PHYSICO-CHEMICAL COMPONENTS OF WATER DISTRIBUTED BY KERICHO WATER AND SANITATION COMPANY

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

ABSTRACT

Many of the developing countries have a challenge of providing safe and portable water to their people. Challenges faced range from inadequate control, operation and maintenance of the water distribution system. Among the components that can make water unsafe for human consumption is physico-chemical components, which is the basis of this study. This study was conducted to ascertain the extend of portability of water supplied by Kericho Water and Sanitation Company (KEWASCO). Physico-chemical parameters analysed were: conductivity, total alkalinity, total hardness, pH, Total dissolved solids (TDS), residual chloride, turbidity and heavy metals (Pb, Cd and Cr). Samples were collected from Ngecherock and Timbilil Treatment Plants, Municipal tap water of Kericho prisons staff residence, Kericho main prisons (kitchen tap), Moi estate, Nyagacho estate, dumpsite leachate and river Tiony Soet. Heavy metal contents were determined using atomic absorption spectrophotometer (AAS while residual chlorine was measured using a commercial Colour Wheel and visual comparator. Total alkalinity and total water hardness were measured by titration method, conductivity and TDS by conductivity meter, turbidity by turbidimeter while the pH was determined by pH meter. The results obtained ranged from: pH 6.2-8.2, conductivity 35-70 µs, turbidity 0.4-3.7 NTU, total alkalinity 18-40 mg/L, total hardness 3-20 mg/L, TDS 16-30 mg/L and residual chloride 0-1.2 mg/L. Pb, Cr and Cd from water at the treatment plants and consumer points reported values which were within allowable WHO limits. However, not all stations reported appreciable levels of heavy metals during the sampling period. In January, the mean levels of the metals in the leachate samples reported Cr having the highest value (2.92 mg/L) followed by Pb (1.70 mg/L) and then Cd (1.48 mg/L). From the mean levels, the concentrations for the metals in river water recorded the highest Cr value of 2.34 mg/L followed by Cd (1.34 mg/L) and then Pb (1.29 mg/L) in the month of January. Generally, all the three metals showed a decrease in trend from January to March. The trend in average metal concentrations in both leachate and river water was Cr > Pb > Cd. Overall, the levels of metal concentrations in various sites and stations followed the order: dumpsite leachate > river water > consumer points > treatment plants. Most of the measured parameters were, however, within the water quality standards for municipal piped water and therefore fit for drinking.

Keywords: Turbidity, Water portability, Heavy metals.

INTRODUCTION

Generally water contains metals which if in excess quantity, can make water not fit for human consumption. Apart from traces of organic substances water also contains inorganic substances which too can make it not portable.

Inorganic matter that may pollute treated water within the pipe work include such metals as iron, manganese and zinc, suspended and dissolved solids and other materials that may

infiltrate into the distribution system say via leakages from broken pipes. Inorganic pollutants mainly contribute to the presence of tastes, odours and colour change in the water. Though these may not possess an undesirable effect on the consumers' health, they provide parameters that determine the acceptability of water for human consumption (WHO, 1984).

Control, reduction or total extinction of all these pollutants is meant to be achieved during the process of treatment and distribution of water. Failure to efficiently achieve this target may have far reaching effects from ranging from consumer complaints, disease outbreak and mortality. Standards have been set to ensure that water treatment is made to certain specifications that ensure its portability. World Health Organization (WHO) set water portability standard internationally (WHO, 1984). The same standards are cascaded down to individual countries for domestication. In Kenya, treated water must comply with standards set by the Kenya Bureau of Standards (KEBS) and National Environmental Management Authority (NEMA).

STATEMENT OF THE PROBLEM

Ordinarily surface water contain traces of heavy metals, sometimes in harmful proportions. This pollutes surface water and make its risky human consumption. A valuable initial step in identifying the nature and extent of water quality impacts linked to pollution is to distinguish their point sources and non-point sources. Point sources pollution is commonly linked directly to end-of-pipe releases from industrial and municipal wastes. Its control is more direct and quantifiable and in many developed countries its mitigation has been linked to treatment achieving lower contaminant concentrations before discharge (U.S EPA, 2010). The non point sources are widely spread for example, fertilizers among others are swept into water bodies hence enhance pollution. Water being an essential commodity therefore, needs to be protected from the source and up to the consumer point. Arguably water distributed by water companies contain traces of heavy metals. The purpose of this study was to determine the difference in heavy metal trace levels at different locations within the distribution network namely: water sources, treatment point and consumption points.

