BACTERIOLOGICAL LEVELS IN WATER DISTRIBUTED BY KEWASCO

Mutai Norah Chepkemoi
Lecturer, School Of Biological and Physical Sciences
Moi University, **KENYA**

ABSTRACT

Availability of safe and portable water may not be easy due to inadequate control, operation and maintenance of the water distribution system in developing countries. This study was conducted to ascertain whether water supplied by Kericho Water and Sanitation Company (KEWASCO) is safe for human consumption or not. Bacteriological parameter analysed was: *E. coli*. Samples were collected three times during the months of January, February and March from four stations namely, rivers feeding into the treatment plants, treatment plants (treated water), consumer terminals and dumpsite leachate. LST-MUG method was employed for detecting *E.coli*. *E.coli* tested negative in the first and second test in all stations while it tested positive in the third test in only two stations. The water which tested positive with *E.coli* from the consumer points was an indication that the water systems should be inspected to determine the cause. Sampling and inspection should continue until consecutive samples comply with the standards in the guidelines. The measure of *E.coli* was, however, within the water quality standards for municipal piped water and therefore fit for drinking. It is suggested that further research that focus on more resistant microorganisms, such as bacterio-phages and/or bacterial spores be done.

Keywords: *Water portability, bacteriological load, E-coli.*

INTRODUCTION

Distribution of safe, potable water by Kericho Water and Sanitation Company (KEWASCO) may not be easy due to inadequate control, operation and maintenance of the water distribution system, especially in developing countries (Serageldin, 1994).Thus, the quality of drinking water can deteriorate significantly between the treatment plant and the consumers' taps. Water utilities experience microbial problems in their distribution system that cannot be attributed to either operating or disinfection practices. Drinking water distribution systems provide a habitat for microorganisms that are sustained by both organic and inorganic nutrients present in the pipe and/or the conveyed water. Excessive microbial activity can lead to deterioration of the water in the aesthetic terms of colour, taste and odour. It may also interfere with the methods used to monitor such parameters of health significance as faecal coliform (FC) count, viral and helminthic ratio and biochemical oxygen demand percentage. Lack of information on the deterioration of water quality within a distribution system due to contamination intrusion exposes the consumers to effects stemming from these contaminants. This poses a great risk of such water-related diseases as cholera and typhoid to the consumers (Wilson, 1945).

Water distribution systems need to be safeguarded against pollutants, an end that can only be attained by surveillance. These pollutants can be identified using bacteriological and physico-chemical parameters and include organic and inorganic materials. Major organic pollutants majorly found within water distribution systems include bacteria, viruses and parasites. The

most useful indicators of faecal contamination are thermotolerant coliforms such as *E. coli*, *Salmonella* spp and *Shigella* spp as they are directly related to the presence of faecal contamination hence to the risk of disease. Bacteriological contamination poses the greatest threat to the health of the consumers. Viral and helminthic parasites may also be present in water, though these are less frequent and more difficult to identify in a given water sample

Statement of the Problem

World health organization has set standards torching on virtually every sphere of life and standard on water portability is no exception. Drinking water need to be free of harmful impurities such as bacteria. Water distributed by water authorities for domestic consumption should meet such standard, domesticated to Kenya context by Kenya bureau of standards. The purpose of this study was to analyze the portability of water distributed by KEWASCO in terms of bacteriological load

Objectives of the study

The objective of this study was to determine bacteriological parameter at consumer points of water distributed by Kericho Water and Sewarages Company.

LITERATURE REVIEW

The earliest precursor of pollution generated by life forms would have been a natural function of existence. The attendant consequences on viability and population levels fell within the sphere of natural selection. These would have included the demise of a population locally or ultimately, species extinction. Processes that were untenable would have resulted in a new balance brought about by changes and adaptations. At the extremes, for any form of life, consideration of pollution is superseded by that of survival (Chatwell, 1989).

For humankind, the factor of technology is a distinguishing and critical consideration, both as an enabler and an additional source of byproducts. Short of survival, human concerns include the range from quality of life to health hazards. Since science holds experimental demonstration to be definitive, modern treatment of toxicity or environmental harm involves defining a level at which an effect is observable (Bartone *et al.,* 1994).

The raw water will go through some processes in water treatment plant such as coagulation or flocculation, sedimentation, filtration, stabilization, fluoridation, chlorination and finally before allowing water to be used in the residential area, water will be tested for a few contaminants again. This is to ensure that the drinking water distributed is safe to be consumed by the public.

Mwangi *et al*. (2010) found out that *E. coli* MPN index per 100 ml ranged between 43- > 1100 against WHO standards. The bacteriological quality of the water as indicated by the total and *faecal coliform* counts exceeded the standard (0 cfu per 100 ml) for portable water. In general, the bacteriological quality of the water was unacceptable as it may pose risk to consumers if not treated. The poor quality indicated possible contamination with human or animal waste that could have been contributed by inadequate physical infrastructure, especially heavy reliance on pit latrines and weak solid waste management mechanisms. Lack of functioning solid and liquid waste management system in the rapidly growing urban

centre represents a possible and significant source of pollutants, which may find their way into water resources.

