ABC Journals
a new era in publishing
ABC Research House
Asian Journal of Applied Science and Engineering
Abbreviated key title: Asian j. appl. sci. eng.
Access this article online
http://journals.abc.us.org/index.php/ajase/issue/archive

Recreational Waters under Multiple Stress: Exemplifying Sources, Implications and Sustainability Options for Ecotourism Enhancement in Kisumu County, Kenya

Jared Ouma Okungu[1*], Patrick O. Hayombe[2], Silas C. Lagat[3], Silas O. Maujih[4]

[1]PhD Candidate, School of Spatial Planning and Natural Resources Management, Jaramogi Oginga Odinga University of Science and Technology, **KENYA**
[2]Senior Lecturer, School of Spatial Planning and Natural Resources Management, Jaramogi Oginga Odinga University of Science and Technology, **KENYA**
[3]Senior Lecturer, School of Biological and Physical Sciences, Jaramogi Oginga Odinga University of Science and Technology, **KENYA**
[4]Consultant, UN Habitat, Lake Victoria Region, **KENYA**

ARTICLE INFO

Received: May 06, 2015
Accepted: Jun 12, 2015
Published: Jun 23, 2015

***Corresponding Contact**
Email:
okungujared@gmail.com
Cell Phone: +254(0)723490262

crossref doi Prefix 10.18034

ABSTRACT

Several natural water reservoirs, especially in the developing nations, have systematically experienced high ecological stresses and this has hindered the demonstration of their ecological utility. There have been little or no product and destination opportunities for ecotourism due to the exponential effect of multiple stresses on some Asian and most African lakes. Lake Victoria, the world's largest fresh water lake in Kenya, has experienced increasing stresses which continue to dilute the pride that befits its stature. This study was conducted in four beaches along the shores of Lake Victoria with a focus on ecotourism industry so as to exemplify the sources of pollution, its implications and sustainability options within its Kisumu County buffer areas. Water samples were methodically collected and tested for physical, chemical and microbial status against reference standards. All results satisfactorily compared with past data but showed exponential swell in trends of contamination to the water body. There were indications of suitability of temperature and pH conditions but moderately high turbidity and suspended solid loads, all suitable for recreation. DO was present at fair levels but with the significant Nitrogen and Phosphorous intensities. Eutrophication and algal bloom at the lake were evident threats to recreation but E.Coli levels existed within recommended recreational normal of (206counts/100ml) for undesignated areas, which was significantly behind developed nation's recreation beach designations. The BOD_5 levels were within the recommended 5-15 mg/L for raw water reservoirs or tertiary effluents. Urban beaches depicted higher levels of pollution compared to rural ones while rainy/wet seasons exhibited significant pollution loads. Time of the day was not a pollution factor. The study recommends policy change and planning for shore lean ups, augmentation of existing sanitation infrastructure, public sensitization programmes; enhancement of institutional capacities; and image and destination branding of the sites.

Keywords: Recreational Waters, Multiple Stress, Sustainability Options; Ecotourism Enhancement

Source of Support: Mistra Urban Futures, **No Conflict of Interest:** Declared

How to Cite: Okungu JO, Hayombe PO, Lagat SC and Maujih SO. 2015. **Recreational Waters under Multiple Stress: Exemplifying Sources, Implications and Sustainability Options for Ecotourism Enhancement in Kisumu County, Kenya** *Asian Journal of Applied Science and Engineering,* 4, 110-126.

INTRODUCTION

Various natural water reservoirs have systematically experienced high ecological stresses and this has slowed down their resourcefulness for aquatic species survival and human exploitation. Several such water bodies, especially in the developing nations have failed to demonstrate their ecological utility that have, on the other hand, been satisfactorily demonstrated in most developed nations, for instance, the North American and European countries. Some Asian and most African countries have had their fresh water bodies dogged with underutilization for recreation due to negligence, poor planning and poor management. Disposal of solid wastes have been reported at the deltas of Okavango, Niger, Volta and Zambezi rivers. This has resulted to their low aesthetic stature and to some instances even hydropolitical conflicts among the transboundary riparian entities (Kitissou, *et al,* 2007). Within the Lake Tanganyika's shores, areas have been reported to exist, which resemble waste buffers, causing adverse pollution in some parts thereby distressing the lake's potential for ecological convenience.

In East Africa, Lake Victoria is shared among Kenya, Uganda and Tanzania with their shore buffers being homes to rural and urban communities. There exist various industrial and commercial activities, but unlike the developed countries, the water body has been stressed by a myriad of activities that are only trendy towards the ecosystem degradation. This is supposedly seen by this study as a major stake on the low ecotourism practice in the lake. However, the exact scenario is not clear since a study has not been carried out with a focus on ecotourism. This study seeks to exemplify the sources, implications and come up with sustainability options for Ecotourism Enhancement. Kisumu county was chosen as the study area since, similar to other areas, in Kenya, Uganda and Tanzania, it boarders the Lake Victoria and exhibit similar but slightly more adverse recreational challenges.

Kisumu County is interfaced with the Kenyan side of Lake Victoria within a spatial zone known as Winam-Gulf. Much of its observable arena from a substantial spatial distance constitutes an atmosphere (*Figure 1*) that ought to be serene and attractive (East African Community, 2007). The available water mass within the entire vicinity exhibits an extensively exploitable resource by both inhabitants and prospecting visitors for ecotourism. The lake has had a long and fascinating history with traditional communities living along the waterfronts while running livelihood errands like fishing, transportation, domestic and animal watering, and other cultural events (Lake Victoria Initiative, 2006).

Figure 1: A view of serene front sites of lake Victoria that is suitable for ecotourism venture

Nevertheless, the state of affairs of the lake as a potential recreational surface water resource has long been under multiple stress in the entire spatial reach of the lake, as similarly experienced elsewhere in the developing nations. Lubovich, (2009) observes that Lake Victoria's ecosystem has been under immense threat from multiple pollution sources, each posing its own challenges. Moreover, Kayombo, and Jorgensen, (2006) demonstrates that the ecosystem has undergone substantial and alarming changes that have accelerated over the last three decades. Massive algal blooms have developed (*Figure 2*), becoming increasingly dominated by the potentially toxic blue-green variety.

A report by COWI Consulting Engineers (2002) indicates that the lake's water transparency has declined from 5 m in the early 1930s, to 1 m or less (>70%) for most of the year by the early 1990s. Waterborne diseases also have increased in frequency. Although presently under some control, water hyacinth which was absent in the lake as late as 1989, has choked important waterways, landings and beach areas in Kenya and Uganda. Both point and non-point source pollution is a major problem in the Lake Victoria basin. Kiwango and Wolanski, (2007) observe that industrial facilities frequently discharge effluent directly into the lake, with little prior treatment. This primarily is a problem in the major urban centers of most port towns of Lake Victoria's (Machiwa, 2002). Adding to the industrial contamination is the non-point source pollution from human and animal wastes entering the lake from urban areas and rural villages alike.