Objectives of the study

i. To determine the levels of heavy metals in leachate dumpsite, treatment plant and consumers' points.
ii. To establish the types of heavy metals present in water distributed by Kewasco

LITERATURE REVIEW

According to (Schmoll*, et al*., (eds), 2004) a healthy nation is a wealthy nation (U.S EPA, 2010). Portable water contribute to national health, however, 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).

Human concerns include quality of life and avoidance 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

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).

A study by Fafioye and Adebanjo (2013) 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.

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.
According to the WHO standards, the minimum Free Residual Chloride (FCR) should be 0.2 mg/L (WHO, 1998).

METHODOLOGY
RESACH DESIGN

Experimental design was use in this study which consisted of the following steps:

Reagents and standards
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 variables analyzed were total suspended solids, pH, Total alkalinity, Total hardness (Ca and Mg hardness), turbidity, conductivity, TDS, residual chlorine, pH, heavy metals (Cd, Cr and Pb). Standard methods were followed in determining the above variables. All probes were calibrated prior to measurements with the appropriate traceable calibration solutions in accordance with manufacturer's instructions.

Sampling of water
Sampling of water was carried out monthly for three months from January to March 2010 at designated sampling points namely; at treatment works, at the consumer points within the distribution network and at the dumpsite leachate then kept in a cooler box filled with ice cubes for preservation before analysis. A 200 ml of water samples were taken from the identified collection points using 250 ml sterile glass stop-cocked containers from the various stations and acidified using nitric acid (1+1) and transported to the laboratory in cold and protected from sunlight. They were processed within 6 hours of their collection.

The sampling bottles were first sterilized in the autoclave in the laboratory and kept in aseptic condition in the field. Other field kits were also calibrated to give accurate results in the field. In the laboratory, the samples were removed from the cooler box and left to attain room temperature before analysis. The samples were then analyzed for the following water quality parameters; Total alkalinity, Total hardness (Ca and Mg hardness), Turbidity, Conductivity, TDS, residual chlorine, pH and Heavy metals(Cd, Cr and Pb).

Dumpsite's Leachate Analysis

The analyses were done for three months during low and high rains that was on January, February, and March 2014.

Sampling technique
Leachate sample

A1m deep trial holes of diameter 0.3 m were dug at the intervals of 60 m along the stretch of the dumpsite. The stretch was 5 m from the edge of the dumpsite. Leachate samples were collected from all points located within the perimeter of the dumpsite and points where wastewaters get into the river. A 5 L Plastic buckets, perforated halfway from the top, were placed in the five trial holes and their lids replaced and covered with soil to avoid interference from surface runoff and undue attraction by passersby. Monitoring of the trial holes was done for a month after which the leachate in the buckets was lifted and taken for analysis. In the laboratory, blank solutions de- ionized water without reagent (0.00 mL) were analysed to evaluate the general performance of the analytical procedure in all the three metals.

Water sample

250 mL of Water samples were collected at about 100 m before the dumpsite along the river, along the mid-length of the dumpsite in the river and finally at a point after the dumpsite.
The samples from the respective trial holes and wastewater from the sampling sites were then transferred into 500 mL bottles. The bottles were covered with foil paper at the top to prevent the sun rays from interfering with composition of the leachate. The bottles were then placed in a cool box and transported to the laboratory on the same day for analysis. Standard solutions were also prepared for comparison purposes for all the parameters selected.

Measurements

Measurements of the samples were categorized into two; field and laboratory measurements. This depended on availability and nature of reagents and standards, devices and their portability.

Field measurements

Parameters such as pH and turbidity, were analyzed at the time of sampling that is *in situ* sampling technique was employed.

Determination of pH

The efficacy of disinfection with chlorine is highly pH-dependent with disinfection being less effective where the pH exceeds 8.0. pH meter Hannas model H1 9025 was used. To check the accuracy of the pH meter, buffer tablets were used where one tablet was dissolved in distilled water and made up to 100 ml produces a solution of pH 7.00+-0.02 at room temperature (Hanna® Instruments, 2000).

Measurement of turbidity (Turbidimeter)

Turbidimeter Hach Model FT660 Sc was used. The water sample was put in the instrument and the values read. Turbidimeter was properly calibrated with a primary standard which is StablCal Stabilized Hach Formazin Turbidity stand 4000NTU 508. (Black and Hannah, 1965).

