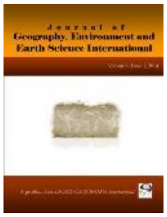

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Potential Environmental Impact of Chemical and Microbial Characteristics of the Sewage Generated in Kakamega County, Kenya

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Authors' contributions

This work was carried out in collaboration between both authors. Author IOB designed the study, managed the literature searches, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author DNS managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Sewage disposal poses serious environmental challenges yet it is largely full of organic compounds that store usable energy in their chemical bonds. A study was carried out on potential environmental impact of chemical and microbial characteristics of sewage generated in Kakamega County, Kenya. Samples of sewage from 75 schools were collected in July 2013 using bottles. The samples were taken to Water Resource and Management Authority (WRMA) and Bora laboratories for the analysis of microbes, organic nutrients and heavy metals. The research design was experimental. The results showed that the microbial characteristics of the sewage generated in secondary schools have a potential negative impact on the environment by causing pollution of the

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soils and water. However, the chemical characteristics of the sewage, notably the P_2O_5, TKN and pH have a potential positive impact on the environment by being beneficial to the soils. From the results, it is recommended that an alternative waste management technique of anaerobic digestion be used sustainably to generate bioenergy from sewage for contribution to future global energy demands and minimize its adverse environmental impact.

Keywords: Environmental impact; secondary schools; sewage chemical characteristics; sewage microbial characteristics.

1. INTRODUCTION

The long term possibilities of using human waste should be considered because of the potential for biogas digesters to improve sanitation and reduce pathogens in the water courses that originate from human faeces [1]. Health problems associated with spread of human wastes can occur due to pit toilets becoming overfull as a result of inadequate depth and toilets being sited too close to water sources. Human waste can also leach into ground water from a functioning pit toilet if sited on a highly permeable soil type. Pathogen prevalence in an environment is affected by local climate, soil type, animal host prevalence, topography, land cover and management, organic waste applications and hydrology [2,3,4,5,6]. According to [7], contamination of groundwater and reservoirs by running storm water and flash floods can result in significant sporadic pollution events. The type of contamination includes enterobacteria, enteroviruses and a range of fungal spore. Some key human/animal pathogens include *Salmonella typhi*, *Staphylococus spp*, *E. coli*, *Campylobacter coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*, Hepatitis B and C viruses, Rotavirus, *Aspergillus spp*, *Candida spp, Trichophyton spp*., *Cryptosporidium*, Mycobacteria, Leptospirosis, Toxoplasma and *Clostridium botulinum* [7]. According to [8], large-scale biogas plants have been installed in Rwandan prisons to treat toilet wastes and generate biogas for cooking. This was undertaken after a realisation that sewage disposal from concentrated groups of people such as prisons was a major health hazard for both the prison and the surrounding areas. Besides, the fuel wood that was being used in the prisons for cooking was putting great pressure on the local wood supplies. This is a clear testimony that sewage can be utilized as renewable energy source generated everyday through waste. According to [9], there is need for research into the energy needs in places such as institutions to know if there are any existing sewage treatment plants or landfills that produce methane. Information about sewage biogas technology at the secondary school scale to improve both environmental and human health in Kakamega County is not readily available.

From the foregoing literature review, it could be established that measures needed to be taken in the human environment to ensure that human faecal disposal is not a threat to human health but instead the threat be turned into an opportunity that can be beneficial to man without harming the surroundings. Such use was biogas utilisation.

2. MATERIALS AND METHODS

The study was carried out in Kakamega County in Kenya. The County was chosen because its number of schools and student population had increased remarkably (303 schools with 73, 220 students). This meant a significant implication on the quantity of sewage generated. Kakamega County is one of the four Western Kenya Counties. Its geographic coordinates are 1° 00′N, 38° 00′E. The County is composed of twelve sub-counties. The County (Fig. 1) lies within an altitude of 1,250 m to 2,000 m with an average annual rainfall ranging from 1250-1750 mmper annum. Its average temperature is 22.50°C.