Figure 2: Satellite Images of deteriorated quality of Lake Victoria (Source: NASA 2007*)*

It is estimated that 80 percent of the riverine phosphorus entering Lake Victoria comes from municipal and industrial sewage, and the dumping of untreated sewage from city suburbs, villages and informal settlements (Kiwango and Wolanski, 2007). The continuously incoming human and animal wastes contain dangerous bacteria that can negatively affect water quality and sicken communities. Development activities, discharge of nutrients and growth of population has caused changes in the lake ecosystem. Massive blooms of algae have developed, water borne diseases have increased in frequency and water hyacinth has choked important waterways, landings, recreational areas as well as water supply intakes (LVEMP, 1995). Recreational adventures are, as a result in the current state, not exactly feasible at the lake water. This has been associated with negative perception and little engagement in recreation (Okungu, Hayombe, and Agong', 2015). Stakeholder discussions at KLIP Ecotourism Symposium (2013) suggest that ecotourism product, destination and city branding should be implemented for Kisumu County. But the environmental threats subsisting in Lake Victoria as explained above denote the multiple stresses experienced by the massive and naturally occurring water resource. This study explores the water quality attributes that signify recreational absence at the lake environs, and aims at demonstrating sustainability options for ecotourism enhancement in Kisumu County.

Effective Implementation of the recommendations would enhance the culture of responsibility among African nations within the upstream and downstream stakeholders. This would result in sustainability of aquatic biodiversity, participation by local and foreign recreationists and encourage development of recreational facilities. It would also demonstrate ease of destination. Cases of water related disease outbreaks would significantly reduce.

REVIEW OF RELATED LITERATURE

Canadian Council of Ministers of the Environment, (2008) upholds the idea that water that is primarily meant for recreational purposes should be suitably free from microbiological risks hazards. In addition WHO (2003) asserts that specific chemical hazards ought to be dependent on circumstances of the surrounding area, hence, should be assessed on a case-by-case basis. A number of such hazards entail potential pathogens. Factors promoting survival and dispersion of pathogens include the nature of the beach, tidal phenomena, presence of sewage outlets, the season, presence of animals and the number of swimmers if any (WHO, 2003).

The temperature of a body of water influences its overall quality. Its adverse changes on recreation-sensitive water resources demonstrate thermal pollution. Temperature ranges within which living organisms can thrive are deemed fit for ecotourism-water contacts (Behar, 1997). Water with a pH of 7 has equal concentrations of H+ ion and OH- ion and is considered to be a neutral solution suitable for skin contact and not detrimental when ingested. If a solution is acidic (pH<7), the concentration of H+ ion is greater than the concentration of OH- ion. Factors that affect pH levels include Acidic rainfall; Algal blooms – generally causing water to be more basic; releases from industrial processes – depends on whether acids or bases are released; release of detergents into water; carbonic acid from respiration or decomposition and Oxidation of sulphides in sediments – generally more acidic. The level of (pH < 6.0) and (PH > 9.0) do not support aquatic life. Behar, (1997) suggests the optimum pH value for recreational activities to be 7.0-8.0.

Turbidity, a measure of the water's lack of clarity, is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. High turbidity ratio (>50 NTU) hinders a recreationist's visibility in water towards immersion recreation, for instance swimming, and may cause physical injuries (American Public Health Association, *et al.,* 2012) or result into fear and skeptism among potential recreationists (Okungu *et al,* 2015). Solids are found along lake shorelines and beaches in suspension and dissolved states. Total Suspended Solids (TSS) includes silt, stirred up bottom sediment, decaying plant matter, or sewage treatment effluent.

Phosphorus (P) and nitrogen (N) are the primary nutrients that, in their excessive amounts, pollute lakes, streams, and wetlands. Nitrogen enters the ecosystem in several chemical forms and also occurs in other dissolved or particulate forms, such as tissues of living and dead organisms. Elevated levels of Nitrogen compounds can have harmful effects on humans and animals (Minnesota pollution Agency, 2008). Common sources of excess nitrate-rich lakes and streams include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps. High nitrate concentrations also contribute to eutrophication, accompanied by unpleasant odour and taste of water, as well as reduced clarity.

The level of *oxygen gas dissolved in water* (*DO*) provides aquatic animals with oxygen to carry out cellular respiration, hence an indicator of the quality of a freshwater lake water quality. Its concentrations ranges depend on seasonal and temperature conditions but should not be less than 4mg/L for recreational quality considerations (Johnson, *et al,* 1999).

Sources of DO include diffusion from the atmosphere and water at the surface, aeration as water flows over rocks and uneven surfaces, aeration through churning action of wind and waves and photosynthesis from aquatic plants. Concentration of DO is affected by plant activity, human activities, temperature; decaying organic matter in water - decomposition releases heat, warming water and decreasing dissolved oxygen capacity; and stream flow - the faster the water moves and churns, the greater the amount of oxygen is dissolved. When comparing water quality of different samples at the same temperature and air pressure, percent saturation is generally used instead of mg/L.

Clean and healthy recreational waters should be void of algal presence. As *algae* die and decompose, the process consumes oxygen. Submerged plants without sunlight die, decompose and consume more oxygen. Without enough DO in the water, fish and other organisms suffer and die because they can't "breathe" (Nyenje *et al*, 2010). Algal blooms, while initially increasing DO levels, may create hypoxic conditions as they decompose (EPA, 2013). When an algal bloom appears, it blocks sunlight from reaching any submerged vegetation, killing those plants and decreasing the amount of DO produced. When the bloom dies off, microbes consume more oxygen as they decompose the organic material. This causes DO levels to plummet even lower, creating hypoxic or even anoxic conditions. Enhanced input of plant nutrients, mainly nitrogen and phosphorus - in general originating from agricultural and urban areas, through the soil or directly into rivers and oceans - contribute to immense eutrophication rate (Gilbert *et al*, 2008).

Escherichia coli, (*E. coli*), is used as an indicator organism because it is easily cultured, and its presence in water in defined amounts indicates that sewage may be present in water. Sewage presence signifies presence of pathogenic (disease-causing) organisms. *E. coli* levels at designated swimming beaches should not exceed 88/100 mm (mL) in any one sample, or exceed a three-sample geometric mean average over a 60-day period of 47/100mL (WHO, 2003). Recreational waters existing in non-designated beaches should not have more than 206 *E. coli*/100mL in any one sample (WHO, 2003). Occasional higher numbers are not unusual, particularly after storm events and where urban or agricultural runoff occurs. Sources of fecal contamination include wastewater treatment plants, failing septic systems, domestic and wild animal waste, and storm water runoff (New Hampshire Department of Environmental Services, 2011).

MATERIALS AND METHODS

Conceptual Framework

The framework in *Figure 3 illustrates* the linkages between the current water quality status and the expected ecotourism development through sustainability options offered by the researcher. Origins of pollution are hinted to include urbanization. It also explains manifestations of recreational water stress as seen in literature.

Sampling stations

Four beaches along the Kisumu County's Lake Victoria shores were purposively picked for the study. Each beach selected for the study was a sampling station from which water samples were taken for four different days: two days during rainy/wet season (11th and 15th July, 2014) and at different times (9.30am and 4.30pm for each of the days); and two days during dry season (29th and 30th December, 2014) and at different times (9.30am and 4.30pm). (*rainy/wet season in Kenya and East Africa fall between the months of May and August; dry season fall between the months of November and February*). *Figure 4* illustrates the physical demographic characteristics of the studied beaches.