Analysis of Heavy Metals

The technique employed was Atomic Absorption Spectroscopy (AAS) Varian, Model Spectra- AA-100/200 was used in determining the levels of Pb, Cd, and Cr found in both leachate and water. In direct aspiration atomic absorption spectroscopy, a sample was aspirated and atomized in a flame. A light beam from a hollow cathode lamp whose cathode was made of the element to be determined was directed through the flame into a monochromator, and onto a detector that measures the amount of light absorbed. Since the wavelength of the light beam was characteristic of only the metal being determined, the light energy absorbed by the flame measured the concentration of that metal in the sample. This principle was the basis of AAS filtration and acid digestion of the suspended material of metallic constituents. The acid digest were subsequently determined and the sum of the dissolved plus suspended concentrations then provided the total concentrations present. The sample was filtered as soon as possible after collection and the filtrate acidified immediately (Paus, 1973).

The characteristic concentration check value is the concentration of element (in mg/L) that produces a signal of approximately 0.2 absorbance units under optimum conditions at the wavelength listed in Table 2. The use of characteristic concentration check was to determine whether instrumental parameters were optimized and whether the instrument was performing up to specifications. Optimum conditions for instrument settings for analysis of the three metals were observed as indicated in Table 3.2 below.

Table 3.2 ASS optimized conditions for determination of Pb, Cd and Cr

Metal	Wavelength (nm)	Slit width (nm)	Flame	Gas flow (L/min)	Instrument mode
Pb	217.0	1.0	Air-Acetylene	2.00	Absorbance
Cd	228.8	0.5	Air-Acetylene	2.00	Absorbance
Cr	357.9	0.2	Air-Acetylene	2.90	Absorbance

(Alloway, 1995)

Preparation of stock and working solutions

Sample solution for analysis of the three metals was prepared following manufacturer's instructions. High purity metal salts dissolved in high purity acids were used to make the stock solution. Working standards were diluted as indicated below for each metal and the values were recorded as shown in Table 3.

Digestion was done using concentrated nitric acid and concentrated hydrochloric acid for leachate sample and the procedure was done as follows:
The samples were collected in acid – cleaned plastic or glass bottles and preserved by adjusting to pH 2 or less by Nitric acid about 2 mL per litre). Before analysis the pH was

adjusted to 4-5 with 5.0N sodium hydroxide. Then 5 mL of Conc. HNO_3 was added to one litre of sample. The acidified sample was transferred to 250 mL flask (Erlenmeyer flask). A 5mL of 1:1 HCl. was added and the sample was heated on hot plate for 15 minutes at $95^{o}C$ thereafter, cooled, filtered through a membrane filter and adjusted the volume to 1000 mL with deionized water.

Table 3.3 Concentrations of the various standard solutions used

Standards	Values in mg/L		
	Pb	Cd	Cr
Blank standard	0.00	0.00	0.00
STD I	2.00	0.05	5.00
STD II	4.00	1.00	10.00
STD III	6.00	3.00	15.00

Preparation of calibrations solutions
A stock solution of 100 ppm was prepared by pipetting 10.0 mL from 1000-ppm stock solution transferring into a volumetric flask of 100 mL and topping to the mark by deionized water. Standard solutions were obtained as 2.00, 4.00 and 6.00 ppm for Pb, 0.00, 0.5, 1.00 and 3.00 ppm for Cd and 5.00, 10.00 and 15.00 ppm for Cr. The absorbance of each solution was then measured and a curve relating the experimentally determined absorbance and the concentration of the standard was prepared. The relationship between absorbance and concentration is linear to indicate that Beer- Lambert's law was obeyed as shown in Figure 3 and Appendix 3. Blank solutions (0.00 mL) as indicated in the Table 3 were analysed to evaluate the general performance of the analytical procedure in all the three metals.

