Assessment of Heavy Metal Contamination in Surface Water of. Masinga Reservoir, Kenya.

Article · January 2015

CITATIONS
3

READS
192

3 authors, including:

Julius Nzeve
Machakos University
3 PUBLICATIONS **10** CITATIONS
SEE PROFILE

Esther Chepkoech Kitur
Kenyatta University
7 PUBLICATIONS **13** CITATIONS
SEE PROFILE

Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.2, 2015

Assessment of Heavy Metal Contamination in Surface Water of Masinga Reservoir, Kenya

Julius Kioko Nzeve*, Steven Gichuki Njuguna and Esther Chepkoech Kitur

Department of Environmental Sciences, Kenyatta University, P.O.Box 43844, Nairobi, Kenya

*Email of Corresponding author: jnzeve@gmail.com

Abstract

An assessment of heavy metal contamination (Cu, Zn, Pb, Cr, Mn and Cd) in surface water of Masinga reservoir was carried out between January 2013 and December 2013. The heavy metal Concentrations were determined using atomic absorption spectrophotometer (AAS). The data obtained was analyzed using one way analysis of variance and significant differences accepted at $p \leq 0.05$. Post Hoc Tukeys' test was used to separate means. The mean metal concentrations (mg L^{-1}) were; Cu (0.003 - 0.019), Zn (0.092 - 0.132), Pb (0.004 - 0.009), Cr (0.003 - 0.006) and Mn (0.006 - 0.146). No significant differences were observed in heavy metal concentrations in surface water among the different sites. The concentrations for all metals in surface water did not exceed the WHO recommended limit for drinking water.

Key Words: Water Quality, Heavy Metals, Contamination, Masinga Reservoir

1. Introduction

Aquatic ecosystems such as rivers, dams and lakes provide livelihood for rural populations in many developing countries in Africa. However, in the recent past, they have been subjected to various forms of degradation due to pollution arising from domestic wastes, industrial effluent, agricultural run offs and bad fishing practices (Ndimele, 2008). Increasing pollution in water bodies is directly or indirectly related to increasing urbanization and indiscriminate disposal of agrochemical and industrial effluents (Dua and Gupta, 2005, Bakare *et al.,* 2003). As a result, many water resources have been rendered polluted and hazardous to man and other living systems. Heavy metals in water can originate both from natural sources, industrial, agricultural and domestic activities in the drainage basin of a water system. As the metal levels in many aquatic ecosystems increase due to anthropogenic activities, they raise the concern on metal bioaccumulation through the food chain and related human health hazards (Wright and Welbourn, 2002; Indrajith *et al.,* 2008; Agah *et al*., 2009). Consumption of biota from contaminated aquatic bodies is an important route of exposure to pollutant compounds. However, water quality criteria for aquatic biota have not received the attention that they deserve. All too often, water has been considered quite adequate for fish as long as there is no obvious mortality ascribed to known pollutants. Trace metal analysis in freshwater is very important because these ecosystems provide drinking water as well as habitat for flora and fauna. Heavy metal contaminations in inland waters can be monitored by using the metal levels in water; sediments and resident biota especially fish (Senarathne and Pathiratne, 2007). The heavy metals of most environmental concern in water are lead (Pb), chromium (Cr), arsenic (As), cadmium (Cd), copper (Cu) and zinc (Zn) (Martin and Coughtrey, 1982). Contamination by these heavy metals can be expressed by their high concentrations in water, as well as in sediments and aquatic organisms (Pham *et al*., 2007). Cadmium, copper, lead and zinc salts are usually found in agricultural and industrial liquid wastes (Qiao *et al*., 2007) which are discharged into water resources.

Over the years, numerous factors have contributed to the degradation of water resources within the upper Tana River catchment. The Tana River is the longest river system in Kenya (approximately 1, 200 km) with a catchment area of about 120, 000 km^2 and an average annual discharge of 4 x $10^9 m^3$ (Kitheka *et al*., 2005). The upper Tana catchment area is characterized by high population densities, rapid urbanization and high agricultural activities. The key environmental issues include catchment degradation due to pollution from agro-based industries, agro-chemicals, urban effluent, car washing, soil erosion (siltation), river bank encroachment and industrial discharge (UN – WATER, 2006). All these human activities within the catchment lead to anthropogenic pollutants being transported in the streams, rivers and other municipal drainage water systems; either dissolved in the water or attached to suspended matter and eventually gets into the Tana River dams (Nzeve *et al.,* 2014). The catchment comprises of three river subsystems, namely Tana River (91%), Thiba River (2.8%) and Thika River (4.2%). The Tana River and Thika River sub basins drain into Masinga reservoir (UN-WATER, 2006). According to UNEP (2000), economic activities in the catchments would affect the status of aquatic ecosystems. This means that impacts caused by human activities in the catchment are transmitted to

receiving waters of Masinga reservoir. This study therefore, sought to assess the extent of heavy metal levels in surface water of Masinga reservoir.