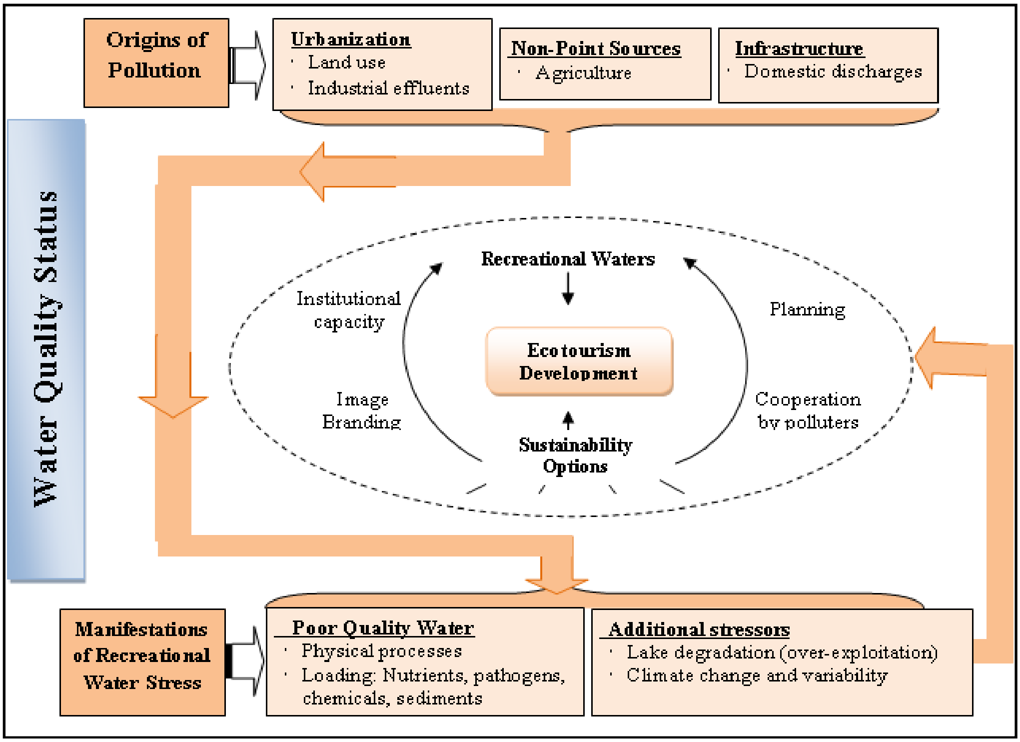
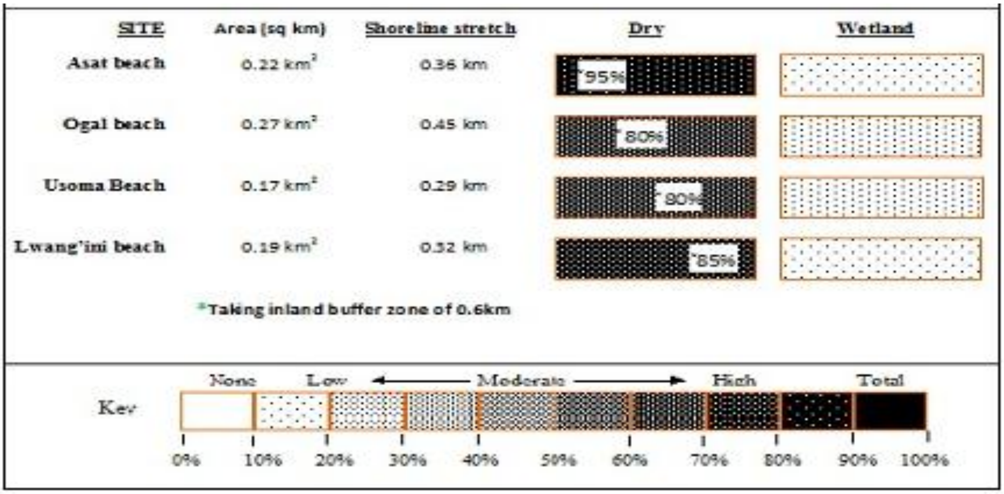


Figure 3: A researcher's study concept for addressing quality status, origins and Sustainability Options



SITE	Area (sq km)	Shoreline stretch	Dry	Wetland
Asat beach	0.22 km²	0.36 km	95%	
Ogal beach	0.27 km²	0.45 km	80%	
Usoma Beach	0.17 km²	0.29 km	80%	
Lwang'ini beach	0.19 km²	0.32 km	85%	

*Taking inland buffer zone of 0.6km

Figure 4: Illustration of physical demographic characteristics of the studied beaches

At each site four sampling points were set up within 4m lateral equidistance, over 3m surface distance into the lake, and 0.5m depth towards the lake bed as illustrated in *Figure 5*.

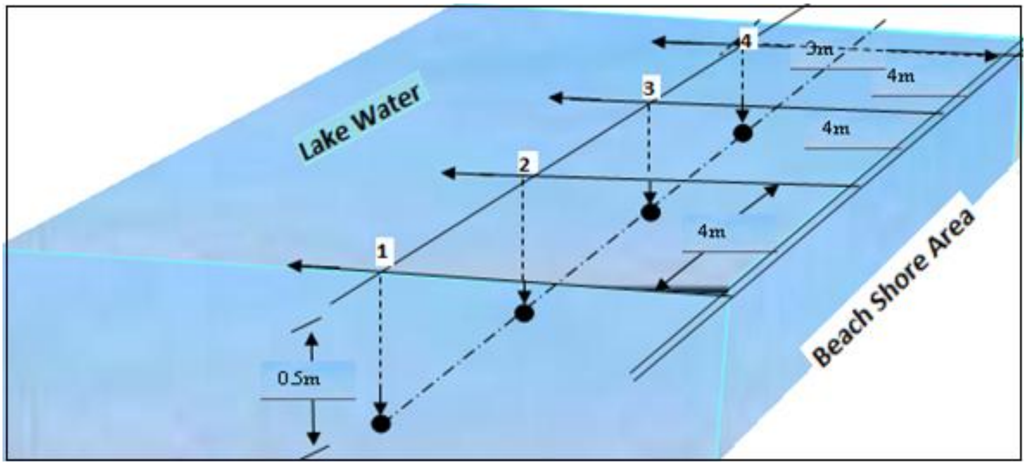


Figure 5: A researcher's model of sampling points as used in the beaches during the study

Standards of Test Parameters

Water samples were collected for confirmatory recreational water quality test procedures at a Kenyan government– calibrated laboratory, against international standards, on the indicators in *Table 1*.

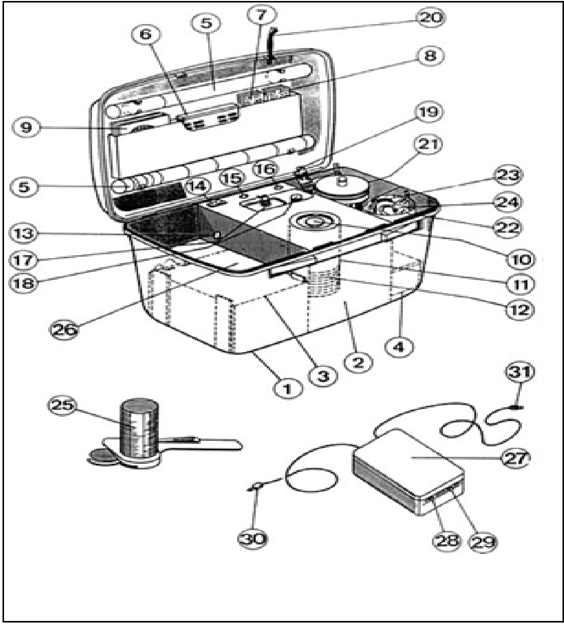
Table 1: Test parameters and their Quality Standards (Source: WHO, 2003; U.S. Environmental Protection Agency, 2012)

Parameter	Indicator	Unit standard (WHO)
Physical Quality	PH	7.0 to 8.0
	Turbidity	50 NTU
	TSS	200 – 250 mg/L
Chemical Quality	DO	DO_1-DO_5>4 mg/L
	TP	Discuss effects of concentration
	TN	Discuss effects of concentration
Microbial quality	Escherichia coli	88 counts /100 ml designated 206 counts/100 ml undesignated

Sampling points were set at the four study sites (Asat, Ogal, Usoma and Lwangni beaches). Water samples were taken for physical, chemical and microbial tests both in-situ and at laboratory.