Although the WHO guidelines placed a lot of emphasis first and foremost on the microbiological safety of drinking water supplies, more than half of the world's population is still exposed to water that is not free from pathogenic organisms. This has resulted in infectious diseases that ultimately lead to increased mortality rates in the population (WHO, 2003).

The current study recorded a general decrease in TDS, conductivity, and total alkalinity from January to March for all sampling points possibly because of dilution effect as a result of heavy rain experienced in March. Mwangi *et al*. (2010) noted that conductivity ranged between 0.07 to 0.85 and 0- 180 EC mS/cm during wet and dry seasons, respectively. These values were, however, not in agreement with the results reported in the current study that ranged from 35 – 70 µs.

The corresponding TDS ranged between 21- 62.40 and 0-123 mg/L during wet and dry seasons as observed by Mwangi *et al*. (2010) which again were higher than the values obtained in the present study that ranged from 16- 30 mg/L. This could be due to as a result of inorganic fertilizers used by farmers. In another study, Akunga (2004) reported mean measurements for electrical conductivity to be 39.95µS for four private man-made reservoirs in the central part of Kericho count conducted between November 2001 and March 2002. This value was in close agreement with the values obtained in the present research.

The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm (APHA, 1992). The values reported in most rivers in USA were comparable to the values reported in this current study which ranged from 35-70 µs. This means majority of the stations recorded values which were 50 µs and above.

Fafioye and Adebanjo (2013) in their study reported several mean physico-chemical parameters of Azikwe River water samples in Nigeria were: pH-7.75 ± 0.3, alkalinity (mg/L) - 80.00 ± 3.74, hardness (mg/L) - 140.00 ± 6.15, conductivity (SC/m) - 480 ± 4.21 and turbidity (TU) - 8.60 ± 0.64. These values were within permissible criteria set by WHO but were much higher than the values obtained during the present study. They also reported TDS (mg/L) value of 510.00 ± 3.54, which was higher than the values indicated in the current research.

All natural waters contain some dissolved solids due to the dissolution and weathering of rocks and soil. It is the general indicator of ionic concentration. In another study Holmbeck-pelham *et al.* (1997) reported the TDS of the river water sample to be 10 mg/L higher than that of the federal US drinking water standards of 500 mg/L which can pose a health effect. It had been observed that water with high total dissolved solids is unpalatable and potentially unhealthy and this may affect the taste of the river water.

In the current study, the residual chloride recorded at main prison, prison staff residence and Moi estate were below the WHO maximum allowable limits and this could be attributed to

water flow velocity, residence time, age and material of the pipe and water pressure (Egorov, 2002).

It was also observed that during the third month most of the samples had no chlorine residual as sampling was carried out in the month when there were heavy rains and this could have led to increased level of suspended matter in the raw water hence need for higher dosages of chlorine for effective treatment. The source of KEWASCO raw water is springs which lie in an agricultural area thus suspended matter is washed into the treatment works. According to the WHO standards, the minimum Free Residual Chloride (FCR) should be 0.2 mg/L (WHO, 1998).

The total alkalinity of the water samples were below the permissible and desirable criteria for domestic water supply. The observed alkalinity was due to methyl orange alkalinity. Consequently, the water samples were not polluted with respect to alkalinity. Also, water hardness for Kericho Municipality as indicated by the results show that it is soft water as classified in Table 1.

METHODOLOGY

Reagents and Standards

To test for E-coli the following reagents and standard were used:

Analytical grade reagents together with distilled de-ionized water were used in preparation of reagents from Sigma Adrich. Among the reagents and standards used were nitric acid, hydrochloric acid,1+1, standard H_2SO_4, 0.02N, 0.1N Na_2CO_3 solution, methyl orange indicator, 16.9 g NH_4Cl, NH_4OH, Mg salt of EDTA (780 g $MgSO_4.7H_2O$), 4.5 g of hydroxylamine hydrochloride, Eriochrome black T indicator, sodium hydroxide, pH butter solutions for calibration, hydrochloric acid for cleaning pH probes and titrators, turbidity standards (StablCal Stabilized Formazin Standards), lab grade dish washing detergent, turbidity-free water, reagents and Bromophenol blue indicator.

Sample analysis

The dependent variable analyzed was *E- coli*. and standard was followed in determining the above variable. All probes were calibrated prior to measurements with the appropriate traceable calibration solutions in accordance with manufacturer's instructions.

Sampling procedure for bacteriological analysis

The taps were cleaned and the tap attachments that could cause splashing were removed. The taps were turned on for maximum flow and the water was left to run for 1-2 minutes to ensure that stagnant water was flushed from the pipes before the samples were taken.

The sampling bottles were taken and carefully the caps were unscrewed. Sodium thiosulphate solution had been added to the bottles before sterilization to neutralize chlorine. While holding the cap and protective cover facing down (to prevent entry of dust, which could contaminate the sample) immediately the bottles were held under the water jet, and filled. A small air space was left to make shaking easier before analysis. The bottles were capped and covered with aluminium foil.