Figure 3: Calibration curve for Lead (mg/L)
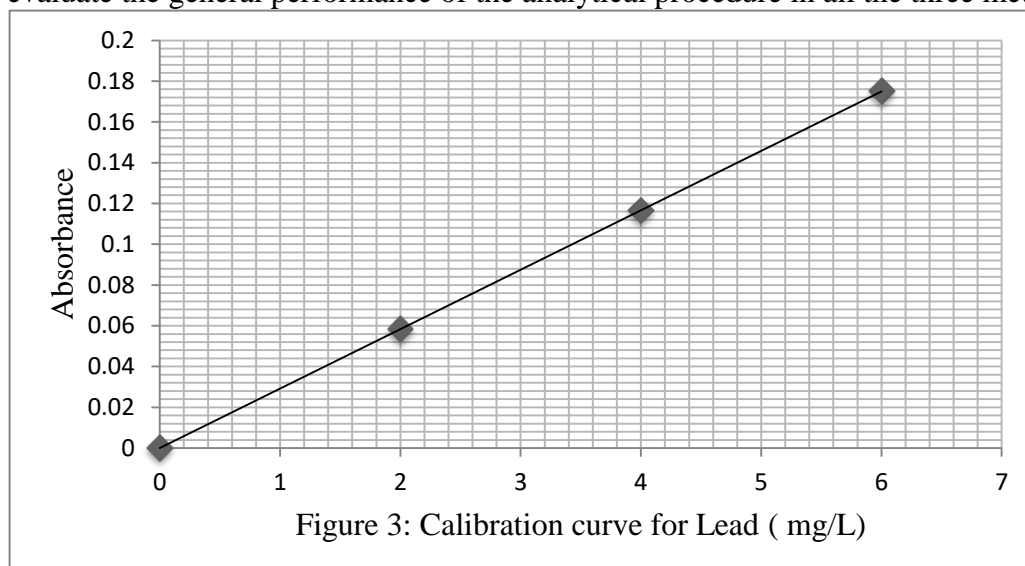
Determination of free residual chlorine
Residual chlorine in a water sample was measured using a commercial Hach mode CN 66 Colour Wheel and visual comparator that consisted of a box with an eyepiece in front and two cells, the whole arranged so that both cells were in the field of vision of the eyepiece. The comparator used was the disc type, containing a wheel of small coloured glasses. The reagent used in the analysis was N, N-diethylparaphenylenediamine (DPD).

One cell, containing a water sample without the reagents, was placed in line with the rotating colour glasses or the ampoules containing the standards. The water sample containing the reagent was placed in another cell. If free chlorine was present, a colour would develop. The concentration of chlorine was estimated by matching the colours in both cells, as seen through the eyepiece. Each colour of the disc or ampoule corresponded to a certain quantity of chlorine in the water and different calibration discs or ampoules were needed for each of the reagents specified (Hach Company, 2002).

Total alkalinity

Alkalinity was measured by titration. A 0.02N sulphuric acid (the titrant) was added to a 200 mL volume of a treated sample of water in which the methyl orange indicator had been added. The volume of acid required to bring the sample to a specific pH level reflects the alkalinity of the sample. The end point indicated by a colour change from orange to pink. To check the accuracy of the sulphuric acid used, fresh 0.02N sodium hydroxide was prepared. Alkalinity is expressed in units of milligrams per liter (mg/L) of $CaCO_3$ (calcium carbonate) (American society for testing and materials, 1982).

Total water hardness

A 100 ml water sample is measured into a plastic beaker containing a stirring bar. The water was at room temperature. A 1 ml volume of buffer solution was added to the stirred water before titration in which the quantity of "hardness ions" was determined by measuring the concentrations of Ca and Mg in water samples by titration. 0.01M EDTA, a weak acid, was used as the titrant. In its ionized form, it is able to form soluble complexes with Ca and Mg cations (Harris, 2003). One packet of the indicator added to the buffered sample was Eriochrome Black T. Initially, the indicator formed a complex with the cations. When complexed it is red in colour. As the EDTA was added drop wise to the sample, it replaced the Eriochrome Black T and formed more stable complexes with Ca and Mg. When the indicator was released by the metal ions, it had a distinct blue colour. Therefore, the endpoint of the titration was marked by the colour change from red to blue. A blank titration was run using distilled water (Clesceri and Greenberg, 1998).

The total water hardness of the sample was calculated by the following equation,

$$\text{Total hardness (mg)} = \frac{(A - B) \times 1000}{L \text{ - Volume of sample (ml)}}$$

Where, A= volume of EDTA consumed for sample, ml
B= volume of EDTA consumed for blank, ml

$CaCO_3$ 10 mg/L Standard EDTA titrant was used during analysis to check the accuracy throughout the process was prepared from the 1000 mg/L standard by diluting 50 ml in a 500 ml volumetric flask.

