EFFECTS OF LIQUID WASTE MANAGEMENT APPROACHES ON WATER QUALITYIN SEKENANI, MAASAI MARA GAME RESERVE, NAROK IN KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENVIRONMENT STUDIES IN THE SCHOOL OF NATURAL RESOURCES, TOURISM AND HOSPITALITY, DEPARTMENT OF ENVIRONMENTAL STUDIES, GEOGRAPHY & AGRICULTURE OF MAASAI MARA UNIVERSITY

2021

DECLARATION

This thesis is my original work and has not been submitted for the award of a degree in any University.

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DEDICATION

This work is dedicated to my late parents Chigulu Chiro Gongolo and Kadzo Kusa who went out of their way to ensure that I get education. I further dedicate this work to my dear wife Idza Patrick Mwanje and sons Bruce Mwamuye, Peter Chigulu and Lawrence Yawa for enduring very difficult times of having to stay for several months without seeing me at home while busy pursuing studies.

ACKNOWLEDGEMENT

I would like to begin by thanking the Maasai Mara University for accepting to admit me for the Masters of Environmental Studies program. I also would wish to express my indebtedness to my supervisors, Professor Romulus Abila and Professor Aggrey Thuo for their unending positive criticism, suggestions, encouragement and guidance during development of the proposal, my field work and thesis writing. Further, my gratefulness extends to Mr. Samuel Gor, the WRA Sub – Regional Manager for South Rift Region for allowing me to use their equipment during field work and also his officer Beatrice Mwangi to assist in the collection of samples.

I would further like to extend my gratitude to the Chief Warden, Maasai Mara National Game Reserve and the management of the lodges within the Mara Reserve namely; AA Lodge, Simba Lodge, Sarova Mara, and Sentrim Lodge for accepting my proposal to conduct the sampling in their facilities.

Last but not least, I would like to greatly acknowledge management of the National Environment Management Authority without whose approval, my desire to undertake studies while working would not have been possible.

ABSTRACT

The Maasai Mara Game Reserve is experiencing expansion in tourist facilities to accommodate increasing traffic. A major impact of this being wastewater released to the fragile environment. The objective of this study wasto examine effects of wastewater management methods on quality of wastewater in 4 purposively selected tourist facilities located in Sekenani by assessing seasonal quality of effluent discharged. Samples were collected randomly from the effluent during wet and dry seasons and analyzed for: pH, Temperature, Chemical Oxygen Demand, Biochemical Oxygen Demand, Phosphates, Nitrates, Electrical Conductivity, Dissolved Oxygen, Turbidity, Total Suspended Solids and Coliforms. Data were analyzed using SPSS and tested using ANOVA at 0.05 confidence level. Water quality index of the effluent was used to examine the efficiency of the treatment approaches. Quality of wastewater was generally poor. Dissolved Oxygen ($p=0.006$; $p=0.001$); TSS ($p=0.005$; $p=0.001$), and phosphates ($p=0.006$; $p=0.001$) showed variation between seasons. Single septic tank (26) and septic tank and soak away treatment (27) approaches produced water with the lowest quality based on Water Quality Index. This threatens the health of the communities down stream as it may cause water borne diseases such as cholera and disruption of food chains. To mitigate against discharge of poor quality wastewater to the environment, we recommend adoption of sustainable wastewater management technologies e.g. constructed wetlands and robust enforcement of national environmental regulations. Further studies should include monitoring changes in macroinvertebrate species diversity and abundance along the recipient streams to provide a more holistic and integrated assessment of the ecological impact of the wastewater on the receiving lotic environments.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
APHA	American Public Health Association
BDL	Below Detectable Levels
CFU	Colony forming units
COD	Chemical Oxygen Demand
CIDP	County Integrated Development Plan
CSIRO	Commonwealth Scientific and International Research Organization
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
DI	Direct Input
FAO	Food and Agricultural Organization
GEF	Global Environmental Facility
GHG	Green House Gas
GIWA	Global International Waters Assessment
GPA	Global Plan of Action
GPS	Global Positioning System
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
ICS	International Classification for Standards
KEBS	Kenya Bureau of Standards

KNPHC	Kenya National Population and Housing Census
KW	Kilowatt
KWS	Kenya Wildlife Service
MEA	Millennium Ecosystem Assessment
MFC	Media for faecal coliform
Mg	Milligrams
MMWCA	Maasai Mara Wildlife Conservancies Association
MRBMI	Mara River Basin Management Initiative
NACOSTI	National Council for Science, Technology and Innovation
NEMA	National Environment Management Authority
NTU	Nephelometric Turbidity Units
OECD	Organization for Economic Cooperation and Developing countries in Europe
pH	Hydrogen ion Concentration
RNA	Ribonucleic Acid
SPSS	Statistical Packages for Social Sciences
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UN	United Nations
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WEAP	Water Evaluation and Planning
WHO	World Health Organization
WIO	Western Indian Ocean

WRA	Water Resources Authority
WWF	World Wildlife Fund

OPERATIONAL DEFINITION OF TERMS

Black Water	Water polluted with food, animal or human waste
Effluent	Point at which the wastewater leaves the treatment system
Effluent discharge	Liquid waste other than waste from kitchen or toilets, surface water or domestic sewage
Grey Water	Wastewater produced from kitchens, bathrooms and/or laundry, which normally does not have high concentrations of excreta Plan Bleu UNEP, (2012)
Influent	Where the wastewater enters the treatment system
Per Capita	Per person
Pollution	Addition of substances or energy that directly or indirectly alters the nature of a water body in such manner that negatively affects its legitimate uses
Sludge	Semi – liquid residue from industrial processes and treatment of sewerage and wastewater
Sustainable	Need to develop sustainable models necessary for both human race and planet earth to survive
Standards on water reuse	Different types of documents that provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that water reuse projects achieve an acceptable level of health and/or environmental protection (adapted from the ISO definition is in line with the ISO definition of a standard).

Temporal	Time Related
Water quality	Physical, chemical, biological and aesthetic qualities of water that determine its fitness for human as well as for maintenance of a healthy ecosystem DWAF, (1996).
Water Scarcity	Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system (EEA).
Wastewater	Domestic effluent consisting of black water (excreta, urine and fecal sludge) and grey water (kitchen & bathing wastewater) that is either dissolved or suspended
Treated wastewater reuse	Beneficial reuse of appropriately treated wastewater (Directive 91/271 CEE). In the present study, the terms ‘water reuse’ and ‘water recycling’ are used synonymously with the term ‘treated wastewater reuse’.

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.0 Introduction

This chapter gives the background of the study, a highlight of the research problem and objectives of the study. It also covers hypothesis to be tested the justification for conducting the study, scope and limitations of the study.

1.1 Background of Study

Wastewater is defined as domestic effluent consisting of black water (excreta, urine and faecal sludge) and grey water (kitchen & bathing wastewater) that is either dissolved or suspended. Water is a crucial aspect of life, the defining feature of our planet, more than 97% of which is found in the oceans. Of the remaining 3%, only 1% is available for use. According to a UN water quality analytical brief, the world is said to be experiencing a water quality crisis which results from the ever- increasing population and urbanization, fast industrialization, and extensive agricultural activities are all putting pressure on water resources.

This crisis is further compounded by the illegal discharge of poorly treated effluent within and beyond national borders (Corcoran et al., 2010). Depending on their origin, wastewaters may be classed as sanitary, commercial, industrial or surface runoff. Sanitary sewage dispense water from residences and institutions carrying body wastes, ablution wastes, food preparation wastes, laundry wastes and other waste products of normal living. This wastewater can also be referred to as domestic sewage. Commercial waste refers to liquid-carried wastes from stores and service establishment serving the immediate community, termed commercial wastes may be included in the sanitary or domestic sewage category if their characteristics are similar to household flows. Surface run-off which is also known as storm flow or overland flow is that portion of precipitation that runs rapidly over the ground surface to a defined channel (Ibrahim and Esther, 2014).

The wastewater is both an asset and a problem in an urbanizing world (Drechselet al.2015a; UN-Water, 2015). Untreated wastewater is a critical source of pollution and a hazard to human health and ecosystems services. The costs related to the pollution of water bodies can be significant: the Millennium Ecosystem Assessment report suggests the cost of degradation of ecosystem services in coastal waters is mostly related to impacts on human health (MEA, 2005), while the overall economic value of the goods and services rendered by healthy coasts and oceans are worth trillions of dollars. Recognition that wastewater is an economic resource capable of supplying water, nutrients, energy and other valuable materials and services has become a major justification to improve water quality and stimulate effective wastewater management. Each year, 330 m^3 of municipal wastewater are generated worldwide.

Theoretically, the resources embedded in this wastewater would irrigate and fertilize millions of hectares of crops and produce biogas to supply energy for millions of households. However, despite the potential benefits of treatment and reuse, managing wastewater is typically perceived only as a cost. Most difficulties include the diversity of wastewater types and sources at city level and lack of infrastructure to collect wastewater flows from diverse areas to one common point of proper treatment. As a result, only a small proportion of wastewater is treated, and the portion that is safely reused is significantly smaller (Mateo-Sagastaet al. 2015).

Multilateral development banks, bilateral donors and other development agencies find it challenging to get policymakers and managers in national and local governments to develop policies to address wastewater management effectively. (Corcoran et al.2010), identifies transformation of wastewater from a major health challenge to a clean and economically attractive resource. However, the lack of effective economic and risk management frameworks have deterred investors from engaging in wastewater management and sanitation projects. Investments in wastewater management are required both in developed and developing countries. The selection of the most appropriate wastewater management approach requires an economic appraisal of alternate options (FAO, 2010; Hanjra et al. 2015). The cost-benefit analysis (CBA) and, more recently, the life-cycle assessment (LCA) are the most widely applied tools to evaluate the feasibility of water and wastewater management programmes (Garcia et al. 2008). Wastewater treatment and reuse involves significant environmental, social and health benefits (Hanjraet al.2015). However, the value of these benefits is often not calculated because there is no baseline or control (Drechsel et al. 2015b), or the market does not determine these values. Valuation of these benefits is nevertheless necessary to justify suitable investments and financing mechanisms to sustain wastewater management.

Health risks associated with untreated wastewater depend on the different forms of exposure faced by diverse social groups. They also vary with gender, class and ethnicity. (Buechleret al.2006) report fevers, diarrhoea and sores on the hands and legs of farmers and labourers exposed to domestic wastewater. Exposure to industrial wastewater can be much more severe. Wastewater can disrupt aquatic ecosystems with far reaching impacts on aquatic biodiversity, landscapes and recreational opportunities. Moreover, improper wastewater management produces CO_2 and CH_4 without the opportunity for carbon sequestration and energy recovery and, thus, contributes to global warming: CO_2 and CH_4 emissions associated with wastewater discharges could reach a level of 0.19 million tons of CO_2 per day in 2025, with even more dramatic impact in the short-term (Rosso &Stenstrom, 2007).

Lastly, the use of polluted waters may also affect economic activities. For instance, land and water salinization induced by industrial wastewater discharges may impact adversely on agricultural productivity if these waters are used for irrigation (Chapman &French, 1991). Some chemicals in wastewater can have negative impacts on agricultural productivity due to phytotoxicity; a pollutant (trace metals, pesticides, personal care products and/or salts) could have a toxic effect on plant growth. Consumers of wastewater-irrigated farm produce are also susceptible to risk of illness when they handle and ingest contaminated crops, especially vegetables eaten raw or if not well cooked (Cissé et al.2002). Toxic effects of wastewater on aquatic fauna, including fish and shellfish, can dramatically reduce their stocks and catches, and can poison people via heavy metal and contamination with bacteria such as *E. coli*.

The human population has increased more than a thousand times from 2-20 million at the dawn of settled agriculture about 10-12 millennia ago to 7.2 billion in 2013. It is projected to reach 9.6 billion by 2050 and ~11 billion by 2100 (U.N, 2012). The unprecedented growth, not only in the number, but also in the affluent life style, is impacting earth on the biogeochemical processes, and some even beyond the planetary boundaries (Rockstrom et al., 2009). The agroecosystems and related activities are already covering 38% of the earth's terrestrial surface, emitting 30-35% of the global greenhouse gases (GHGs) and using 71% of the global freshwater withdrawal (Foley et al., 2011).

With the focus on agricultural intensification since the 1960s, the irrigated land area has increased by a factor of 2, fertilizer use by 5, and nitrogen use by 8. The present water use by agriculture of 3100 km3/yr is expected to increase to 4500 km3/yr by 2030 (McKinsey et al.2009). Consequently, global food production must be increased by 50% by 2030 and 100% by 2050 (OECD, 2010). Above all, 24% of the terrestrial ecosystems are degraded and more are prone to anthropogenic perturbations, and land, water and air quality are at risk (Bai et al., 2012; Tilmanet al.2011). Estimates of food-insecure population in 2012 vary from 868 million (FAO, 2012) to 1.33 billion (Small Planet Initiative, 2013). Despite large appropriation of global net primary productivity (NPP) by humans, more than 1 out of 7 persons are food-insecure (Small Planet Initiative, (2013), 2 out of 7 are prone to deficiency of iron and other micronutrients (WHO, 2013), and almost all of the food-insecure people live in the developing countries where natural resources are already under great stress (FAO, 2012). Faced with these challenges, and the concern that the current increase in crop yields may not feed the human world, there is increased concern on what is next for agriculture (Beddington et al., 2012). This therefore calls for robust and innovative strategies towards sustainable intensification of agroecosystems.

Kenya is among the developing countries with one of the highest population growth rates in the world currently standing at 4.7% (Republic of Kenya, 2010). It has a fresh water *per capita* of 630m^3/ year which is short of the globally recommended per capita of 1000 m^3/ year. Despite being classified as water scarce, the country's fresh water *per capita* is predicted to decline to a further 350 m^3 per year in 2020 (Mweru, 2014). Sekenani area in Narok County where the study area lies, apart from being water scarce, the supply of fresh water is characterized by very high spatial and temporal availability due to prolonged droughts and floods. This situation coupled with the increase in number of tourist lodges in the area will result in lack of water for both livestock and wildlife. To avoid this kind of scenario, it is therefore imperative that the water resources are managed sustainably.