Sampling Procedure, Laboratory Tests and Data Analysis

Determination of PH: Water samples were taken using a hand-held turbidity meter at the test kit *(Figure 5)* for *in situ* field measurements, and poured in 125ml pre-cleaned plastic bottles (made of *polypropylene*). Excessive turbulence was avoided to minimize presence of air bubbles near the measurement cell while the container was completely filled to the top. pH level was then red from a scale of 0-14 and recorded in a chart.



1. Case
2. Incubator
3. Battery
4. Spares case
5. Turbidity tubes (pair)
6. Chlorine and pH comparator
7. Chlorine test tablets
8. pH test tablets
9. Membrane filters
10. Incubator lid
11. Incubator pot
12. Petri dishes
13. Power socket
14. On/Off socket
15. Power "On" indicator
16. Heater "On" Indicator
17. Methanol dispenser
18. Culture medium bottle
19. Lighter
20. Tweezers
21. Filtration assembly with sample cup
22. Vacuum cup
23. Sample cable
24. Vacuum pump
25. Absorbent pad dispenser
26. Storage space
27. Battery charger/mains power unit
28. Power "On" Indicator
29. Charged battery indicator
30. Incubator plug
31. Mains supply plug

Figure 6: The test kit used to carry to test for Thermo-tolerant Coliforms, Turbidity and pH

Determination of Turbidity and Total Suspended Solids: Using a test kit (*Figure 6*), each water sample was agitated gently within the turbidity tubes, and about 2 minutes was allowed until air bubbles disappeared. The tub was held vertically and turbidity level was read using the calibrations. TSS levels were determined using the same kit.

Determination of Dissolved Oxygen: Electrometric method was suitable for the field determination of DO as the method is simple to perform (HACH Company, 1997-2009). Apparatus used included battery-powered meter, designed specifically for DO measurement; and oxygen-sensitive membrane electrode. The electrode in a portion of the sample to be analyzed for DO was rinsed then electrode immersed in water, ensuring a continuous flow of water past the membrane to obtain a steady response on the meter.

Determination of Total Nitrogen: Samples were acidified in the field with 2ml/L concentrated Sulphuric acid. A suitable volume of sample was measured into digestion bottles and 5 ml of the oxidizing reagent (KSO_4 in NoH with distilled water) added into each bottle. The digestion bottles were closed and autoclaved at 121°C for 30 minutes. After the samples were cooled to room temperature, digestion bottles were opened and 1 ml of buffer solution (H_3BO_3 and NaO) in distilled water was added. The solution from the digestion bottles was transferred to a measuring cylinder, filled to 60ml with the ammonium chloride buffer and mixed. The 60ml was then transferred to a conical flack and poured into Cadmium reduction column. The absorbance was recorded from a spectrophotometer at 543nm wavelength with a detection limit of 0.025mg/L.NO_2 – for a 1 cm cell.

Determination of Total Phosphorus: Principle: 25mL of the samples were transferred to digestion flasks and 5 ml of the ammonium per-sulphate solution added. The solution was autoclaved for 30 minutes at 121°C and then brought to room temperature. The 30 ml solutions were transferred into a reaction bottle and 1 ml ascorbic acid added, mixed and left for about 30 seconds after which 1 ml combined solution was added. The absorbance was measured and recorded in mg/L on a spectrophotometer within 10-30 minutes. All the glassware used were soaked in a 10% hydrochloric acid solution and rinsed with distilled water (HACH Company, 1997-2009). .

Determination of Escherichia Coli: A small amount (0.5-5mL) of water sample was poured into a bottle of Coliscan Easygel and mixed by swirling the bottle. The mixture was then poured into a labeled petri-dish, covered, and swirled to uniformly distribute the sample. After settling undisturbed for approximately 45 minutes, the Petri dishes are inverted and incubated at 35 degrees C for 48 hours. Purple/blue E. coli colonies on a microscopic plate were counted and results calculated per 100 ml of water sample (HACH Company, 1997-2009).

BOD was determined under the following environmental assumptions (HACH Company, 1997-2009; Nanyang Technological University, 2004): Sufficient Nitrogen, Phosphorous, Sulphates, Potassium and certain trace elements; free from toxins (BOD was sufficiently present, hence toxins were not tested); presence of a mixed culture of microorganisms.

The confirmatory tests for BOD were carried out during dry and wet seasons, one sample for each beach. Standard Dilution technique was used where by: dilution water was prepared by adding 1mL of phosphate buffer, $MgSO_4$ solution, calcium chloride solution, ferric chloride and 2ml of settled raw late water seed. Dilution water was siphoned into BOD bottle. Samples were incubated at 20 ℃ for 5 days. DO in each bottle was then measured by DO probe and BoD_5 was calculated as follows:

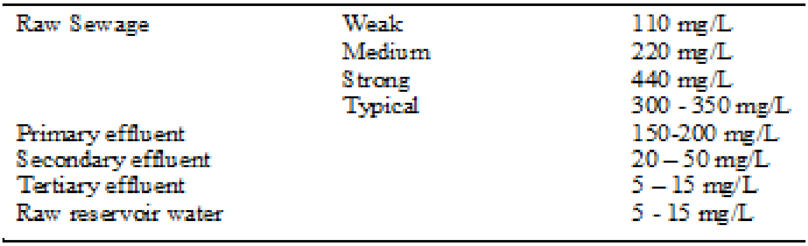
$$(BOD_5 - as - mgO_2/L) = (\frac{(D_1 - D_2) - (B_1 - B_2)f}{(P)}) \text{..................} \textit{Equation 1}$$

Where: D_1 = Initial DO of sample, mg/L; D_2 = Final DO of incubated sample after 5 days, mg/L; B_1 = DO of seed control before incubation, mg/L; B_2 = DO of seed control after incubation, mg/L; and P = Decimal volumetric fraction of sample used

$$f = (\frac{(\%..seed..in..D_1)}{(\%..seed..in..B_1)}) = (\frac{(voolume..of..dilution..water..in.sample)}{(volume..of..BOD..bottle)}) \text{....} \textit{Equation 2}$$

The BOD_5 test results were compared to typical values *(Table 2)* for various waters

Table 2: Typical BOD_5 values in mg/L for various waters (NTU, 2004)



Raw Sewage	Weak	110 mg/L
	Medium	220 mg/L
	Strong	440 mg/L
	Typical	300 - 350 mg/L
Primary effluent		150-200 mg/L
Secondary effluent		20 – 50 mg/L
Tertiary effluent		5 – 15 mg/L
Raw reservoir water		5 - 15 mg/L

COD was not determined since it cannot provide any evidence of the biological decomposition rate that precedes either in natural or man-made conditions. Toxins were also not determined because of their little presence deduced once DO is present ion substantial amount.