2. Materials and Methods

2.1 Study Area

The study was carried out in Masinga reservoir which is located 100km North East of Nairobi City, Kenya. It lies between latitude (0^0 45'S; 1^0 11' S) and longitude (37^0 0' E; 37^0 46'E) with an altitude of 1056.5 m above sea level. It is the upper most cascade dam of the seven forks development scheme on the Tana River. The dam was constructed between 1976 and 1980 as a storage reservoir to regulate water flows to the lower dams whose water levels fluctuated drastically during the dry season. It is a multi-branched type with a large number of shallow bays and high shore line surface area ratio. The dam has a full operation surface area of 125km^2 and extends 45km upstream along the Tana River (Figure 1). The mean depth is 13.8 m while the maximum depth at the dam wall is 48 m (Jumbe, 2003). The dam provides hydro-electricity power (40mw), irrigation water for agriculture and commercial fishing.

2.2 Sampling and Frequency

During a field reconnaissance, five sampling stations were selected from the Masinga reservoir (Figure 1). The dam was divided into three regions; the upper, middle and lower regions. The upper and middle regions had two stations each (Tumutumu, Riakanau, Manyatta and Kathini respectively), while the lower region had one station (Mathauta). The five sampling sites were chosen to represent different sub basins that drain into the reservoir in order to under standard the influence of natural and human activities on the reservoir. The geographical location of each selected sampling site within the reservoir is shown in Table 1. Sampling was carried out once a month for one year (January 2013 – December 2013) in all the sampling sites.

2.3 Sampling of Water and Storage

Water sampling was done according to the procedure described by Ndimele and Kumolu-Johnson (2012). Water samples from all five (5) sampling sites were collected at a depth of about 0.3m below water surface into 500 ml plastic bottles. Prior to sampling, the bottles were cleaned with 10% nitric acid and rinsed with distilled water. The bottles were rinsed three times with the dam water at the time of sampling. Samples were then collected by direct immersion of the sampling bottle into the dam. Immediately after sample collection, 2 ml nitric acid (AR grade) was added to the water samples to reduce adsorption of metals onto the walls of the plastic bottles. Sample bottles were then labeled to indicate date of sampling and the sampling site. Samples were transported in an ice-box to the laboratory at Kenyatta University and stored at 4^0C awaiting analysis.