Effective methods for treating the wastewater can be one of the best strategies to address this challenge of water quality crisis that is affecting human nature. A report from the Organization for Economic Cooperation and Developing countries in Europe (OECD, 2012) acknowledges the role of wastewater management in achieving water security in a world where water scarcity is bound to rise. Once treated up to the standards set out in the third schedule of the Environmental Management and Coordination (Water Quality) Regulations 2006, the water can be reused in the facility. The typical component of wastewater can be grouped into five main categories namely physicochemical, chemical, heavy metals, oil & grease and bacteriological parameters. Other than temperature, pH, conductivity the rest are pollutants. Most countries have own standards for discharge in to public sewers as well as discharge in to the environment. Table below shows quality limits for release into the municipal sewers as recommended by the National Environment Management Authority (NEMA-Kenya).

Table 1.1: NEMA limits for discharge to the environment

Parameter	**NEMA Guideline Value**

pH	6.5-9
BOD (Mg/L)	30
COD (Mg /L)	50
DO (Mg/L)	
Turbidity (NTU)	50
E.C (µS/cm)	
Temperature (° C) based on ambient temperature	Ambient Temperature +3
Phosphates (Mg /L)	2 guideline value
Coliforms (Cfu/100ml)	30
TSS (Mg/L	30
Phosphates (Mg /L)	30

Source: Water quality Regulation, 2006

1.1.1 Physico-Chemical Parameters

These refer to the parameter to which the physical properties of wastewater are attributed. They include Temperature, pH, color, conductivity, turbidity, settleable solids, total dissolved solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), and biological oxygen demand (BOD). Amongst the parameters, BOD and COD comprise of biodegradable organic compounds which originate from domestic and industrial wastes as well as from agricultural runoff. These wastes may upset the oxygen balance of surface water because their breakdown consumes oxygen. The optimum Dissolved Oxygen (DO) in natural water is 4-6 mg/l and this is essential for supporting aquatic life (Omoto, 2006). Any alterations on this optimum level may lead to massive destruction of aquatic life.

1.1.1.1Temperatures

Rates of reaction increase as temperatures rise in anaerobic ponds. The optimum temperature for methane forming bacteria is given as above 20°C and methane producing rate increases twice as much for each 10°C to 15°C rise in temperature in the atmosphere. Bacteria are categorized in order of their optimal temperature range for development. Mesophilic bacteria develop in temperatures of between 10-400°C while thermophilic bacteria thrive in ranges of temperatures of 45-50°C (Droste, 1997).

1.1.1.2 pH

The optimal pH for methanogenesis is between 6 and 8. A pH of 6 is probably the lowest value for anaerobic ponds and pH range outside of 6.5 to 8.5 can influence the occurrence and activity of toxic chemicals. According to (Haandel&Lettinga1994) acidogenic populations are more tolerant to pH variations and as a result, acidogenic fermentation is likely to predominate over methanogenic fermentation which often leads to the reactor contents being sour. Consequently, the system must therefore contain sufficient cushion capacity to counteract the production of unstable acids and carbon IV oxide that dissolve at the working pressure. Normally, the bicarbonate buffer capacity of wastewater is sufficient to prevent acidity and reduce pH, while carbon dioxide production by micro-organisms tends to control the alkalinity of high pH wastewaters. Where industrial discharges force the pH of a municipal wastewater outside the optimum range, addition of a chemical may be required for neutralization (Droste, 1997).

1.1.1.3 Color

Water color may be due to presence of innate metallic ions like iron and manganese, humus and peat material, plankton, weeds, and manufacturing waste. Removal of color is very important as it makes water suitable for general and industrial use. Wastewater from the industries might require color removal before discharge into a watercourse. True color refers to the color of wastewater that is turbidity free while apparent color involves color as a result of substances in solution as well as that due to suspended matter.

1.1.1.4 Conductivity

The measure of the capacity of an aqueous solution to transmit electric current is referred to conductivity and is denoted by the letter, k. This capacity is dependent on the concentration, mobility and valence of the ions present in the solution as well as on the temperature of measurement. Inorganic compounds normally form solutions which are excellent conductors whereas solutions of molecules of organic compounds are generally poor conductors in nature. Laboratory conductivity measurements are used to establish extent of mineral formation to establish the consequence of overall concentration of ions on chemical equilibrium, physiological impacts on flora and to review the scale of mineral formation of distilled and deionized water (Shoemaker et al. 1989). The SI unit for conductivity is Siemen per centimeter (S/cm) or micro Siemen per centimeter (µS/cm) (APHA, 1998).

1.1.1.5 Turbidity

Turbidity is the computation of the murkiness of the water, from the existence of suspended material as well as fine colloidal matter such as clay and microorganism. Nephelometry is the technique used to evaluate turbidity and it is defined as the measurement of the dispersion of light as it bounces off particles in solution. The technique is simple as the light beam is directed at a sample while the strength of the light is measured at 90^{o} from the initial angle of the beam (Paul &Bjourn, 1998). The SI unit for measuring turbidity is Nephelometric Turbidity Units (NTU).

1.1.1.6 Settleable Solids

Settleable solids refer to the particles that stay at the base of a container when a water sample is left to stand for a certain period of time usually one hour. Settleable solids usually come from domestic wastes and storm runoff. Settleable solids create sludge deposits leading to siltation of the water reservoirs and frequent blockages of treatment facilities. Adsorption of heavy metals and other micro-pollutants onto suspended matter often result to accumulation of the same in sludge. Suspended solids in a water body are most likely to obstruct sunlight which is essential for photosynthesis by the underneath plants (Omoto, 2006).

1.1.1.7 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) are particles present in a given water sample and can be trapped with an aid of a filter. A high concentration of TSS in water affects light penetration thereby interfering with the aquatic life. Any rise in the levels of TSS may in addition elevate the temperatures of surface water as a suspended solids absorb heat. TSS is often composed of different types of materials such as decaying organic matter, industrial wastes and sewage. The aperture size, region and width of the filter, the material nature and the particle size influence the separation of suspended solids from dissolved solids, and amount of material deposited on the filter.

1.1.1.8 Chemical Nitrates (NO3-)

Almost every rainwater and groundwater aquifers have a little Nitrates-nitrogen. Nitrates build up in farming water catchment areas in which farmers use inorganic fertilizer and animal manure on the crops. In the absence of oxygen, decomposition of organic matter in water containing Nitrates reduces the Nitrates to ammonia and free nitrogen, consequently, the Nitrates are depleted (Wolfgang,2002). This therefore means that

Nitrates are rarely, if ever, found in putrid sewage. However, the composition of sewage could be deeply altered should the industrial effluents be discharged into the public sewerage system. In waste stabilization pond systems, the nitrogen cycle works with the feasible exclusion of nitrification and denitrification. In anaerobic ponds, organic nitrogen is hydrolysed to ammonia after which the concentration of ammonia is found to be higher in anaerobic pond effluents than raw wastewater unless the transit time to the treatment plant is so long.

Volatilization for ammonia seems to be the main pathway for nitrogen removal, being reported at very low rates in anaerobic ponds (Soareset al, 1996). Generally, health effects as a result of Nitrates are mainly related with the presence of methemoglobinemia which is sometimes called the blue baby syndrome. In the stomach, Nitrates is converted to nitrites in infants between 0 to 4 months. The nitrite so formed then binds to the oxygen carried in the red blood cells resulting to oxygen depletion and consequently suffocating the young one. The bluish skin color, particularly around the eyes is understandably the symptom of the harmful effects of nitrite. This condition is rarely fatal if detected at an earlier stage as it is easily diagnosed and the situation managed through medical treatment. Methemoglobinemia ceases to be a threat once the baby is past the age of six months since the nitrite forming bacteria is no longer in the stomach of the baby. Adults may also be affected by Nitrates especially in drinking water; expectant mothers can pass the Nitrates to the fetus leading to low birth weights (Lukens, 1987).

1.1.1.9 Phosphates

Phosphates are largely present in wastewater in the form of inorganic phosphate ions $PO4^{3-,}$ HPO^{4-} and polyphosphates. Inorganic Phosphates are present in the non-ionic form in organic molecules such as DNA, RNA and nucleotides Algae and phytoplankton for their growth and for the treatment of water besides silica, utilize Phosphates as detergents such as densol and calgon. Phosphates finally lead to eutrophication of lakes and rivers. Primary inorganic phosphorus is precipitated as an insoluble hydroxyapatite, Ca5 (PO4)3(OH), at pH levels above 9.5. The mechanism of phosphorus elimination most likely occurs in maturation pond. In general, when Nitrates and Phosphates are present in natural waters at high levels, excessive algal growth (eutrophication) is likely to occur. Drying algae contribute to organic matter which requires oxygen for biodegradation (Burks &Minnis, 1994).

1.1.2 Biological Parameters

These include parameters such as coliforms and algae.

1.1.2.1 Total coliforms

Wastewater has varied levels of micro-organisms originating not solitary from the human wastes but also from soil and water. Pathogenic micro-organisms like viruses, bacteria, fungi, rotifers, protozoa, and worms which occur in human excreta and to some extent urine can cause fatal infectious water borne diseases such as cholera, giardiasis, paratyphoid, amoebic dysentery, leprosy, yellow fever, skin infections or malaria. Disinfection is therefore, the prime step in controlling the pathogenic micro-organisms (Tebbut, 1998).

Wastewater is gaining popularity as the source of fresh water diminishes. Treated wastewater reuse is gaining acceptance in many parts of the globe. Wastewater reuse is normally accepted in situations where other sources of water are not readily available or for economic reasons. Wastewater reuse is accepted as long as the impurities are removed. This is generally for economic reasons more than cultural. The practice of reuse is accepted provided impure water is changed to pure water) by any of the following the following methods (Farooq & Ansari, 1983): self- purification, addition of pure water in sufficient quantity to dilute the impurities or removal of impurities by passage of time or by physical effects (Hespanhol, 1997).

Wastewater treatment or sewage treatment is a broad term that applies to any process, operation or combinations of processes and operations that can reduce the objectionable properties of water carried waste and render it less dangerous and repulsive to man (Punmia et al..2007). Wastewater treatment entails application of known technology to improve or upgrade the quality of a wastewater. In most cases, wastewater treatment will involve collecting the wastewater in a central segregated location (the wastewater treatment plant) and subjecting the wastewater to various treatment processes. Most often, since large volumes of wastewater are involved, treatment processes are carried out on continuously flowing wastewaters (continuous flow on “open systems) rather than as “batch” or a series of periodic treatment process in which treatment is conducted on parcels or “batches” of wastewater.

While many wastewater treatment processes are continuous flow, other operations, such as vacuum filtration, involving as it does storage of sludge, the addition of chemicals, filtration and removal or disposal of the treated sludge are routinely handled as periodic batch operations. Hence, the wastewater should be treated before its final disposal in order to reduce the spread of communicable diseases caused by the pathogenic organisms in the sewage and avoid pollution of surface and groundwater. Wastewater treatment, however, can also be categorized by the nature of the treatment process operation being used such as physical (application of physical forces predominate. They consist of screening, mixing, flocculation, sedimentation, floating), chemical (chemical precipitation, gas transfer, adsorption, ion exchange, electro dialysis) or biological (activated sludge process, tricking filtration, sludge digestion). A complete treatment system may consist of the application of a number of physical, chemical and biological processes to the wastewater.

Before wastewater is reused, it is paramount that it is subject to treatment so as to meet public safety and the intended needs. These needs could be either recreational, drinking by humans and or domestic animals or irrigation. The wastewater can be subjected to basic treatment such as physical processes, biological processes or chemical processes (UNEP, 2005) before reuse. Physical processes are used to improve or treat wastewater with no gross chemical or physical changes. The process occur in steps which include; clarification (sedimentation), aeration, screening, filtration floatation, degasification and equalization. Biological processes are another method used in the treatment of wastewater before reuse. The approach entails the use of microorganisms like bacteria in Biochemical decomposition of wastewater to stable end products. More microorganisms proliferate during the process and portion of waste is converted to carbon dioxide, water and other products. Chemical processes are also an approach used in treating wastewater and involves the use of chemical reactions to improve the water quality. The processes involved include chlorination, ozonation, neutralization, coagulation, iron exchange and adsorption.

In most cases, conventional methods are used for treating wastewater. In these methods, the wastewater goes through four steps namely; preliminary, primary, secondary and disinfection. Preliminary and primary stages are physical processes that involve removal of debris, large solids and sedimentation using screens for example. While secondary involves the use of biological methods that involve use of stabilization ponds, trickling filters, activated sludge and sedimentation of the sludge. Tertiary and advanced treatments involve removal of more pollutants like phosphorus using more advances technologies. The above discussed processes play a major role in ensuring that the wastewater being used is safe. This however comes with a cost; each method or a combination of two or three methods has associated cost, both in terms of the structure and running. People however generally expect to pay less for using recycled water since they consider it to be of lower quality (Marks, 2002). This is a big challenge in encouraging them to embrace wastewater reuse as a means of conserving water as well as environment. This therefore requires users are enlightened on the economic advantages of recycled water (Murni, 2003).