Multistage/cluster sampling was used to select both public and private secondary schools in the county. The schools categorized as Boarding, Boarding & and Day schools were randomly obtained by utilising a sample frame from the County education office. These schools formed the units of analysis. Key informants within the schools were the principals, their deputies, senior or boarding teachers, school bursars, nurses, head cooks and one member of the executive board. These key informants were selected purposively. Proportions were randomly used to pick the teachers and the students in the selected schools. Other key informants were stakeholders from organisations such as National Environmental Management Authority (NEMA), Ministries of Education, Health, Energy and Environment from whom representatives of Focus Group Discussions (FGD) were sourced.

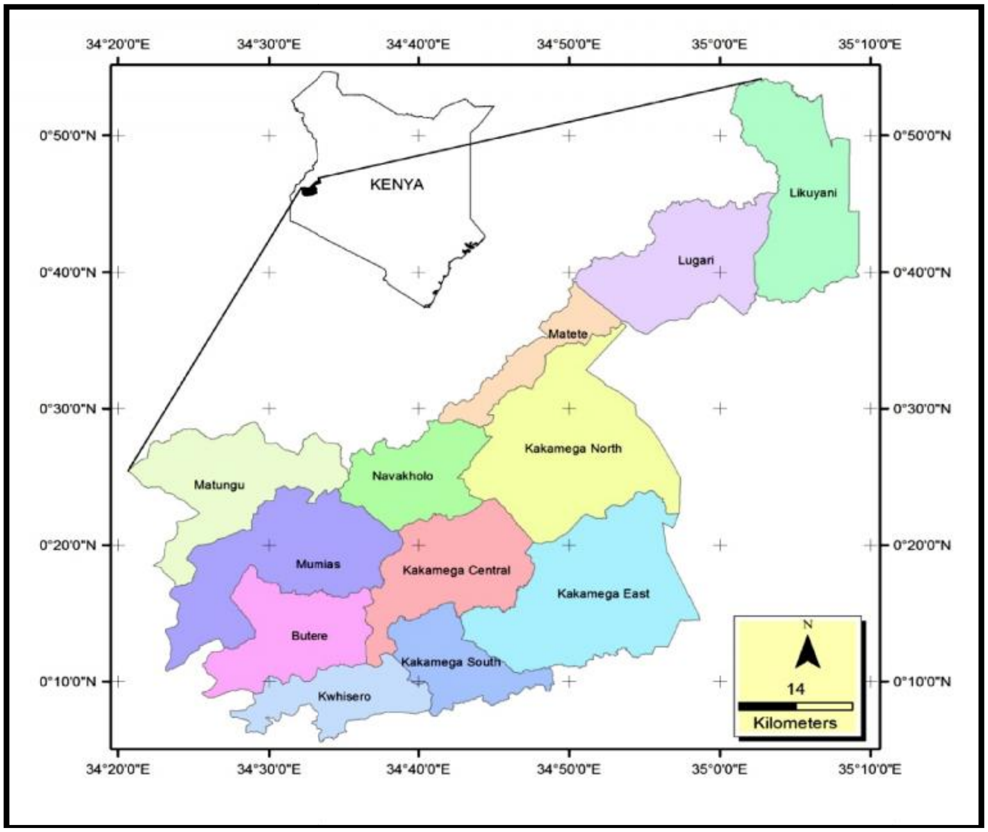

Fig. 1. Map showing Kakamega County (the study site)

2.1 Laboratory Procedures

Samples of sewage were collected from the schools sewage systems in bottles and taken to water resource and management authority (WRMA) and Bora laboratories for the analysis of microbes, organic nutrients and heavy metals. Various materials and methods were used to investigate different parameters in the study. The parameters included Total Kjeldal Nitrogen, Total Phosphate (Total P_2O_5), heavy metals, pH, and microbial characteristics of the sewage.

2.2 Total Kjeldal Nitrogen (TKN)

1.0 g sample was digested in 10 ml H_2SO_4, distilled with 20 ml NaOH into a flask containing boric acid and titrated with sulphuric acid to a violet end point, [10].

2.3 Total Phosphate (Total P_2O_5)

3.0 g sample was weighed and moistened with 1 ml water, swirled with 21 ml of hydrochloric acid followed by 7 ml of nitric acid plus boiling aids and heated for 2 hours, allowed to cool, filtered and phosphorus measured by ICP-OES, [11].