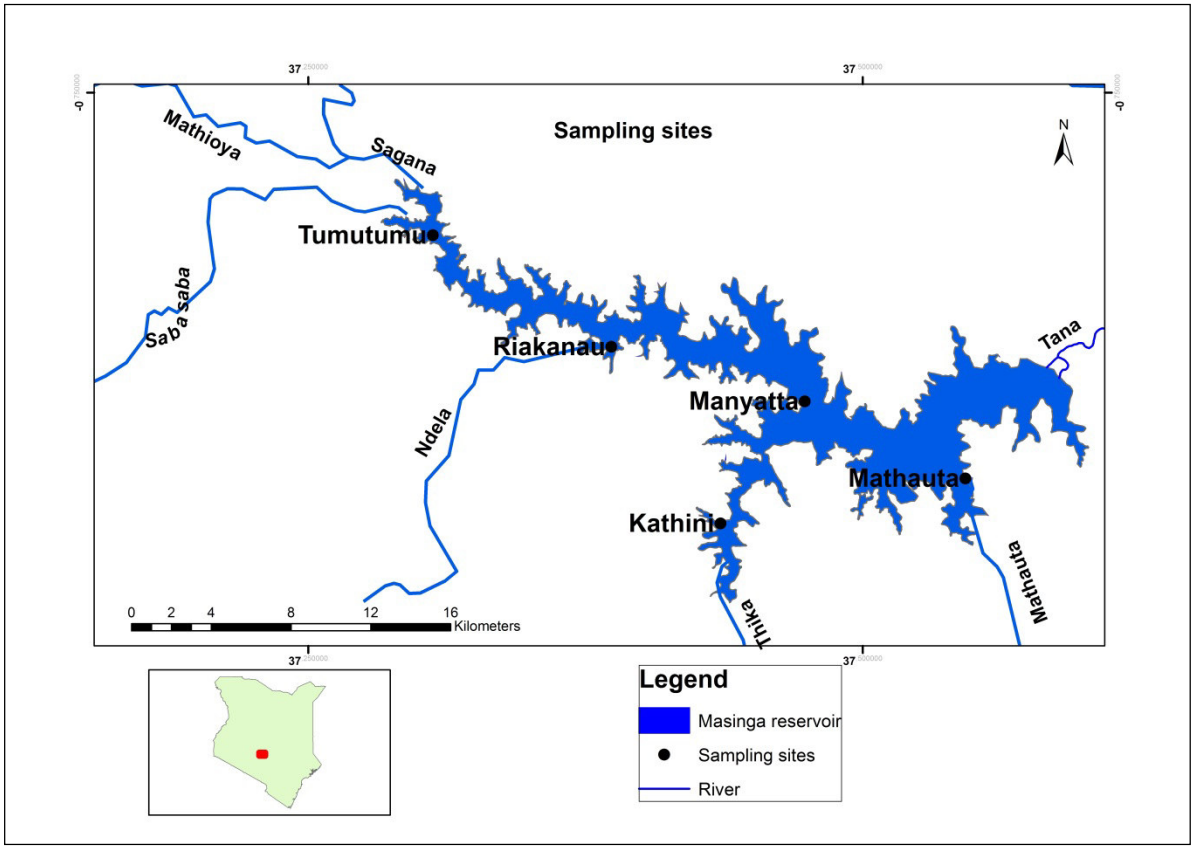

Figure 1: A map of Masinga reservoir showing the five sampling sites

Table 1: Geographical coordinates and water depth of sampling sites in Masinga Reservoir

Sampling Site	Latitude	Longitude	Depth (m)
Kathini (S1)	00^0 94 322 S	037^0 43 237 E	10.33 ± 0.99
Mathauta (S2)	00^0 92 571 S	037^0 54 548 E	22.42 ± 2.50
Manyatta (S3)	00^0 88 736 S	037^0 47 279 E	21.00 ± 6.70
Riakanau (S4)	00^0 86 476 S	037^0 38 770E	7.25 ± 1.14
Tumutumu (S5)	00^0 81 416 S	037^0 30 621E	7.58 ± 2.02

2.4 Digestion of Water samples for Metal Analysis

Digestion of the water samples were done in triplicates using concentrated nitric acid (Analytical Grade) according to method described by Zhang (2007). Concentrated acid (5 ml) was added to 50 ml of sample water in a 100 ml beaker, and then heated on a hot plate (100^0C) to boil until its volume reduced to 20 ml. Another 5 ml of concentrated HNO_3 was added and then heated for 10 minutes and allowed to cool. About 5 ml of nitric acid was used to rinse the sides of the beaker and the solution filtered using Whatman 0.42µm filter paper into a 50 ml volumetric flask and topped up to the mark with distilled water. A blank solution was similarly prepared. Heavy metal analysis was done using Varian Atomic Absorption Spectrometer (model Spectra AA-10) at Mines and Geological department, Nairobi - Kenya. The blanks were aspirated along with the analytical samples in order to collect background adsorption. The operating conditions of the instrument (AAS) were set according to manufacturer's specifications (Table 2).

Table 2: Instrument (AAS) operating conditions

Element	Cu	Zn	Cd	Pd	Cr	Mn
Lamp current (mA)	3	3	5	8	7	5
Fuel	Acetylene	Acetylene	Acetylene	Acetylene	Acetylene	Acetylene
Support/ Oxidant	Air	Air	Air	Air	Nitrous oxide	Air
Wave length (nm)	324.7	213.9	228.8	217.0	357.9	279.5
Slit width (nm)	0.5	1.0	0.5	1.0	0.2	0.2
Detection limit (ppm)	0.003	0.002	0.006	0.02	0.005	0.003

2.5 Statistical Data Analysis

Data analysis was done using a computerized statistical programme (STATISTICA 8.0, 2007). The data were subjected to one way analysis of variance (ANOVA) and significant differences accepted at $p \leq 0.05$ (Zar, 2001). Where significant differences were found, the mean values were separated using post-hoc Tukey's (HSD) test. Descriptive statistics for all collected data were also obtained using STATISTICA software.