Analytical Procedure for bacteriological load

The method employed LST-MUG method for detecting *E.coli*. The LST-MUG assay is based on the enzymatic activity of β- glucuronidase (GUD), which cleaves the substrate 4 - methylumbelliferyl β-D glucuronide (MUG), to release 4-methylumbelliferone (MU). When exposed to long wave (365 nm) UV light, MU exhibit a bluish fluorescence that is easily visualized in the medium or around the colonies (Doyle and Schoeni, 1987). Cerium oxide, which is added to glass as a control measure, fluoresces under UV light and interferes with the MUG test (Hartman, 1989). One tube was inoculated having LST-MUG with a known GUT- positive *E. coli* isolate as positive control, ATCC standard reference Materials™ (ATCC 25922). In addition, another tube inoculated with a culture of *Enterobacter aerogenes* (ATCC 13048) as negative control, to facilitate differentiation of sample tubes that show only growth from those showing both growth and fluorescence. Both tubes were incubated for 48 h at 35 ^{0} C and were examined for growth (turbidity, gas) then again examined in the dark under long wave UV lamp (365 nm) and a bluish fluorescence was a positive presumptive test for *E.coli*.

RESULTS AND DISCUSSION

Variations in concentration of the bacteriological Parameters

Table 4.1 show physicochemical parameters analysed during the sampling period
After the analysis of the sampled water, the results for E-coli were as shown table 4.1 below

Table 1.1 Mean values of bacteriological and physicochemical parameters analysed in January

Stations	Parameter															*E.coli* **(-VE)**		
																Jan	Feb	Mar
Ngecherok																-VE	-VE	-VE
Timbilil																-VE	-VE	-VE
Prison staff reside																-VE	-VE	-VE
Main prison tap																-VE	-VE	-VE
Moi estate																-VE	-VE	**+VE**
Nyagacho																-VE	-VE	**+VE**

NB: bolded and in the brackets are WHO, (2004) standards.
Key: -VE – Nil, +VE - Presence

From Table 4.1, the results show that test parameter for E-coli was above the recommended WHO standard in some stations (Moi estate and Nyagacho). (See Appendix I)

The *E.coli* detected at Moi estate and Nyagacho during the month of March could be due to mineral content and pH that brought about the corrosion of the water pipes and growth of bacteria in the distribution network (Wagner, 1994). In addition, the presence of thermo tolerant coliforms in the samples suggests contamination of the water by faecal matter. Since these changes were only observed in samples from consumer collection points and not from treatment plants, it implies contamination along the reticulation system or at the collection points. This could be attributed to the regular bursting of water pipes along the distribution system. Another contributing factor could be contamination at the collection site and in the laboratory during analysis or possibly due to microbial resistance to chlorine. The water from other stations did not record any bacteriological activity since all the tests for *E. coli* turned out to be nil. Thus the chlorine levels were adequate to disinfect the water throughout the distribution system and this guaranteed that the water quality was suitable for drinking.

Mwangi *et al*. (2010) found out that *E. coli* MPN index per 100 ml ranged between 43- > 1100 against WHO standards. These were comparable to the results obtained in the current study since it was an indication that water was not fit for consumption. The bacteriological quality of the water as indicated by the total and *faecal coliform* counts exceeded the standard (0 cfu per 100 ml) for portable water. In general, the bacteriological quality of the water was unacceptable as it may pose risk to consumers if not treated. The poor quality indicated possible contamination with human or animal waste that could have been contributed by inadequate physical infrastructure, especially heavy reliance on pit latrines and weak solid waste management mechanisms. Lack of functioning solid and liquid waste management system in the rapidly growing urban centre represents a possible and significant source of pollutants, which may find their way into water resources.

Although the WHO guidelines placed a lot of emphasis first and foremost on the microbiological safety of drinking water supplies, more than half of the world's population is still exposed to water that is not free from pathogenic organisms. This has resulted in infectious diseases that ultimately lead to increased mortality rates in the population (WHO, 2003).

The current study recorded a general decrease in TDS, conductivity, and total alkalinity from January to March for all sampling points possibly because of dilution effect as a result of heavy rain experienced in March. Mwangi *et al*. (2010) noted that conductivity ranged between 0.07 to 0.85 and 0- 180 EC mS/cm during wet and dry seasons, respectively. These values were, however, not in agreement with the results reported in the current study that ranged from 35 – 70 µs.

The corresponding TDS ranged between 21- 62.40 and 0-123 mg/L during wet and dry seasons as observed by Mwangi *et al*. (2010) which again were higher than the values obtained in the present study that ranged from 16- 30 mg/L. This could be due to as a result of inorganic fertilizers used by farmers. In another study, Akunga (2004) reported mean measurements for electrical conductivity to be 39.95µS for four private man-made reservoirs in the central part of Kericho count conducted between November 2001 and March 2002. This value was in close agreement with the values obtained in the present research.