2.4 Heavy Metals Analysis in Sewage

1.0 g of sample was digested with 20.0 ml nitric acid (1:1), heated at 120°C for 30 minutes, cooled, filtered and the metals determined by Inductive Couple Plasma Atomic Emission Spectrum (ICP-AES) at 226.502 nm for Cd and 220.353 nm for Pb, [12]. Analysis of copper was done using atomic absorption spectrophotometer (220.2) as described in standard methods of examination of water and waste water, 21st edition, 2005 (American public health association). Analysis of mercury was performed using procedures based on U.S.EPA Method 245.7, oxidative digestion using bromination, and analysis using Cold Vapour Atomic Fluorescent Spectroscopy.

2.5 Microbiological Analysis

Microbiological analysis of the samples was done within 24 hours after sampling. Microorganisms included in the study were: total coliforms, *E. coli*, Giardia and Cryptosporidium. A sample volume of 100 ml (in case of sewage, 0.1 ml of either raw sewage or digestate in 99.9 ml of peptone saline -PS: 0.1% peptone in 0.09% saline) was passed through a membrane filter with a pore size of 0.45 µm, gridded, type HA, (Millipore Corp., Bedford, Mass.) to retain the microbes present in the sample. The filters were then transferred to M-Endo medium (Difco) and incubated at 35°C± 0.5°C for 24 hours. Pink to dark red with a green metallic surface sheen colonies were counted. Colony Forming Units (C.F.U) was calculated as:

CFU/ml of original sample = No. of Colonies/ Inoculum size (ml) x Dilution Factor.

3. RESULTS AND DISCUSSION

3.1 Potential Environmental Impact of Chemical Characteristics of the Sewage

The study investigated the potential environmental impact of chemical characteristics of the sewage generated in secondary schools. The chemical parameters that were analysed included the sewage TKN, Total P_2O_5, pH, heavy metals, Dry Matter (DM), and nutrient content. The data analysis and interpretation revealed that the TKN in the influent is 8.30 mg/l with SE of 0.45. The total P_2O_5 in the influent of the human excreta was 1.15 mg/l with SE of 0.46. This finding is consistent with a previous study in Ghana, [12].

The analysis also revealed that the DM content of the influent of human excreta is 13.80% with SE of 0.66. This finding is consistent with similar results by [13,14,15] and [12]. The influent of human excreta had a pH value of 5.75 with SE of 0.13. The finding agrees with similar findings by [16]. This implies that the pH of the influent is acidic. This may negatively impact on the environment.

The analysis of heavy metals in the influents of human waste revealed that cadmium (Cd) and lead (Pb) were quite traceable. The quantity of Cd was 0.0249 mg/l and Pb was 0.0046 mg/l. This finding is in agreement with the report by [17] and [12]. A physical-chemical analysis revealed that there were no significant variations between the physical-chemical contents in the influent. A Chi Square test using the graphpad prism software gave a *P* value of 0.9472 (df=5) at a 95% confidence interval. The findings were as summarised in Table 1.

3.2 Potential Environmental Impact of Microbial Characteristics of the Influent of Human Excreta

This section presents the findings of the potential environmental impact of microbial characteristics of the Sewage generated in secondary schools. The microbial parameters analysed were *E. coli* and faecal coliforms.

First, respondents in the school management were asked whether their schools experienced any diseases associated with sewage disposal. The responses were as given in Fig. 2.

Fig. 2 shows majority of the sampled schools experienced many cases of typhoid compared to cholera disease. A Chi Square test conducted on the data showed that there was a highly significant (P<0.01) variation in responses ($\chi^2_{1,0.01} = 10.46$).

The study then investigated the microbes present in the sewage that could be associated with these diseases. The content of *E. coli* in the influent was found to be 390 MPN/100 mls while that of faecal coliforms was 450 MPN/100 mls. Thus, the *E. coli* concentration was 390 times higher than the WHO/NEMA standard levels (nil). Faecal coliform concentrations were 450 times higher than the WHO/NEMA standard levels (nil). Faecal coliforms are indicators of contamination. This means that the microbial characteristics of sewage generated in secondary schools pose a health risk on the environment. The results were as summarised in Table 2.

