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Effects of Liquid Waste Management Approaches in High End Hotels on Wastewater Quality in Sekenani, Masai Mara Game Reserve, Kenya

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Abstract The world famous Masai Mara Game Reserve is experiencing an unprecedented expansion in tourist facilities to accommodate increasing traffic in this water scarce environment. A major direct environmental impact of this expansion is wastewater released to the fragile environment from these facilities. The objective of this study is to examine the effects of wastewater management methods on quality of wastewater in 4 purposively selected high-end tourist facilities located in Sekenani within Masai Mara Game Reserve by assessing seasonal quality of effluent discharged. Water samples were collected randomly from the effluent of the facility during both wet and dry seasons and were subjected to analysis for: pH, Temperature, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Phosphates, Nitrates, Electrical Conductivity (E.C), Dissolved Oxygen (DO), Turbidity, Total Suspended Solids (TSS) and Coliforms. Data were analysed using SPSS software and tested using analysis of Variance at 0.05 confidence level. Quality of wastewater was generally poor and dissolved oxygen, TSS, and coliforms showed variation between the wet and dry seasons. Single septic tank and septic tank and soak away treatment approaches produce water with the lowest quality based on Water Quality Index (WQI). This poses a great threat to not only the health of the communities relying on the recipient rivers as sources of water but also the Masai Mara ecosystem. To mitigate against discharge of poor quality wastewater to the environment, we recommend incorporation of modern innovative environmentally sustainable wastewater management technologies e.g. constructed wetlands to water treatment systems 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.

Keywords: *Sekenani, Masai Mara Game Reserve, wastewater, wastewater management, physico - chemical parameters*

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1. Introduction

Masai Mara Game Reserve (MMGR) is located in the Mara river basin (MRB), an ecologically sensitive semi-arid landscape (ASAL) in Kenya [1]. The Masai Mara Game Reserve hosts the 7th Wonder of the World i.e. the annual wildebeest migration across the Mara River from Tanzania’s Serengeti ecosystem [2]. The game reserve is therefore one of the premier global biodiversity-based tourism destinations. To accommodate the heavy tourist traffic, a number of tourist facilities including high end hotels and lodges have been developed in the Masai Mara Game Reserve and its environs. The Mara river basin, unfortunately is a highly water stressed environment [3]. The basin is experiencing human induced threats resulting from land use and climate changes, increase in human population and unsustainable use of ecosystem goods and services e.g. overgrazing and deforestation [4,5,6,7]. These factors are contributing to degradation of the Mara basin bio physical environment and presents a serious threat to water resources in this ecosystem.

A number of ephemeral rivers and streams transverse the Masai Mara Game Reserve and provide convenient treated wastewater discharge points to the numerous tourist lodges and hotels either directly or through aquatic systems connectivity [8]. This is likely to compromise the water quality and ecological integrity of these aquatic ecosystems and their ability to support and provide life support to dependent biodiversity and human communities. It is therefore important to protect the river systems from all forms of aquatic pollution.

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 [9]. The wastewater is both an asset and a problem in an urbanizing world. Untreated wastewater is a critical source of pollution and a hazard to human health and ecosystems services [10,11]. The costs related to the pollution of water bodies may range from degradation of ecosystem services to adverse impacts on human health while the overall economic value of the goods and services rendered by healthy coasts and oceans are worth trillions of dollars [12]. 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. Wastewater has diverse and interrelated and cascading effects on the receiving environments. These effects are likely to be more compounded and severe in fragile conservation areas like the Masai Mara Game Reserve.

Sekenani area within the Masai 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 waste water 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 Masai Mara Game Reserve have been terrestrial biodiversity based. Studies targeting the Mara river tributaries have focused largely on effects of catchment based land use activities on river water quality [7,8,13] 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 to protect and conserve the Masai Mara Game Reserve [5]. To safeguard the environmental integrity of the Masai Mara Game Reserve especially its aquatic habitats, it is important to obtain information regarding quality of wastewater discharged to the environment. Such information is important in formulating policies and enforcing environmental standards to protect this fragile ecosystem. This study therefore sought to assess quality of effluent discharged from different tourist facilities in Sekenani area of Masai Mara Game Reserve and their likely environmental effects on water quality and biodiversity of recipient sources of water in the wider Sekenani region of Narok County by pursuing the following objectives: determine quality of wastewater from 4 purposely selected high end hotels and lodges, examine wet and dry seasonal differences in water quality from the four facilities and evaluate the effects of various wastewater treatment approaches used by the facilities on the water quality.