Considered Standards, Assumptions and limitations to the method of study
Obtaining the best samples required careful selection; hence only clean containers were used - rinsed several times with distilled water. It was hard to obtain a truly representative sample when collecting surface water samples at the beaches since contamination levels varied from point to point. Best results were obtained by testing more than one sample from various points. No time was allowed to elapse between collecting the sample and analyzing it with regard to respective test parameters. Depending on the test, special precautions in handling the water samples were necessary. This prevented natural interferences such as organic growth or loss or gain of dissolved gases. Each test parameter was described with unique sample procedure, preservations and storage technique.

RESULTS AND DISCUSSIONS

Laboratory test results obtained from the analyzed physical, chemical and microbial quality parameters using different procedures were synthesized in a matrix of sites, cluster, season and time as in *Table 3*. Discussions of the findings followed each test parameter, whose results were weighed against the recommended guidelines (*Table 2).*

Table 3: Mean levels of measured beach water quality compared across sites, cluster, season and time

	Physical Quality				Chemical Quality			Microbial quality
	Temp (°C)	PH	Turbidity NTU	TSS (mg/L)	DO (mg/L)	TN (mg/L)	TP (mg/L)	*Escherichia Coli* (Count/100ml)
Sites								
Asat	25.56	7.62	47.99	209.88	7.13	1.18	0.16	152.69
Ogal	25.44	7.55	50.51	228.68	7.08	1.16	0.15	158.64
Usoma	26.93	7.51	69.04	235.44	6.62	1.30	0.26	200.25
Lwangni	25.97	8.18	58.85	218.55	6.58	1.18	0.41	210.69
Cluster								
Rural	25.50	7.59	49.25	219.28	7.10	1.17	0.16	155.66
Urban	26.45	7.84	63.94	226.99	6.60	1.24	0.34	205.47
Season								
Rainy	24.82	7.70	59.19	254.83	6.89	1.19	0.21	197.61
Dry	27.13	7.73	54.00	191.44	6.81	1.22	0.28	163.52
Time								
Morning	25.50	7.59	49.25	230.34	6.60	1.21	0.25	180.46
Evening	26.45	7.84	63.94	210.73	7.10	1.20	0.24	175.55

Temperature: The average temperature for rural sites was 25.50^{o}C while that of urban sites was 26.45^{o}C. Average temperature for rainy/wet seasons was 24.82^{o}C across the sites as compared to the 27.1 ^{o}C for the dry season. Yet, generally, all morning and evening hours exhibited temperatures of 25.40^{o}C and 27.0^{o}C respectively, with near-uniform distribution across individual study sites. These resultant temperature conditions are considerably moderate for human body (Behar, 1997) during water-contact recreation activities in Lake Victoria at any site, any season and any time of the day.

PH: PH levels did not exhibit significant variation across individual sites, clusters, season and time. Rural clusters had a pH of 7.59 while urban cluster was a pH of 7.84. PH levels for rainy and dry seasons were uniform but depicted slight differences in the time of the day. Levels of pH (*Figure 7*) were generally within the recommended 7.0 to 8.0 limits in *Table 1*, hence, conducive for all forms of recreational contact

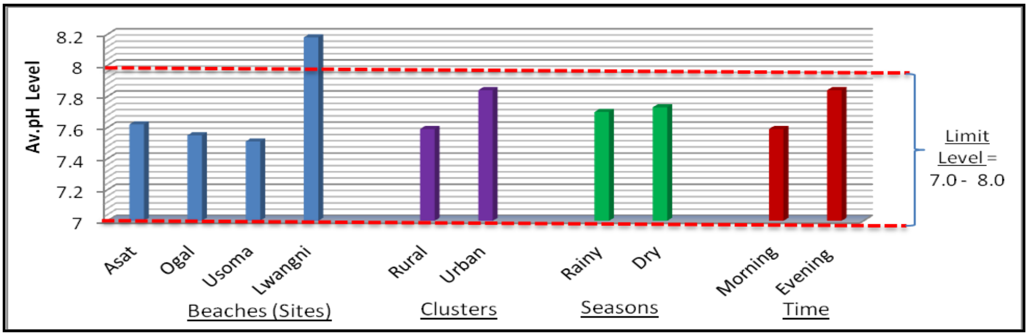


Figure 7: The illustration of pH results against recommended standards

Turbidity: Turbidity levels for the individual sites had some fluctuations in their averages with urban sites being 23% higher than rural sites, but remained within the recommended level of 50NTU. Consequently, the lake water was slightly more turbid during rainy season (59.19NTU) compared to dry season (54.00NTU). Turbidity levels changed with evening hours being higher at 63.94NTU. Morning demonstrated 49.25NTU. Turbidity levels were slightly higher than the recommended levels for recreational water clarity, but its fluctuations with time and cluster (*Figure 8*) meant that the levels can be controlled and sites can be managed within recreational turbidity limits.

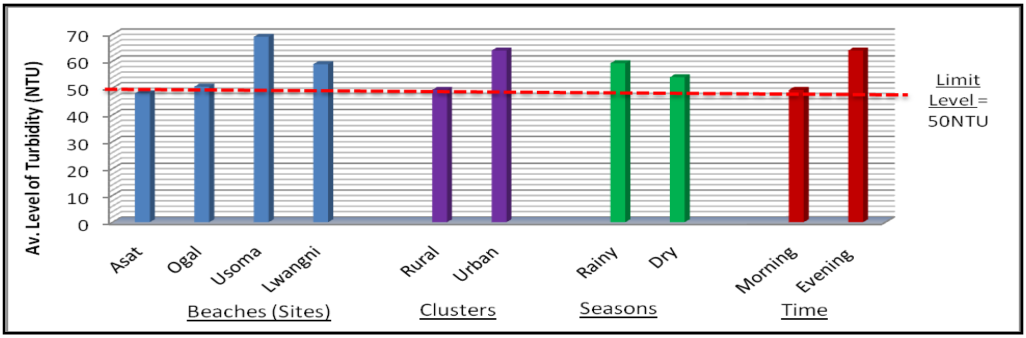


Figure 8: The illustration of Turbidity results against recommended standards

Total Suspended Solids (TSS): The levels of Total Suspended Solids were high in urban beaches at 226.99mg/L compared to rural areas at 219.28mg/L, a mere 3.4% difference. Rainy season saw TSS of 254.83mg/L, a lower load the dry season (191.44mg/L). Likewise, TSS during morning hours higher than the evening loads at 230.34mg/L and 210.73mg/L respectively. These results showed a range that falls within the limits of 200–250 mg/L, implying that the levels of suspended solids had no detrimental effects but significantly created hindrances against clarity of water meant for swimming (*Figure 9).* Results confirm COWI Consulting Engineer's (2002) assertion that the lake's water transparency has declined by over 70% since 1990.