Conductivity and Total Dissolved Solids

Hach conductivity meter, model 3084 was used to measure the conductance generated by various ions in the water. Conductivity/TDS standard (1413 µs/cm) was used to correct the accuracy of the meter. The Hach Conductivity Probe was equipped with a thermostat to allow automatic temperature compensation when attached to the sension5 Conductivity Meter. The probe was inserted into the 100 mL water sample solution making sure the slot in the tip was fully immersed. The probe was agitated vertically and the readings was allowed to stabilize, then recorded and stored it in the meter memory. Conductivity readings were converted to

TDS readings by multiplication with a known mathematical factor by placing the Conductivity Probe into the 500 mg/L TDS standard solution. Total Dissolved Solids (TDS) Model 3084 automatically calculates the TDS from the conductivity reading by multiplying the preset factor [.625] and Set keys. Manual Range (A – F) and Auto Range displays TDS in Parts per Million (PPM) as a function of conductivity and the TDS multiplier. The TDS multiplier was adjustable from 40% to 90%. (Annual Book of ASTM Standards, 2000).

RESULTS AND DISCUSSION

The results of analysis of various samples based on mean values indicated that the measured parameters were within the WHO standards in nearly all the sampled stations except residual chloride where the level was above the recommended standard (See Table 4.1).

Table 1.1 Mean values of physico -chemical parameters analysed in January 2014

Stations	TDS (mg/L) **(Max 1200)**			Residual chloride (mg/L) **(0.2 -0.9)**			conductivity (µs) **(Max 2000)**			Total alkalinity (mg/L) **(Max 500)**			Total hardness(mg/L) **(Max 500)**		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Ngecherok	28	24	20	1.2	0.4	0.9	56	52	40	36	32	27	18	17	14
Timbilil	23	20	21	0.7	0.4	0.3	48	47	35	40	35	32	20	15	12
Prisonstaff resident	26	22	16	0.1	0.5	ND	57	50	45	30	25	20	16	14	09
Main prison tap	25	21	17	0.1	0.7	ND	50	48	43	24	20	18.2	06	05	03
Moi estate	29	24	20	0.1	0.3	ND	59	54	46	25	23	18	13	11	14
Nyagacho	30	27	19	0.2	0.6	1.0	70	65	55	25	26	40	12	14	20

NB: bolded and in the brackets are WHO, (2004) standards.

Key: -VE – Nil,   +VE – Presence

The highest parameter viewed was, however, residual chlorine at Ngecherok (1.2 in January) and this could be due to the presence of a dosing point that was quite close to the point where the samples were drawn. The rest of the stations recorded values between 0.1-0.7, which is within acceptable range for assurance of safety of drinking 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 (see Appendix A) 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. 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.

The values obtained in this study (which ranged from 35-70 µs. This means majority of the stations recorded values which were 50 µs and above) are comparable to those obtained in studies done in most rivers in USA.

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 inTable 5 below and Figure 5

Table 4.2: Values of heavy metals in the water samples from the three sampling sites analysed in the three subsequent months

Sampling sites	Heavy Metals (mg/L)								
	Pb			Cd			Cr		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Site I	1.342	0.210	0.17	1.778	0.157	0.015	1.675	0.982	0.773
Site II	1.270	0.224	0.18	1.170	0.134	0.013	2.501	1.120	0.858
Site III	1.245	1.314	0.21	1.06	0.109	0.060	2.850	1.187	1.351
Mean	**1.29**	**0.58**	**0.19**	**1.34**	**0.13**	**0.03**	**2.34**	**1.10**	**0.99**

From Table 4.2, Pb levels decreased in trend in January but increased in both February and March downstream. Cd showed a general increase in January and March but decreased in February while Cr generally increased in all the months from sites I-III. Pb levels in water samples were by far higher than the recommended maximum WHO (1999) standards for drinking water (0.05 mg/L) (see Appendix A). Pb concentration was higher in January and lowest in March possibly due to lack of dilution effect. This could imply that water pollution is contributed mostly from the surrounding runoffs rather than solid waste dumpsite's leachate. However, in most contaminated aquatic systems, almost all the Pb is tightly bound to sediments and only a small fraction of it is dissolved in the water.

Decreased trend in Cd levels could be due to its presence in phosphatic fertilizers and the phosphatic rock (WHO, 1998). Also, the bedrock in the area could be of Cd related residues. Other sources could be volcanic activities in the Rift Valley where water passes through to the receiving river, runoffs from waste batteries, paints and forest fires that could lead to release of Cd related oxide to the environment (Ongulu, 2008).