2. Materials & Methods

2.1. Research Design

The study adopted experimental, purposive and quantitative research design.

2.2. Study Area

The study was conducted in tourist hotels and lodges located within Sekenani, a town center within the Mara River Basin (MRB). The MRB is located in the south - western of Kenya and Tanzania and covers approximately 13,500 km^2 [3]. Sekenani lies on longitude 1º31’8’’S and latitude 35º20’16’’E.

Sekenani area occupies an area measuring 642 Km^2 and is located at the boundary between the Masai Mara Game reserve and private land and two group ranches namely the Siana and Koiyaki Group Ranches. Located about 100km from Narok town, the area lies at an altitude of 1811 meters above the Sea level. Annual rainfall in this locality averages 600mm and is distributed bimodally although currently the area experiences seasons of prolonged droughts. Natural vegetation is mainly Acacia woodlands and shrublands. Administratively, Sekenani lies in Sekenani Sub- location, Nkoilale Location in Mara Division of Narok West Sub-County within Narok County. Main economic activities of communities living around Sekenani include livestock keeping, bee keeping, basic business activities and tourism related ventures. The four tourist facilities purposively selected for this study were AA Lodge, Simba Lodge, Sarova Lodge and Sentrim Mara (Figure 1).

2.3. Data Collection

The study adopted a mixture of study designs. Purposive sampling was employed to identify the 4 high end tourist facilities for sampling. The four tourist facilities purposively selected for this study were AA Lodge, Simba Lodge, Sarova Lodge and Sentrim Mara. Within each facility, random sampling was used to take water samples from the effluent. At each of the sites shown in Figure 1, random sampling was done at each facilities’ point of effluent discharge in three occasions at one week’s interval during the wet (low tourist) season and during the dry (low tourist) season using standard sterile Duran bottles. All the samples were collected in the mid - morning hours (between 8.30Am and 10.30Am). The wet / low tourist season sampling was done on 24th May, 31st May and 7th June, 2016 while dry / peak tourist season on 10th August, 17th August and finalized on 24th of August 2016.

