURCES

Telephone/ Nakuru
Email: coenrew@gmail.com

When replying please quote,

REF: **CGN/ENREW/PC/79/98**

Chief Officer
Environment Energy and Natural Resources
P.O. BOX 2870-20100
NAKURU.
Date: 3rd July, 2017.

TO ALLWHOM IT MAY CONCERN (INDUSTRIES)

RE: DATA COLLECTION

This is to inform you that Bancy Chege of ID number 5507462 and P/NO. 1987078327 is currently a student in Egerton University undertaking Masters Degree in Environmental Science. She is currently undertaking a research project on "**FACTORS AFFECTING EFFICIENCY OF INDUSTRIAL WASTEWATER TREATMENT: CASE STUDY OF NJORO INDUSTRIAL SEWAGE WORKS, NAKURU COUNTY, KENYA**".

Please assist her with the appropriate information to her complete her studies.

CHIEF OFFICER
ENVIRONMENT, ENERGY &
NATURAL RESOURCES
NAKURU COUNTY
Sign:

TIMOTHY M. KIOGORA
CHIEF OFFICER – ENVIRONMENT ENERGY AND NATURAL RESOURCES
NAKURU COUNTY.