The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm (APHA, 1992). The values reported in most rivers in USA were comparable to the values reported in this current study which ranged from 35-70 µs. This means majority of the stations recorded values which were 50 µs and above.

Fafioye and Adebanjo (2013) in their study reported several mean physico-chemical parameters of Azikwe River water samples in Nigeria were: pH-7.75 ± 0.3, alkalinity (mg/L) - 80.00 ± 3.74, hardness (mg/L) - 140.00 ± 6.15, conductivity (SC/m) - 480 ± 4.21 and turbidity (TU) - 8.60 ± 0.64. These values were within permissible criteria set by WHO but were much higher than the values obtained during the present study. They also reported TDS (mg/L) value of 510.00 ± 3.54, which was higher than the values indicated in the current research.

All natural waters contain some dissolved solids due to the dissolution and weathering of rocks and soil. It is the general indicator of ionic concentration. In another study Holmbeck-pelham *et al.* (1997) reported the TDS of the river water sample to be 10 mg/L higher than that of the federal US drinking water standards of 500 mg/L which can pose a health effect. It had been observed that water with high total dissolved solids is unpalatable and potentially unhealthy and this may affect the taste of the river water.

In the current study, the residual chloride recorded at main prison, prison staff residence and Moi estate were below the WHO maximum allowable limits and this could be attributed to water flow velocity, residence time, age and material of the pipe and water pressure (Egorov, 2002).

It was also observed that during the third month most of the samples had no chlorine residual as sampling was carried out in the month when there were heavy rains and this could have led to increased level of suspended matter in the raw water hence need for higher dosages of chlorine for effective treatment. The source of KEWASCO raw water is springs which lie in an agricultural area thus suspended matter is washed into the treatment works. According to the WHO standards, the minimum Free Residual Chloride (FCR) should be 0.2 mg/L (WHO, 1998).

The total alkalinity of the water samples were below the permissible and desirable criteria for domestic water supply. The observed alkalinity was due to methyl orange alkalinity. Consequently, the water samples were not polluted with respect to alkalinity. Also, water hardness for Kericho Municipality as indicated by the results show that it is soft water as classified in Table 1.

A few drops of concentrated nitric acid were added to water samples to reduce the pH to less than 2. This was done in different sampling sites of the study, the results of the analysis are given in three sections according to where the water sample was taken from, and the results of the outcome are indicated in Figure 5 and Table 5.

CONCLUSION AND RECOMMENDATIONS

Based on the findings, the water supplied by KEWASCO was found to be far much safer for drinking purposes as compared to other untreated water. The water, which tested positive with *E.coli* from the consumer points, was an indication that the water systems should be inspected to determine the cause and sampling should continue until consecutive samples comply with the standards in the guidelines. Other physico- chemical parameters tested in the treatment plants and consumer points were within the acceptable standards and thus do not need any further treatment once it reaches the consumer points.

E. coli provides conclusive evidence of recent faecal pollution and should not be present in drinking water. In practice, testing for thermo tolerant coliform bacteria can be an acceptable alternative in many circumstances. While *E. coli* is a useful indicator, it has limitations. Enteric viruses and protozoa are more resistant to disinfection; consequently, the absence of *E. coli* will not necessarily indicate freedom from these organisms. Under certain circumstances, it may be desirable to include more resistant microorganisms, such as bacteriophages and/or bacterial spores in future research. Such circumstances could include the use of source water known to be contaminated with enteric viruses and parasites or high levels of viral and parasitic diseases in the community. It is suggested that further research that focus on more resistant microorganisms, such as bacterio-phages and/or bacterial spores be done.

REFERENCES

Afiukwa, J.N. (2013). Evaluation and correlation study of heavy metals load in drinking water and update of water-related disease cases in Ebonyi State from 2001 – 2011. American Journal of Scientific and Industrial Research, Science Hup, http://www.scihub.org/AJSIR, ISSN: 2153-649X, doi: 10. 5251/ajsir. 2013.4.2. 221.225.

Agard, L., Alexander, C., Green, S., Jackson, M., Patel, S. and Adesiyun, A. (2002). Microbial quality of water supply to an urban community in Trinidad. J. Food Prot. 65(8), 1297–1303.

Agency for Toxic Substances and Disease Registry (ATSDR) (2008). Toxicological Profile for Cadmium *(Draft for Public Comment).* Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Akunga D.N and Wamicha W.N (2004): Bacteriological Quality in Freshwater Reservoirs in Kericho Tea Estates in Kenya: Implications for Environmental Health Education. . In Status of Environmental Health education in the eastern African Region: Opportunities challenges and the Way forward, Joy pet Publishers, Nairobi.

Alloway, B.J. (1995). Heavy metals in soils 2nd edition. Blackie academic and professional. 122 – 305.

Almgren T., Dyrssen .D. & Fonselius S., (1983). Determination of alkalinity and total carbonate. In; method of sea water analysis.