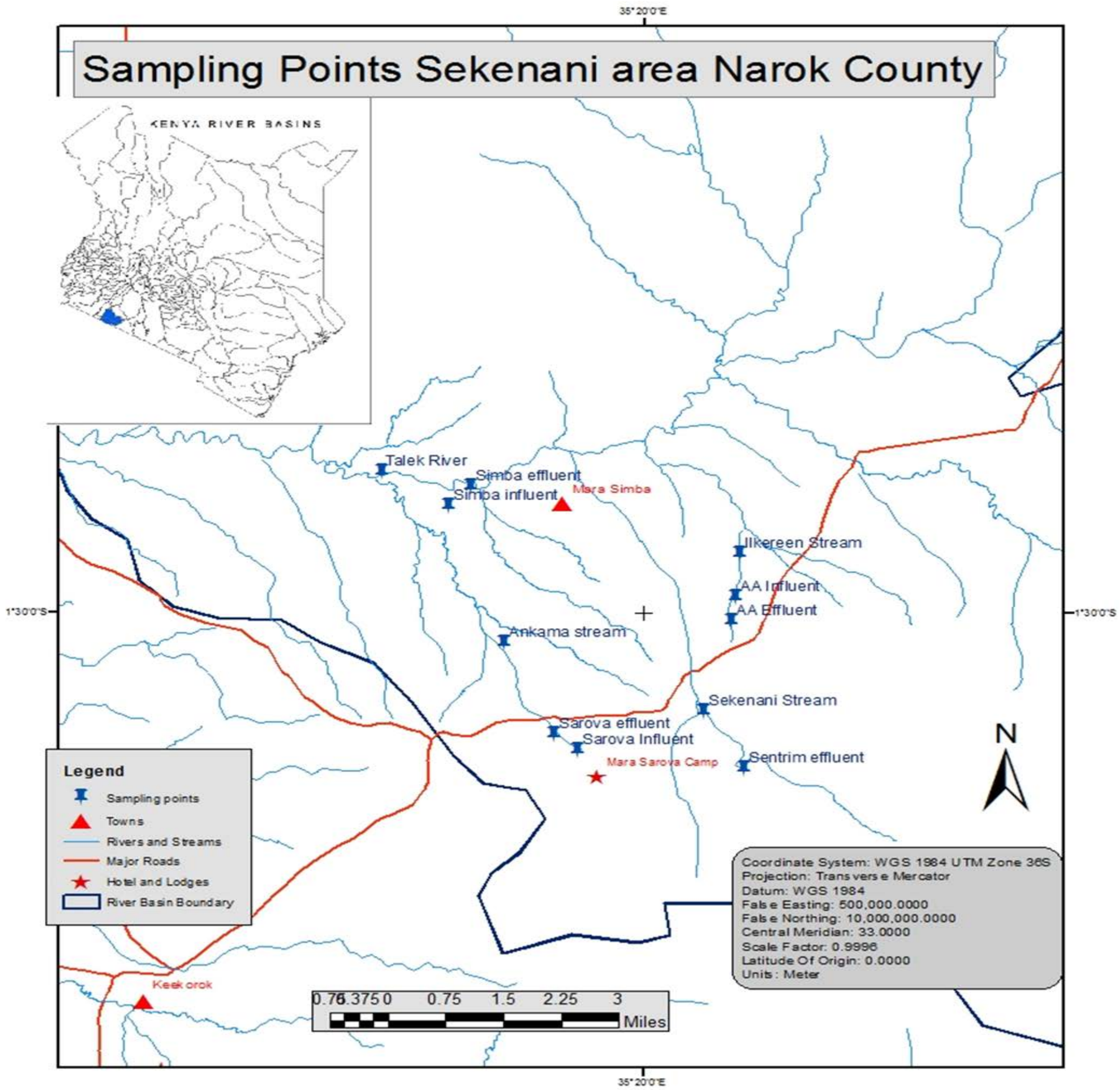

Figure 1. Map of Sekenani area showing sampling points in the study area

2.4. Physico-chemical & Biological Parameters

pH, Temperature, Dissolved Oxygen (DO), Electrical Conductivity (E.C) and Turbidity were determined using Pro Plus multi parameter water quality meter (DID 305). 20ml of the sample was put in a cell, rinsed with tissue paper then placed in a cell holder in the meter. The readings were taken directly after one minute from the meter. The same procedure was repeated in testing for all the 5 parameters. Chemical Oxygen Demand (COD) was assessed using titrimetric method as described in [14]. Biochemical Oxygen Demand (BOD5) was determined using BOD Oxi Top meter [15]. Nitrates were analysed using spectrophotometric method as detailed in [14]. Phosphates were determined using spectrophotometric method as described in [14]. Samples were examined for Total Suspended Solids (TSS) using gravimetric method as stipulated in the standard methods for analyzing water and wastewater [14]. Total Coliforms were analyzed using membrane filter technique as prescribed in [14].

2.5. Statistical Analyses

ANOVA analyses were done using SPSS version 20. 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. The data was organized by dry season and wet season and then analysed to check whether there was variation. [16].

2.6. Water Quality Index

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;

$$WQI = \frac{K \_ \Sigma_i^{Ciwi}}{\Sigma_i^{wi}}$$

Where:
K - Constant.
WQI- Highly polluted to good water quality ranging from 0.25-1.
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 [17]. The parameters used were selected based on its impacts on the overall quality of the water. Additionally, it is 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 [18]. 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. Results

3.1. Quality of Wastewater

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 in this study are shown in Table 1.

3.1.1. pH

The wastewater from all the facilities had pH values that were within the limits set by the National Environment Management Authority (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. The pH values varied between facilities.

3.1.2. 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 were within the limits set out in the NEMA water quality regulations. (+-3 of ambient temperature).

3.1.3. Dissolved Oxygen

The wastewater in all the facilities had lower DO levels compared to the limits set by the World Health Organization guidelines (>5 mg/L). DO levels of the wastewater in all facilities were higher during the dry season the wet season.

3.1.4. Electrical Conductivity

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

3.1.5. Turbidity

As shown in Table 1 below, wastewater from AA lodge and Sentrim lodge had lower turbidity levels during both dry and wet seasons compared to the limits set in the NEMA 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 had higher turbidity levels compared to the limits set in the NEMA water quality standards (153.70 NTU, 175.10 NTU); (121.30 NTU, 113.90 NTU).

3.1.6. Chemical Oxygen Demand

Wastewater from all the four facilities during the wet season had higher COD values than the limits set in the NEMA water quality regulations (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) compared limits set in the NEMA water quality regulations.

3.1.7. Biochemical Oxygen Demand (BOD_5)

Wastewater from Simba Lodge, Sarova and Sentrim had higher BOD_5 compared to the limits set in the NEMA water quality regulations (30mg/L). Wastewater from AA lodge had lower BOD_5 compared to the limits set in the NEMA water quality regulations.