3 Results and Discussions

3.1 Copper (Cu) concentration (mg L^{-1})

Copper is a natural element which is widely distributed in soils, rocks and in rivers. It is released into water as a result of natural weathering of soil and discharges from industries and sewage treatment plants (Romo-Kroger *et al.,* 1994 and Hutchinson, 2002). The mean concentrations of Cu (mg L^{-1}) in surface water from all sampling sites are shown in Table 3. There was no significant variation ($p > 0.05$) in Cu concentrations levels between the different sampling sites. The mean Cu concentrations recorded were 0.003 ± 0.002 mg L^{-1} (Riakanau), 0.006 ± 0.003 mg L^{-1} (Kathini), 0.008 ± 0.003 mg L^{-1} (Tumutumu), 0.018 ± 0.007 mg L^{-1} (Manyatta) and 0.019 ± 0.003 mg L^{-1} (Mathauta). Cu in surface water is from extensive use of pesticides sprays which contain Cu compounds for agricultural purposes (Al-Weher, 2008). In the dissolved form, Cu is potentially very toxic to aquatic animals and plants, especially to young life-stages such as fish larvae. However, the toxicity is greatly reduced when Cu is bound to particulate matter in the river water and when the water is hard (Damodharan, 2013).

The mean Cu levels obtained in this study were lower compared to 0.69 – 0.94 mg L^{-1} observed in surface waters of Lake Victoria, Kenya (Oyoo-Okoth *et al.,* 2010). However, they were within same range 0.005 – 0.01mg L^{-1} of mean Cu levels recorded in five Rift Valley lakes in Kenya (Ochieng *et al.,* 2007). Studies by Ochieng *et al.,* (2008) found higher mean Cu levels 0.012 – 0.043 mg L^{-1} in surface water of Lake Kanyaboli, Kenya. The mean Cu levels obtained in Masinga reservoir did not exceed the WHO limits of 1.00 mg L^{-1} of Cu concentration in water for drinking (WHO, 2004).

3.2 Zinc (Zn) concentration (mg L^{-1})

Zn is introduced into water bodies through artificial pathways such as by-products of steel production or coal-fired power stations and burning of waste materials (Damodharan, 2013). It is also through leaching from fertilizers, effluents of commercial industries during mining and smelting (metal processing) activities. Other sources of Zn into aquatic ecosystems include urban runoff and municipal sewages (Damodharan, 2013). In this study the mean Zn concentration levels in surface water for all the sampling sites are presented in Table 3. The results indicated no significant difference in mean Zn concentration levels ($p > 0.05$) among the different sampling stations. The mean Zn levels recorded ranged from 0.092 ± 0.013 mg L^{-1}(Kathini), 0.108 ± 0.018 mg L^{-1} (Riakanu), 0.109 ± 0.018 mg L^{-1} (Mathauta), 0.111 ± 0.019 mg L^{-1} (Tumutumu) and 0.132 ± 0.019 mg L^{-1} (Manyatta). Zn is an essential nutrient for body growth and development; however drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. The concentration of Zn in surface water recorded in this study did not exceed the recommended limit of 3 mg L^{-1} for Zn levels in drinking water (WHO, 2008).

Similar studies done in Lake Victoria, Kenya have recorded Zn concentration levels as high as 0.220 mg L^{-1} (Lalah *et al.,* 2008 and Mwamburi, 2009). Also, Muiruri *et al.,* (2013) observed higher mean Zn levels (0. 055 – 0.695 mg L^{-1}) in Athi River tributaries. Ochieng *et al.,* (2007) observed mean Zn levels ranging 0.029 – 0.235 mg L^{-1} in five rift valley lakes (Nakuru, Naivasha, Baringo, Elementaita and Bogoria). At Lake Kanyaboli mean Zn levels in surface water ranging from 0.015 – 0.056 mg L^{-1} have been recorded (Ochieng *et al.,* 2008). Olatunji and Osibanjo (2012) obtained higher mean Zn levels (1.98 – 4.03 mg L^{-1}) in River Niger, North Central Nigeria compared to those observed in Masinga reservoir. Fahmy and Fathi (2011) obtained higher Zn levels in Wetland Lake, Al-Asfar, Saudi Arabia.