The study also sought to find out the possible impact of the underground sewage seepage on the water sources in the schools and their environs. In single pit latrines that are mostly used here, the main hazard is caused by

Table 1. Physical-chemical characteristics of human excreta influent

Parameters	DM (%)	TKN (mg/l)	Total P_2O_5 (mg/l)	pH	Cadmium (Cd)	Lead (Pb)
Influent SE	13.8±0.66	8.3 ±0.45	1.15 ±0.46	5.75±0.13	0.0249±0.35	0.0046±0.34

SE: Standard Error, TKN: Total Kjeldal Nitrogen, P_2O_5: Phosphate, DM: Dry Matter

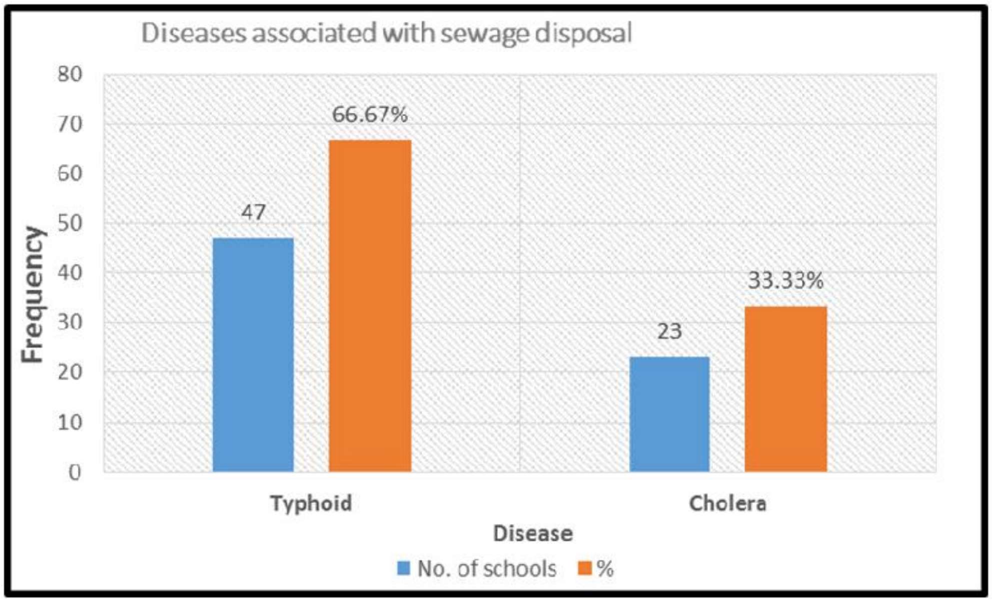

Fig. 2. Diseases associated with sewage disposal methods

Table 2. Microbes in the influent of human excreta

Parameters	*E. coli* (MPN/100 mls)	Faecal coliforms
Influent	390	450

MPN: Most Probable Number, SE: Standard Error

underground contaminated water that finally reaches the nearby water sources. If water from such sources is consumed by humans then the pathogens find their way into human digestive system. The movement of protozoa and cysts and helminthes ova can be expected to be very limited because of their size. Therefore, the study sought to find out an association between the bio-chemical parameters in the school environs during the wet season and typhoid as well as cholera were reported in the schools. The results showed that the pH at sewage discharge point was 6.1 which is below the WHO/NEMA standard of 6.5-8.5. This pH of 6.1 is indicative of accumulation of acidic substances from the sewage discharge which can lead to a more acidic medium in the environment thereby adversely affecting the general biota in the ecosystem.

The concentration of heavy metals was found to be 0.07 mg/l of Lead and 0.1 mg/l of Mercury. These are higher concentrations when compared to the WHO/NEMA standards of 0.05 mg/l of Lead and 0.01 mg/l of Mercury. These heavy metal concentrations at the sewage discharge point were higher than the accepted levels of the WHO and NEMA standards. Thus, the Lead metal concentration was 1.4 times higher than the 0.05 acceptable levels of the WHO/NEMA standards. Mercury levels were 10 times higher than the WHO/NEMA standard levels (0.01). These detected higher heavy metal concentrations exceeded WHO/NEMA concentration limits and are pointers to possible hazardous contamination by heavy metals in these school environs. As such, there is potential for the occurrence of deleterious health effects on humans and general biota in the surroundings.

