

Levels of Heavy Metals (Pb, Mn, Cu and Cd) in Water from River Kuywa and the Adjacent Wells

Wasike P. W., Nawiri M. P. *, Wanyonyi A. A.

Department of Chemistry, Kenyatta University, P.O 43844-00100 Nairobi, Kenya

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Abstract Worldwide, over one billion people lack access to clean drinking water, this being attributed to industrial effluents, agricultural chemicals and residential wastes. As such, contaminants in drinking water including heavy metals pose fears on human health especially if levels exceed limits set by WHO and the Kenya Bureau of Standards (KEBS). Water sourced from River Kuywa in Bungoma County, Kenya and its adjacent wells risk heavy metal contamination due to the surrounding industrial and agricultural activities. Never the less, the waters are used for domestic purposes. Water samples from River Kuywa and in adjacent wells were analyzed for Pb, Mn, Cu and Cd during a dry and rainy season employing Flame atomic absorption spectroscopy and ANOVA for instrumental and data analysis respectively. The mean values (mg/l) of Pb, Cu and Cd in water from the river during the two seasons were: Pb (0.57 ± 0.09 - 3.36 ± 1.15), Cu (1.01 ± 0.12 - 1.92 ± 0.14) and Cd (0.32 ± 0.02 - 0.99 ± 0.67). In wells, the waters had the ranges: Pb (1.43 ± 0.34 - 2.43 ± 0.41), Cu (1.39 ± 0.24 - 1.92 ± 0.14) and Cd (0.35 ± 0.03 - 0.46 ± 0.03). These were above those set by KEBS and WHO with significant differences noted between seasons ($p < 0.05$). Strategies that would reduce further contamination of water in river Kuywa and in the adjacent wells are called for to intervene for the unforeseen health risks associated with heavy metal poisoning.

Keywords River Kuywa, Wells, Heavy Metals, Bungoma County

1. Introduction

The presence of high concentrations of heavy metals in drinking water poses in underdeveloped countries, a high risk to human health The Agency for Toxic Substances and diseases Registry (ATSDR) compiled a priority list of top 20 toxic substances among them the heavy metals Pb, Cd, Cu and Mn [1]. Heavy metals are not only increasingly

being introduced into water bodies but also increasing above recommended levels [2, 3]. The recommended limits set by WHO and KEBS are 0.10, 0.03, 0.05 and 0.50 mg/l for Pb, Cd, Cu and Mn respectively [4, 5, 6]. Among the various sources on the heavy metals are human activities such as burning of fossil fuels, mining and smelting of metal ores, agricultural activities, industrial wastes and poor disposal of compounds and the metal levels vary with seasonality [7] These raises concern on the effects attributed to heavy metal poisoning since they are not only persistent but also have potential for bio-accumulation and bio-magnification [8, 9]. Heavy metals are toxic and can damage human body organs and other internal organs of animals tissues easily even at very low concentration. This is due to lack of good mechanisms of their elimination from the body [10, 11]. Heavy metal toxicity can result to damage or reduced mental, central nervous functions lower energy levels, damages blood composition, lungs, liver, kidney and other vital organs [1; 12]. Repeated long term contact with low concentration of some of these metals or their compounds may also cause cancer [4, 5]. They can enter the human body through water, food, air or absorption through the skin when in contact with the human body [7, 13].

The ever increasing human population in developing countries has led to scarcity of safe and clean water and especially with fears of pollution by heavy metals [14]. It is reported that more than one billion people worldwide lack access to clean drinking water and 5-10 million people die annually of water borne related illnesses [14, 15]. In the East Africa region, water from the River Nile has been reported to contain heavy metals above the recommended limits while in Kenya, River Nzoia and other major rivers that drain into L.Victoria showed presence of Cd, Cu, Zn, and Pb [16, 17, 18]. Environmental pollution data though varies extensively subject to various types of uncertainties such as distance from pollution sources and pathways (solubility of metal salts and adsorption to the sediments), natural background variation and pollution buildup or degradation over time [16, 19]. The solubility of metal salts