3.3 Lead (Pb) concentration (mg L^{-1})

Mean Pb concentration levels in surface water are shown in Table 3 and revealed no significant difference ($p > 0.05$) among the sampling sites. The lowest mean Pb levels were recorded in Manyatta 0.004 ± 0.001 mg L^{-1} and Riakanau 0.004 ± 0.002 mg L^{-1} while the highest mean Pb level was observed at Kathini 0.009 ± 0.005 mg L^{-1}. Mathauta and Tumutumu had similar mean Pb levels of 0.005 ± 0.002 mg L^{-1}. Pb concentration in natural water increases mainly through anthropogenic activities (Geol, 1997). Hence, likely source of Pb in water bodies is from soil erosion, municipal and industrial wastes and run off (DWAF, 1996). Soil erosion within Masinga reservoir catchment coupled with municipal waste discharges could be the source of Pb levels observed in this study. Kathini sampling station had slightly higher Pb levels than other sites and this could be attributed to industrial effluents discharged into Thika River from industries within the Thika Sub basin. The Pb levels observed in all the sampling stations were lower than the recommended limit of 0.01mg L^{-1} in drinking water (WHO, 2008). This means that the water in Masinga reservoir is not polluted by Pb.

Studies done elsewhere in Kenya indicate higher Pb concentration levels. For example Oyoo-Okoth *et al.,* (2010) found mean Pb levels ranging from 0.26 – 0.99 mg L^{-1} in Lake Victoria. Also, Muiruri *et al.,* (2013) recorded lower and higher mean Pb levels at different sites (nd – 0.047 mg L^{-1}) in surface water of Athi River tributaries. Other studies in Kenya that have recorded higher mean Pb levels include open waters of Winam gulf (0.2 mg L^{-1}), River Nyando (0.19 mg L^{-1}), and 0.015 mg L^{-1} in River Sondu Miriu (Tole and Shitsama, 2003). Ochieng *et al.,* (2007) obtained higher mean Pb levels ranging 0.025 – 0.563 mg L^{-1} in surface water of five Rift valley Lakes. Ochieng *et al.,* (2008) recorded Pb concentration levels of 0.006 – 0.048 mg L^{-1} in Lake Kanyaboli, Kenya. Studies carried out by Olatunji and Osibanjo (2012) also recorded higher mean Pb levels (0.02 – 0.04 mg L^{-1}) in surface water of River Niger, Nigeria.

Table 3: Mean ± Standard deviation and range for heavy metal concentrations in surface water during the study period. Means in same row with different superscripts are significantly different at $p < 0.05$ levels. Nd – Below detectable limit

Element/Site	Kathini	Mathauta	Manyatta	Riakanau	Tumutumu
Cu (mg L^{-1})	0.006 ± 0.003[a]	0.019 ± 0.009[a]	0.018 ± 0.007[a]	0.003 ± 0.002[a]	0.008 ± 0.003[a]
Range	Nd – 0.026	Nd – 0.057	Nd – 0.073	Nd -0.020	Nd – 0.024
Zn (mg L^{-1})	0.092 ± 0.013[a]	0.109 ± 0.018[a]	0.132 ± 0.019[a]	0.108 ± 0.018[a]	0.111 ± 0.019[a]
Range	0.046 – 0.184	0.056 – 0.282	0.062 – 0.255	0.060 – 0.262	0.071 – 0.291
Pb (mg L^{-1})	0.009 ± 0.005[a]	0.005 ± 0.002[a]	0.004 ± 0.001[a]	0.004 ± 0.002[a]	0.005 ± 0.002[a]
Range	Nd -0.063	Nd – 0.023	Nd – 0.015	Nd – 0.023	Nd – 0.021
Cr (mg L^{-1})	0.003 ± 0.002[a]	0.005 ± 0.005[a]	0.003 ± 0.001[a]	0.006 ± 0.004[a]	0.006 ± 0.003[a]
Range	Nd – 0.028	Nd – 0.058	Nd – 0.013	Nd – 0.042	Nd – 0.039
Mn (mg L^{-1})	0.085 ± 0.084[a]	0.006 ± 0.005[a]	0.038 ± 0.037[a]	0.012 ± 0.006[a]	0.146 ± 0.046[a]
Range	Nd – 0.504	Nd – 0.033	Nd – 0.221	Nd – 0.031	0.003 – 0.348
Cd (mg L^{-1})	Nd	Nd	Nd	Nd	Nd

3.4 Chromium (Cr) concentration (mg L^{-1})

The mean Cr concentration levels recorded at different sampling stations during the study period ranged from 0.003 ± 0.001 mg L^{-1} (Manyatta) to 0.006 ± 0.004 mg L^{-1} (Riakanau). Mean Cr level at Tumutumu was 0.006 ± 0.003 mg L^{-1}, Mathauta 0.005 ± 0.005 mg L^{-1} and 0.003 ± 0.002 mg L^{-1} (Kathini). The Cr levels showed no significant variations ($p > 0.05$) at different sites. The main sources of Cr are industrial wastes such as Cr pigment, tannery wastes, leather manufacturing wastes and municipal sewage sludge (Rahman *et al.,* 2012). In

this study, the elevated Cr levels at Tumutumu and Riakanau could be attributed to municipal and tannery wastes from the towns located in the upper Masinga reservoir catchment. However, the mean Cr levels obtained in this study did not exceed the recommended limit of 0.05 mg L^{-1} for Cr in drinking water (WHO, 2008).