The *E. coli* and faecal coliforms concentrations at the sewage discharge point were 238 MPN/100 mls and 330 MPN/100 mls respectively. These concentrations were 238 and 330 times higher than the WHO/NEMA standards that are nil. Water sources used by schools and the surrounding communities also experienced contamination by *E. coli* and faecal coliforms. The water sources sampled included storm water points at River Isiukhu and Lusumu, shallow wells, boreholes and tap waters. The *E. coli* in these water sources was 320 MPN/100 mls, 125 MPN/100 mls, 15 MPN/100 mls 0.0 MPN/100 mls and 0.0 MPN/100 mls respectively. This is higher than the WHO/NEMA standard which is nil. This means that the *E. coli* was 320 times higher in River Isiukhu, 125 times higher in River Lusumu and 15 times higher in shallow wells than the WHO/NEMA standard levels.

The faecal coliforms in these water sources were 240 MPN/100 mls, 195 MPN/100 mls, 390 MPN/100 mls, 0.0 MPN/100 mls and 0.0 MPN/100 mls. Thus, the faecal coliforms were 240 times higher in River Isiukhu, 195 times higher in River Lusumu and 390 times higher in shallow wells than the WHO/NEMA standard levels (0.0). Thus, the faecal coliform concentration is an indicator of sewage contamination of waterways and the possible presence of other pathogenic organisms implying that a potential health risk exists for individuals exposed to this water. Diseases and illnesses that can be contracted in water with high fecal coliform counts include typhoid fever, hepatitis, ear infections, gastroenteritis and dysentery. A study carried out on well water contamination by pit latrines in Langas of Eldoret town, Kenya [18] showed that most wells were contaminated and posed a health risk to the residents. The presence of toilets in the community is a probable source of contamination. However, the severity of the contamination will depend on the clay content of the soil in the region. Where the clay content is high (Southern, SW and NE parts of Kakamega County), the soil and groundwater contamination will be limited.The findings were as summarised in Table 3 and Fig. 3 showing the clay content distribution map of Kakamega County.

Table 3. Bio-chemical parameters in school environs

	Source of sample	pH	Copper (mg/l)	Lead (mg/l)	Mercury (mg/l)	*E. coli* (MPN/100 mls)	Faecal coliforms (MPN/100 mls)
1	Borehole	6.9	0.02	0.01	0.0	0.0	0.0
2	River Lusumu	6.4	1.1	0.09	0.0	125	195
3	Sewage discharge point	6.1	0.09	0.07	0.1	238	330
4	Shallow wells	6.8	0.02	0.07	0.006	15	390
5	Storm water discharge point (river Isiukhu)	7.2	0.7	0.095	0.015	320	240
6	Tap water	6.9	0.01	0.01	0.0	0.0	0.0
7	WHO/NEMA standard	6.5 -8.5	0.1	0.05	0.01	0	0