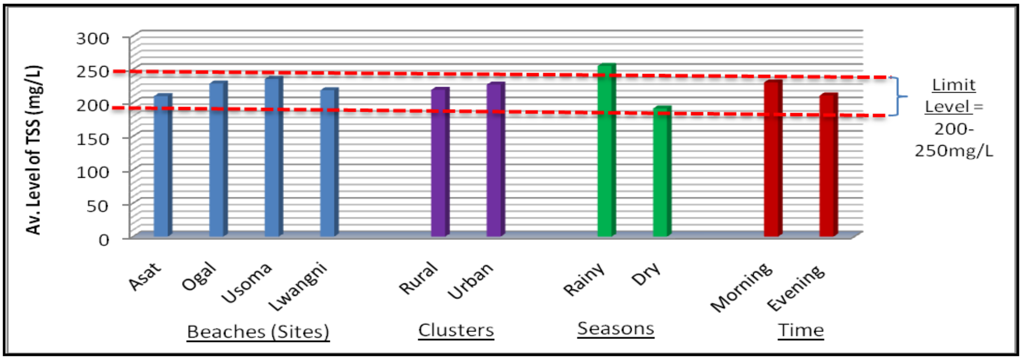


Figure 9: The illustration of TSS results against recommended standards

Dissolved oxygen: Results pointed to a distribution of Dissolved Oxygen (DO) at 7.13 mg/L, 7.08mg/L, 6.62mg/L and 6.58mg/L for Asat, Ogal, Usoma and Lwangni beaches respectively. Rural beaches, however, had higher DO (7.10mg/L) compared to the urban beaches (6.60mg/L). Rainy and dry season shared similar rates, though evening hours represented slightly more DO compared to morning hours across all the sites. The resultant DO of between 7-15mg/L is deemed conducive for recreational water contact (EPA, 2013) because it supports aquatic life. Overall DO results portrayed beaches studied to be recreation friendly.

Nitrogen and Phosphorous: Levels of Total Nitrogen (TN) was found to be at an average level of 1.17mg/L, across all sites with the exception of Usoma beach which was 1.30mg/L. By cluster, Total Phosphorous (TP), however, varied with rural sites indicating low levels (0.16mg/L) as compared to the urban sites (0.34mg/L). Drier seasons experienced higher Nitrogen and Phosphorous concentrations (1.22mg/L and 0.28mg/L) respectively. The concentrations for both TN and TP, however, did not have significant differences in time of the day (*Table 2*). Nevertheless, results suggest lake water is polluted with Nitrogen, which is above 1 mg/L against which (with the high Phosphorous levels), there occurs speedy eutrophication, algal bloom and multiplication of water hyacinth - which create an eyesore condition. This condition eventually bars people from participating in recreational activities like swimming and sunbathing.

Escherichia-Coli: Counts of *E.Coli* were recorded for all the sites to read 152.69counts/100ml, 158.64counts/100ml, 200.2counts/100ml 5 and 210.69counts/100ml of water for Asat, Ogal, Usoma and Lwangni beaches respectively. Rural beaches exhibited less counts (155.66 counts/100ml) compared to urban beaches (205.47counts/100ml), a difference of 24.2%. The *E.Coli* counts were higher during rainy season (197.61counts/100ml) as compared to dry seasons (163.52counts/100ml), a difference of 20.8%. E.Coli counts did not have significant variations for morning and evening as illustrated in *Table 2*. Results (*Figure 10)* demonstrate the fact that E. Coli was not an immediate threat against the recommended limit of 206 counts/100 ml for the recreational waters in Lake Victoria under undesignated genre. Levels were far above the levels of designated sites in developed nations by an average of 105.2%, though control need to be done in the urban sites to bring down the levels below 88 counts for swimming.

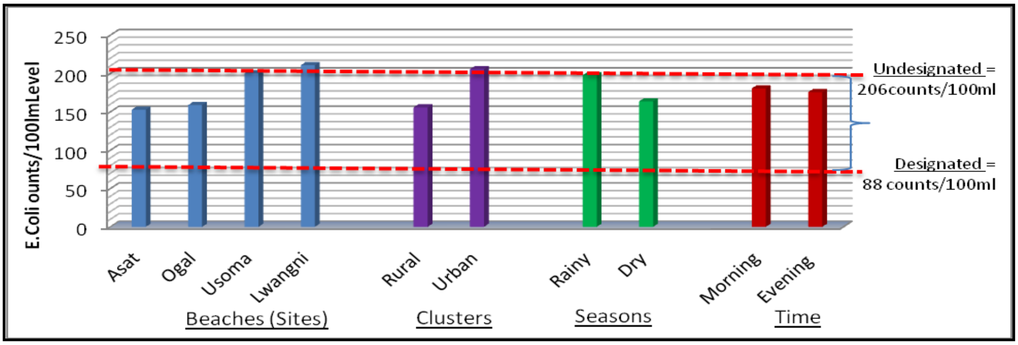


Figure 10: Illustration of E.Coli counts at the beaches

Table 4: Physical quality of beach water at Lake Victoria

Site		Temp (°C)	PH 7.0	Turbidity (NTU)	TSS (mg/l)
Asat	*Average (Rainy)*	*24.23*	*7.44*	*55.13*	100.88
	Average (Dry)	*26.90*	*7.80*	*37.72*	*77.13*
	Total	**25.56**	**7.62**	**46.43**	**73.50**
Ogal	*Average Rainy)*	*23.61*	*7.59*	*52.34*	*66.13*
	Average (Dry)	*27.26*	*7.51*	*29.30*	*71.23*
	Total	**25.44**	**7.55**	**40.82**	**68.68**
Usoma	*Average Rainy)*	*26.23*	*7.49*	*58.93*	*88.25*
	Average (Dry)	*27.64*	*7.52*	*26.21*	*85.13*
	Total	**26.93**	**7.51**	**42.57**	**86.69**
Lwangni	*Average Rainy)*	*25.19*	*8.29*	*58.06*	*95.08*
	Average (Dry)	*26.74*	*8.07*	*54.76*	*94.52*
	Total	**25.97**	**8.18**	**56.41**	**94.80**

Table 5: Chemical and Microbial quality of beach water at Lake Victoria

Site		DO (mg/L)	TN (mg/L)	TP (mg/L)	Escherichia coli (Counts/100ml)
Asat	Average (Rainy)	*6.97*	*1.26*	*0.38*	*174.63*
	Average (Dry)	*7.29*	*1.09*	*0.43*	*130.75*
	Total	**7.13**	**1.18**	**0.41**	**152.69**
Ogal	Average Rainy)	*7.38*	*1.11*	*0.13*	**181.81**
	Average (Dry)	*6.77*	*1.49*	*0.17*	**135.47**
	Total	**7.08**	**1.30**	**0.15**	**158.64**
Usoma	Average Rainy)	*6.48*	*1.13*	*0.16*	*218.69*
	Average (Dry)	*6.75*	*1.18*	*0.17*	*181.81*
	Total	**6.62**	**1.16**	**0.16**	**200.25**
Lwangni	Average Rainy)	*6.72*	*1.26*	*0.17*	*215.31*
	Average (Dry)	*6.44*	*1.10*	*0.34*	*206.06*
	Total	**6.58**	**1.18**	**0.26**	**210.69**

BOD$_5$: Results revealed BOD$_5$ of 11.53mg/L and 11.38mg/L for wet and dry seasons respectively while those of urban and rural clusters were 9.78mg/L and 13.13 mg/L respectively (*Table 6*).