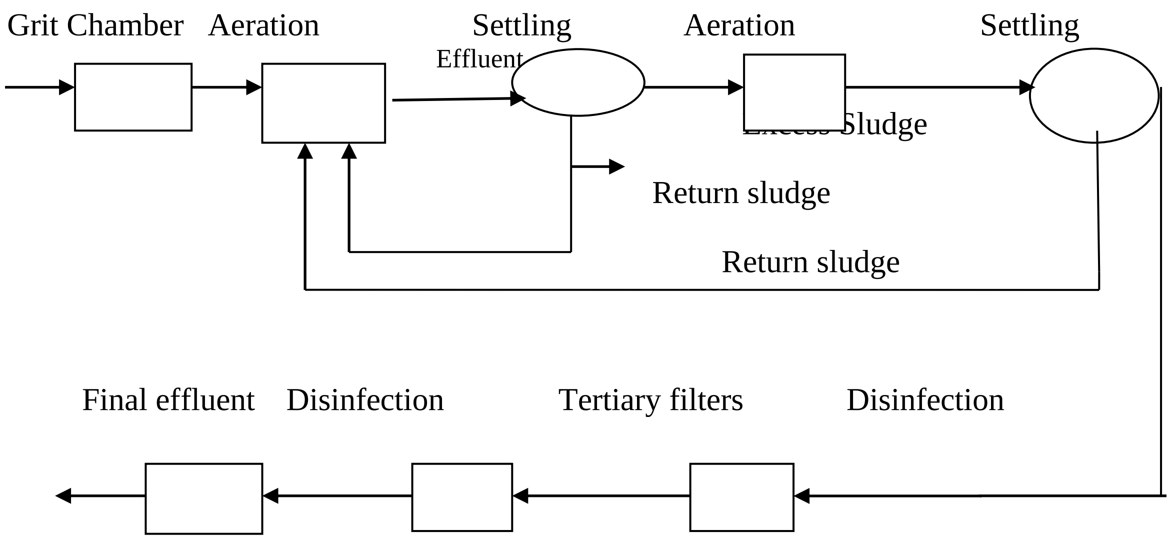

Figure 1.1: Schematic presentation of steps in wastewater treatment

Surface water is exploited for several uses by humans. It acts as a source of potable water after treatment and as a source of domestic water without treatment especially in rural parts of developing countries. It has been used for irrigation purposes by farmers, and fishermen get their occupation from harvesting fish in so many freshwater sources. It is used for swimming and also serves as centers for tourist attraction. This therefore implies that surface water should be protected from pollution. Major point sources of freshwater pollution are raw and partially treated wastewater. The release of domestic and industrial wastewater has led to the increase in freshwater pollution and depletion of clean water resources (Global Research, 2012).

Most quantities of wastewater generated in developing countries do not undergo any form of treatment. In few urban centers, various forms of wastewater treatment facilities (WWTFs) exist but most of them are producing ill-treated effluents, which are disposed of onto freshwater courses. In some developed countries of the world, adequate supply of potable water and improved sanitation facilities have been achieved. Strict environmental laws and monitoring for compliance prevent undue pollution to freshwater sources. Good waste management technologies and increased environmental protection awareness have contributed immensely to the success story. This has resulted in fewer cases of waterborne diseases reported compared to developing countries.

Many people in developing countries of the world still rely on untreated surface water as their basic source of domestic water supply. This is so because either there is an incessant supply of potable water or inadequate water supply systems. This problem is exacerbated in rural areas. Surface water is increasingly under undue stress due to population growth and increased industrialization. The ease of the accessibility of surface water makes them the best choice for wastewater discharge. Wastewater which is made up of several microorganisms, heavy metals, nutrients, radionuclides, pharmaceutical, and personal care products all find their way to surface water resources causing irreversible damage to the aquatic ecosystem and to humans as the aesthetic value of such water is compromised. These pollutants reduce the supply of useable water, increase the cost of purifying it, contaminate aquatic resources, and affect food supplies (Edokpayi et al., 2014).

Pollution combined with the human demand for water affects biodiversity, ecosystem functioning, and the natural services of aquatic systems upon which society depends on. Urban areas in most developing countries do have several wastewater management systems some of which are very effective and meet international standards, but many others are plagued with poor designs, maintenance problems, and expansion including poor investment in wastewater management systems. Most rural and poor communities often do not have any form of wastewater management systems. Effluents from large-and small-scale industries are usually channeled to surface water courses, which often result in pollution, loss of biodiversity in the aquatic ecosystem, and possibly health risk to humans.

The approaches used for treating wastewater by the targeted tourist facilities range from a combination of septic tanks and soak away pits, a combination of septic tanks, soak away pits and lagoons with reeds to constructed treatment plants. The result of these wastewater treatment methods is effluent of varying quality soaking into the underground streams and finding their way into the water in the boreholes, rivers and streams which serve as sources of water for use not only by the camps and lodges but also livestock, wildlife and households for domestic use and even drinking as the area is not supplied with piped water. This therefore only predisposes the residents to both zoonotic diseases and other waterborne communicable diseases like cholera, dysentery and typhoid.

1.2 Problem Statement

Liquid waste from sewerage contains high levels of organic matter. It is with a view to remove this organic matter that the waste is subjected to treatment so that it can be rendered safe for discharge into the environment. The treatment process involves physical, biological processes aimed at removing solids, organic matter and other components (Ramesh, 2004). The aim of treatment is to prevent pollution of water and protect the public from communicable water borne diseases. In Narok County, liquid waste is inadequately treated due to lack of efficient and inadequate infrastructure for managing the waste. In the study area, this situation is compounded by the increase in number of tourist lodges experienced in the last 5 years. Each of these facilities has to manage its waste before discharge into the environment. This is a big threat to both the biota in the receiving water sources and communities living downstream and wildlife.

Sekenani area within the Maasai Mara Game Reserve hosts a high number of exclusive high-end tourist lodging facilities. A number of wastewater management technologies are employed within these facilities to treat and dispose water used from the hotels and lodges. The technologies are deployed either singly or as a system integrating several techniques. The approaches used for treating wastewater by the targeted tourist facilities range from a combination of septic tanks, soak away pits, lagoons with reeds to constructed treatment plants. The product of these wastewater treatment methods is effluent of varying quality soaking into the underground and finding their way into the water in boreholes, rivers and streams which serve as sources of water for use not only by the camps and lodges but also livestock, wildlife and households for domestic use in the wider Sekenani region as the area is not supplied with piped water. This therefore highly predisposes the residents to outbreaks of both zoonotic and other water borne communicable diseases like malaria, cholera, dysentery and typhoid.

Numerous studies in Maasai Mara Game Reserve have been terrestrial biodiversity based. Information on water resources (quality and quantity) for the Mara River Basin (MRB) is limited, undependable and full of gaps (Wamalwa, 2009). Additionally, the effects of the various wastewater treatment approaches utilized by the 4 facilities on the effluent (water quality) and the environment is yet to be known. Studies targeting the Mara river tributaries have focused largely on effects of catchment-based land use activities on river water quality (Mango et al.2011, Kilonzo et al,.2014, Minaya, 2010) and there is a paucity of studies targeting wastewater quality and their likely effects on the aquatic ecosystems. It is now recognized that such studies are essential as they contribute to design and implementation of integrated natural resource management programs to protect and conserve the Maasai Mara Game Reserve (Richards &Syallow, 2019). This study therefore, seeks to examine the quality of effluent discharged by selected tourist facilities and assess efficiency of their wastewater treatment systems as first step towards enhancing sustainable management of water resources in the area.

1.3 Objectives of the Study

1.3.1 General Objective

To assess quality of effluent discharged from different tourist facilities in Sekenani location, Narok County.

1.3.2 Specific Objectives

The Study will be guided by the following specific objectives;

i. To compare the quality of wastewater in four tourist facilities within the Maasai Mara National Game Reserve

ii. To examine the wet and dry seasonal differences in water quality from tourist facilities.

iii. To determine the effects of various wastewater treatment approaches used by the facilities on the water quality.

1.4 Hypotheses

The study tested the following hypotheses;

i. H_o There is no significant difference in water quality from the 4 different tourist facilities

ii. $H_{0:}$ There is no significant difference in water quality between wet and dry season

iii. $H_{0:}$ There is no significant difference in effluent treatment efficiencies between the 4 wastewater treatment approaches

1.5 Justification of the Study

Domestic and industrial wastewater (effluent) have been associated health risks and biodiversity loss and therefore the need for the present study. Currently, scanty information exists on studies that have systematically assessed the quality of effluents from such facilities and their likely environmental effects on water quality and biodiversity of recipient water sources. Such studies are currently deemed important as securing environmental integrity of natural resources supporting biodiversity has been identified as key to sustainable tourism.

1.6 Significance

Findings will be important to the academia by contributing knowledge. Additionally, findings of the study will be of great benefit to Kenya as a Country as it will go a long way in helping to realize one of the aspirations of the National Environmental Research agenda 2008-2030 (NEMA, 2008) which is to assess effectiveness of various wastewater treatment technologies and thereby help in development of wastewater treatment guidelines. Findings of this study will help in enhancing sustainable tourism therefore contributing towards attainment of the economic pillars of vision 2030 which is to realize prosperity in all regions of the country through achieving 10 % gross domestic product.

Furthermore, findings will go a long way in helping to achieve sustainable development goals 3, 6 and 12 which are to ensure health lives for all, ensuring sustainable management of water and sanitation and ensure sustainable patters of consumption. In addition, tourist facility operators will be able to gain knowledge on the effective approaches for treating wastewater, boost their visitor numbers as this will facilitate improved ranking by tourism facility accreditation institutions such as the Eco Tourism Kenya as well as savings from reduced water bills. The communities in the neighbouring areas will on the other hand benefit as they will spend lesser money on treating water borne diseases as they will be lesser pre-disposed to these diseases and also commit much of their time in development activities and not in search for fresh water for their domestic needs and livestock.

1.6 Scope and Limitations of the Study

The study covered four facilities namely AA Lodge, Mara Simba Lodge, Sarova Mara and Sentrim Mara Lodge within Sekenani area of the Maasai Mara ecosystem. This is because study area is Sekenani. These include; Hydrogen ion concentration (pH), Temperature, Total Suspended Solids (TSS), Nitrates, Phosphorous, Coliforms, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Turbidity and Electrical Conductivity (E.C.) since these are the basic parameters used to ascertain levels of pollution as prescribed in the Environment Management and Coordination (Water Quality) Regulations, 2006.Several challenges were encountered during the study. However, these did not impact of the results in any way. They include; lack of a laboratory in Narok which meant samples had to be ferried to Nairobi for analysis and the fact that this made the cost of the study high.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter covers review of literature relevant to the study. It begins by providing an insight on key liquid waste management approaches and their impacts globally. The chapter further provides details on liquid waste management approaches in conservation areas within the African region. It then reviews information on liquid waste management in conservation areas in Kenya and finally, discusses about liquid waste management within tourist facilities of the Mara ecosystem.

2.1 Liquid Waste Management approaches and their impacts on Water Quality

A study conducted in a number of countries in the Caribbean region by (World Bank 2001), established the absence or insufficiency of wastewater treatment facilities in many countries of the region. The study further revealed that only 13% of the population was connected to sewerage system in Saint Lucia within North America. In Barbuda and Antigua, it established unregulated human waste disposal and inadequate drainage as being responsible for standing pools of contaminated water which during severe weather became major causes of sanitation related disease outbreak. This study was limited in scope because it only focussed on the extent of population served by sewer line and its impacts. In addition, the study focussed mainly in cities within the coastal regions of the WIO –Regional Countries and not conservation area. Another study (UNEP /GEF, 2004) under the Global International Water Assessment on Regional Assessment for the Islands of the Greater Antilles showed untreated sewerage as the major sources of pollution in the marine environment.

Wastewater treatment facilities were fewer in many locations. The study further reveals that this led to fish mortalities, biodiversity loss and eutrophication. This study was limited by the fact that it only focused on the negative impacts associated with inadequate coverage of sewerage within the Greater Islands of Antilles.

A study by (UNEP / GPA 2006) in Caribbean Islands cited high cost of building and maintenance of traditional effluent treatment plants as being responsible for failure to treat sewerage before disposal. This study despite the significance of its implications in terms of policy review was limited since it never focussed on the various liquid waste management approaches. In a study on the extent of sewerage coverage and demonstration of cost-effective effluent management strategies and the cost of implementing such strategies in each of the 5 countries in Central and Eastern Europe namely; Poland, The Czech Republic, The Slovakia, Republic of Hungary, and Bulgaria (La'szlo' &Shanahan, 1997), it was revealed very low coverage of sewerage treatment across all the countries except in Czech Republic. The limitation of this study was that it focussed on wastewater that is treated, challenges that were affecting the treatment plants, the effect of the challenges on BOD removal efficiency of the treatment plants. This study also focussed only on treatment plants.

In a study to examine the possible impact of domestic sewage on the lotic water in and around Cuttack, India by (Das&Acharya,2003) revealed that majority of samples exceeded the maximum permissible limit set by WHO. Nitrates and coliform counts in all the samples were high and the waters were not potable. The nutrient characteristics of the study area exhibited drastic temporal variation indicating highest concentration during the summer season compared to winter and rains. This study was limited in the sense that it looked at domestic wastes but in a residential set up not within a conservation area. Additionally, the aspect several parameters were not considered in the study. These were Phosphates, Chemical Oxygen Demand, total coliforms, Electrical Conductivity and turbidity.

In Nigeria, a study on the impacts of effluent discharge from Kaduna Refinery on the water quality of River Lumi (Lekowot et al., 2012) revealed Chemical Oxygen Demand, Biological Oxygen Demand and Total Suspended Solids levels higher than the ones recommended by the World Health Organization. The gap in this study was that it only focussed on treatment plant approach to management of effluent. In addition the focussed source of effluent was refinery and not domestic and kitchen wastes which are the main sources for effluent from tourism facilities. In a study to examine the effluent characteristics of some selected food processing industries conducted in Enugu and Anambra States in Nigeria (Emanuel & Jacob, 2013) the results showed Total Suspended Solids (TSS) from 0 to 230 mg/L. The pH of the effluents varied from 6 to 8, the COD from 684 to 3,192 mg/L, the TKN from 5.6 to 33.6 mg/L and the total coliform from 43 to 150 MPN/100 mL of effluent sample. Compared to the effluent limitation guidelines given by Nigerian Federal Environmental Protection Agency, the TSS, and COD exceeded regulatory limits while the TKN, pH and coliform did not.

This study was limited in that it did not examine different wastewater management approaches. A study to assess Wastewater Treatment Plant Efficiency at Ama Breweries Plc, Enugu State, Nigeria by (Ogwo, &Ogu, 2014) showed Results showed that EC, TSS, alkalinity, COD, total plate count and total coliform were significantly above the permissible limits, while other parameters were within the limits. A study that was limited because it only focused on one wastewater treatment plant. Another study to assess wastewater management practices conducted in Kigali city, Rwanda by (Umuhozaet al.2010) revealed pH, conductivity, Dissolved Oxygen, Total Dissolved Solids, Chemical Oxygen Demand, Total Nitrogen, and Total Phosphorous, the effluent quality far exceeded the limits for effluents discharged into sensitive waters. Another study on effects of poor-quality effluent from stabilization ponds to receiving bodies in Kilombero in Tanzania (Machibya & Mwanuzi, 2006), established BOD_5levels of41 mg/l. This was higher than what is recommended by WHO of 30mg/l. The main gap with this study was that its scope was limited to stabilization ponds. Further, the aspect of whether there were some seasonal variations was not considered during the study.