The mean concentration of Cr was higher for the three months as compared to those for Pb and Cd which were, however, much higher than the WHO (1999) standards (0.05 mg/L) (See Appendix A). Chromium is found chiefly in chome-iron ore. Chromium is used in alloys, in

electroplating and in pigment. Chromium salts are used extensively in industrial processes and may enter a water supply through the discharge of wastes. Chromate compounds are frequently added to cooling water for corrosion control (Vitale *et al.,* 1997).

The general trend of the mean concentration of the three metals was January> February> March could possibly be due to dilution effect brought about heavy rains that occurred in March. This could have led to an increase in volume of water which was higher than the increase in the amount of mobilised pollutants, consequently, slight decreased concentration (Draft Final Report, 2005).

In a similar study conducted by Koech (2003) on water quality of the Dionsoyiet River, it was reported that Pb concentration at a station downstream was much higher (2.22 ppm) than upstream with a much lower value of 0.74 ppm. These values were much higher than the values obtained in the present research and this leads to a conclusion that urban runoff and effluent from the sewage treatment plant could be the main contributors to the observed trend.

In another related study, Ochieng' *et al.* (2002) conducted analysis of water and surface sediments of five Rift Valley lakes Nakuru, Elementaita, Naivasha, Bogoria and Baringo and observed that the dissolved mean levels (mug/L) of metals in water ranged within 2.0-43.0 (Cd), 25.0-188.0 (Cr), and 25.0-563.0 (Pb). These values were, however, not in agreement with the values obtained in the current study because they were much higher implying anthropogenic factors in addition to the fact that lakes receive a lot of drainage from rivers, most of which pass through areas where several human activities involved.

In a similar study, Moore *et al*. (2009) analysed total concentrations of a number of metals including Cr, Cd, and Pb in lake water. The respective mean concentrations for dissolved metals Cd and Pb were 0.28 μg/L and 5.17 μg/L while Cr was not detected. These values, however, showed a great variation with what has been reported in the present study indicating lake pollution could be resulting mainly from anthropogenic sources and rivers draining into it.

Macdonald and Christopher (2011) reported mean concentration of the heavy metals in surface water samples from Warri river in Delta State, Nigeria to be: Cr: 0.0 mg/L - 0.06 mg/L; Cd: 0.0 mg/L - 0.05 mg/L and Pb: 0.0 mg/L - 0.001 mg/L. The heavy metals concentrations in the surface water samples from this river decreased in the order: Cr > Cd > Pb (among other metals). These values, however, were lower and did not agree with the trend observed in the present research which was Cr > Pb > Cd. The difference in the results and trend could be due to the fact that river Warri receives a lot of wastes from industrial, agricultural and domestic sources. This river serves as the main source of drinking water, fish and irrigation for the various communities settling along its banks and catchment area. Therefore, with more industries discharging their effluents into the river, the prospects of a greater pollution is high, so also is an increased risk to public health.

Among the three metals studied, Cr had the highest level and this implies that the metal is likely to affect human health (Ongulu, 2008).

The mean concentration of heavy metals found in leachate samples from three sampling sites: I, II and III are presented in Table 4.3. This was done in the laboratory for three months and the values in mg/L were recorded.

Table 4.3: Mean concentration (mg/L) of the three heavy metals in leachate from the three sites analysed in January, February and March

Sampling sites	Heavy metals (mg/L)								
	Pb(**WHO-0.05**)			Cd(**WHO-0.05**)			Cr(**WHO-0.05**)		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Site I	1.36	0.27	0.26	2.75	1.25	1.66	2.98	1.34	1.29
Site II	1.45	0.34	0.34	1.23	0.16	0.05	2.87	1.50	1.50
Site III	1.49	0.40	0.36	1.56	0.12	0.05	1.93	1.67	1.60
Mean	**1.70**	**0.69**	**0.32**	**1.48**	**0.50**	**0.55**	**2.92**	**1.50**	**1.46**

From Figure 4.3 all the three metals showed a general decreasing trend downstream. Pb contents in leachate samples from the three sites were, however, higher than in water samples, as depicted in and Table 6. Pb levels showed a general increase from sites I - III over the three months from January to March while Cd showed a general decrease over the same period. Moreover, Cr level decreased in January and increased in both February and March from sites I – III. There was no rainfall, in February there was light showers while in March, there was heavy rainfall. These differences in rain patterns could have contributed to the differences in results obtained during the study. Among the three heavy metals analyzed, Cr had the highest deviations from the WHO (1999) standards (See Appendix A). The high levels of the element could be attributed to the use of phosphate fertilizers in farms, which end up being washed into the water bodies, leading to Cr enriched water.