Table 6: Classification of BOD_5 results by season and cluster

Wet	Dry	Rural	Urban
11.53 mg/L	11.38 mg/L	9.78 mg/L	13.13 mg/L

Using the formula in section (*Equation1*), that is:

$$(BOD_5 - as - mgO_2/L) = \left(\frac{(D_1 - D_2) - (B_1 - B_2)f}{(P)}\right)$$

This formula guided the results summarized in *Table 7,* as illustrated in details in *Table 8*.

Table 7: Detailed illustration of average BOD_5 results

Site	Asat		Ogal		Usoma		Lwangni	
Season	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sample Vol. (mL)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bottle Vol. (mL)	200	250	250	250	250	250	250	250
D_1	6.70	6.61	7.01	6.71	7.01	6.85	7.03	6.96
D_2	6.56	6.37	6.72	6.49	6.68	6.62	6.76	6.66
Sample Deplet (D_1 - D_2)	0.14	0.24	0.29	0.22	0.33	0.23	0.27	0.30
Average B_1	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Average B_2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Blank Deplet (B_1 - B_2)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
f	0.025	0.02	0.02	0.02	0.02	0.02	0.02	0.02
(D_1 - D_2) - (B_1 - B_2)f	0.12	0.22	0.27	0.20	0.31	0.21	0.25	0.28
Reported BOD_5, mg/L	4.6	11.0	13.5	10.0	15.5	10.5	12.5	14.0

These results support earlier tests that demonstrated that rural sites are less polluted as compared to urban sites, and that wet seasons exhibit high pollution levels as compared to dry season. The BOD_5 results were within the recommended 5 – 15 mg/L for raw water reservoirs or tertiary effluents , and below the 30mg/L limit beyond which a water body cannot support aquatic life (*Nanyang Technological University, 2004*).. It is above this limit that toxins exist and the water cannot be used for recreation. The results confirm findings of a sister study by Okungu, *et al,* (2014) that the sites are engulfed with suffers low popularity in ecotourism industry due to risk perceptions. It confirms assertion by Okungu, *et al,* (2015), that dire ecological status of the waterfronts generates risks which significantly influence low participation by local people in recreational activities.

COMPARISON OF CONFIRMATORY RESULTS WITH HISTORICAL DATA

Table 8: Comparison of study results with Historical Data (2000 – 2005)

Quality Parameter	α	Unit standards (WHO, 2003)	Historical data *2000-2005* (LVEMP, 2005)		Confirmatory Research Data (2014)	
			Wet	Dry	Wet	Dry
Physical	Temp	-	24.16	26.31	24.82	27.13
	pH	7.0 to 8.0	8.08	8.53	7.7	7.73
	Turb	50 NTU	48.38	44.36	59.2	54
	TSS	200 – 250 mg/L	206.8	186.34	254.8	191.44
Chemical	DO	DO_f-DO_s>4 mg/L	6.58	6.01	6.89	6.81
	BOD_5	5 – 15 mg/L	10.02	9.11	11.53	11.38
	TP	Mg/L (No levels)	0.188	0.207	0.21	0.28
	TN	Mg/L (No levels)	0.992	0.901	1.19	1.22
Bacteriological	E. Coli	206 counts/ 100 ml undesignated	166.39	147.81	197.6	163.5

α = Indicator

Historical data and the data generated by the research results can be compared for the study locations as generalities. This is because the historical data did not specifically target the studied areas locations (Asat, Ogal Usoma and Lwangni beaches). Table 4 illustrates the comparison by wet and dry season.

The above data demonstrates an average increase in all the physical, chemical and bacteriological parameters (except pH under physical). The analysis yielding percentage change is further presented in *Table 9*.

Table 9: Comparison of average results with Historical Data (2000 – 2005)

Quality Parameter	α	Unit standards (WHO, 2003)	Historical data *2000-2005* (Av)	Confirmatory Research Data (2014) (Av)	Average Deviation	Percentage change
Physical	Temp	-	25.235	25.975	0.74	2.9%
	pH	7.0 to 8.0	8.305	7.715	-0.59	-7.1%
	Turb	50 NTU	46.37	56.6	10.23	22.1%
	TSS	200 – 250 mg/L	196.57	223.12	26.55	13.5%
Chemical	DO	DO_1-DO_5>4 mg/L	6.295	6.85	0.555	8.8%
	BOD_5	5 – 15 mg/L	9.565	11.455	1.89	19.8%
	TP	Mg/L (No levels)	0.1975	0.245	0.0475	24.1%
	TN	Mg/L (No levels)	0.9465	1.205	0.2585	27.3%
Bacteriological	E. Coli	206 counts/100 ml undesignated	157.1	180.55	23.45	14.9%

α = Indicator

The *Figure 11* presents graphical outlook of the percentage of the deviations of the recreational waters of Lake Victoria as established from table 9.

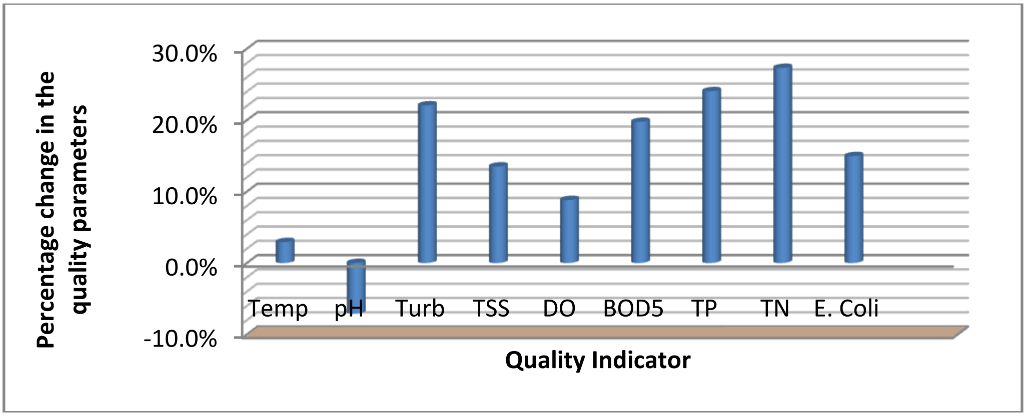


Figure 11: Percentage comparison of status of historical and research data (2000-2005)

From Figure 11 temperature remained relatively constant because of persistent thermal stratification, and vertical mixing through the density currents across the lake. The pH in the other hand declined towards neutrality. The rest of the indicators were way above 10% mark (except DO). These results confirms the increasing an increased magnitude of pollution

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Lake Victoria's water stress arise from uncontrolled and undesirable human activities in the face value, and poor planning and lack policy implantations on a focused scenario. The same is akin to other riparian countries that share the lake with their buffers being riddled with pollution agents from industrial, commercial and agricultural activities. The river basin networks leading to the lake contribute to the high turbidity levels, but their dilution effects lowers the pathogenic risk of contagious illnesses. The beach water temperatures and pH in Lake Victoria, Kisumu County are both conducive for recreational water-bodily contact during rainy/wet and dry seasons, in both urban and rural waterfronts, and in the morning and evening hours. This signifies suitability of the sites for recreational activities. The beach waters remain relatively turbid with considerably high amounts of Total Suspended solids across board but not above the acceptable levels for swimming and aesthetics, but this can only be profiled for natural water bodies. However, the present turbidity levels do not enhance adequate water clarity that should enhance a swimmers' estimation of depths and dangerous objects or aquatic reptiles. The levels of turbidity and suspended loads escalate during rainy/wet seasons as compared to dry seasons.

Levels of Dissolved Oxygen are relatively moderate in Lake Victoria with meagerly dwindling ratios, which, however is a confirmation of industrial lake pollution and Biochemical Oxygen Demand levels. Likewise, the lake water's pollution with Nitrogen element results to the speedy eutrophication, algal bloom and multiplication of water hyacinth. This has created an eyesore condition and skeptism among potential recreationists as ecotourists. By releasing lots of nitrogen and phosphorous into the lake, agricultural sector bear the responsibility for high eutrophication rates, leading to the algal bloom and high BOD concentrations. This scenario acquaints this study with the reason why sister studies did not find recreational activities to be popular in all the areas studied. Urban waterfronts are prone to high E.Coli levels while both rural and urban waterfronts experience high E.Coli counts during rainy seasons as opposed to dry seasons. But for either clusters or seasons, time of the day does not determine levels of beach water pollution. The determined E.Coli levels, though not too detrimental for swimming, deserve controls for the beach waters to be rated favorably for recreational activities.

Recommendations

Solutions for the stress on the recreational waters, especially in African countries, can be arrived at through efficient planning and policy implementation. The study recommends planning and implementation of infrastructure augmentation and site sanitization, including public sensitization programmes; cooperation among locals, polluters and authorities with an aim of enhancing responsibility towards sustainability of safe recreational waters; enhancement of institutional capacities so as to enable them respond to pollution prevention policy; image and destination branding of the sites, including designation of beaches for recreational activities.

The study recommends profiling of the following through proper planning and implementation within the facets of recreational waters: designation of recreational areas; Identification of contaminant sources and assemble relevant information; control discharge of municipal wastewater.

Further research is suggested on recreational water quality modeling for specific water fresh water bodies in Africa to establish possible time and levels at which the such waters would no longer be useful for any meaningful economic venture, especially recreation.

REFERENCES

American Public Health Association, American Water Works Association and Water Environment Association. *(2012). Standard methods for the examination of water and wastewater*. Cenveo Publisher Services, U.S.A.

Behar, S. (1997).*Testing the Waters: Chemical and Physical Vital Signs of a River* . Montpelier, VT: River Watch Network, ISBN-0-782-3492-3.

Canadian Council of Ministers of the Environment. (2008). *Recreational water quality guidelines and aesthetics*; Ottawa, Canada

COWI Consulting Engineers (2002). Integrated Water Quality/Limnology Study for Lake Victoria. Lake Victoria Environmental Management Project, Part II Technical Report.

Drechsel. P, C.A. Scott, L. Raschid-Sally, M. Redwood, and A. Bahri. (2010). *Wastewater Irrigation and Health. Assessing and Mitigating Risk in Low-Income Countries*, IWMI-IDRC Earthscan. 432pp.

East African Community (2007). *Regional Transboundary Diagnostic Analysis for the Lake Victoria Basin.* Kisumu, Kenya. http://iwlearn.net/iw-projects/2405/reports. accessed on 18th December, 2014.

EPA. (2013). *Dissolved Oxygen Depletion in Lake Erie*. In Great Lakes Monitoring. Retrieved from http://www.epa.gov/glindicators/water/oxygenb.htm - accessed on 28th Dec., 2014.

Glibert, P.M., E. Mayorga and S. Seitzinger. (2008). *Prorocentrum minimum tracks anthropogenic nitrogen and phosphorus inputs on a global basis*: Application of spatially explicit nutrient export models. Harmful Algae 8(1): 33-38, 2008.

HACH Company (1997-2009). Calorimeter Procedures Manual. DR/980.

Johnson, R.L, Holman, S, Holmquist, D.D (1999). Water Quality with CBL Vernier Software, Oregon.

Kayombo, S. and Jorgensen S. E (2006). Lake Victoria, Experience and Lessons Learned Brief Dar es Salaam University, Dar es Salaam, Tanzania, *kayombo@wrep.udsm.ac.tz & Royal Danish University of Pharmaceutical Sciences, Copenhagen, Denmark.*

Keys, P., Barron, J., and Lannerstad, M. (2012). *Releasing the Pressure: Water Resources Efficiencies and gains for Ecosystem Services*. Nairobi: UNESCO; Stockholm Environment Institute.

Kitissou M., Ndulo M., Mechthild N. and Grieco M. (2007). The Hydropolitics of Africa A Contemporary Challenge. Cambridge Scholars Publishing. 15 Angerton Gardens, Newcastle, NE5 2JA, UK.

Kiwango, Y.A., and Wolanski, E. (2007). Papyrus wetlands, nutrients balance, fisheries collapse, food security, and Lake Victoria level decline in 2000–2006. *Wetlands Ecology Management* December.

KLIP Ecotourism Symposium (2013). *Ecotourism Symposium and Expo July 25th -27th 2013*. Mistra Urban Futures-Kisumu Local Interaction Platform 3-day ecotourism symposium and expo held at Kisumu Museum on 25th - 27th July 2013.

Lake Victoria Initiative (2006) Lake Victoria Initiative January – August 2006 Report, September.

Lubovich, K. (2009). *Cooperation and Competition: Managing Transboundary Water Resources in the Lake Victoria Region.* Working Paper No. 5. Foundation for Environmental Security and Sustainability.

LVEMP, (1995). *Lake Victoria Environmental Management Project Document*. Governments of Kenya, Uganda and the United Republic of Tanzania.

Machiwa, Praxeda K. (2002). *Water quality management and sustainability: The experience of Lake Victoria Environmental Management Project (LVEMP) – Tanzania*. Paper presented at the WaterNet/Warfsa Symposium, Dar es Salaam.

Minnesota Pollution Agency (2008). Phosphorus, Nitrogen Sources, *Impact on Water Quality* - A General Overview Water Quality/Impaired Waters #3.22.

NASA. 2007. Water hyacinth reinvades Lake Victoria. http://earthobservatory.nasa.gov/ Newsroom/ New Images/images.php3?img_id=17560.

Nyenje, P.M., J.W. Foppena, S. Uhlenbrooka, C.R. Kulabakob and A. Muwanga. (2010*). Eutrophication and nutrient release in urban areas of sub-Saharan Africa* — A review Science of The Total Environment Volume 408, Issue 3, 1 January 2010, Pages 447-455.

Okungu J. O, Hayombe, P. O., and Agong',' S. G., (2015). *Ecological Risk Perceptions and Public Participation in Recreational Activities within Lake Waterfronts in Kisumu County* . IJREES & K.A.J; ISSN 2311-2484. Jan. 2015. Vol. 2. No. 8.

Okungu J. O., Hayombe, P. O., and Agong',' S. g., (2014): *Assessing Water- Based Recreational Activities to Project Beach Ecotourism Potentials in Kisumu County.* IOSR Journal of Computer Engineering (IOSR-JCE) Volume 16, Issue 6, Ver. II (Nov – Dec. 2014).

U.S. Environmental Protection Agency (2012). Safe and Sustainable Water Resources**.** Strategic Research Action Plan 2012 – 2016. Resources EPA 601/R-12/004 | June 2012 | www.epa.gov/research.

USGS. (2008). Eutrophication. http://toxics.usgs.gov/definitions/eutrophication.html.

World Health Organization, (2003). *Guidelines for Safe Recreational Water Environments - Volume 1: Coastal and Fresh Waters*; WHO Library Volume 1.