American Public Health Association, American Water Works Association, and Water Environment Federation (1998). *Standard Methods for the Examination of* Water and Wastewater. American Public Health Association, Washington, D.C.

American Society for testing and Materials (1982). Standards methods for acidity or alkalinity of water, ASTM Publ. D1067-70,Philadephia,Pa

American Water Works Association, (1999). Waterborne Pathogens Manual, Manual M48 (Denver: AWWA).

American Society for Testing and Materials, (1977). Annual l Book of STM Standards, Part 26, Method D3112-77, American Soc. Testing and Materials, Philadelphia, Pa.

Annual Book of ASTM Standards, (2000). Volume 11.01 Water (I), Revised Annually, ISBN 0-80312814-2, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

APHA (1992). Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association, Washington, DC.

APHA, AWWA and WEF, 21st Ed., (2005). Standard Methods for the Examination of Water and Wastewater. New York American Public Health Association, Washington DC.

Bailey, I. W. and Thompson, P. (1995). Monitoring water quality after disinfection. Water Supply. 13(2), 35–48.

Baylis, J. R. (1922). "Microorganisms in the Baltimore Water Supply"J.AWWA, 9: 712

Baylis, J.R. (1930)." "Bacterial After growths in Water Distribution Systems" J. AWWA, 77:335.

Bartone, C., Bernstein, J., Leitmann, J. and Eigen, J. (1994). Toward Environmental Strategies for Cities: Policy considerations for Urban Development Management in Developing Countries. UNDP/UNCHS/World Bank, Urban Management Programme, Washington, D.C.

Bernard, A. (2008). Cadmium and its adverse effects on human health. Review Article. Indian J Med Res 128, pp 557-564.

Besner, M.C. (2001). "Understanding distribution system water quality" Journal of the American water works Association,Vol 93.

Besner, M. C., Gauthier, V., Servais, P. and Camper, A. (2002). Explaining the occurrence of coliforms in distribution systems.J.AWWA, 94(7): 96- 105

Bhargava, D.S. (1982). Usefulness of Ganga. Journal Indian Water Works. Associations ; 14(3) : 54-60

Black, A.P. and Hannah, S.A. (1965). Measurement of low turbidities. J. American water Works Ass, 57 :901.

Blowes.D., *(*2002*).* "Tracking Hexavalent Cr in Groundwater". Science 295 *(*5562*):* 2024–25. doi*:*10.1126*/*science.1070031. PMID 11896259.

Bopp, C.A., Brenner, F.W., Wells, J.G., Strockbine, N.A. (1999). Escherichia, Shigella and Salmonella. In: Murray, P.R., Baron, E.J., Pfaller, M.A., Tenover, F.C., Volken, R.H. (eds), *Manual of Clinical Microbiology*, 7th edition. ASM Press, Washington DC, pp 459-474.

Boyd, G.R., Tarbet, N.K., Kirmeyer, G.J., Murphy, B.M., Serpente, R.F., and Zammit, M., (2001). selecting lead pipes rehabilitation and replacement technologies, Journal of American water works associations, Vol 93 No 7, pp 74- 87.

Castelle, A.J., Johnson, A.W. and Connolly, C. (1994). Wetland and stream buffer size requirements: A review. *Journal of Environmental Quality.* 23(5): pp 878-882.

Chandrashekara, K.V., (2002). Microbiological load analysis methods-qualitative and quantitative (focusing on emerging waterborne pathogens and consequences)., In Water Quality Management : South Asian Perspective, Vision 2025. ILSI – India & UNICEF.

Chapman, D., (1992). Water quality Assessment; A guide to the use of biodata, sediments and water in environmental monitoring. University press, Cambridge, pp. 585

Chatwell, G.R. (1989). Environmental Water Pollution and Control, Anmol Publication , New Delhi.

Chen, X. and Stewart, P.S. (2000). Biofilm removal caused by chemical treatments. Water Res34:4229-4233.

Chinese Department of Preventive Medicine (1994). *Threshold for Food Hygiene.* Beijing: China Standard Press. (In Chinese).

Citizens' report card, (2007). Urban water, sanitation and solid waste services in Kenya. Pp 29- 30

Clesceri, L.S. and Greenberg, A.E. (1998). Standard methods for the examination of water and wastewater, 20th ed.Amercan Public Health Association, Washington DC, pp 1325

Copyright @ 2008-09 www.mapsoftworld.com- retrieved 6/8/2010

Congressional Budget Office Study (2002). Future Investment in Drinking Water and Wastewater Infrastructure.

Cosser, P.R., (1989). Nutrient concentration-flow relationships and loads in the South Pine River, southeastern Queensland, I, Phosphorus loads. Aust. J. Mar. Freshwater Res. 40: 613-630

Coultate, T.P. (1992). Food, the Chemistry of Its Components. 2nd Ed., Royal Society of Chemistry, Cambridge CB4 4WF, pp: 325. Countries. Intermediate Technology Publications, London.