Compared to other studies, the mean Cr levels in surface water of Masinga reservoir were lower than 0.23 – 0.79 mg L^{-1} recorded in Lake Victoria (Oyoo-Okoth *et al.,* 2010), 0.025 – 0.188 mg L^{-1} in five rift valley lakes (Ochieng *et al.,* 2007) and 0.068 mg L^{-1} in Athi River tributaries (Muiruri *et al.,* 2013). Ochieng *et al.,* (2008) found mean Cr levels of 0.005 – 0.061mg L^{-1} at different sites in Lake Kanyaboli while Olatunji and Osibanjo (2012) recorded a much higher mean Cr levels of 1.19 – 3.16 mg L^{-1} in River Niger, Nigeria compared to Cr levels in Masinga reservoir. A higher mean Cr level of 0.049 ± 0.02 mg L^{-1} has been recorded in Owen multi-purpose dam water, Nigeria (Oyhakilome *et al.,* 2012). However, mean Cr levels observed at Masinga reservoir were within the range of 0.003 – 0.088 mg L^{-1} recorded in River Nile, Egypt (Osman and Kloas, 2010).

3.5 Manganese (Mn) concentration (mg L^{-1})

There was no significant difference ($p > 0.05$) in Mn levels in surface water at the different sampling sites. The mean Mn concentration ranged from 0.006 ± 0.005 mg L^{-1} (Mathauta) to 0.146 ± 0.046 mg L^{-1} (Tumutumu). Kathini had the second highest mean Mn level (0.085 mg L^{-1}) in surface water while Manyatta and Riakanau had 0.038 mg L^{-1} and 0.012 mg L^{-1} respectively. In all the sampling sites the mean Mn concentration levels in surface water was found to be lower that recommended limit of 0.40 mg L^{-1} for Mn in drinking water (WHO, 2008). Mn is an abundant metal in earth's crust and usually occurs with iron. It is used in the manufacture of iron and steel alloys, as an oxidant for cleaning, bleaching and disinfection (as potassium permanganate) and as an ingredient in various products (WHO 2011). It gets into the aquatic ecosystems from industries manufacturing dry-cell batteries, glass, and fertilizer and in leather and textile (Ziemacki *et al.,* 1989). The high levels observed at Kathini could be due to industrial activities in the Thika sub catchment while at Tumutumu the Mn levels recorded may be due to high use of agricultural fertilizers, soil erosion and quarry activities within the catchment.

Comparable studies carried out in Kenya have recorded higher mean Mn values than observed in Masinga reservoir. These studies include those done by Lalah *et al.,* (2008) in Winam Gulf, Lake Victoria (0.05 – 3.276 mg L^{-1}) and Ochieng *et al.,* (2008) in Lake Kanyaboli, Kenya (0.185 – 0.376 mg L^{-1}). Also, Ochieng *el al.,* (2007) obtained higher mean levels of Mn in five rift valley lakes (0.050 – 0.282 mg L^{-1}). Akoto *et al.,* (2008) recorded similar mean Mn values ranging from 0.099 – 0.140 mg L^{-1} in Owabi reservoir, Ghana while Mahadev and Gholami (2010) in KRS reservoir, India observed (0.0001 – 0.107 mg L^{-1}) and Osman and Kloas (2010) in River Nile, Egypt (0.033 – 0.099 mg L^{-1}). Oyhakilome *et al.,* (2012) recorded higher Mn Values (0.346 ± 0.391 mg L^{-1}) in Owen multi-purpose dam water, Nigeria.

4.0 Conclusion and recommendation

The results revealed the presence of heavy metals in Masinga reservoir. The metal concentrations were in the sequence Zn>Mn>Cu>Cr>Pb>Cd. All the heavy metals studied (Cu, Zn, Pb, Cr, Cd and Mn) had lower levels than WHO recommended limit for drinking water. However, since the local communities around Masinga reservoir use the water for irrigation and watering their livestock, there is need for regular monitoring of the heavy metals in the reservoir.