In a study to determine the seasonal differences of wastewater treatment that employs screens, trickling filters, and oxidation ponds at the boundary sewage treatment plant in Eldoret Municipality, Kenya (Chebor et al., 2017), established physical chemical parameters that were significantly different ($p<0.05$) in all stages of treatment during both the dry and wet season. This study was limited as did not interrogate the various approaches for wastewater treatment. In another study on the evaluation of performance of an onsite wastewater treatment plant in Ongata Rongai and Kabete flats in Kenya (Mweru, 2014), the study established various removal efficiencies for Chemical Oxygen Demand, Biological Oxygen Demand, and Total Suspended Solids and from the two sites studied. This study was also limited in the sense that the approach for liquid waste treatment that was being examined was only the treatment plant. In addition to this, the study never looked at the effects of the treatment on the river system water quality and its biodiversity.

Findings of a study on the characterization and treatment of wastewater from Saphire Textile Industries in Pakistan by (Naved et al., 2013) showed greater reduction in the levels of parameter in the wastewater after passing through the wastewater treatment plant. The study concluded from the results of analysing of the wastewater after the passing through the effluent treatment system that the wastewater treatment plant is effective. However, this study was limited in the sense that not all physic-chemical characteristics were considered and the aspect of seasonal variation was also left out. A study which looked at the physic-chemical and bacteriological quality of water from five rural catchment areas of Lake Victoria Basin in Kenya by (Ouma, 2015) found that levels of the parameters in the wastewater varied with season as pollution loads were higher during the wet season that the dry season. The study did not look at all the parameters and never focussed on the treatment approaches.

In another study to examine the efficiency of Kariobangi Wastewater treatment plant by (Miruka2016) reported Total Suspended Solids and pH to be within the limits set by the water quality regulations. Biochemical Oxygen Demand and Chemical Oxygen Demand, Nitrates, Phosphates, Dissolved Oxygen, Conductivity and Turbidity values were higher compared to the standards set in the Water quality Regulations of 2006 and hence not efficient. It further reported that the Chemical Oxygen Demand, Total Suspended Solids and Biochemical Oxygen Demand showed variations with seasons with COD and BOD reporting very high values during the dry season compared to the wet season. TSS Levels were higher during the wet season than the dry season. The limitation with this study was that it did not look at the other treatment approaches. Another study by (Mbugua, 2016) to evaluate the effects of septic tanks sewerage disposal system distance on the borehole water quality in Ongata Rongai within Kajiado County in 2016 revealed pH ranges of 6.5-8.4, Turbidity values were 1.9-4.9 µS/cm while Phosphates levels were BDL.

Chemical Oxygen Demand levels were between 4.0-75 Mg/l, whereas Electrical Conductivity was in the ranges of 802-1265 NTU. The study revealed that the level of the water contaminants in the boreholes samples increased with decrease in the distance from the septic tanks and was also higher during the wet season than the dry season. It also found out that most parameters value for the borehole samples were within the standards set by WHO for discharge and that water quality is affected by seasonal variations. However, this study was limited in the sense that it focussed on only one treatment system.

This study addressed the limitations highlighted above by covering a wider range of parameters viz; pH, Temperature, turbidity, Biochemical Oxygen Demand, Dissolved Oxygen, Chemical Oxygen Demand, Electrical Conductivity, Total Suspended Solids, Phosphates, Nitrates and coliforms, investigated the variations of the parameters with seasons and last but not least compared the treatment efficiencies of 4 wastewater treatment approaches namely single septic tanks, septic tank and soak away pits, treatment plant and integrated septic tanks and lagoons.

2.2 Liquid Waste Management and Environmental Sustainability in conservation areas in Africa

All water ways are networked. The illegal discharge of effluent therefore has detrimental effects on the health of aquatic ecosystems which then undermines the resilience of biodiversity and ecosystem goods and services on which human wellbeing depends (Corcoran et al., 2010). The facilities found in conservation areas in Africa are varied.

They range from eco-camps, tented camps to five star hotels and lodges. Management of wastewater in conservation areas in the African region is mainly on site. On site wastewater management refers to the approach where sanitation is contained within the confines of the plot within which the discharging facility is located but may also include facilities by several households living inside the same compound (Cotton &Saywell, 1998). This is attributed to the inadequacy of sewerage infrastructure. In the few countries where this is present, its efficiency in managing the liquid waste is largely inefficient. This is the reason why most facilities opt for the onsite system for management of the wastewater.

In South Africa where the level of wastewater management is advanced with 47% of its population dwelling in the coastal cities being connected to central sewer systems (Momba et al., 2006), reported that the poor management of the central sewerage treatment plants as the major reason for the pollution of the water bodies thence posing a serious health and socio-economic threat to those living downstream of such water bodies. As a result of this, most facilities in conservation areas like the three luxury hotels in the Sabi Sabi Game Reserve use an on-site treatment system (Republic of South Africa, 2003).

In the United Republic of Tanzania, about 90% of the coastal population is served by pit latrines and septic tanks (United Republic of Tanzania, 2013). The Chumbe Reef Sanctuary in Zanzibar which has seven eco-bungalows, each of them utilizes eco-composting toilets with no septic tanks nor flush toilets. No effluent therefore is generated (IUCN, 2013). A study undertaken to assess the impact of industrial effluents on Nwiyi River Enugu, Nigeria by (Ogwo & Ogu, 2014) showed EC, turbidity, phosphate, Fe, COD, BOD, alkalinity, total plate count, total coliform that were above WHO permissible limits, while TDS, TSS and pH were within the limits but hade the potentials to exceed the limits if the trend continued without proper monitoring. The limitation of this study was that the source of the effluent was not tourist facility and the aspects of seasonality and different wastewater treatment were not examined.

The 300 Hectare Nusa Dua Resort city in Bali, Indonesia uses an integrated waste treatment system which treated wastewater from hotels within the resort city and other establishments within the area. The design allowed for provision of water for maintenance of gardens and golf course while the last wastewater station called eco-lagoon hosted various species of birds and further added to the aesthetic appeal of the area (Corcoran et al., 2010). In a study by (Mohammed, 2010) conducted in South Sudan to examine the efficiency of soba waste stabilization ponds showed efficiencies of Biochemical Oxygen Demand 85.6% while Chemical Oxygen Demand was 83.0%. Total suspended Solids was 81.3% whereas total coliform was 97%. In a study to analyse the effect of brewery effluent from Nigerian brewery Enugu on Ajali River in Eke, Udi Local Government Area, Enugu State in by (Ogbu et al., 2016) revealed turbidity, Total Suspended Solids and Dissolved Oxygen of both brewery effluent and Ajali River were far above the national and international permissible thresholds for discharge to the environment. This study was limited in the sense that it focused on effluent from brewery and not tourism facilities within a conservation area.

2.3 Liquid Waste Management in Kenya's Conservation areas

Eight per cent of Kenya's land area is protected for wildlife conservation with more than 23 National Parks, 31 National Reserves, 6 sanctuaries, 4 Marine National Parks and 6

Marine National Reserves spread all over the country. These ecosystems are very sensitive and therefore call for more robust strategies for managing wastewater (KWS, 2012).

The approaches used in liquid waste in managing conservation areas within Kenya vary from one facility to the other. Severin Safari Camp in Tsavo West National Park uses 2 wastewater treatment plants. One of these is the Aqua Simplex Pionier ASP with swimming aerators in a closed concrete packaging with three chambers installed at the ground level. The second is a Bio Clear 60 Plant, where the clearing process of the wastewater is carried by sprinkling over lava stones in a separated basin. The energy requirement for the two combined is 10.4 KW per day. Kilaguni Serena Safari Lodge located in the same ecosystem on the other hand manages its liquid waste by channelling it through the septic tanks into an enclosed system comprising 4 treatment compartments.

A bio enzyme is added in the 1st and the 2nd chambers to enhance sludge digestion. From the compartment the waste flows through a chlorination tank before discharge into the environment. Ngulia Safari Lodge found within the Tsavo West National park uses septic tanks and soak away pits. Turtle Bay Resort situated within Watamu Marine National Park manages its liquid waste using a treatment plant comprising 5 enclosed chambers with various stages of filtration, biological and enzyme treatment with chlorine being added in the last chamber to purify the water before discharge. Baobab Holiday Resort sited near the Kisite Mpunguti Marine National Park treats its liquid waste by using a septic tank and four co-joined lagoons.

2.4 Liquid Waste Management in Lodges, Hotels and Camps in Maasai Mara Ecosystem

In the Maasai Mara ecosystem the methods used differ greatly depending on the type of facility. For instance, the flying camps use eco-composting toilets while some tented camps use soak away pits only which are stacked with rock pebbles where the wastewater flows and percolates slowly into the soil. Majority of the semi-permanent lodges use septic tanks and soak away pits. The approach used by lodges vary with some using septic tanks and soak away pits, others use septic tanks, soak away pits and lagoons. Some use bio-boxes and other treatment plants. The advantages associated with each of the methods are also varied. For instance, septic tanks alone have several advantages and disadvantages. The advantages are that it is easy to operate and maintain, requires lesser land, less costly and can be built in rural settings. However, the disadvantages are that it has low wastewater treatment efficiency, the sludge and effluent must be pumped occasionally and that requires land fill for periodic disposal of the septage (Ahrens, 2005).

A study to evaluate water quality and ecosystem health in the Maasai Mara ecosystem by (McMahan, 2006) in the Mara River Basin revealed varying levels of DO, Electrical Conductivity, temperature, Total Suspended Solids, Nitrates and phosphorus with most deviating from the recommended standards. For coliforms the findings were inconsistent due to excessive culture growth. He attributed these deviations from standards to local soils, geology and water levels. For TSS and Nitrates the variance from the set standards was associated with the intensive agricultural and pastoral activities in the area. In a study by the (LVBC & WWF- ESARPO, 2006) conducted to assess the Reserve flows within the Mara River revealed pH, Total Suspended Solids, Temperature, Electrical Conductivity, Dissolved Oxygen and Nitrates levels that were within the standards set by WHO for discharge to the environment. This study was inadequate in the sense that it did not focus on the seasons and also the various wastewater treatment systems' efficiencies.

A study on the land use influence on benthic macroinvertebrate communities in streams of Nyangores and Amala tributaries of the Mara River by (Minaya, 2010) established that conductivity, turbidity, TSS varied with land use while pH did not vary with land use. The high levels of E.C., Turbidity and TSS were indicative of ecosystem disturbance. The limitation of this study is that it did not look at the aspect effects of seasonal variation on the water quality and also the treatments system and their relative efficiencies. Another study by (Ngugi, 2014) which evaluated the impacts of Water, Hygiene and Sanitation activities to the environment in the upper Mara River Basin using the WEAP model, reported Anthropogenic activities specifically open defecation is closely related to the deteriorated water quality within the Mara division with, most water points relied a upon by the inhabitants as sources of domestic water not being adequately protected from faecal matter.

This study has gaps due to the fact that it failed to look into seasonal variations and wastewater treatment system efficiencies. The advantages of using soak away pits include, use of locally available materials for its construction, does not require highly specialized skills, requires small land, low capital and operating cost. The disadvantages are; requires waste to undergo primary treatment to prevent clogging, may negatively impact on the soil and water properties, not applicable in clayey and compacted soils, not suitable in cold climates and also when huge volumes of wastewater are involved (Heeb et al,.2012). Due to water scarcity, the method adopted is therefore critical. This calls for approaches that conserve water to ensure sustainability.

2.5 Conceptual Framework

The conceptual framework was based studies conducted previously. It is made up of dependent and independent variables. The independent variables included treatment approaches, season's parameters and legislations which influenced the dependent variables such as such as pH, temperature, BOD, DO, COD, E.C. Turbidity, Nitrates, Phosphates, T.S.S and Coliforms.

Independent Variables **Dependent Variables**

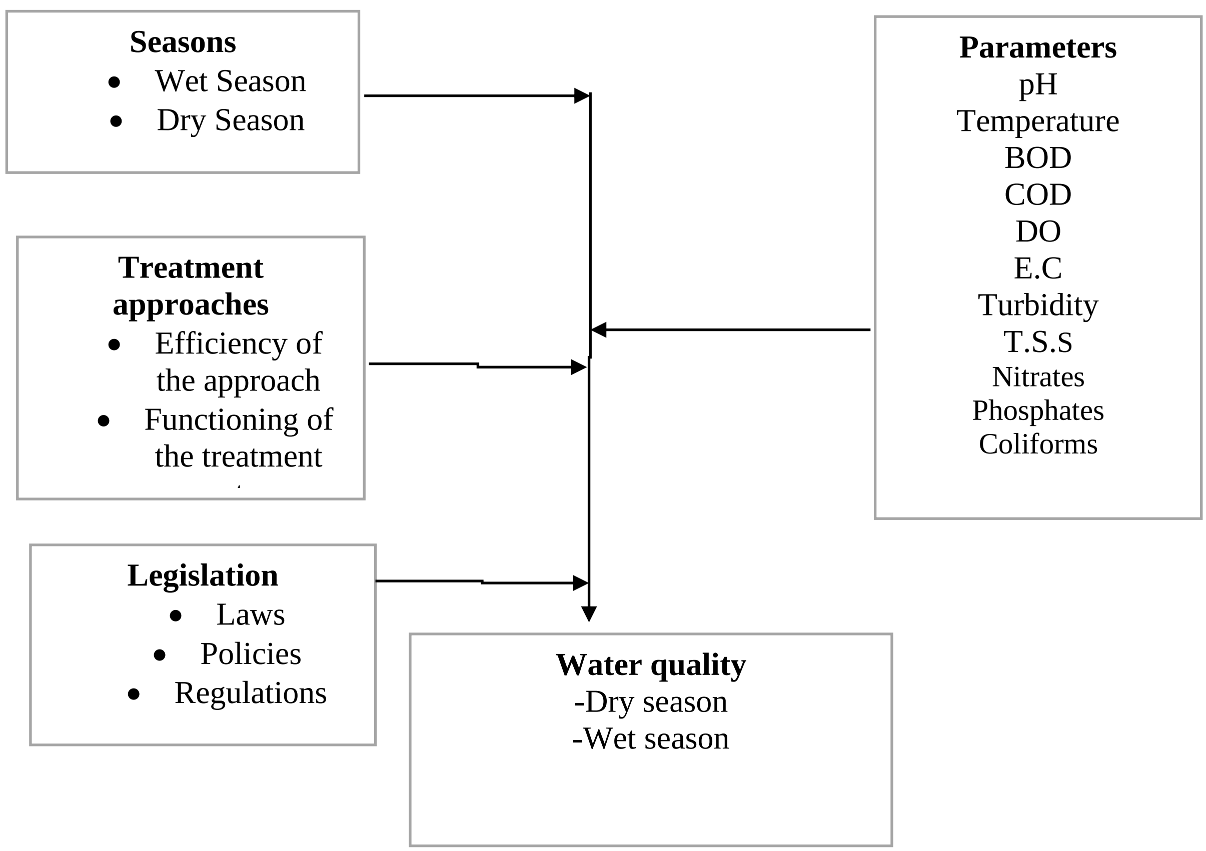

Figure 2.1: Conceptual Framework

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter is dedicated to the description of the methods, procedures and instruments that were utilized in obtaining the research data, how the data was analysed, interpreted, and how the conclusion was drawn. All these helped in the processing of the data and the formulation of the conclusions. Specifically, this chapter covers: the research design and methodology, the sample collection instrument, validity and reliability of the instruments, ethical consideration and the data analysis.