Department of fisheries and environment, Canada, (1977). Water quality branch, surface water quality in Canada. An overview, Ottawa.

Doyle, M.P. and Schoeni J.L., (1987). Isolation of Escherichia coli 0157:H7 from retail meats and poultry. Appli.Environ.Microbiol.53:2394-2396.

Doyle, E. (2002). "Production and distribution of drinking water," Walkerton Inquiry Commissioned Paper 8, p. 76.

Duffus, J.H. (1980). Environmental toxicology, Edward Arnold, London. pp 68-78.

Draft Final Report, (2005). Buffering Processes and Capacity of wetlands on the Kenya Side of Lake Victoria, LVEMP and MENR. Pp 4.3 -4.9

Drinking water treatment- www.epa.gov/safewater.- 8/6/11

Ecology Fact Sheet, (2002).Treatment – specific guidance: Carbon Adsorption , Washington *#96-415.*

Egorov, A. (2002). Deterioration of drinking water quality in distribution system and gastrointestinal morbidity in a Russian city. Int.J.Environ. Health Res. 13(3), 221-233.

Ellen, G., van Loon, J.W. and Tolsma, K. (1990). Heavy metals in vegetables grown in the Netherlands and in domestic and imported fruits. Z Lebensm Unters Forsch, 190: 34-39.

Elizabeth K.M. and Premnath N.L. (2005). Effect of polluted water on human health, *pol res*, 24(2) ,337

EPA. (2006). Basic Information about E. coli 0157:H7 in Drinking Water. From http://www.epa.gov/safewater/contaminants/ecoli.html- 6/8/2010

EPA. (2008). National Primary Drinking Water Regulations & National Secondary Drinking Water Regulations. From http://www.epa.gov/safewater/contaminants/index.html#primary- 6/8/2010

Ewing, W.H. (1986). Edwards and ewing's identification of Enterobacteriaceae, 4th ed. Elsevier, New York.

Fafioye, O. O. & Adebanjo D. T., (2013). Water parameters and biochemical composition of two fish species (*Tilapia niloticus* and *Sardinella aurita*) obtained from Azikwe River, Nigeria. Academia Journal of Scientific Research 1(1): 010-015

http://www.academiapublishing.org/ajsr; ISSN: 2315-7712, ©2013 Academia Publishing

Feng, P.C.S. & Hartman, P.A. (1982). Fluorogenic assays for immediate confirmation of *Escherichia coli*.Appl. Environ. Microbiol. 43: 1320- 1329.

Fergusson, J.E. (1990). The Heavy Elements: Chemistry, Environmental Impact and Health Effects. Oxford: Pergamin Press; pp. 382–399.

Guidelines for Canadian drinking water quality (1996), 6th edition. Canada Communication Group – Publishing Ottawa, Canada K1A 0S9.

Hach Company, (1992). Hach water analysis handbook. 2nd ed. Loveland, CO.

Hach Company (2002). Water Analysis Handbook, 4th Ed., Orientation of Sample Cells, Matching of Sample Cells, pp. 36-37.

Hanna® Instruments, (2000). Instruction Manual HI 9023C – HI 9023 CN – HI 9024C – HI 9025C – HI 9110 – HI 9210 Portable Waterproof pH Meters. Bedfordshire

Harris, D. C. (2003). " Quantitative Chemical Analysis 6th ed."; pp. 259-267.

Hart,B.T. (1992), Australian water quality quidelines, Dratf for public comments. Ausralian and New Zealand Environment and conservation council, Australian.

Hartman, P.A. (1989). The MUG (glucuronidase) test for Escherichia coli in food and water, pp. 290-308. In: rapid Methods and Automation in Microbiology and Immunology. A.Balows, R.C. Tilton, and A. Turano (eds). Brixia Academic Press,Brescia, Italy.

Holmbeck-pelham S.A and Rasmussen T.C (1997). Characterization of temporal and Spatial Variability of turbidity in the upper Chattahoochee River pp. 72-79.

Internet: Wikipedia – www.fallingrain.com/world/KE/08/Kericho.html-8/6/2010

ISO 7027: (1999).Water Quality – Determination of Turbidity, International Standards Organization, Geneva, Switzerland.

ISO 9174 :(1990). Water quality-determination of total chromium. International Standards Organization. Geneva.

Jones, J.C. (2008). Atmospheric pollution. 1st edition. Jones and ventures Pub. APS California, pp 64-71.

Koech, W.K. (2003) "Assessment of Water Quality Parameters and Concentration of Selected Metals in Dionosoyiet River in Kericho Municipality." MPhil Thesis, Moi University School of Environmental Studies

KWAHO/UNDP Initiative: Report on the Assessment of the Capacity
of Water Actors to Effectively Participate in Water Sector Reforms in Bondo District- Retrieved 12/8/2011, pp 25-26

Kofoid, C.A. (1923). Microscopic Organisms in Reservoirs in Relation to the Esthetic Qualities of Potable Waters, J. AWWA 10:183.