in water for example is influenced by pH value dissolving below a value of 6.5 and precipitates at the range of 6.5 to 8.5 [20]. Hot water dissolves more salts of heavy metals than cold water and thus there is variation in the level of heavy metals during the wet and dry seasons [21]. The levels increase with decrease in pH value, below pH of 5.5 most of metal ions dissolve in water and when the bed rock or aquifer rock has high percentage of metal ions at low pH and high temperature levels of metal ions will increase [20, 21]. Non the less, there has been continuous calls for intervention since water bodies pose health risks to human beings and other animals as their waters are used for drinking and other domestic purposes. River Kuywa is among the major rivers that traverse Bungoma County in Kenya. It is worth noting that although water from River Kuywa is used for irrigation, domestic (including drinking) and in coffee and sugar factories, streams and rivers that are tributaries to this river collect impurities from surface runoffs, sewage discharges, industrial effluents and agro-chemicals hence a health hazard [14, 18, 21]. Waters from R. Kuywa and the adjacent wells serve a large population in Bungoma County but there is no documentation on the levels of heavy metals in the waters noting the surrounding activities. It is important to identify and quantify hazardous compounds in rivers and wells especially those used for drinking purposes. The levels of Pb, Mn, Cu and Cd in water from River Kuywa and adjacent wells were therefore studied during the rainy and dry seasons.

2. Materials and Methods

Sampling and Pre-treatment

Water samples were collected during the wet (October) and dry seasons (January) from the upper, middle and lower sections of R. Kuywa, sections that were approximately 2 km apart and based on their different surrounding activities. During each season, eight samples were obtained from each section of the river making a total of 48 samples. A 2 liter plastic container was used to draw water to a depth of approximately 10-15 cm. Triplicate samples from a site were mixed thoroughly before a sub-sample of 500 ml for laboratory analysis was obtained. Water from wells that were approximately 2 Km away from River Kuywa were sampled. Three wells were randomly selected adjacent to each of the sections of the river. Water was collected in 500 ml plastic and from the resultant homogenized sample a 500 ml sub-sample was obtained. The protocol for collecting water grab samples in rivers, streams, and freshwater wetlands was adopted. Briefly, prior to collection of water samples, sample containers were labelled with the date, time, and site name and rinsed three times in river/well water. Water was collected stirring neither the river nor the wells. The

uncapped bottle was held upside down and submersed then tipped upright and water was allowed to fill the bottle. This was then removed from the water and in each sub-sample, (5 ml) concentrated nitric acid was immediately added for pre-treatment, the cap screwed on before storage and transportation to the laboratory in cooler with ice on the same day of sampling. Samples were stored in the refrigerator before being transported to Kenyatta University laboratory for analysis.

Cleaning of apparatus

All glassware were first washed with soap tap water and then soaked in the freshly prepared concentrated chromic acid overnight. They were then cleaned with soap, tap water, followed by nitric acid, and finally the acid was washed off by de-ionized water. They were then dried in the oven at 100°C. The plastic containers were washed with soap, 6% nitric acid then rinsed with distilled water to remove traces of the acid.

Chemicals and Reagents

Nitric acid (AR) and 30% hydrogen peroxide, lead nitrate standard copper nitrate manganese chloride solutions of Pb, Mn, Cd and Cu.

Calibration and sample Preparation

Standard solutions of Pb, Cu, Cd and Mn were prepared and consequently diluted for working standard solutions for calibration as per procedures by Jackson [22]. Samples were filtered using Whatman glass 4.5 µm micro fiber filter paper of diameter 4.25 cm after digestion since most of the samples had solid particles. Exactly 100 ml of the water sample from each sample was digested with 5 ml ultra-pure nitric acid in a beaker using a heating block digestion, while adding few drops of hydrogen peroxide until the volume reduced to 50 ml. The remaining solution was poured into a 100 ml volumetric flask and diluted to the mark with deionized water for aspiration into the FAAS [23].

Instrumental conditions

A Lamp current of 4 mA was used for Cd and Cu while Mn and Pb the current was 5 mA. C₂H₂ fuel was used for all the heavy metals supported by Air (Cd, Cu, Mn) and N₂ O (Pb). The respective wavelengths, slit width and detection limit were 288.8, 324.7, 279.5, 217.0 (nm); 0.7, 0.5, 0.7, 0.7 (nm) and 0.025, 0.04, 0.05, 0.5 mg/l for Cd, Cu, Mn and Pb respectively.

Data Analysis

One-Way ANOVA at 95% level using SPSS 18 for windows assuming that there were significant differences among them when the statistical comparison gives p<0.05. The student t-test was used to compare the means in levels of the heavy metals between the dry and wet season and between river water and well water.

3. Results and Discussions

The correlation co-efficient (r) for the resultant calibration curves for the heavy metals were linear with values of 0.9947, 0.9951, 0.9999 and 0.9992 for Pb, Cu, Mn and Cd respectively upholding good performance of the FAAS instrument and accuracy of results [24]. The mean level of the heavy metals in water from R. Kuywa and the adjacent well during the rainy and dry season are given in tables 1 and 2.