The Cd values in leachate samples were far higher than WHO (1999) standards for drinking water (0.05 mg/L). This shows that municipal effluents could have been the major source of pollution to the environment. These values were, however, higher compared to those found in water. Other factors such as use of phosphate fertilizers, insecticides, fungicides, Ni - Cd batteries, PVC plastics, cigarettes and paint pigments which when disposed of are washed into the water bodies, consequently, leading to Cd enriched water. Also Cd may enter into water as a result of industrial discharges or the deterioration of galvanized pipe (Ganotes et al., 1962).

Generally, the level of metals decreased from January to March in all the three Sites (I- III). Analogous to filtration or screening, the presence of plant matter within a wetland provides a physical barrier that prevents sediment and sediment attached pollutants from being swept downstream by the flow (Waters, 2004). The very dense vegetation that is present within the wetland causes high flow resistance and thereby severely moderates flows. Most of the flow is transmitted by through a dendritic open water stream network within the wetland that comprises of five streams arising from each of the inlets, which merge within the first few hundred metres of the length of wetland into a single stream that flows through the centre of the wetland to the outlet. Apart from these limited number of fast flowing streams, water in the vegetated sections of the wetland is near stagnant (Draft Final Report, 2005).

Table 7 shows the analysis of heavy metals in mg/L in water samples from the selected stations for the three months.

Table 4.4: Mean concentration of heavy metals in the water samples from the selected stations in January, February and March

Stations	Heavy metals (mg/L)								
	Pb			Cr			Cd		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Ngecherok	ND	ND	ND	ND	0.001	0.001	ND	0.001	0.003
Timbilil	ND	ND	ND	ND	0.005	0.002	0.001	0.003	0.001
Prison staff Resident	0.003	0.004	0.007	0.001	0.004	0.002	ND	0.001	ND
Main prison tap	0.002	0.003	0.005	0.002	0.002	0.001	0.004	0.005	ND
Moi estate	0.001	0.015	0.003	0.007	0.005	ND	0.003	0.004	ND
Nyagacho	0.005	0.006	0.009	0.005	0.005	ND	0.006	0.008	0.010

From the results indicated in the Table 7.4 heavy metal levels in drinking water were within the recommended WHO standards. However, only in some few instances were the metals in trace amounts therefore not detected. The reason could be due to alkalinity, which not only helps regulate the pH of a water body, but also the metal content. Bicarbonate and carbonate ions in water can remove toxic metals such as Pb, As, and Cd leading to precipitation. The levels of the metals observed could also be due to seepage of pollutants from the surroundings into the broken water pipes for example, Pb being naturally available in the soil as a result of weathering of rock fragments on which soils develop (Omoga and Kagwanja, 1999).

The Draft Final Report (2005) gave Pb levels that were relatively high and therefore industries upstream of both wetlands and rivers should be encouraged to dispose of their wastes more diligently and careful attention is required to check on activities that may directly add heavy metals to the wetlands such as car washing. Pb in a water supply may result from smelter discharges and from the dissolution of plumbing and plumbing fixture. Tap water is inherently not corrosive but if not suitably treated may contain Pb resulting from an attack on Pb service pipes, Pb interior plumbing, brass fixtures and fittings on solder pipe joints chiefly from galena (PbS). Pb is used in batteries, solder, piping, pigments, insecticides and alloys. Pb also was used in gasoline for many years as an anti-knock agent in the form of tetraethyl lead. The Food and drug administration regulates lead content in food and in house paints (American Society For Testing And Materials, 1977).

The presence of Cr in drinking water could be due to use of Cr related products such as seed protectants and wood preservatives (Ongulu, 2008). Afiukwa (2013) observed that mean concentrations (mg/L) of elevated metals in drinking water (surface water) in Ebonyi State, Nigeria ranged from: Cd- 0.004 – 0.011, Cr - 0.16 – 1.65 and Pb - 0.02 – 2.5 This study showed that some metal concentrations exceeded the WHO guideline limits for drinking water in the order: Pb > Cr > Cd in surface water. These levels were, however, higher than those reported in the present study. A non-point source of pollution which included indiscriminate waste dumps in water bodies, poor sanitation and other uncontrolled anthropogenic sources of pollution could be the cause for the observed trend. Also high amounts of nutrients such as nitrates and sulphates arising from fertilizer applications could be a contributing factor.

The levels of Pb in the two water works were not detected over the sampling period of three months. At the consumer points, however, the metals were detected but with higher levels in the leachate samples which resulted from the dumpsite. In January, Cd was not detected in the Ngecherok treatment plant but was detected in the Timbilil treatment sample. The highest level was recorded at the dumpsite leachate followed by water sample from the river adopting the general concentration trend of: Leachate sample > water sample from the river > consumer points > treatment plants.

For Cr, the general trend of concentration was leachate sample > river water > consumer points > treatment plants. The reason for could be because the water which is obtained from protected springs goes through two treatment works, therefore, reducing pollutants levels. At the consumer points, water pollutant levels were within permissible criteria set by WHO and KEBS except when the pollutants entered the pipes through leakage, bursting of pipes and when the river water gets pollutants from the immediate dumpsite and municipal waste water runoffs.

CONCLUSION AND RECOMMENDATIONS

From the three metals analysed, the highest levels were recorded in the dumpsite leachate and this could be a possible source of water pollution to the river water that were concurrently analysed for comparison purposes.

The levels of heavy metals in the treatment plant and consumer points were within the acceptable limits as compared to WHO standards. Therefore water from treatment plant is far much safer for human consumption and frequent users of untreated water are at risk of contracting any disease brought about by polluted water.
Since not all parameters were analyzed, it is recommended further research to be done that encompass other heavy metals and living organisms that constitute turbidity of water.
The KMC dumpsite has not met any of the recommended WHO guidelines. Important issues such as topography and walkover site surveys that are required to address the following design issues-topography of the surrounding landscape, preliminary inspection of actual or offsite pollution that causes a distinct threat to local communities need a further study of its own.

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APPENDIX A

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
PH	6.5-8.5	6.83	6.6	6.2	7.52	7.5	6.00	7.5	7.0	6.85	7.36	7.25	7.0	7.2	6.78	7.5	8.2	7.36	8.2
Conductivity (µs)	Max 2000	56	52	40	48	47	35	57	50	45	50	48	43	59	54	46	70	65	55
Turbidity (ntu)	5	1.49	1.47	1.40	0.55	0.56	0.4	0.7	0.68	1.67	0.18	0.17	2.00	0.6	1.78	0.1	2.0	1.92	3.7
Total alkalinity(mg/l)	Max 500	36	32	27	40	35	32	30	25	20	24	20	18.2	25	23	18	25	26	40
Total hardness(mg/l)	Max 500	18	17	14	20	15	12	16	14	09	6	5	3	13	11	14	12	14	20
TDS(mg/l/)	Max 1200	28	24	20	23	20	21	26	22	16	25	21	17	29	24	20	30	27	19
RC(ppm	0.2-0.9	1.2	0.4	0.9	0.7	0.4	0.3	0.1	0.5	0.00	0.1	0.7	0.00	0.1	0.3	0.00	0.2	0.6	1.00
Lead	0.05	ND	ND	ND	ND	ND	ND	0.003	0.004	0.007	0.002	0.003	0.005	0.001	0.015	0.003	0.005	0.006	0.009
Chromium	0.05	ND	0.001	0.001	ND	0.005	0.002	0.001	0.004	0.002	0.002	0.004	0.001	0.007	0.005	ND	0.005	0.005	ND
Cadmium	0.05	ND	0.001	0.003	0.001	0.003	0.001	ND	0.001	ND	0.004	0.001	ND	0.003	0.004	ND	0.006	0.008	0.010

Appendix II: Absorption data from standard solution for lead, cadmium, and chromium respectively

Concentration of standard solution of lead	Absorbance, A= log (I_0/I)
0.00	0.00
2.00	0.0583
4.00	0.1166
6.00	0.1749

Concentration of standard solution of Cadmium	Absorbance, A= log (I_0/I)
0.00	0.00
0.5	0.0135
1.00	0.027
3.00	0.081

Concentration of standard solution of Chromium	Absorbance, A= log (I_0/I)
0.00	0.00
5.00	0.0413
10.00	0.0826
15.00	0.1239

0.0   is blank solution

Appendix III: Calibration curve for Cadmium and chromium respectively.

(a)

Calibration curve for Cadmium (mg/L)

(b)