LeChevallier, M.W. (1989). Treatment to meet the microbiological MCL in the face of a coliform regrowth problem. American water works association.

Lee, E. J., & Schwab K. J. (2005). Drinking water distribution systems in developing countries. Journal of Water and Health.

Macdonald D.W and Christopher E. O (2011). Pollution studies on Nigerian rivers: heavy metals in surface water of warri river, Delta State. Journal of Biodiversity and Environmental Sciences (JBES) ISSN: 2220-6663, Vol. 1, No. 3, p. 7-12, 2011.

Mato, R.A.M. (2002). Ground water pollution in urban Dar es Salaam, Tanzania: Assesing vulnerability and protection priorities, Eindhoven University of technology, Netherlands.

Mazingira news Magazines – May/June 2008- Unpublished.

Michaud, J. P. (1994). "Measuring Total Suspended Solids and Turbidity in lakes and streams." A Citizen's Guide to Understanding and Monitoring Lakes and Streams. State of Washington, Department of Ecology.

Miller, B. M. and Litsky, W. (1976). Industrial Microbiology, McGraw-Hill, NY.

Moore, F., Forghani, G. and Qishlaqi, A., (2009). Assessment of heavy metal contamination in water and Surface sediments of the maharlu saline lake, sw iran. Iranian Journal of Science & Technology, Transaction A, Vol. 33, No. A1 Printed in the Islamic Republic of Iran, © Shiraz University.

Mulder, E. G. (1964). "Iron Bacteria, particularly those of the *Sphaerotilus-Leptothrix* Group, and Industrial Problems," J. Appl. Bact., 27:151.

Mwangi, J.K., Thiongo,G.T., Gathenya, J.M.,(2010). Assessment of the water quality status of Sasumua watershed, Kenya: A proceeding of 2010 JKUAT Scientific technological and industrialization conference.

Napacho, Z.A & Manyele, S.V. (2008). Drinking Water Quality Assessment inTemeke District, Part I: Characterization of Physical Parameters, 6th IET International Conference, Arusha International Conference Centre (AICC), Tanzania, 10-12 Dec., pp. 222-233.

Nelson, K.E. (2001). Early history of infectious disease; epidemiology and control of infectious diseases. Aspen Publishers, Gaithersburg, Maryland.

Nygard, K., Wahl, E., Krogh, T. & Tveit, O.A. (2007). Breaks and maintenance work in the water distribution systems and gastrointestinal illness: a cohort study, International journal of epidemiology, 36, pp 873-880.

Ochieng, E.Z., Lalah, J.O. & Wandiga, S.O., (2002). Analysis of heavy metals and surface sediments in five Rift Valley lakes in Kenya for assessment of recent increase in anthropogenic activities. Bulletin of environmental contamination and toxicology, 79: 570-576

Ogundiran, O.O. & Afolabi, T.A. (2008). Assessment of the physicochemical parameters and heavy metal toxicity of leachates from municipal solid waste open dumpsite. Int. J. Environ. Sci. Tech., 5(2): 243-250.

Omoga, T.O & Kagwanja, S.M. (1999). Determination of levels of cadmium, lead, chromium, zinc and copper in honey samples from selected areas in Kenya. J. Biochemphysics. 8 (1 and 2).

Ongulu, R. A. (2008). A study of selected heavy metals, phosphorus and Nitrogen contamination in water and sediments in the Chemelil Sugar belt, M Phil Thesis, Moi University.

Paus, P.E., (1973). Determination of some heavy metals in seawater by atomic absorption spectroscopy. Frecenius Zeistchr. Anal, Chem. 264:118.

Population and Household (2009 census). Kenya open data – retrieved 4/6/2010

Ryu H, Alam A. & Abbaszadegan M. (2005). Microbial characterization and pollution changes in non potable reclaimed water distribution systems, Environ. Sci. Technol., 39, 8600- 8605.

Sadar, M.J. (1996).Understanding turbidity science. Technical Information Series, Booklet II. Hach Co., Loveland, CO.USA.

Serageldin, I. (1994). Water supply, sanitation and environmental sustainability: the financing challenge. Keynote address to The Ministerial Conference on Drinking Water and Environmental Sanitation: Implementing Agenda 21, Noordwijk, the Netherlands,22-23 March.

Schock, M. R. (1999). "Internal corrosion and deposition control". In Water Quality & Treatment. A Handbook of Community Water Supplies. 5th edition. Chapter 17. AWWA, R.D. Letterman, editor New York. McGraw Hills.

Schuringa, M. (1999). Strategic Element in water supply and sanitation services in urban low income areas. Water front Japan, 14: 3-6.

Schmoll, O., Howard, G., Chorus, I. and Chilton, J (eds) (2004). Protecting groundwater for health: a guide to managing the quality of drinking-water sources. World Health Organization, Geneva.

Shitsama, J. M., (1999). Heavy metal contaminants in fish, water and sediments in Lake Victoria, Kenya. MPhil thesis, Moi University.