All the four heavy metals were found in water from the three sections of river Kuywa in both sampling seasons. In the wet season, the range (mg/l) was Pb (1.50±0.26 - 3.36±1.15), Mn (0.20±0.05- 0.17±0.02), Cu (1.01±0.12-1.20±0.15 and Cd (0.32±0.02-0.99±0.67). During the dry season, the range was Pb (1.38±0.31-1.93±0.33), Mn (0.12±0.01-0.14±0.02), Cu (1.58±0.13-1.86±0.32) and Cd (0.35±0.04-0.43±0.09). In wells adjacent to R. Kuywa, heavy metals levels (mg/l) ranged across its three sections as follows: Pb (1.71±0.42-2.43±0.41), Mn (0.15±0.01- 0.25±0.03), Cu (1.39±0.24-1.92±0.14) and Cd (0.31±0.03-0.36±0.05) in the wet season. During the dry season the ranges were, Pb (0.57±0.02-1.11±0.14), Mn (0.15±0.02-0.23±0.04), Cu (1.37±0.27- 1.96±0.27), and Cd (0.35±0.06-0.46±0.03).

Consequently, the pollution indexes (ratio of mean level of heavy metals to the recommended level set by WHO) for Mn, Pb, Cu and Cd were above unity, being higher than the

recommended limits by KEBS and WHO [4, 5, 6]. The observed pollution data though varies extensively subject to various types of uncertainties including but not limited to runoff from agricultural farms, industrial areas, municipal and residential areas and leaching of wastes that containing the heavy metals [4, 9, 11, 16, 19, 21]. With the lack of good mechanisms of elimination of heavy metals from the human body, the implication of these findings point to the dangers of heavy metals at these concentrations [10, 11]. Heavy metal toxicity is known to damage the mental, central nervous functions, lower energy levels, damage blood composition, lungs, liver, kidney, other vital organs and can cause cancer [1; 4, 5, 12].

4. Conclusions and Recommendations

The mean values (mg/l) of Pb, Cu and Cd in water from R. Kuywa indicate the water is unsafe according to KEBS and WHO standards. There were significant differences noted between seasons (p<0.05). These observed differences indicate the need for better control of sources and control technologies hence strategies that would reduce further contamination of water in river Kuywa and in the adjacent wells are called for. These would intervene for the unforeseen human health risks associated with heavy metal poisoning.

Table 1. Mean Levels (mg/l) of Heavy Metals in Water from River Kuywa

Section of river	Concentration of heavy metals (Mean±SE mg/l) and seasons of sampling							
	Wet season		Dry season		Wet season		Dry season	
	Pb	Mn	Cu	Cd	Pb	Mn	Cu	Cd
Upper Section	1.36±0.18	1.38±0.3	0.13±0.01	0.12±0.010	1.01±0.12	1.58±0.13	0.32±0.02	0.35±0.040
Middle section	3.36±1.50	1.93±0.33	0.20±0.05	0.14±0.02	1.20±0.15	1.70±0.30	0.99±0.67	0.43±0.09
Lower section	1.50±0.26	1.52±0.16	0.17±0.02	0.14±0.02	1.11±0.22	1.86±0.32	0.59±0.25	0.38±0.03
p-value	0.146	0.354	0.326	0.505	0.728	0.785	0.385	0.621

One-way ANOVA, SNK-test, α=0.05.

Table 2. Mean levels (mg/l) of Heavy Metals in Water from wells Adjacent to River Kuywa during Sampling Seasons

Sites	Concentration of heavy metals (Mean±SE mg/l) and sampling seasons							
	Wet season		Dry season		Wet season		Dry season	
	Pb	Mn	Cu	Cd	Pb	Mn	Cu	Cd
Upper Section	2.43±0.41	0.82±0.13 ^{ab}	0.17±0.01 ^a	0.15±0.02	1.39±0.24	1.96±0.27	0.36±0.05	0.35±0.06
Middle section	1.43±0.34	1.11±0.14 ^b	0.15±0.01 ^a	0.23±0.04	1.86±0.14	1.37±0.27	0.36±0.04	0.53±0.05
Lower section	1.71±0.42	0.57±0.09 ^a	0.25±0.03 ^b	0.15±0.02	1.92±0.14	1.46±0.11	0.31±0.03	0.46±0.03
p-value	0.285	0.010	0.011	0.058	0.090	0.158	0.521	0.05

Mean values within the same column followed by different small letter(s) are significantly different (one-way ANOVA, SNK-test, α=0.05), while those without did not show significantly different.

Acknowledgements

The authors are thankful to Kenyatta University for laboratory space and equipment.

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