3.1 Location of Study Area

Narok County is situated in Kenya along the Great Rift Valley. It covers an area of 17,944 sq. Km with a population of 1,157837 (Republic of Kenya, 2019). The temperature ranges from 12 to 28°C with the average rainfall ranging between500 – 1800 mm per annum (Republic of Kenya, 2013). Sekenani is one of the town centers within the Maasai Mara. It lies on longitude 1º31’8’’S and latitude 35º20’16’’ E. It occupies an area that measures 642 Km^2 and is located at the boundary between the Maasai Mara Game reserve and private land and two group ranches namely the Siana and Koiyaki Group Ranches. Situated about 100 Km South West of Narok town, the area lies at an altitude of 1811 meters above the Sea level. Administratively, the town is found in Sekenani Sub-location, Nkoilale Location in Mara Division of Narok West Sub- County within Narok County.

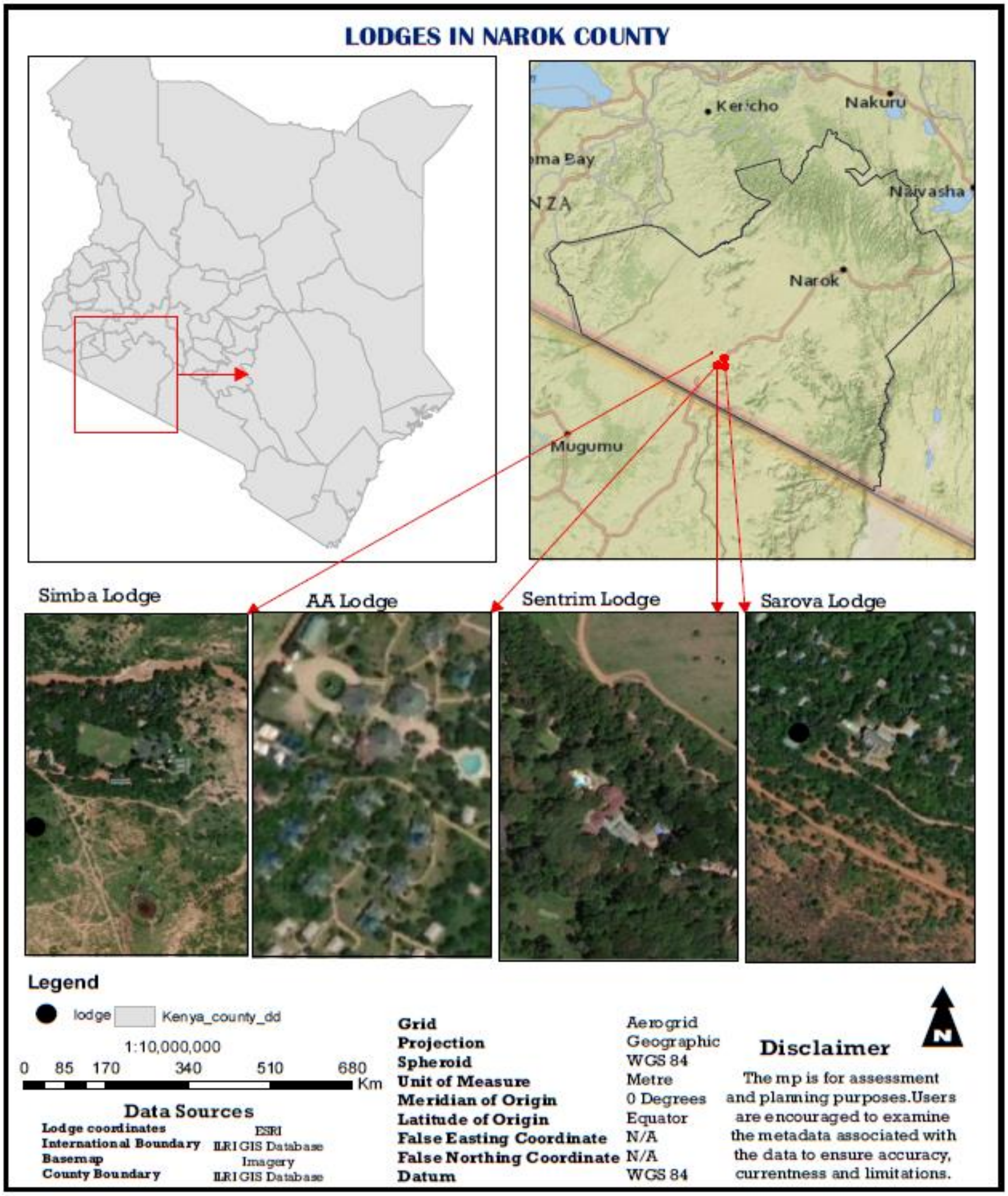

Figure 3.1: Map of Study Area

3.1.1Physical Environment

The area is semi- arid with temperatures ranging from 25ºC – 30ºC. Rainfall in the area ranges between 500mm-1800mm per year (Republic of Kenya, 2013). The area experiences a bimodal rainfall pattern with long rains experienced during the months of March, April and May while the short rains are experienced during the months of September, October and December period.

3.1.2 Water Use and Water Quality

Sources of water in the Mara River Basin include boreholes, springs, springs, rivers and shallow wells. This water is used for domestic, irrigation, wildlife and tourism. During the wet season, the main source of water in the Mara is unprotected springs while during the dry season residents rely on rivers as all the other sources become dry. During this dry spell the river water is utilized for both domestic, livestock and wildlife is normally contaminated with environmental effluents (Njigua, 2006). Mara River basin water quality has been deteriorating as a result of sediments occasioned by deforestation, poor agricultural practices high loads of coliforms from urban centres and tourist hotels (MRBMI, 2005). Sources of water are small rivers most of which are seasonal and streams such as Sekenani, ilkireen, Ankama, Olepire, Talek and RupileOlala. Other sources of water are springs, boreholes, swamps and water pans.

3.1.3 Biological Environment

The area is a mosaic of well adapted ecosystem mainly in the form of desert shrubs, grasslands, bush lands and woodlands. Vegetation in the area comprises woodland, bush land, open grassland and riverine vegetation. Examples of the plant species found in the area include; the fever tree (*Acacia xanthophloea)*, croton species, euclea species and euphorbia. Some of the animal species found in the area include the cheetah

(*Acinonyxjubatus*), lion (*Pantheraleo*), leopard (*Pantherapardus*), African elephant (*LoxodantaAfricana)*, spotted hyena (*Crocutacrocuta*), white bearded wildebeest (*Connochaetestaurinus)*, African Buffalo (*Synceruscaffer)*, plains Zebra (*Equusburchelliboehmi)*, Giraffe (*Giraffacamelopardalis)*and Gazelle (*Gazellarufrifrons)* (KWS, 2012).

3.1.4 Socio – Economic Environment

There are several socio-economic activities in Narok County. These include Gold mining in Lolgorian, farming, pastoralism and tourism. In Sekenani, the main economic activities are tourism and pastoralism. This is because the area receives lower amounts of rainfall to support agriculture. Tourism is flourishing in the area and serves as sources of market for local goods, services and the rich Maasai culture. The main driver of tourism is the high number of wildlife harbored in the Maasai Mara National Game Reserve. This protected area started as a wildlife sanctuary in 1948 later in 1961 after the expansion it acquired the status of a Game Reserve and finally in 1978 got designated as National Game Reserve (Wadpole, 2003). The major attraction so far is the famous world re-known Wild beest Migration. The rivers in the area also harbor rare species of fish and therefore serves as a source of livelihoods to the communities further downstream (Gereta, 2003, Mati, 2005).

3.1.5 Geology

Geology, Climate and anthropogenic activities are the main factors that affect water quality in Kenya. The Mara River Basin is comprised of 2 major soil types. The upper and mid regions of the basin have cambisols while the lower has vertisols. Cambisols are very stable structurally, are highly porous, with good capacity to retain water and moderately fertile. Vertisols on the other hand are more clayey, darkish brown in colour with good water holding capacity and are not very good for agriculture (Mati, 2005). The bedrock is composed of quartzite, gneiss and schists (Lamprey, 2004).

3.2 Research Design

The research adopted experimental, purposive and quantitative design to investigate the quality of effluent discharged as not all the facilities within the area have visitors throughout the year and therefore have wastewater running throughout. A total of forty-two samples were collected from 4 tourist facilities and 11 different parameters examined. These are; Hydrogen ion concentration (pH), Temperature, Turbidity, Electrical Conductivity, Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrates, Phosphates and coliforms. The researcher used Geographical Positioning system (GPS) to mark the location of the sampling points which were then transferred to Arc GIS software to generate maps showing the distribution of the sampling points. Data was analysed by Statistical packages for social sciences (SPSS) and tested for significant difference using ANOVA at 0.05% alpha level. Additionally, review of secondary data, Photography, sterile bottles, water, dettol, detergent, distilled water, cooler box, ice packs were used.

3.2.1 Sampling Procedure

Samples from four tourist facilities situated in Sekenani area were considered in the study viz; AA lodge, Mara Simba lodge, Mara Sarova and Sentrim Mara lodge. Samples from each of the facilities were collected from effluent that is the point at which the wastewater leaves the treatment plant. The sampling was done both during the wet season and also during the dry season. At each of the sites, sampling was done in three occasions at one week's interval during the wet season and during the dry season with a view to enhance the statistical accuracy of the data. All the samples were collected in the mid - morning hours (between 8.30Am and 10.30Am). The wet / low tourist season samples were collected on 24th May, 31st May and 7th June, 2016 while the dry / pick tourist season on 10th August, 17th August and finalized on 24th of August 2016.

The samples for total coliforms were collected using about1 litre clear sterile bottles while the ones for Nitrates, TSS, phosphorus, COD and BOD were collected in one litre non sterile bottle. The liquid waste was mixed to homogenise then sample collected using a sampling bottle to fill then screwed. The sample in the non-sterile bottle was not filled to the brim but small space was left and then screwed. The bottles with the sample were then put in a cooler box with ice packs to ensure the temperatures were at 8° C. Temperature, pH, Electrical Conductivity and Turbidity were measured in – situ using Pro Plus multi parameter water quality meter (DID 305). The equipment was zeroed then the probe was inserted inside the liquid waste collected in the sample bottle. Then readings were taken and recorded after one minute when the readings on the equipment stabilized. Once done, the probe was rinsed with distilled water and then zeroed before the next reading was taken. The used gloves were then dumped in a waste bin at the lodge. The sampler and team then washed their hands using Dettol. The samples in the cooler box packed with ice were transported to Nairobi at the WRA Central Testing Laboratories for analysis within 12 hours.