Suess, M.J. [Ed.], (1982). Examination of Water for Pollution Control. Volume 2, Physical, Chemical and Radiological Examination Pergamon Press, London.

Trivedy, R.K. and Goyal, P.K. (1986). Chemical and Biological Methods for water pollution studies, Env. Publications, Karad, 35-96.

Tuovinen, O. H., & Hsu, J. C. (1982). "Aerobic and Anaerobic Microorganisms in Tubercles of the Columbus, Ohio, Water Distribution System" Appl. Environ. Microbial. 44:761.

Tuovinen, O. H., Button, K. S., Vuroinen, A., Carlson, L., Mair, D. M., and Yut, L. A. (1980). Bacterial, Chemical and Mineralogical Characteristics of Tubercles in Distribution Pipelines J. AWWA 72:626.

Tyagi, O.D. & Mehra M. (1990). A Textbook of Environmental Chemistry, New Delhi, Animal publications.

UN-Water / World Water Assessment Program. (2006). Kenya National Water Development Report. 2nd UN World Water Development Report "Water: A shared responsibility.

U.S. EPA. (2010). IRIS Toxicological Review of Hexavalent Chromium (External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/635/R-10/004A.

U.S. EPA, (1990). EPA guidance manual for compliance with filtration and disinfection requirement. U.S. Environmental Protection Agency, Washington DC.

U.S. EPA, (2010). Waste and cleanup risk assessment glossary: U.S. Protection Agency, access date April 4, 2011

Van Loon, J.C., 1982. Chemical Analysis of Inorganic Constituent of Water. CRC Press.2: 12-46

Vitale, R.J., Mussoline G.R., & Rinehimer, K.A (1997). Environmental Monitoring of chromium in air, soil, and water. Regul. Toxicol. Pharmac, 26: S80.

Wagner, D., Chamberlain, A.H.L., Fischer, W.R., Wardell, J.N.,Sequeira, C.A.C., 1997. Microbiologically influenced corrosion of copper in potable water installations—a European project review. Materials and Corrosion 48, 311–321.

Water Quality Criteria (1972). Environmental Studies Board, National Academy of Sciences.

Waters, (2004) Natural and Constructed Wetlands, Course Notes OENG, RMIT University.

WHO (1984), Guidelines for drinking water Quality. Health criteria and other supporting Information. Vol.2, World Health Organization, Geneva. Pp 231.

WHO (1988) Chromium. International Programme on chemical safety. Environmental Aspects, Environmental Health Criteria, Geneva.

WHO (1989). Lead-Environmental Aspects. International Programme on chemical safety Environmental Health Criteria 85, World Health Organization, Geneva. pp.223.

WHO (1998). Guidelines for drinking-water quality, 3rd ed. Vol. 1. Incorporating the first and second Addenda. Geneva, World Health Organization.

WHO (1999). Guidelines for drinking-water quality. Health criteria and other supporting Information.Vol.2 second edition, World Health Organization, Geneva.

WHO (2003). Constraints affecting the development of the water supply and sanitation sector.from http://www.who.int/water_sanitation_health/bathing/srwe1/en/ - 21/2/2011

WHO (2004). *Guidelines for drinking-water quality, Volume 1: recommendations*, 3rd ed. Geneva

WHO (2005). Managing drinking water quality from catchment to consumer. http://www.who.int/water_sanitation_health- retrieved 18/8/2011

WHO (2008). Guidelines for drinking-water quality [electronic resource]: incorporating 1st and 2nd addenda, Vol.1, Recommendations. – 3rd ed. Geneva.

WHO/UNICEF, (2010). *Progress on sanitation and drinking-water: 2010 update*. Geneva, New York: WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation.

WHO/UNICEF, 2012. Progress on Drinking water and sanitation. Pp 4

Wierzbicka, M. (1995). How lead loses its toxicity to plants. Acta Societatis Botanicorum Poloniae, 64: 81-90.

Wilson, C. (1945). "Bacteriology of Water Pipes" J. AWWA 37:52.

World Bank (2009). Country Status Overview of Water Supply and Sanitation Kenya, Consultation Draft, Nairobi.

Zurera-Cosano, G., Moreno-Rojas, R., Salmeron-Egea, J. & Lora, R.P. (1989). Heavy metal uptake from greenhouse border soils for edible vegetables. J. Sci. Food Agric., 49: 307-314.

APPENDICES

Appendix I: Table of laboratory analysis analysed for the three months from various selected stations in comparison with WHO standards

Parameters	**WHO stand**	**Ngecherock plant**			**Timbilil plant**			**Prison staff resident**			**Main prisons -Kitchen tap**			**Moi Estate**			**Nyagacho Estate**		
		Jan	**Feb**	**Mar**	**Jan**	**Feb**	**Mar**	**Jan**	**Feb**	**Mar**	**Jan**	**Feb**	**Mar**	**Jan**	**Feb**	**Mar**	**Jan**	**Feb**	**Mar**
E.coli(No/100ml)	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	+ve	-ve	-ve	+ve