3.1.8. Nitrates

The wastewater from AA Lodge and Sarova had nitrates levels that were within the limits set by the NEMA water quality regulations (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 nitrate levels that were beyond the limits set out in the NEMA water quality regulations (2.40mg/ L); (3.00mg/L).

3.1.9. Phosphorus

The wastewater from AA Lodge and Sarova had phosphates levels that were within the limits set in the NEMA water quality regulations (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 nitrate levels that were beyond the limits set out in the NEMA water quality regulations (8.00mg/ L); (7.00mg/L).

3.1.10. Total Suspended Solids (TSS)

Wastewater from Simba lodge, Sarova lodge and Sentrim had TSS levels beyond the limits set in the NEMA water quality regulations (1688.33mg/L, 933.33mg/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.

3.1.11. 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.

3.2. Seasonal differences in Water Quality

As shown in Table 2 below, the results of the ANOVA for the parameters for the wet and dry wet season at (p<0.05) are detailed on Table 2 below. Dissolved Oxygen [$F(2,33)=0.06$, $P^*=0.006$] during dry season and [$F(2,33)=57.12$, $P^*=<0.000$] during wet season, Total Suspended Solids [$F(2,33)=6.33$, $P^*=0.005$] during dry and [$F(2,33)=11.21$, $P^*=<0.000??$] 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 non-significant differences.

3.3. Water Quality Index (WQI)

The WQI values as indicated in Table 3 ranges 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 1. Seasonal variation in effluent wastewater quality in four high end hotels

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	824	0.1	0.6	13.33	327700
	Simba Lodge	21.7	6.9	0.4	333	66.7	153.7	745	0	1.8	933.33	3367500
	Sarova	27.2	7.7	0.4	800	175	121.3	451	0.5	1.5	2506.67	1033333
	Sentrim	22	7.1	0.2	80	34.5	33.2	562	0.4	1.8	1246.67	3073933
Dry	AA Lodge	22.7	5.1	2.5	6.5	10.2	18	777	0.2	1.3	15	614400
	Simba Lodge	22.8	7.1	2.7	22	43	175.1	937	2.4	8	1688.33	947267
	Sarova	26	7.7	1.8	58	87.5	113.9	327	0.5	1.9	2485	43653333
	Sentrim	21.7	7.1	0.2	12	31.7	46.6	692	3	7.6	2487.33	3015000

Table 2. ANOVA of 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]
Nitrate Dry Season	[F(2,33)=0.638, p=0.535]
Nitrate 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.

Table 3. Water Quality Indices (WQI) from effluent at 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)	0.42	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. Discussion

The study assessed the effects of liquid waste management approaches in high end hotels on water quality in Sekenani within Masai Mara Game Reserve, Kenya. As shown in Table 1, 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 [19] 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 [20] who reported pH values of 7.47 in her study of effluent from Olonana Camp within the Mara river Basin, Kenya. However, they did not correspond with those in literature by [21] 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 values for the wastewater as shown in Table 1 above did not show significant differences with seasons, a finding that deviates from studies by [19] who found significant variation between pH and seasons ($p>0.05$) from a study on impacts of wastewater from urban slums in Ghana. [22] 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. 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 [23]. Wastewater with such pH results in corrosion of pipes [24] 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 Figure 1 above were generally within the ranges recommended by the NEMA Water quality regulations. These findings were consistent with those reported in literature by [22] who reported temperatures of in 20°C his study but not [19] reported higher temperature ranges of 30.08° C during the dry and 28.9°C during the wet season in his study. As shown on Table 2, the temperature showed non-significant variation between seasons, a finding that did not correspond with literature by [22] who found statistically significant variation ($p<0.001$) between temperature and seasons in his study. Higher temperatures have a tendency of limiting oxygen availability in 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 [19] 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 [25,26] and [21] 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 DO levels as shown on Table 2 above showed statistically significant difference between dry and wet season, findings that were similar to those of [27] who reported no 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. 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. [28] 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 [22] and [21] who reported E.C levels of about 1000 µS/cm and 816 µS/cm in their studies. However, these findings do not agree with those of [29] and [30] who reported E.C levels 0.5 µS/cm - 6.34 µS/cm and 0.052 µS/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. The E.C. levels in the wastewater as shown in Table 2 did not show statistically significant difference with seasons. These findings were not in agreement with those of [19] and [22] 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. Wastewater with high conductivity may affect aquatic organisms as this affects the osmotic balance in freshwater organisms