Table 3.1: Sampling points by GPs Coordinates

S/NO	Site	Latitude	Longitude
1	AA Effluent	01.49536° S	035.35041°E
2	Simba effluent	01.47308°S	035.29515°E
3	Sarova effluent	01.52989°S	035.31549°E
4	Sentrim effluent	01.53538°S	035.35153°E

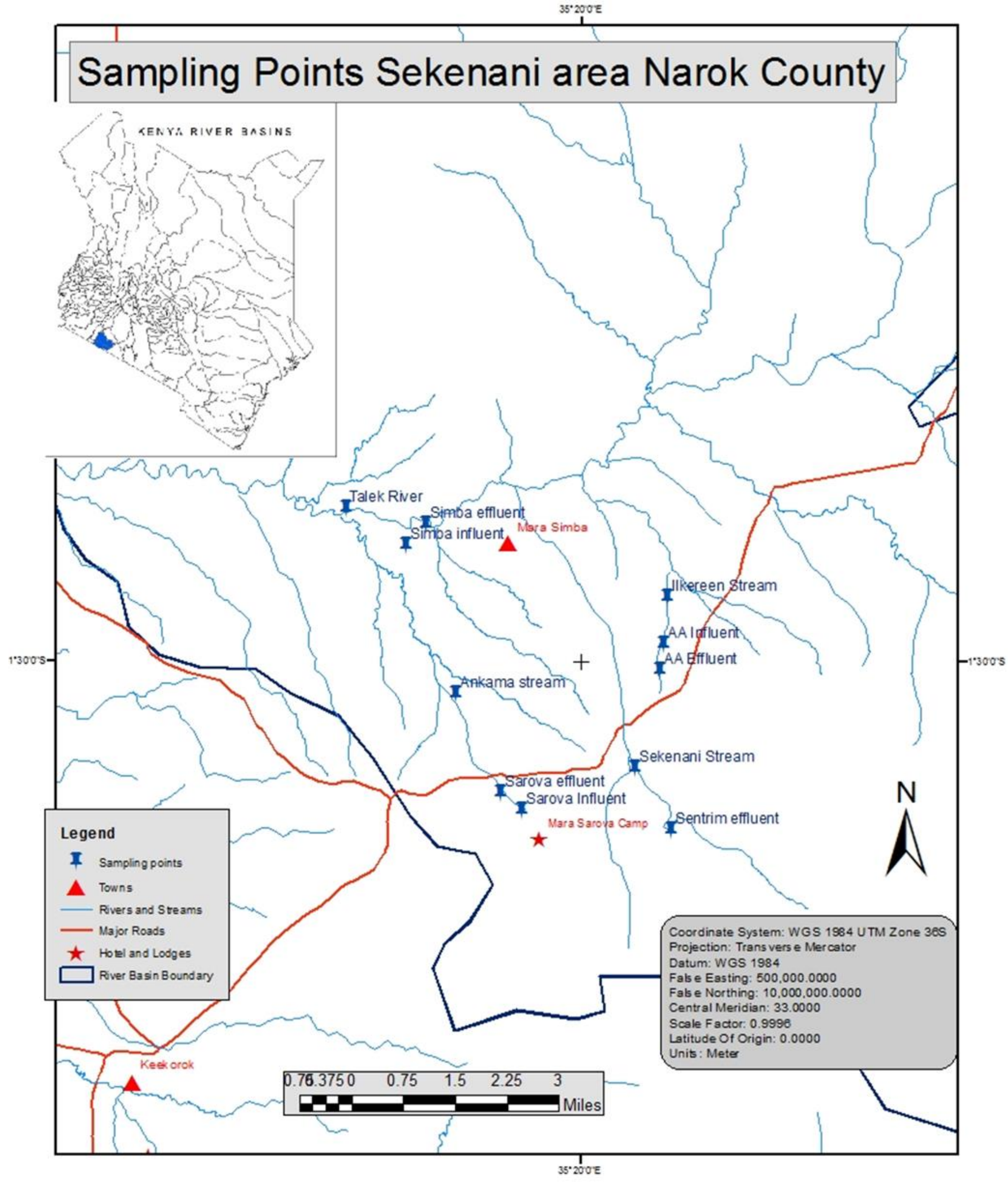

Figure 3.2: Map of Sekenani Showing sampling points during the study

Plate 3.1: Sampling at AA Lodge

Plate 3.2: Sampling at Simba Lodge

Table 3.2: List of Parameters measured in situ

Parameter	Procedure
pH	20ml of the sample was put in a cell, rinsed with tissue paper then placed in a cell holder in the Pro Plus multi parameter water quality meter (DID 305). The readings were taken directly after one minute from the meter
Temperature	20ml of the sample was put in a cell, rinsed with tissue paper then placed in a cell holder in the Pro Plus multi parameter water quality meter (DID 305). The readings were taken directly after one minute from the meter
E.C	20ml of the sample was put in a cell, rinsed with tissue paper then placed in a cell holder in the Pro Plus multi parameter water quality meter (DID 305). The readings were taken directly after one minute from the meter
DO	20ml of sample was put in a cell, rinsed with a tissue paper then inserted into a cell holder in the Pro Plus multi parameter water quality meter (DID 305). Readings were then measured and recorded.
Turbidity	20ml of sample was put in a cell, rinsed with a tissue paper then inserted into a cell holder in the Pro Plus multi parameter water quality meter (DID 305). Readings were then measured and recorded.

3.3 Laboratory Analytical procedures

3.3.1 Chemical Oxygen Demand

This was conducted using titrimetric method. Several boiling stones were placed in a reflux flask.50.0ml of sample were added followed by 1g of mercury sulphate (6.5). 50ml of concentrated sulphuric acid (6.8) were added and swirled until the mercuric sulphate dissolved. The reflux flask was then placed in an ice bath while swirling. 25ml of 0.025N Potassium dichromate (6.2) was added. This was followed by addition of 70mls of sulphuric acid – Silver Sulphate solution to the cooled reflux flask while swirling continues. The flask and reflux were heated for two hours to allow for maximum oxidation. The flask was after that allowed to cool and the condenser washed down using 25ml of distilled water. The acid solution was diluted to about 300ml with distilled water then allowed to cool to about room temperature. Eight drops of ferroin indicator were added to the solution and the excess dichromate titrated with 0.25N Ferrous ammonium sulphate solution to the end point where colour change appears from blue-green to a reddish blue (APHA,1998).

3.3.2Biochemical Oxygen Demand(BOD5)

Determined using BOD OxiTop meter (Yuan et al.2001). 100mls of sample being examined was added into dark BOD bottles with magnetic stirrer. Two pellets of NaOH were added into the bottles and then corked tightly. The bottles were then put in BOD meter and incubated at 20° C for a period of 5 days. The resulting BOD_5measurement was taken from the readings.

3.3.3Nitrates

Analysed using spectrophotometric method. The Nitrates tube was filled with sample up to the 30ml mark. One spoonful of Nitrates powder and one Nitrates tablet were then added. The cap was replaced and the tube shaken for one minute. The tube was allowed to stand for one minute then gently inverted three times to aid mixing. The screw cap was then removed and the clear solution decanted into a test tube and filled to the 10ml mark. One Nitricol tablet was crushed then added and mixed till it dissolved. The mixture was then allowed to stand for 10 minutes till colour developed. The test tube was then inserted into a photometer from which the readings were taken (APHA, 1998).

3.3.4 Phosphates

Analysed using spectrophotometric method. 25ml of sample was measured in50ml graduated tube. 4 ml of combined reagent comprising of ascorbic acid, ammonium molybdate, potassium antimonyltartarate prepared as per manufacturer's specifications were added. The tube was then covered with a parafilm and left for 10-30 minutes until some blue colour appeared. Readings were taken at 880nm absorbance by use of a spectrophotometer.

3.3.5 Total Suspended Solids

This was conducted using gravimetric method as stipulated in the standard methods for analyzing waste and wastewater (APHA, 1998). During the analysis, the initial weight of 0.45µm pore size filter paper was recorded. Then 100ml of sample was filtered through the filter paper in a filtration unit. The filter paper containing the residue was then wrapped in an aluminum foil then dried in an oven at 105°C for a period of one hour and its weight recorded. The change in weight of the filter paper depicted the concentration in Mg/L (TSS).

3.3.6 Total Coliforms

This was conducted using membrane filter technique according to the standard methods (APHA, 1998). 9mls of sample is filtered through membrane filter which retains the bacteria found in the sample. The filters containing the bacteria were then placed on adsorbent pad saturated with lauryl tryptose broth and incubated at 35° C for 2 hours. The filters were later transferred to adsorbent pad petri dish containing M-Indo agar and incubated for another 21 hrs. At 35° C. Sheen colonies were then counted under magnification and reported per 100ml of the sample.

$$\text{Total Coliform Count} = \frac{\text{Coliform colony counts X100}}{\text{Volume of sample filtered}}$$

3.4 Water Quality Index

(WQI) is a scale with points ranging from (1-100) which integrates data arising from varied physicochemical parameters using a computer program from the National Sanitation Foundation, USA. For this study, nine parameters essential for water quality determination were used pH, Temperature, DO, TSS, BOD, COD, Phosphates, Nitrates and coliforms. The index reduces bigger data sets to single numbers finally ranking water into of five categories namely very bad water (0 - 25), bad (25 - 50), medium (50 - 70), good (70 - 90) and finally, excellent quality of the sampled water (90 - 100). The formula used to work out the water quality index is represented by the equation below;

$$WQI = K \frac{\Sigma_i C_i w_i}{\Sigma_i w_i}$$

Where:

K - Constant.

WQI- Highly polluted to good water quality ranging from 0.25-100.

C_i - Value assigned to each parameter measured after normalization on a scale of 0 to 100 with zero indicating water that is not suitable for the intended use without further treatment while 100 represent perfect water quality.

W_i-Relative weight assigned to each parameter.

A maximum weight of 4 was assigned to parameters of relevant importance to aquatic life such as DO, with the minimum value (unit) assigned to parameters of minor relevance such as temperature and pH (Yuanet al. 2015). The parameters used were selected based on its impacts on the overall quality of the water. Additionally, it done on the basis that effectiveness of treatment systems at improving water quality is normally measured by Biochemical Oxygen Demand (BOD), nutrients and fecal indicator bacteria (pathogens) removal (WHO, 1999). In this study, nine parameters pH, Temperature, BOD, COD, Nitrates, phosphates, coliforms TSS and turbidity were considered from the effluent from each of the treatment approach and their water quality index determined.

Details of the index and a program for the calculations are on the following website http://www.water-research.net/watrqualindex/waterqualityindex.htm

3.5 Statistical Analyses

Analysis of variance (abbreviated as ANOVA) is a statistical method used to determine the variation between means of a large group of data or variables to evaluate their statistical significance. ANOVA analyses were done using the SPSS. The test assumed null hypotheses that; There is no significant difference in water quality from the 4 different tourist facilities; There is no significant difference in quality of water between wet (low tourist) and dry (high tourist) season and there is no significant difference in effluent treatment efficiencies between the 4 wastewater treatment approaches. A 95% confidence level was considered to be significant statistically. Hence, a p value ≤ 0.05 would be considered statistically significant. Therefore, if the analysis was found to be statistically significant then the null hypothesis is rejected and the alternative one accepted. The data was organized by treatment method, dry (high tourist season) and wet (low tourist season) and then analysed to check whether there was variation (Kothari, 2004).

3.6 Ethical Issues

Permission was sought from the NACOSTI to undertake the research. Permission was also sought from the Chief Warden in charge of the Maasai Mara National Game Reserve for entrance into the sections of the study sites which fell within the reserve especially. Additionally, permission was also sought from the Sub-Regional manager in charge, WRA South Rift Sub -region so as to be allowed to use one of their staff to assist in the exercise and the equipment. Before the data gathering was executed, a visit was done to the target facilities where the researcher introduced himself and explained the purpose of the research which he emphasised to be for academic purposes. He then sought for consent from the management. The schedule of the data gathering exercise was shared with the management. The information gathered was treated with utmost confidentiality.

CHAPTER FOUR

RESULTS AND DISCUSSION

3.0 Introduction

This chapter gives the results of the analysis for the samples collected from various points and also the outcome of the ANOVA test. It further provides a detailed discussion of the results.

4.1 Results of the Study

This section presents the results according to the objectives;

4.1.1 Quality of wastewater in four tourist facilities within the Maasai Mara National Game Reserve

The facilities utilize different approaches in treating wastewater. These are, septic tank and soak away pit at AA lodge, aerated treatment plant for Simba lodge, Septic tank, soak away and 2 lagoons at Sarova and single septic tank at Sentrim lodge. The parameters determined for the wet and dry season is in this study are shown in table 4.1below

4.1.1.1 pH

The wastewater from all the facilities had pH values that were within the limits set by the NEMA water quality standards (6.5-8.5) both during the wet and dry seasons. The pH values for AA lodge during the during the dry season were lower compared to the limits set in the NEMA water quality regulations.

4.1.1.2 Temperature

The temperatures of the wastewater in all the facilities ranged from 22.0 °C in Sentrim lodge to 27.2°C in Sarova Mara. The temperatures for the wastewater from all the facilities in all seasons did not exceed levels set out in the NEMA water quality regulations. (+-3 of ambient temperature).

4.1.1.3 Dissolved Oxygen

The wastewater in all the facilities had lower DO levels compared to permissible levels set by the Water quality Regulations (>5 mg/L). DO levels of the wastewater in all facilities were higher during the dry season the wet season.

4.1.1.4 Electrical Conductivity

The wastewater from all facilities generally had E.C. levels beyond permissible levels set out in the NEMA water quality regulations (<400 μS/cm) during the dry and wet seasons.

4.1.1.5 Turbidity

As shown in table 4.1 below, wastewater from AA lodge and Sentrim lodge had lower turbidity levels during both dry and wet seasons compared to permissible levels spelt out by the water quality standards (17.50 NTU,18 NTU); (33.20 NTU,46.60 NTU). Wastewater from Simba lodge and Sarova during both the dry and wet seasons turbidity had turbidity levels beyond regulatory limits (153.70 NTU, 175.10 NTU); (121.30 NTU, 113.90 NTU).

4.1.1.6 Chemical Oxygen Demand

Wastewater from all the four facilities during the wet season had higher COD values than regulatory levels (30mg/L). Wastewater from AA lodge, Simba lodge and Sentrim during the dry season had lower COD levels (6.50Mg/l), (22.20mg/L), and (11.50mg/L) than permissible level.

4.1.1.7 Biochemical Oxygen Demand (BOD_5)

BOD_5levels in wastewater from Simba lodge, Sarova and Sentrim were beyond permissible limits (30mg/L). Wastewater from AA lodge had lower BOD_5than regulatory limits.

4.1.1.8 Nitrates

The wastewater from AA lodge and Sarova had Nitrates levels that were within regulatory limits (2 guideline value) during both the dry and wet seasons (0.10 mg/L, 0.20mg/L); (0.50mg/L, 0.50mg/l). Wastewater from Simba lodge and Sentrim during the dry season had Nitrates levels beyond the regulatory limits (2.40mg/ L); (3.00mg/L).

4.1.1.9 Phosphorus

Phosphates levels in wastewater from AA lodge and Sarova were within regulatory thresholds (2 guideline value) during both the dry and wet seasons (1.30 mg/L, 0.60mg/L); (1.90mg/L, 1.50mg/l). Wastewater from Simba lodge and Sentrim during the dry season had Nitrates levels exceeded regulatory levels (8.00mg/ L); (7.00mg/L).

4.1.1.10 Total Suspended Solids (TSS)

Wastewater from Simba lodge, Sarova lodge and Sentrim had TSS levels beyond regulatory standards (1688.33mg/L,933.33 mg/L); (2485mg/L, 2506mg/l), (2487.33mgg/L, 1246.67mg/L). The TSS levels in the wastewater were generally higher during the dry season than the wet season.

4.1.1.11 Coliforms

The wastewater from all the facilities during all seasons had coliform values that were far beyond the limits set by NEMA water quality regulations. The wastewater generally had higher total coliform levels during the dry season than the wet season.

Table 4.1: Seasonal variation in effluent quality in the four facilities

Season	Facilities / Parameter	Temp (°C)	pH	DO (Mg/L)	COD (Mg/L)	BOD (Mg/L)	Turbidity (NTU/s)	E.C. (µ /cm)	Nitrates (Mg/L)	Phosphates Mg/L	TSS Mg/L	Coliforms CFU/L
Wet	AA Lodge	22.2	7.2	0.4	80	20.7	17.5	823.9	0.1	0.6	13.33	327700
	Simba Lodge	21.7	6.9	0.4	333.3	66.7	153.7	744.8	0	1.8	933.33	3367500
	Sarova	27.2	7.7	0.4	800	175	121.3	450.8	0.5	1.5	2506.7	1033333
	Sentrim	22	7.1	0.2	80	34.5	33.2	561.6	0.4	1.8	1246.7	3073933
Dry	AA Lodge	22.7	5.1	2.5	6.5	10.2	18	776.7	0.2	1.3	15	614400
	Simba Lodge	22.8	7.1	2.7	22.2	43	175.1	937.1	2.4	8	1688.3	947267
	Sarova	26	7.7	1.8	58.3	87.5	113.9	327.1	0.5	1.9	2485	43653333
	Sentrim	21.7	7.1	0.2	11.5	31.7	46.6	692.1	3	7.6	2487.3	3015000

4.1.2 Response on dry and wet seasonal difference in quality of water from the facilities

As shown in table 4.2 below, the results of the ANOVA for the parameters for the wet and dry wet season at ($p<0.05$) alpha level.Dissolved Oxygen [$F(2,33)=0.06$, $P^*=0.006$] during dry season and [$F(2,33)=57.12$, $P^*=<0.001$] during wet season. Total Suspended Solids [$F(2,33)=6.33$, $P^*=0.005$] during dry and [$F(2,33)=11.21$, $P^*=<0.001$] wet season and Phosphates[$F(2,33)=6.078$, $p^*=0.006$] during the dry and [$F(2,33)=0.064$, $p^*=0.001$] wet season showed significant difference between the dry and wet seasons.

Temperature [$F(2, 33)=0.60$, $P=0.560$] for dry and wet season [$F(2,33)=1.04$, $P=0.364$]; Turbidity [$F(2,33)=0.413$, $P=0.670$] during the dry and [$F(2,33)=0.87$, $P=0.427$] during wet season; pH [$F(2,33)=0.699$, $P=0.504$] during dry and [$F(2,33)=3.031$, $P=0.062$] during wet season; Biochemical Oxygen Demand (BOD) [$F(2,33)=0.94$, $P=0.401$] .During dry and [$F(2,33)=1.31$, $P=0.283$] during the wet season; Chemical Oxygen Demand (COD) [$F(2,33)=0.28$, $P=0.756$] during dry and [$F(2,33)=0.17$, $P=0.846$] during the wet season; Nitrates [$F(2,33)=0.64$, $P=0.535$] during the dry and [$F(2,33)=0.32$, $P=0.729$] during the wet season; Electrical Conductivity[$F(2,33)=0.68$, $P=0.513$]during dry season and [$F(2,33)=0.05$, $P=0.950$] during the wet season and coliforms [$F(2,33)=0.00$, $P=0.999$] during the dry and [$F(2,33)=1.10$, $P=0.345$] during the wet season showed no significant differences.

Table 4.2: ANOVA for Parameters from effluent during dry and wet season

Parameter	***p*-value**
pH dry seasons	[F(2,33)=0.699, P=0.504]
pH Wet seasons	[F(2,33)=3.031, P=0.062]
BOD dry season	[F(2,33)=0.939, p=0.401]
BOD Wet season	[F(2,33)=1.313, p=0.283]
COD dry season	[F(2,33)=0.282, p=0.756]
COD Wet Season	[F(2,33)=0.168, p=0.846]
DO Dry season	[F(2,33)=6.061, p*=0.006]
DO Wet season	[F(2,33)=57.115, p*=0.001]
Turbidity Dry	[F(2,33)=0.413, p=0.665]
Turbidity Wet season	[F(2,33)=0.874, p=0.427]
Conductivity Dry season	[F(2,33)=0.681, p=0.513]
Conductivity Wet season	[F(2,33)=0.052, p=0.950]
Temperature Dry season	[F(2,33)=0.591, p=0.560]
Temperature Wet season	[F(2,33)=1.042, p=0.364]
Nitrates Dry Season	[F(2,33)=0.638, p=0.535]
Nitrates Wet season	[F(2,33)=0.318, p=0.729]
Phosphate Dry season	[F(2,33)=6.078, p*=0.006]
Phosphate Wet season	[F(2,33)=0.064, p*=0.001]
Coliforms Dry Seasons	[F(2,33)=0.001, p=0.999]
Coliforms Wet Seasons	[F(2,33)=1.100, p=0.345]
TSS Dry season	[F(2,33)=6.332, p*=0.005]
TSS Wet Season	[F(2,33)=11.210,p*=0.001]

*p**- shows significant difference

4.1.3 The effect of the wastewater treatment approaches on water quality

The findings of determining the effects of wastewater treatment approaches on water quality are presented in Tables 4.3, below. The water quality indices ranged between 25 - 50. The septic and lagoons treatment approach at Sarova reported the highest efficiency with a water quality index of (40) while the single septic treatment system at Sentrim (26) with a single septic tank recorded the least efficiency.

Table 4.3:Water Quality Indices (wqi) of effluent from different treatment plants

Parameter	AA (Septic & Soak away)	Simba (Treatment plant)	Sarova (septic tank & Lagoons)	Sentrim (Single septic Tank)
pH	7.75	7.07	7.09	6.88
BOD (Mg/L)	175	34.5	20.67	66.67
COD (Mg/L)	800	80	80	333.33
DO (Mg/L)	0.39	0.18	0.45	0.43
Turbidity (NTU)	121.33	221.12	17.45	153.67
E.C (µS/cm)	450.83	561.6	823.9	744.77
Temp (° C)	27.2	22	22.23	21.73
Nitrates (Mg/L)	0.46	3.03	0.24	2.41
Phosphates (Mg/L)	1.53	1.81	0.64	1.82
Coliforms (Cfu/100ml)	131000000	3010000	325000	43700000
TSS (Mg/L)	1306.67	1810	120	953.33
WQI	27	31	40	26

4.2 Discussion

4.2.1 The quality of wastewater in four tourist facilities within the Maasai Mara National Game Reserve

The study assessed the effects of liquid waste management approaches in high end hotels on water quality in Sekenani within Maasai Mara Game Reserve, Kenya. As shown in table 4.1 above, pH values of the wastewater from Sarova, Simba and Sentrim during the wet and dry seasons were within limits for discharge in the environment and were generally alkaline. This could be attributed to bicarbonates and presence of detergents and soap. These findings were nearer those in literature by (Monney et al., 2013) who reported pH levels of 7.58 during the dry and 7.87 during the wet season in his study on impacts of wastewater from urban slums in Ghana. The findings also corresponded with those of (Ngugi, 2014) who reported pH values of 7.47 in her study of effluent from Olonana Camp within the Mara river Basin, Kenya. However, these results did not correspond with those in literature by (Atwebembeire et al., 2019) who reported higher pH values (8.6) despite being within the standards in his study on physic-chemical quality of effluent from Taso sewerage treatment plant draining in River Rwizi in Uganda. The pH value for the wastewater from AA lodge during the wet season was acidic. This could be attributed to anaerobic degradation of organic matter resulting in the production of organic acids and gases such as CO_2 and hydrogen ions which upon dissolution produce mild organic acids hence lowering the pH (IETC-UNEP, 2002). Wastewater with such pH results in corrosion of pipes (KEBS, 2010) leading to increased cost of maintenance of the sewerage infrastructure unless subjected to further treatment.

The temperatures of the wastewater from facilities in the study site as shown in table 4.1above were generally within the ranges recommended by the NEMA Water quality regulations. These findings were consistent with those reported in literature by (Chebor et al. 2016) who reported temperatures of 20°C his studybut not (Monney et al., 2013) reported higher temperature ranges of 30.08° C during the dry and 28.9°C during the wet season in his study. Higher temperatures have a tendency of limiting oxygen availability water therefore may affect aquatic life in receiving water bodies.

The DO levels of wastewater from the facilities were generally lower compared to the limits set in the NEMA water quality standards (5 mg/L). This could be attributed to the fact that the effluent had high levels of organic matter. These results were similar to those of (Monney et al., 2013) who found lower DO levels (<0.01mg/L and 0.21mg/L) during dry and wet season respectively in the effluent than the limits set in standards during his study. However, these findings did not agree with those in literature by (Bharvand, 2019), (Amotayo et al., 2017) and (Atwebembeire et al., 2019) who reported DO levels of 10 mg/L, 20 mg/L, 68.27 Mg/L in their studies at Kermanshah wastewater treatment plant in Iran, treatment plant in Lagos Nigeria, and Taso wastewater treatment plant Uganda respectively. The low DO levels of the effluent from the wastewater is damaging to aquatic life upon discharge into water bodies as it can cause a dip in DO levels in the water though this depends on the volume. (USEPA, 2000) asserts that waters with extremely low DO are not able to support aquatic life.

High E.C in the wastewater from the facilities than the limits set in NEMA water quality regulations could be attributed to high concentration of ions. These findings were near those reported in literature by (Chebor et al., 2016) and (Atwebembeire, et al.2019) who reported E.C levels of about 1000µS/cm and 816 µS/cm in their studies. However, these findings do not agree with those of (Miruka, 2016) and (Echiegu et al., 2016) who reported E.C levels 0.5 µS/cm - 6.34 µS/cm and 0.052µS/cm that were lower than limits set by regulatory agencies in their studies at Kariobangi's wastewater treatment plant in Kenya and Nsukka wastewater treatment plant in Nigeria respectively. Wastewater with high conductivity may affect aquatic organisms as this limits light penetration into the water body therefore aquatic photosynthetic organisms will be impacted negatively therefore limiting the amount of oxygen for aerobic processes in the water body.

As shown in table 4.1 below, high turbidity levels in wastewater from Simba lodge and Sarova could be associated with high concentrations of organic and inorganic matter present in the wastewater. These findings were similar to those reported in literature by (Atwebembeire et al., 2019) who reported turbidity levels of 216 NTU in his study but not similar to those in literature by (Miruka, 2016) who reported turbidity levels within limits11.70 NTU - 62.40 NTU set by NEMA standards in his in study. Wastewater with high turbidity may affect aquatic organisms as this limits light penetration into the water body therefore aquatic photosynthetic organisms will be impacted negatively thereby limiting the amount of oxygen for aerobic processes in the water body.

The higher COD values than limits set in the regulatory standards were consistent with those in literature by (Miruka,2016) and (Echiegu et al., 2016) who reported higher COD values 170 - 315mg/L and 264mg/L in the effluent from treatment plant in their studies in Kenya and Nigeria. These findings however did not correspond with those in literature by (Amoo et al., 2017) and (Amotayo et al., 2017) who reported 48.2 mg/ L and 20 mg/L in their studies on wastewater treatment plants in Wupa and Lagos, Nigeria respectively. The higher COD levels in the wastewater implied that the levels of organic matter requiring breakdown by chemical processes was high. This could affect processes in aquatic life forms that depend on oxygen as they would die due to hypoxia.

As shown in table 4.1 above, the higher Biochemical Oxygen Demand values in the effluent from the three facilities; Sarova Mara, Simba Lodge and Sentrim lodge, means the operations in the facilities result in production of wastewater with higher concentration of organic matter. These were near those reported in literature by (Miruka, 2016) and (Echiegu et al., 2016) who reported110-280 mg/L and 102mg/L in their studies of wastewater treatment plants in Kariobangi, Kenya and Sunkka wastewater treatment plant in Nigeria. These findings however, contradicted those those reported in studies by (Ngugi, 2014), (Amotayo et al., 2017) and (Amoo et al., 2017) who reported lower BOD values of 23 mg/L, 3 mg/L and 8.9 mg/L compared to the limits set by NEMA standards and WHO in their studies on effluent from wastewater treatment plants in Kenya, Lagos in Nigeria and Wupa in Abuja, Nigeria. This therefore implies that lots of the oxygen is utilized in breaking down the organic matter in the wastewater leaving very little for supporting biological processes. Unless the wastewater is subjected to further treatment, lesser oxygen is available to support aquatic life process in receiving water bodies (Monney et al., 2013; Standel, 1990).

The Nitrates levels in the effluent were generally within the limits set in the NEMA water quality regulations. This finding corresponded with those reported in literature by (Echiegu et al., 2016) whore reported 0.14mg/L in his study. These findings were not similar to those reported in literature by (Atwebembeire et al., 2019) and (Amotayoet al., 2017) who reported Nitrates levels of 5.83mg/l and 22.11 mg/L in their studies in Uganda and Nigeria. This excessive presence of the Nitrates in wastewater causes algal blooms when released in receiving water bodies without further treatment results in the death of aquatic organisms.

The generally lower phosphate levels in wastewater corresponded with those reported by (Echiegu et al., 2016) who reported phosphate levels of 1.845 Mg/Lin his study in Nigeria but not those by (Atwebembeire et al., 2019) who reported phosphate levels of 32.20mg/L. They associated these with animal wastes, fertilizer, cleaning products, cosmetics, medicated shampoos, food products and urine. From the study, these could be as a result of detergents and soaps that are used in the kitchens and bathrooms of the tourist facilities and also feaces and urine. The high Phosphates levels during the dry season could also be attributed to the highest usage of these detergents which could be attributed to the high tourist volumes the facilities recorded during this period compared to the wet season. When wastewater with high Phosphates content is discharged to the environment can lead to un-controlled algal growth hence depleting oxygen levels in recipient water.

TSS is a measure of particulate matter suspended in water and one of the important indicators of pollution in wastewater and also serves as a good indicator for the turbidity of the water (Suleiman et al., 2016). The high TSS level in wastewater than the limits set in the standards could be attributed to the presence of inorganic particulate matter in the wastewater (Anikiaye et al. 2019). The higher TSS levels than limits set in NEMA standards did correspond with those reported. (Ngugi, 2014) reported high TSS (1076 mg/L) levels than those set in the limits by NEMA in her study of wastewater treatment plants within the Mara River basin in Kenya. However, these findings were not similar to those by (Amotayo et al., 2017) who reported TSS levels of 14 mg/L that were within the limits set by regulatory agencies.

Higher TSS levels than limits may affect water clarity and lead to reduction photosynthesis. This ultimately results to less Dissolved Oxygen levels reaching the water from photosynthetic plants. In situations where light becomes completely blocked from bottom dwelling plants, photosynthesis stops and the plants die off leading to consumption of more of the oxygen inherent in the water by bacteria during decomposition of the plants. These lowered Dissolved Oxygen levels can lead to fish deaths. The elevated TSS levels may also result in increased surface water temperatures as the suspended particles absorb heat from sunlight, thereby further limiting oxygen permeability resulting in lower Dissolved Oxygen levels. These TSS levels can decrease clarity of water therefore leading to not only a reduced ability of fish to see and catch food but also escape predators. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development.

The higher coliform counts in the effluent than the limits set in standards by the water quality regulations corresponds with findings of (Miruka, 2016) who recorded higher coliform levels ($3.434x10^5$ Counts/100ml) compared to limits set by NEMA in Kariobangi wastewater treatment Plant in Kenya but did not correspond with findings from literature by (Echiegu et al,.2016) and (Amoo et al., 2017) who recorded 4.71 cfu/100ml and 100 cfu/100ml in their studies respectively. This could be attributed to the fact that the source of water for operations within the facility was recharging and also the fact that the facility sits in the Maasai Mara game reserve where animal feaces could have contributed to this total coliform load. The higher coliform counts in the wastewater during the dry season than the wet season corroborate findings of (Musyoki et al., 2013) and (Kannan, 2016) who reported higher bacterial densities in dry season than wet season and attributed it to dilution by rain water. The higher coliform counts during the dry season is due to multiplication of the microbes at high temperature. This wastewater therefore has to be subjected to further treatment so as the coliforms, BOD, COD and TSS levels can get to the limits set by NEMA before discharge to the environment.

4.2.2 Dry and wet seasonal difference in quality of water from the facilities

The pH values for the wastewater as shown in table 4.1 above did not show significant differences with seasons, a finding that deviates from studies by (Monney et al., 2013) who found significant variation between pH and seasons ($p>0.05$)from a study on impacts of wastewater from urban slums in Ghana (Chebor et al., 2016) however, reported statistically significant variation ($p<0.001$) between pH and seasons in his study on effects of seasonal variation on performance of conventional wastewater treatment system in Eldoret, Kenya. Temperature showed no significant variation between seasons, a finding that did not correspond with literature by (Chebor et al., 2016) who found statistically significant variation ($p<0.001$) between temperature and seasons his study.

Higher temperatures have a tendency of limiting oxygen availability water therefore may affect aquatic life in receiving water bodies. The DO levels as shown on table 4.2 above showed statistically significant difference between dry and wet season, findings that were similar to those of (Kannan, 2016) who reported statistically significant difference ($p=0.005$) between the DO levels and seasons in his study on seasonal variation in physico-chemical and microbiological characteristics of sewerage water from sewerage treatment plants in India. As shown in table 4.2 above, E.C. levels in the wastewater showed no significant difference between seasons.

These findings were not in agreement with those of (Monney et al., 2013) and (Chebor et al., 2016) who reported $p<0.05$ and $p=0.001$ statistically significant difference in E.C. levels with seasons in their studies in Kenya and Ghana respectively.There was no statistically significant difference between turbidity levels and seasons, findings that were similar to those reported by(Zare, 2013) who reported turbidity values had no statistically significant difference ($p<0.05$) between seasons in his study on annual and seasonal variation of selected parameters in Parsabad water treatment plant in Iran. COD values showed no statistically significant seasonal differences findings which contradicted those in literature by (Kannan, 2016) and (Chebor et al., 2016) who reported statistically significant differences between COD and seasons $p=0.001$and $p=0.001$ in their studies in India and Nairobi, Kenya respectively. The BOD values in wastewater from the facilities showed no statistically significant difference with seasons, findings which did not agree with those in literature by (Cheboret al., 2016) and (Kannan, 2016) who reported statistically significant difference $p=0.001$ and $p=0.006$ between BOD and seasons in their studies on wastewater treatment plants in Eldoret, Kenya and rom Iran respectively.

The Nitrates levels also showed no statistically significant difference between seasons as shown in table 3.2 above, findings that were not similar to those reported in literature by (Monneyet al.2016) and (Kannan, 2016) who reported statistically significant difference between Nitrates level with seasons ($p<0.05$) and ($p<0.5$) in their studies at Urban slums treatment plant in Ghana, domestic sewerage from Cuttack city in India in India respectively. Phosphate levels showed no statistically significant difference between seasons as shown on table 4.2. These findings contradicted those by (Monney et al., 2013) and (Kannan, 2016) who reported statistically significant difference between phosphate levels and seasons ($P<0.05$) and ($p<0.05$) in their studies on wastewater treatment from urban slums in Ghana and sewerage treatment plants in India. As shown in table 4.2 above, the TSS levels showed statistically significant difference between seasons.

These findings correspond to those by (Chebor et al. 2016) and (Monney et al., 2013) who reported statistically significant difference between TSS levels and seasons ($p=0.001$) and ($p=0.05$) in their studies of effluent from wastewater treatment plants in Kenya and urban slums in Ghana respectively. The coliform counts showed statistically significant difference with seasons as shown in table 3.2 above. These findings were consistent with ones reported by (Musyoki et al., 2013) who also reported statistically significant difference between coliform counts with seasons ($p<0.001$) in his study of wastewater treatment plant in Dandora, Kenya.

4.2.3 The effects of the wastewater treatment approaches based on the water quality

Despite most parameters not meeting the standards for discharge to the environment, integrated septic tank and lagoons treatment approach in Sarova lodge recorded the highest efficiency as shown in table 4.3 above. These findings correspond with findings from other studies such as (Mairi et al., 2012) and (Ngugi, 2014) who reported higher efficiency septic tank and lagoon system approach in their studies in Tanzania and Mara River Basin in Kenya respectively. They attributed this to the fact that after the effluent goes through anaerobic processes in the septic tanks and the soak away pits, the ponds afford adequate time for the waste to be broken down further by aerobic microbes hence further purifying the wastes.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This section contains information on the conclusion drawn from the study. It additionally provides recommendations both in terms of areas for further research and policy.

5.1.Conclusion

From the results of the study, the water quality from the four facilities was generally poor since Coliforms, TSS, BOD and COD were beyond the maximum allowable limits for discharge of effluent into the environment. There was no seasonal variation in quality of water from the four facilities since eight of the parameters tested Temperature, pH, Turbidity, coliforms, Electrical Conductivity, BOD, COD and Nitrates did not exhibit seasonal variation except T.S.S, phosphates and Dissolved Oxygen. The treatment approaches thus have an effect on the quality of wastewater. Wastewater from the hotels and lodges is likely to be detrimental to the receiving aquatic biota especially those that cannot tolerate low oxygen level.

5.2 Recommendations

From this study we recommend that:

i. Adoption of sustainable liquid waste treatment approaches such as constructed wetlands by hotels and lodges
ii. The Ministry of Water and Narok County Government to construct a sewerage system in the area

iii. Strict monitoring of the regulated facilities through regular joint inspections by NEMA, County government, water Resources Authority to ensure they comply with the standards set out in the water quality regulations 2006

iv. Awareness programmes by NGOs operating in the area and the county government of Narok with a view to sensitize locals on the need to treat water before drinking especially during the wet season to avoid spread of diseases

v. Review of the water quality regulations so that NEMA takes a lead role in the collection and analysis of water samples instead of the management of the facilities

vi. Further studies to be done by academia on the variability within the treatment system such as age, of the treatment system, number of guests and how this affects the treatment process

vii. Further studies by academia on impacts of the various treatment approaches on the quality of water in the recipient water sources by examining indicator species harboured by such water

viii. Further research by academia in similar ecosystems to establish whether the findings will be similar to the ones of this study.

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LIST OF APPPENDICES

Appendix 1: Letter to WRA Sub Regional Manager

JILANI CHIGULU CHIRO
P.O. BOX 510-20500
NAROK
12TH MAY, 2016

THE SUB-REGIONAL MANAGER
WATER RESOURCES MANAGEMENT AUTHORITY
SOUTH RIFT SUB-REGION
P.O. BOX 1029-20500
NAROK
Dear Sir,

RE: REQUEST FOR AN OFFICER TO ASSIST IN DATA COLLECTION FOR MY RESEARCH PROJECT.

I have been pursuing a Masters of Environmental Studies course at the Maasai Mara University since 2014. Having successfully defended my research proposal in February 2016, I am supposed to start collecting samples from the wastewater treatment systems of 5 facilities for analysis of both physico-chemical (PH, turbidity, Dissolved Oxygen, conductivity, Chemical Oxygen Demand, biological oxygen demand, phosphates, Nitrates and Total Suspended Solids) and biological (coliforms) parameters at the WRMA laboratory in Nakuru during the rainy and dry seasons at Sekenani area within the Maasai Mara ecosystem.

The time for collection of the samples during the rainy season is due and therefore the work is scheduled to take place on 18th, 25thand 1st of June, 2016. The purpose of this letter therefore is to request your good office to appoint an officer to assist in the collection and delivery of the same samples to the Laboratories in Nakuru for analysis.

Sincerely yours,

JilaniChigulu Chiro

Appendix 2: Letter to WRA Sub Regional Manager

JILANI CHIGULU CHIRO
P.O. BOX 510-20500
NAROK
25TH JULY, 2016

THE SUB-REGIONAL MANAGER
WATER RESOURCES MANAGEMENT AUTHORITY
SOUTH RIFT SUB-REGION
P.O. BOX 1029-20500
NAROK
Dear Sir,

RE: REQUEST FOR EQUIPMENT AND AN OFFICER TO ASSIST IN DATA COLLECTION FOR MY RESEARCH PROJECT.

I have been pursuing a Masters of Environmental Studies course at the Maasai Mara University since 2014. Having successfully defended my research proposal in February 2016, I am supposed to start collecting samples from the wastewater treatment systems of 5 facilities for analysis of both physico-chemical (PH, turbidity, Dissolved Oxygen, conductivity, Chemical Oxygen Demand, biological oxygen demand, phosphates, Nitrates and Total Suspended Solids) and biological (coliforms) parameters at the WRMA laboratory in Nairobi during the dry and high tourist season at Sekenani area within the Maasai Mara ecosystem.

The dry and high tourist season is due and given that the peak tourist season in the ecosystem is very short, the work is scheduled to take place on 3/8/2016, 10/8/2016 and 18/8/ 2016. The purpose of this letter therefore is to request your good office for equipment and an officer to assist in the collection of samples on the dates indicated above.

Sincerely yours,

JilaniChigulu Chiro

Appendix 3: Letter to Chief Park Warden

JILANI CHIGULU CHIRO
P.O. BOX 510 - 30500
NAROK

10th May, 2016

THE CHIEF PARK WARDEN
MAASAI MARA NATIONAL GAME RESERVE
P. O. BOX
NAROK

Dear Sir,

RE: ACCESSING THE PARK FOR ACADEMIC RESEARCH WORK

This is to request for unrestricted access to the park for purpose of collecting samples for my Master of Science research at the Maasai Mara University during the months of May – June and August to September, 2016.

Thank You

Jilani Chigulu Chiro

Appendix 4: Ethical Issues Letter

MAASAI MARA UNIVERSITY

P.O. BOX 861 – 20500, Narok, Kenya **Tel: +254 – 20 -2066042**
www.mmarau.ac.ke **+254 – 20 - 8081874**

SCHOOL OF TOURISM AND NATURAL RESOURCE MANAGEMENT

26th July, 2017

RESEARCH PERMITS SECTION
NACOSTI
UTALII HOUSE

RE: JILANI CHIGULU CHIRO (MES10/1007/2014)

We wish to confirm that the above named is a *bona fide* student at Maasai Mara University pursuing an MSc. in Environmental Studies from the School of Tourism and Natural Resource Management. His proposed research topic is: ***EFFECTS OFLIQUID WASTE MANAGEMENT APPROACHES ON QUALITY OF WATER FROM VARIOUS SOURCES IN SEKENANI, MAASAI MARA GAME RESERVE***.

He would like to apply for a research permit from NACOSTI before he can proceed for field work.

We wish to confirm that the candidate has adhered to all research protocol requirements of the University and his proposed research has been rated as having no known adverse impacts onto the environment and does not pose any ethical concerns.

This is therefore to request your office to issue him with a research permit.

Yours sincerely

Prof. Romulus Abila, Ph.D.
Department of Environmental Studies, Geography and Agriculture
School of Tourism and Natural Resources Management
Maasai Mara University

Appendix 5: NACOSTI Research Authorization Letter

NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/16/31250/12827**

Date **26th October, 2016**

Jilani Chigulu Chiro
Maasai Mara University
P.O. Box 861-20500
NAROK.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "***Effects of liquid waste management approaches on quality of water from various sources in Sekenani, Maasai Mara,***" I am pleased to inform you that you have been authorized to undertake research in **Narok County** for the period ending **24th October, 2017.**

You are advised to report to **the County Commissioner and the County Director of Education, Narok County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Narok County.

The County Director of Education
Narok County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

Appendix 6: NACOSTI Research Permit

THIS IS TO CERTIFY THAT:
MR. JILANI CHIGULU CHIRO
of MAASAI MARA UNIVERSITY,
510-20500 narok,has been permitted to
conduct research in *Narok County*

Permit No : NACOSTI/P/16/31250/12827
Date Of Issue : 26th October,2016
Fee Recieved :ksh 1000

on the topic: *EFFECTS OF LIQUID WASTE MANAGEMENT APPROACHES ON QUALITY OF WATER FROM VARIOUS SOURCES IN SEKENANI, MAASAI MARA*

for the period ending:
24th October,2017

....
Applicant's Signature

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

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officer will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one (1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEACH CLEARANCE PERMIT

Serial No.A 11418

CONDITIONS: see back page