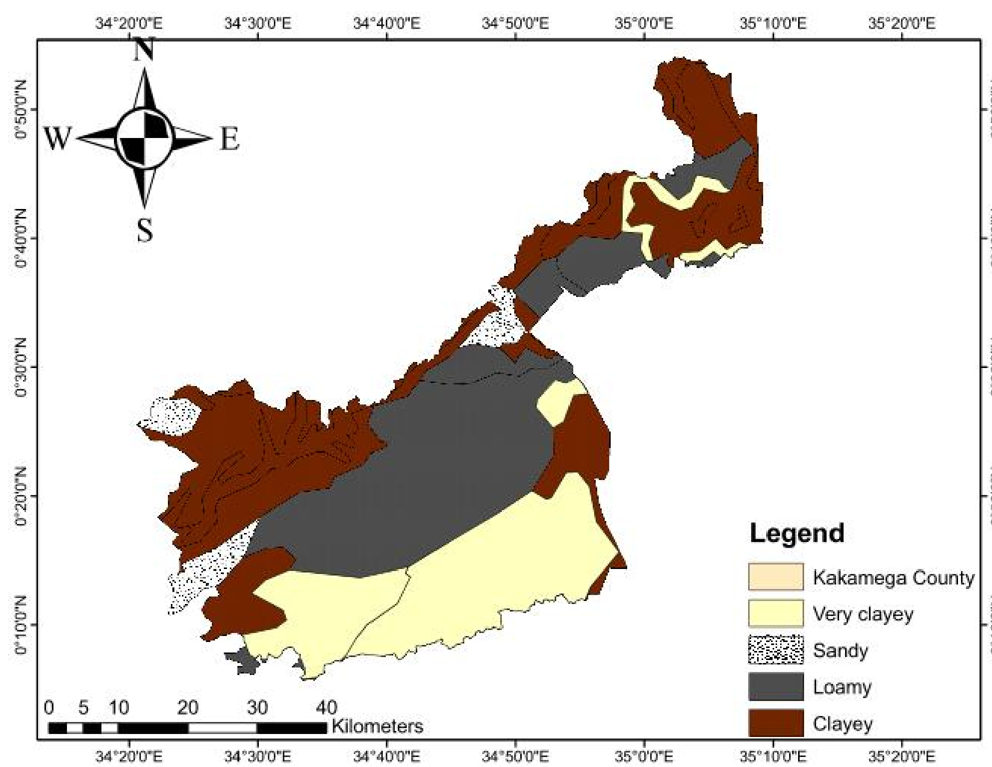

Fig. 3. A map of Kakamega County showing distribution of clay content in soil

Table 4. Kakamega County health data from 2009 to 2013

Kakamega County health data from 2009 to 2013										
Year	**2009**		**2010**		**2011**		**2012**		**2013**	
Age (in years)	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**	**<5**	**>5**
Typhoid	205	3580	103	1749	154	6708	75	3683	202	3332
Dysentry	141	282	32	88	116	304	197	400	71	232
Diarrhoea	8255	5289	2867	1530	6383	4182	6095	4134	5484	3750
Mal. Con	16042	26494	6840	10202	12906	21014	10118	17772	14738	28578
Mal. Cl	53310	61930	24244	26369	29951	48558	25217	39120	11194	19111

Source: [20]

During the focused group discussion, NEMA pointed out that the municipal sewerage plants in the town discharge partially treated or untreated wastewater into surface water courses posing significant environmental health hazards. Pit latrines and septic tanks in the municipality constitute a health risk in form of groundwater contamination. Similar findings on water quality status of Kakamega Municipality were reported by [19].

No wonder we had the kind of diseases observed at Kakamega County General Hospital. The study, therefore, further sought to find out if there is any relationship between the biochemical parameters and the diseases recorded at Kakamega County General Hospital. Diseases recorded were typhoid, dysentery and diarrhoea and malaria for age groups below five years and those above five years. The results showed that typhoid cases in the age group over 5 years were on an upward trend. This age group included that of secondary school students for which this study was investigating. Most typhoid cases are not handled at the school level and therefore, they are referred to the Kakamega County General Hospital. Dysentery and typhoid are the likely causes of the diarrhoea cases recorded at the hospital. These findings imply that the microbial characteristics of sewage lead to health hazards in the environment through water and soil pollution. Table 4 above gives a summary of the findings.

4. CONCLUSION

The microbial characteristics of the sewage generated in secondary schools have a negative impact on the environment by causing pollution of the soils and water by the *E. coli* and faecal coliforms. The chemical characteristics (P_2O_5, TKN and pH) have a potential positive impact on the environment by being beneficial to the soils. These findings will aid the government in policy development and implementation of environmental sanitation in institutions of learning through anaerobic digestion of sewage for bioenergy generation. This will be enhanced through the understanding of the water sanitation problem and the environmental health issues. From the results, it is recommended that an alternative waste management technique of anaerobic digestion be used sustainably to generate bioenergy from sewage for contribution to future global energy demands and minimize its adverse environmental impact.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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