As shown in Table 1, 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 [21] who reported turbidity levels of 216 NTU in his study but not similar to those in literature by [29] who reported turbidity levels within limits 11.70 NTU - 62.40 NTU set by NEMA standards in his in study. As shown on Table 2, there was no statistically significant difference between turbidity levels and seasons, findings that were similar to those reported by [31] 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. 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 [29] and [30] 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 [32] and [26] who reported 48.2 mg/ L and 20 mg/L in their studies on wastewater treatment plants in Wupa and Lagos, Nigeria. The COD levels showed no statistically significant seasonal differences as shown in Table 2, findings which contradicted those in literature by [27] and [22] 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 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 1, 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 [29,30] who reported 110-280 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 [20,26] and [32] 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. The BOD values in wastewater from the facilities showed no statistically significant difference with seasons as shown in Table 2. These findings did not agree with those in literature by [22] and [27] who reported statistically significant difference p=0.001 and p=0.006 between BOD and seasons in their studies in Eldoret, Kenya and from wastewater treatment plant in Iran respectively. 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 [19,33].

The Nitrate 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 [30] whore reported 0.14mg/L in his study. These findings were not similar to those reported in literature by [21] and [26] who reported nitrate levels of 5.83mg/l and 22.11 mg/L in their studies in Uganda and Nigeria. The nitrate levels also showed no statistically significant difference between seasons as shown in Table 2, findings that were not similar to those reported in literature by [19] and [27] who reported statistically significant difference between nitrate 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. 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 [30] who reported phosphate levels of 1.845 Mg/L in his study in Nigeria but not those by [21] who reported phosphate levels of 32.20mg/L. The phosphate levels showed no statistically significant difference between seasons as shown on Table 2. These findings contradicted those by [19,27] 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. 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 [34]. 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 [35] The higher TSS levels than limits set in NEMA standards did correspond with those reported [20] who 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 [26] who reported TSS levels of 14 mg/L that were within the limits set by regulatory agencies. As shown in Table 2, the TSS levels showed statistically significant difference with seasons. These findings correspond to those by [22] and [19] 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. Higher TSS levels than limits may affect water clarity and lead to reduced 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 [29] who recorded higher coliform levels (3.434×10^5Counts/100ml) compared to limits set by NEMA in Kariobangi wastewater treatment Plant in Kenya but did not correspond with findings from literature by [30] and [32] who recorded 4.71 cfu/100ml and 100 cfu/100ml in their studies respectively. The coliform counts showed statistically significant difference with seasons as shown in Table 2. These findings were consistent with ones reported by [36] who also reported statistically significant difference between coliform counts with seasons (p<0.001) in his study of wastewater treatment plant in Dandora, Kenya.

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 3. 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 Masai 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 [36,37] 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 needs 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. These findings correspond findings from other studies by [37] and [20] 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.

5. Conclusion and Recommendations

A number of findings and conclusions can be drawn from this study. First, Temperature, pH, Turbidity, Phosphates, Electrical Conductivity, BOD, COD, Nitrates and coliforms levels do not exhibit seasonal variation and it is concluded thus that there is no seasonal variation in these parameters. Secondly, Coliforms, TSS, BOD and COD levels are not within the maximum allowable limits for discharge of effluent into the environment. The study findings thus suggest that some physical parameters do not meet standards for discharge to the environment. Thirdly, Single septic and septic and soak away pits treatment approaches appear to produce water with poorer quality while integrated septic and lagoons treatment approaches produces effluent of better quality. We conclude that 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 levels.

From this study we recommend that:

1) Awareness programmes be established by NGOs and the County Government with a view to sensitize locals on the need to treat water before drinking especially during the wet season to avoid spread of diseases
2) Strict monitoring of the regulated facilities by NEMA and County government to ensure they comply with the standards set out in the water quality regulations 2006
3) Review of the water quality regulations, 2006 so that NEMA takes a lead role in the collection and analysis of water samples instead of the management of the facilities
4) Further studies should include monitoring changes in macro-invertebrate species diversity and abundance along the recipient streams to provide a more holistic and integrated assessment of the quality of the receiving lotic environments
5) Development and implementation of other sustainable liquid waste treatment approaches such as constructed wetlands to be integrated into wastewater treatment facilities by the high end hotels and lodges.

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Conflict of Interest

The authors declare no conflict of interest in this research, their findings and applications.

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