Acknowledgements

The authors are grateful to National Commission for Science, Technology and Innovation (NACOSTI), Kenya for funding the research project. Also, the authors thank Mr. Mark Asiango of Kenya Marine Fisheries Research Institute, Naivasha for his assistance during sample collection. The authors also acknowledge all the technicians working at Environmental Science laboratory, Kenyatta University for their assistance during the study period.

References

Agah H., Leermakers M., Elskens M., Fatemi S. M.R and Baeyens W (2009). Accumulation of trace metals in the muscles and liver of five fish species from the Persian Gulf. *Environ. Monit. Assess*. 157: 499-514

Al-Weher, S. M (2008). Levels of heavy metal Cd, Cu and Zn in three fish species collected from the Northern Jordan Valley. *Jordan Journal of Biological Sciences, 1(1), 41 – 46*

Bakare, A.A., Lateef, A., Amunda, O.S and Afulabi, R.O (2003). The aquatic toxicity and characterization

of chemical and microbiological constituents of water samples from Oba River, Odo-Oba, Nigeria. Asian *J.Microbiol.Biotechnol.Environ. Science 5:11 - 17*

Damodharan, U (2013). Bioaccumulation of heavy metals in contaminated river water – Uppanar, Cuddalore South East Coast of India. htt//.dx.doi.org/10.5772/5334.

Dua, A and Gupta, N (2005). Mercury toxicology as assessed through fish scales. *Bull. Environ. Contam. Toxicol*. 74: 105 – 110

DWAF (Department of Water Affairs and Forestry) (1996) *South African*. W*ater quality guidelines. Volume 7: Aquatic ecosystems*, DWAF, Pretoria

Fahmy, G.H and Fathi, A.A (2011). Limnological studies on the Wetlnad Lake, Al-Asfar, with special references to heavy metal accumulation by fish. *American Journal of Environmental sciences 7(6): 515-524*

Goel, P.K (1997). Water pollution causes, effects and control. New Delhi, New.Age, 1997

Hutchinson, T. H (2002). Reproductive and developmental effects of endocrine disruptors in invertebrates: in vitro and in vivo approaches. *Toxicology Letters 2002; 131: 75–81*.

Indrajith, H.A.P., Pathiratne, K.A.S and Pathiratne, A (2008). Heavy metal levels in two fish species from Ngembo estuary, Sri Lanka: Relationships with the body size. *Sri Lanka J. Aquat. Sci*. 13 (2008): 63-81

Jumbe, J.J (2003). The effects of changing water level, the fishes and fisheries of Masinga and Kamburu Dams, Tana River, Kenya. Unpublished PhD. Thesis Kenyatta University, Kenya.

Kitheka, J.U., Obiero, M., and Nthenge, P. (2005). River discharge, sediment transport and exchange in the Tana Estuary, Kenya. *Estuarine and Coastal Shelf Science* 63: 455-468.

Lalah, J.O., Ochieng, E. Z and Wandiga, S.O (2008).Sources of heavy metal input into Winam Gulf, Kenya.. *Bull. Environ. Contam. Toxicol*. (2008) 81: 277 – 284

Mahadev, J and Gholami, S (2010). Heavy metal analysis of Cauvery River water along Krs Dam, Karnataka, India. *Journal of Advanced Laboratory Research in Biology Vol.1 Issue 1: 10 - 14*

Martin, M.H and Coughtrey P.J. (1982). Biological Monitoring of heavy metal pollution, 'land and air' 475pp. London and New York

Muiruri, J.M., Nyambaka, H. N and Nawiri, M.P (2013). Heavy metals in water and tilapia fish from Athi –Galana-Sabaki tributaries, Kenya. *International Food Research Journal 20(2): 891 – 896*

Mwamburi, J (2009). Trace metal concentration in water and sediments of satellite lakes within Lake Victoria (Kenya) basin. *Lakes and Reservoirs: Research and Management 2009 14: 203-219*

Ndimele, P.E (2008). Evaluation of phyto-remediative properties of water hyacinth (*Eichhornia crasspies*) and biostimulants in restoration of oil-polluted Wetland in the Niger Delta. PhD. Thesis, University of Ibadan, Nigeria.

Ndimele P.E and Kumolu-Johnson C.A (2012). Some aspects of the physicochemistry and heavy metal content of water, sediment and *Cynothrissa mento* (Regan, 1917) from Badagry Creek, Lagos, Nigeria *Trends in Applied Sciences Research* 7(9): 724-736, 2012.

Ochieng, E. Z., Lalah, J.O and Wandiga, S.O (2007). Analysis of heavy metals in water and surface sediments in five Rift Valley lakes in Kenya for Assessment of recent increase in anthropogenic activities. *Bull. Environ. Contam. Toxicol. (*2007) 79: 570 -576

Nzeve J.K., Kitur C.E and Njuguna S.G (2014). Determination of heavy metals in sediments of Masinga reservoir, Kenya. *Journal of Environment and Earth Science* Vol. 4 No. 20, (2014) pp. 125 – 132.

Ochieng, E. Z., Lalah, J.O and Wandiga, S.O (2008). Water quality and trace metal distribution in a pristine lake in the lake Basin in Kenya. *Bull. Environ. Contam. Toxicol. (2008) 80: 362 – 366*

Olatunji, O.S and Osibanjo, O (2012). Determination of selected heavy metals in inland fresh water of

lower River Niger drainage in North Central Nigeria. African *Journal of Environmental Science and Technology 6(10): 403 - 408*

Osman A.G.M and Kloas W. (2010). Water quality and heavy metal monitoring in water, sediments and tissues of the African catfish *Clarias gariepinus* (Burchell, 1822) from the River Nile, Egypt. *Journal of Environmental Protection,* 2010, Vol. 1. 389 – 400.

Oyhakilome, G. I., Aiyesanmi, A. F and Akharaiyi, F.C (2012). Water Quality Assessment of the Owena Multi-Purpose Dam, Ondo State, Southwestern Nigeria. *Journal of Environmental Protection*, 3, 14 – 25.

Oyoo-Okoth, E., Wim,A., Osano,O., Kraak,M.H.S., Ngure, V., Makwali, J and Orina, P.S (2010). Use of the fish endoparasite *Ligula intestinalis* (L., 1758) in an intermediate cyprinid host (*Restreneobola argentea*) for biomonitoring heavy metal contamination in Lake Victoria, Kenya*. Lakes & Reservoirs: Research and Management 2010, 15: 63 – 73.*

Qiao – qiao, H.I., Guang-Wei, Z.H.U and Langdon,A (2007). Bioaccumulation of heavy metals in fishes from Taihu Lake, China. *J. Environ. Sci.* 19: 1500 – 1504

Rahman, M. M., Fikria, A.F., Kamaruzzaman, B.Y and Wan Nik, W.B (2012). Distribution of trace metals in pore water along Terengganu beach. *Australian Journal of Basic and Applied Sciences, 6(7), 213 - 217*

Romo-Kroger, C. M., Kiley, J.R., Dinator, M.I and Llona, F (1994). Heavy metals in the atmosphere coming from a copper smelter in Chile, *Atmospheric Environment 1994; 28, 705–711.*

Senarathne P and Pathiratne K.A.S (2007). Accumulation of heavy metals in a food fish, *Mystus gulio* inhabiting Bolgoda Lake, Sri Lanka. *Sri Lanka J. Aquat. Sci.* 12 (2007): 61-75

Tole, M.P and Shitsama, J.M (2003). Concentrations of heavy metals in water, fish and sediments of the Winam Gulf, Lake Victoria, Kenya. In: *Lake Victoria Fisheries: Status, biodiversity and Management*, by M.van der Knaap and M. Munawar (Eds), 2003, *Aquatic Ecosystem Health and Management.*

UNEP. (2000). Global Environment Outlook. Earth Scan Publications Ltd, London; pp.132-133.

UN-WATER. (2006). Kenya National Water Development Report. Case Study: Kenya 2nd UN World Water Development Report: A shared responsibility, 2006.

WHO (2004). Guidelines for drinking Water Quality: Recommendations 3rd Edn. World Health Organization, Geneva, pp. 516

WHO (2008). Guidelines for drinking water quality, World Health Organization, Geneva, 2008

WHO (2011). Guidelines for drinking water quality, 4th edn. World Health Organization, Geneva, 2011, pp. 564.

Wright D.A. and Welbourn P. (2002). Environmental Toxicology, Cambridge press, Cambridge

Zar, J.H. (2001). Biostatistical Analysis. Printice –Hall, Englewood Cliffs, N.J

Zhang, C. (2007). Fundamentals of environmental sampling and analysis. John Wiles & Sons: p. 109

Ziemacki, G., Viviano, G and Merli, F (1989). Heavy metals: Sources and environmental presence. Annali dell' *Instituto Superiore di Sanita*, 25 (3), 531- 536

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar