Heavy Metal Pollution from Migori Gold Mining Area, Kenya: Health Implications for Consumers of Fish and Water

Veronica Ngure [1*] Francis Lelo[2] Benson Obwanga[1]
1. Department of Biological Sciences, Laikipia University, P.O. Box 1100-20300, Nyahururu, Kenya
2. PAES Department, Laikipia University, P.O. Box 1100-20300, Nyahururu, Kenya

Abstract
Potentially harmful elements (PHE) also referred to as heavy metals (HM) were analyzed in water, fish, nails and scalp hair in children between 5 and 10 years in Migori gold mining belt, Kenya. The samples were digested using acids and analyzed by atomic absorption spectrometry (AAS). The results revealed that the continued consumption of water and fish contaminated from gold mining activities within the vicinity, have significantly increased the concentrations of selected PHE in the nails and scalp hair. There was correlation between the HM in the water and fish and those established in the nails and scalp hair of the children going to school in the gold mine Region, Kenya. Mercury (Hg) and Arsenic (As) in water showed elevated levels above WHO maximum acceptable level in reported studies. Results showed that concentrations of cadmium (Cd), chromium (Cr), and lead (Pb) in water were recorded above the permissible limits set by WHO while zinc (Zn) and copper (Cu) were recorded below the permissible limits. Lead (Pd) and cadmium (Cd) concentrations in nails showed elevated levels above those reported in occupationally exposed residents. Concentrations of Pb, Cd, Cr, and Cu were significantly higher ($p < 0.05$) in the hair samples collected from the polluted area as compared to control area. Older children (10 years) tended to show higher mean concentrations of PHE as compared to the younger ones (5year) within the same area. The research indicate that the children in the study area are exposed to high health risks associated with ingestion of PHE through contaminated ingestion of fish and drinking water from the rivers flowing through the gold mining area. Education and drastic interventions need to be put in place to protect the young generation from multiple health risks associated with gold mining activities in Migori Gold Belt in Kenya.
Keywords: Bioaccumulation; heavy metals; water, human hair; nails, fish matrix

1 INTRODUCTION

Potentially harmful elements (PHE) such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu) as well as a number of other PHE occur naturally in water, soil and biota (Oyoo-Okoth, *et. al*., 2010, Ruchita *et. al*., 2015). Concentrations depend on local geology, addition from mining and industry and/or globally distributed pollution from other geogenic and anthropogenic sources (Cui *et al*., 2004; 2005; Zheng *et al*., 2007; Khan *et a*l., 2008; Hang *et al*., 2009, Kathleen *et. al.,* 2011, Arhin *et. al.,* 2016). Geologically enriched environments may contain high concentrations of these metals as reported by Ogola *et. al*., 2002. In areas with superficial industrial exposures, children may be exposed to PHEs through soil (Alloway, 1995, Mol and Outboter, 2004, Hang, 2009), drinking water (Davies, 1994, USEPA, 2002, Ngure *et. al*., 2012, Oyoo- Okoth, *et. al.,* 2013, and consumption of locally grown food crops (Orish *et. al.,* 2012, Ngure *et. al*., 2015) and commonly available food items such as fish (Webb *et. al*., 2004, Mbabazi and Wasswa, 2010, Oyoo-Okoth, 2010, Tian *et.al.,* 2011, Oyoo-Okoth *et. al*., 2012, Ngure, *et., al*. 2014). Copper is an essential element at low levels, a component of various enzymes and used in normal development of connective tissues (Amaral *et al.,* 2008). Chromium is reported as an essential element at very low levels in blood sugar regulation by insulin but in large amounts it is highly toxic (Shadreck and Mugadza, 2013). Many of the PHEs such as As, Pb, and Hg have no known biochemical, physiological or metabolic functions in humans, and can elicit toxic effects even at very low exposure levels (Khan *et al*., 2008; Hang *et al*., 2009). However, an element such as Cu, harmful at elevated levels, is an essential element and a component of various enzymes, involved in collagen synthesis, for instance, and in the normal development of connective tissues, nerves and immune system (Amaral *et al.,* 2008).

Analyses of human biomarkers have been used to demonstrate occupational or environmental exposure to toxic elements (Samanta *et al*., 2004; Were *et al.,* 2008, Reena *et. al.,* 2011). Human hair as a tool of choice for monitoring the exposure is linked with the availability of suitable analytical procedures, sensitive enough to quantify the content of the respective element in the biological specimen tested (Szynkowsk *et. al*., 2009). It reflects metal mean level in human body during a period of 2–5 months (Aharoni and Tesler, 1992). Nail analysis is now considered a useful alternative technique for assessing health effects resulting from longer exposure periods, say between 12 and 18 months (Suzuki *et al*., 1988; Were *et al.,* 2008). Metal content of hair and nails varies from one geographical location to another, depending on the natural background conditions, including composition of soil, element concentration in water and food crops and eating habits (Hefferre, 1976; Teraoka, 1981, Uwah *et. al*., 2009). Most studies have either used the human hair or nails (Were *et.al*., 2008) for biological monitoring as an indicator of the heavy metal body burden but few studies have combined the human hair and nails in relation to fish consumption making it difficult to draw tangible correlations with the exposure levels. This study assessed the contribution of drinking water and fish to the metal body burden in children aged between 5 and 10 years in an area of small scale gold mining practice in Migori Gold Belt, Kenya. It also determined the concentration of metals in fish, drinking water, hair and nails and established the relationship between the metal body burden of the children with metal concentrations in water and fish consumed. The study finally established the relationship between metal body and potential health risks.

2 STUDY SETTING

Lake Victoria basin in Kenya is volcanic in nature and contains rich deposits of metals from geological origin (Ogola *et al*., 2002; Kenya Geological Survey, 2008). Compounding the problem of metal pollution in the region is the continuous operation of small scale and artisanal gold mining over the last few decades. Water for human consumption is obtained directly from the rivers draining through the gold mines basin and from the lake. Most commonly consumed fish species, the silver sardines (*Rastrineobola argentea).* This fish is the most commonly used for food as it is a cheap. However, the fish contain high metal concentrations as observed in other studies (Mbabazi and Wasswa, 2010, Oyoo-Okoth *et al*., 2012). This study focused on establishing the mean concentrations of the PHE in the fish and water to inform on the current status over the years.

The geology of the study area is shown in fig 1. It is comprised of granite rocks.

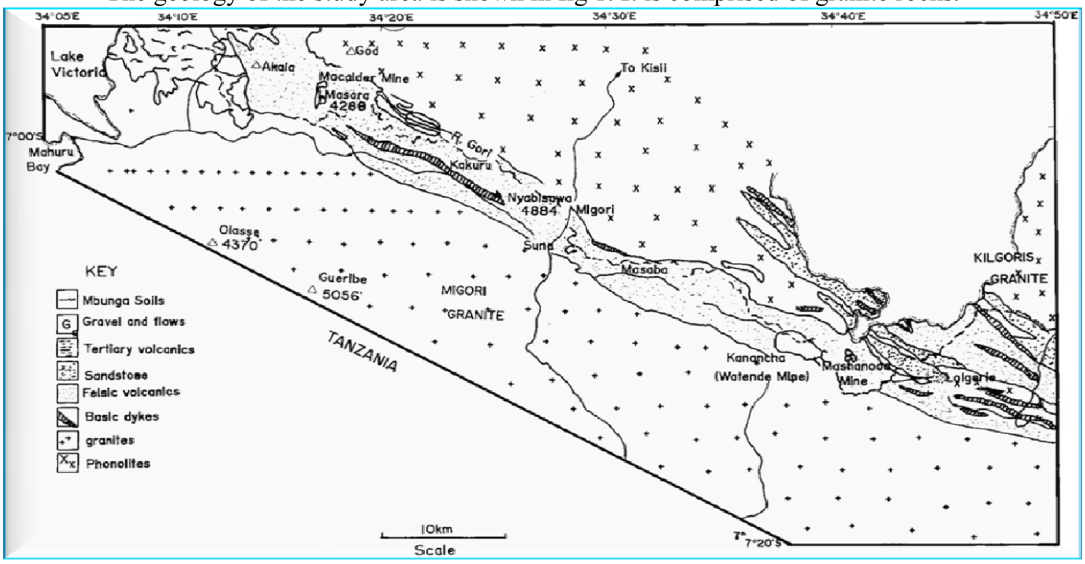


Fig. 1 Geology of the study area

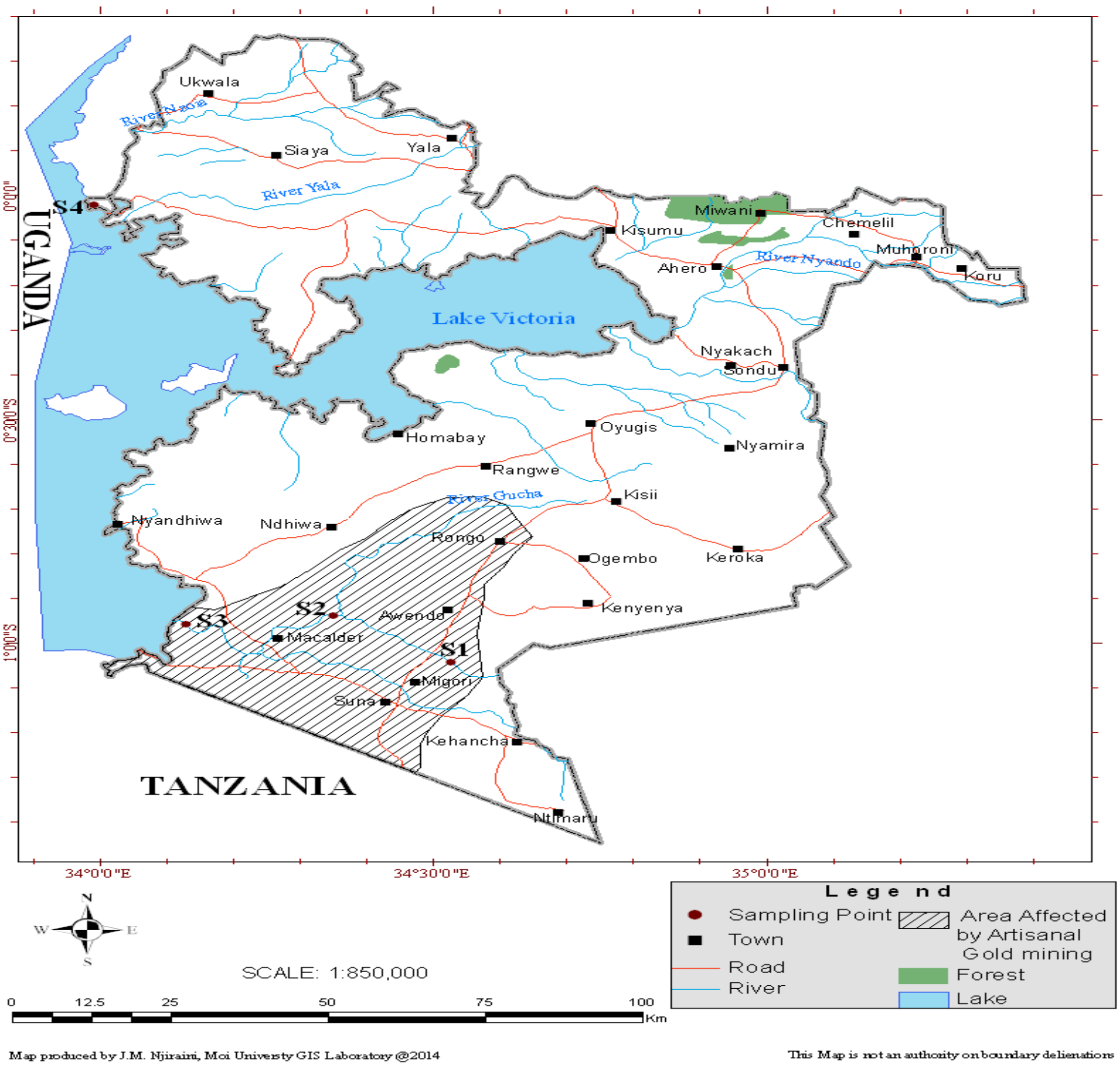


Fig.2. Sampling sites in the Study area

2.1 Sampling design and procedures

Samples of drinking water, hair, nails and fish were collected from the study sites 1-4 between January and December 2013 as shown in figure 2. All equipments used were pre-soaked with concentrated nitric acid (65%) and sulphuric acid (30%) solutions of 1:1 volume ratio, washed in 2 L of tap water, rinsed three times with ultra pure water and dried prior to the field work. Hair samples were collected from 120 children (S1 = 40, S2 = 30, S3 = 50) from the exposed sites [S1(Macalder), S2(Gucha) and S3(Karungu)] and 70 children from the reference site [S4(Kisumu rural)]. Children and their parents were informed of the purpose of the study and their consent obtained. Inclusion criteria were as follow: Sample population comprised children aged between 5 and 10 years with no diagnosed terminal illnesses or dyed hair and subjects who must have lived in the area for at least 3 years. Helsinki 1996 protocols were followed and permission to carry out the study was obtained from the Research and Ethics Committee (IREC) of Moi University, Kenya.

At least 0.20 g hair was collected from the scalp region of each individual in triplicate washed in a beaker with distilled water on a stirrer for 15 min and then washed with acetone–water–water–water–acetone (IAEA, 1985). Washed samples were placed individually in glass beakers and allowed to dry at 50 $^{\circ}$C overnight in a drying oven. Nail samples were obtained from the children using stainless razors and were treated in a similar way as the hair samples. Water and fish were collected from the same sites where the hair and nail samples were obtained. Water samples were obtained from the four sites approximately 20 m from the main rivers, Kucha and Migori, at about 0.50–0.75 m below the surface using a 3 L Van Dorn bottle. Water samples were acidified to pH 2 with concentrated nitric acid (65%), placed into cool boxes and transported to the laboratory for chemical analyses. Adult fish species *R. argentea*, were obtained from the respondents, packed in polyethylene bags and kept frozen until analysed. Fish samples were crushed in a pulverizer, then lyophilized (72 h) and subjected to acid digestion. 0.200 g of each sample was placed in a Teflon digestion vessel with 7.0

mL of concentrated nitric acid (65%), 1.0 mL concentrated hydrochloric acid (30%) and 1.0 mL hydrogen peroxide (30%). Ethos D (Type Ethos plus 1) microwave (purchased from Milestone Inc., Monroe, CT, USA) was used to digest the samples. Digestion involved four steps namely: 25–200 ˚C for 10 min at 1000 W; 200 ˚C for 10 min at 1000 W. Digests were made up with ultra pure de-ionised water to 25.0 mL in acid washed standard flasks, The final diluted solutions were transferred into acid cleaned polyethylene bottles respectively.

2.2 DATA ANALYSIS

Data on the metal concentrations in the water and fish were presented as means (± SEM) per sampling site. For the hair samples, geometric mean (GMs ± 0.95*Confidence Interval) was calculated for each metal at every sampling site. For comparison of metal concentrations in the samples (between sampling sites), one-way ANOVA was used. Whenever the null hypothesis was rejected, a multiple comparison test (DMRT) was used for post hoc comparison. Principal Component Analysis (PCA) was used to determine the contributions of water and fish to the metal burden of the children.

3 RESULTS

This section presents concentration of potentially harmful elements at different sites in drinking water (µgL^{-1}), scalp hair (mg/kg), nails (mg/kg) and fish *R. argentea* (mg/kg). The results indicate significant differences in concentrations of the PHE between sites with Site 3 generally recording highest average concentrations of PHE in all elements.

From Table 1 results, the PHE concentration reported in µgL^{-1} show high levels of contamination by the PHE. There was also significant difference between PHE concentrations in the 4 sites of study by each element. Water PHE concentration were all above the recommended maximum limit by WHO standards as shown in Table 1 summary of the calculated means of the observed samples from the 4 sites. Arsenic concentration in S4 was equal to WHO maximum limit in water. Figure 3, shows the mean concentrations of each studied PHE in water for each site compared to WHO limits. The height of the bars corresponds to the concentration of the PHE studied. Mercury, Pb, and Cd recorded the highest mean concentrations in S3 (Kaduna) while highest concentration of Cu was recorded in the control S4.

Table 1. Concentration of potentially harmful elements (µgL^{-1}) in water at the different sampling sites

Metals	S1	S2	S3	S4	WHO
Hg	0.92± 1.9^a	18.1±1.6^b	18.9± 3.6^b	0.06± 31^a	<0.002
As	0.042±6.8^a	0.029±6.2^a	0.097±2.9^b	0.001±4.6^c	<0.001
Pb	59.2±7.5^c	69.6±1.7^a	89.3 ±5.1^b	13.1±2.2^a	<0.005
Cd	83.3±5.1^c	91.1±3.3^a	136.1±2.9^d	32.3±7.7^b	<0.001
Cr	27.7±5.1^a	26.3±6.4^a	87. 7±7.2^c	14.1±2.7^b	<0.005
Cu	99.2±2.5^c	69.1±3.8^b	34.1±5.4^a	41.7±4.2^b	<0.005

Means with the same superscripts a, b, c and d in a row are not significantly different (P>0.05).

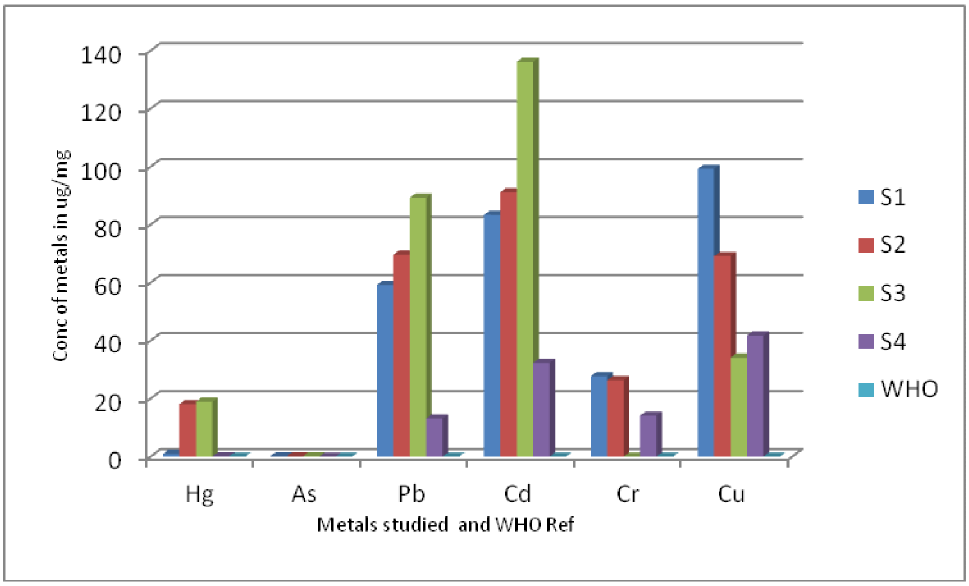


Fig 3. Potentially harmful elements concentration in water in the different study sites.

Table 2: Concentration of heavy metals (mg/Kg) in scalp hair at the different sampling sites

Metals	S1	S2	S 3	S 4	I/J/Eng
Hg	0.19 ± 0.012[a]	0.21± 0.019[a]	0.32 ± 0.011[b]	0.12 ± 0.019[a]	0.02-0.2
As	0.012 ± 0.012[a]	0.021 ±0.1 4[ab]	0.019 ± 0.73[c]	0.009 ± 0.017[a]	0.02-0.5
Pb	0.61 ± 0.025[b]	0.606 ± 0.03[b]	0.86 ± 0.026[c]	0.68 ± 0.022[b]	0.03-1.4
Cd	0.18 ± 0.014[b]	0.840 ± 0.019[a]	0.079 ± 0.009[b]	0.077 ± 0.012[b]	No Value
Cr	0.032 ± 0.090[e]	0.041 ± 0.042[b]	0.054 ± 0.024[c]	0.005 ± 0.019[b]	0.03-1.88
Cu	0.021 ± 0.001[a]	0.025 ± 0.002[a]	0.026 ± 0.002[c]	0.029 ± 0.001[a]	0.03-0.11

Mean (± SEM) values with different superscripts for each metal were significantly different within the study sites at ∝ = 0.05 (I= India, J= Japan, Eng= England)

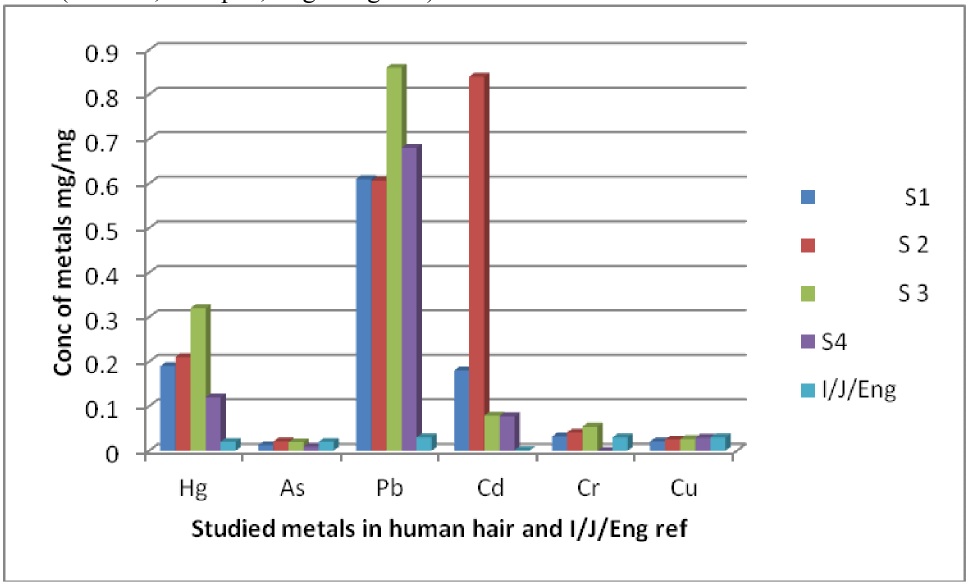
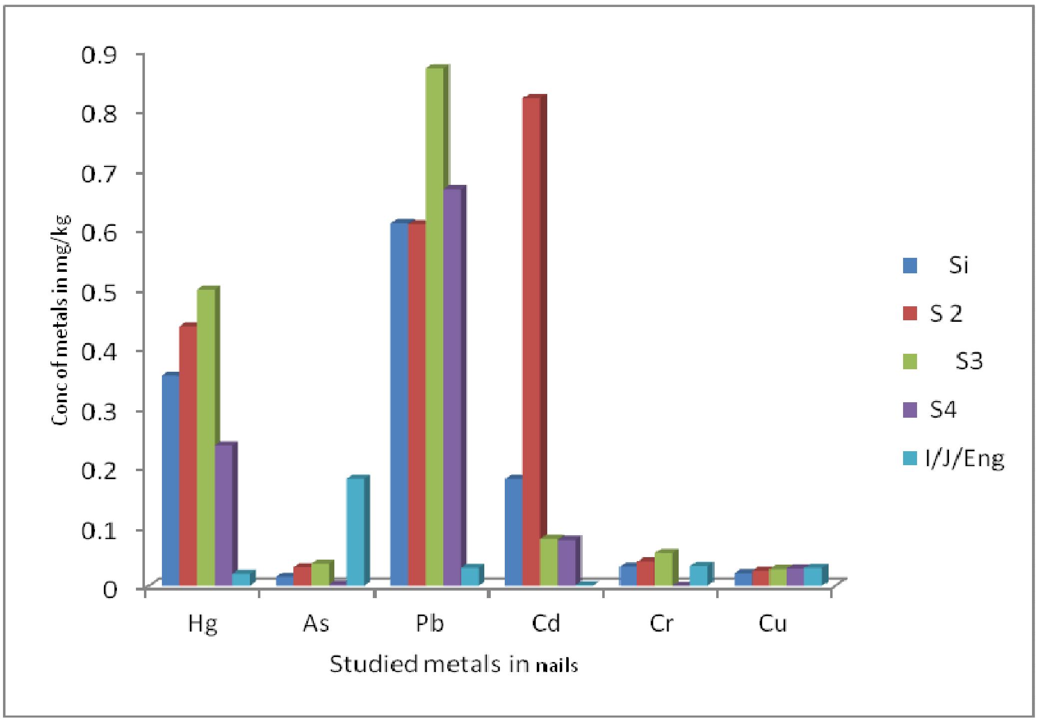


Fig. 4. Concentration of PHE in scalp hair (mg/mg) at the different sampling sites in the study area.

3: Concentration of PHE (mg/Kg) in nails at the different sampling sites

Metals	S1	S 2	S3	S 4	I/J/Eng
Hg	0.353 ± 0.031[a]	0.436 ± 0.031[a]	0.498 ± 0.031[c]	0.236 ± 0.031[b]	0.02-0.5
As	0.015 ± 0.011[a]	0.0311 ±0.074[b]	0.0371 ± 0.072[b]	0.002 ± 0.029[a]	0.18-1.32
Pb	0.61 ± 0.025[a]	0.608 ± 0.031[a]	0.87 ± 0.026[c]	0.667 ± 0.022[b]	0.03-1.4
Cd	0.18 ± 0.014[c]	0.820 ± 0.019[a]	0.079 ± 0.009[b]	0.077 ± 0.012[b].	No value
Cr	0.032 ± 0.090[b]	0.041 ± 0.042[b]	0.055 ± 0.024[c]	0.005 ± 0.019[a]	0.03-1.88
Cu	0.021 ± 0.001[a]	0.025 ± 0.002[a]	0.028 ± 0.002[a]	0.029 ± 0.001[a]	0.03-0.11

Mean (± SEM) values with different superscripts for each metal were significantly different within the zones at ∝ = 0.05. (I= India, J= Japan, Eng= England)

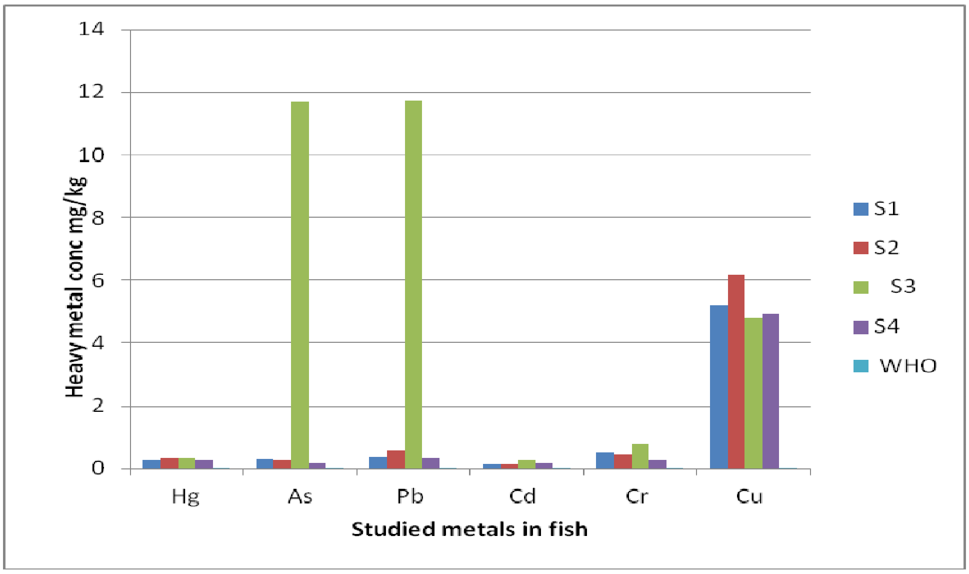


Fi g 5. Concentration of PHE in nails (mg/Kg) at the different sampling sites in the study area.

Table 4: Concentration of PHE (mg/Kg) in *R. argentea* at the different sampling sites

Metals	S1	S2	S3	S4	WHO
Hg	0.285 ± 0.03[a]	0.344 ± 0.04[b]	0.346 ± 0.01[b]	0.28 ± 0.05[a]	<0.05
As	0.31 ±0.02[a]	0.29 ±0.07[a]	11.7 ±0.02[c]	0.19 ±0.03[d]	<0.05
Pb	0.37 ± 0.05[b]	0.57 ± 0.01[a]	11.75 ± 0.02[d]	0.34 ± 0.03[b]	<0.05
Cd	0.15 ± 0.01[a]	0.15 ± 0.01[b]	0.29 ± 0.01[d]	0.17 ± 0.01[b]	<0.001
Cr	0.51 ± 0.03[b]	0.49 ± .07[b]	0.79 ± 0.09[c]	0.27 ± 0.02[a]	<0.05
Cu	5.18 ± 0.03[a].	6.186 ± 1.52[a]	4.78 ± 1.14[a]	4.92 ± 1.21[a]	<0.05

Means with the same superscripts in a row are not significantly different (P>0.05). (I= India, J= Japan, Eng= England)



Fi g 6. Concentration of PHE in fish (mg/Kg) at the different sampling sites in the study area.

4 DISCUSSIONS AND CONCLUSION

The study investigated the heavy metal risks from water and fish consumption among children consuming large quantity of water and fish from rivers flowing through Migori Gold Belt. Human exposure to the PHEs studied is considered high, on the basis of the significantly high concentrations of these elements found in fish and drinking water. This is unsurprising, considering that the area receives increasing pollutants from geological terrains rich in gold deposits. Measuring the concentrations of PHE in hair and nails as biomarker for short term and long- term exposures gave an insight into the levels of exposure for the children. The results show that the children who are in the study area are exposed to great danger of contamination with grave consequences to their health and their future generations. For instance lead poisoning in children has been reported in West Africa with grave outcomes for the exposed children. Lead poisoning interferes with normal formation of the blood heme affecting oxygen transportation in humans among other health risks associated with Pb poisoning. The results also showed that the Gold mining activities in Migori Gold Belt have resulted in the dispersion of increased levels of the metals studied against their background levels in the surrounding areas. Metals from the gold mines activities are rain-washed into near-by streams and rivers causing increased metal concentrations in the water, microbiota and in fish. WHO recommended guidelines and other countries maximum PHE levels for Hg, As, Pb, Cd, Cr and Cu are well exceeded for the water and the fish. Scalp hair Hg concentration is near maximum permissible level based on Italy/Japan/England maximum recommended limits especially sites 3. The analyzed samples of nails showed metal concentration that were within the recommended range limits of Italy/Japan/England for all but Hg concentration in sites 2 and 3 are near maximum permissible levels. All studied metal concentrations in fish exceeded permissible levels. Increased levels of Hg, As, Pb, Cd, Cr and Cu in the environment has degraded the quality of the water and fish in R. Gucha, R. Migori, and L.Victoria. Thus, children consuming water and fish from these localities are exposed to high, probably irreversible health risks over time due to bioaccumulation and bio magnification processes in living organisms. The older the children are in the area the higher the concentrations of the elements indicating bioaccumulation effect due to longer time of exposure. WHO recommended guidelines and other countries maximum metal levels for Hg, As, Pb, Cd, Cr and Cu are well exceeded for the water and fish but this is not duplicated wholly in the nails and scalp hair (Hg) in the study area. The recorded high levels of PHE concentrations indicate that over time the children may accumulate extremely high levels of PHE through ingestion of fish and drinking the water from the rivers in the gold mining vicinity that recorded high levels of PHE contamination, although the observed results do not reflect the same. Further, dependence of gold mining in this area has caused both human and environmental health problems. Drastic measures such as bioremediation need to be employed in the area to curb the menace of contamination to the drinking water and fish. This is to reduce the high health risks posed to the young children who are very vulnerable to PHE poisoning through ingestion of fish and drinking water considering that Hg, Pb, and Cd are highly toxic even in very low concentrations.

Recommendations

In order to safeguard the livelihood of people around mining sites, the following recommendations should be put in place. Continued education on safety measures concerning the human and environmental health, Active education on geological related illnesses or disorders Encouragement to use of protective gear at all times during gold mining and retorts, simple fume chambers, etc during processing.; Active role of Government Authorities on health and pollution control, for example protection of water sources. This research recommends highly the use of biological remediation and interventions such as use of plants that can concentrate the metals thus extracting from the environment. This must be part of the considerations that need to be put in place by the authority before the issuance of permits to carry out gold mining. Furthermore, proper legislation relating to gold mining to be put in place to check against illegal mining activities that degrade the environment through inappropriate mining methods.

Acknowledgements

Moi University for allowing use of the Biochemical Sciences Laboratory, Lake Victoria and Environmental Monitoring Project for funding the project.

References

Aharoni, A., Tesler, Y. (1992). Hair chromium content of women with gestational diabetes compared with nondiabetic pregnant women. *Am. J. Clin. Nutr.*55, 104–7

Akhtar, M.M., 1, T. Zhonghua, 1, Z. Sissou 1 , and B. Mohamadi (2015). Assess arsenic distribution in groundwater applying GIS in capital of Punjab, Pakistan. *Nat. Hazards Earth Syst. Sci. Discuss*., 3, 2119–2147.

Alloway, B.J. (1995), Potentially harmful elements in Soils, London, UK, 2nd edition. Blackie Academic and Professional.

Arhin E, Zango SM, Berdie BS (2016). Geochemical Background of Some Potentially Toxic and Essential Trace Elements in Soils at the Nadowli District of the Upper West Region of Ghana. *J Earth Environ Health*

Sci; 2:56-65.

Cui, Y.J., Zhu, Y.G., Zhai, R.H., Huang, Y.Z., Qiu, Y., Liang, J.Z., 2005, Exposure to metal mixtures and human health impacts in a contaminated area in Nanning. *China Environ. Int.* **31**, 784–790.

Davies, T.C. (1994), Water quality characteristics associated with fluorite mining in Kerio Valley area of Western Kenya. *International Journal of Environmental Health Research*. **4**: 165-175.

Hang, X., Wang, H., Zhou, J., Ma, C., Du, C., Chen, X., 2009, Risk assessment of potentially toxic element pollution in soils and rice (Oryza sativa) in a typical area of the Yangtze River Delta. *Environ. Pollut*. **157**, 2542–2549.

IAEA (International Atomic Energy Agency), 1985, Report on the second research co-ordination meeting of IAEA, Neuherberg, Germany, October 1985.

Kathleen M. McCarty, Hoang Thi Hanh, and Kyoung-Woong Kim (2011). Arsenic geochemistry and human health in South East Asia. *Rev Environ Health*. 26(1): 71–78.

Khairiah, J., Ding-Woei, Y., Habibah, J., Ahmed-Mahir, R., Aminah, A., Ismail, B.S. (2009), Concentration of potentially harmful elements in guava plant parts and soil in the Sungai Wangi Plantation, Perak, Malaysia. *International Journal Agriculture Research*, **4**:310 – 316.

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z., Zhu, Y.G., 2008, Health risks of potentially harmful elements in contaminated soil and food crops irrigated with wastewater in Beijing, China. *Environ. Pollut.* **152**, 686–692.

Mandina Shadreck and Tawanda Mugadza (2013). Chromium, an essential nutrient and pollutant: A review. *African Journal of Pure Applied Chemistry,* Vol. 7(9), pp. 310-317.

Narang, A.P.S., Chawls, LS, & Khurana, S.B. (1987), Levels of arsenic in Indian opium eaters. *Drug Alcohol Depend*. **20**: 149-153

Ngure veronica (2012). Artisanal Gold Mining impact on Human and Environmental Health in Macalder Migori, Kenya:Possible Interventions. *http://abandonedminesafrica.org/downloads/2013-scoop-phase.html?download= 6:ngure-et-al. Retrieved on 30th Dec, 2016.*

Orish, E.O., John Kanayochukwu Nduka, J.K., Amad, C.N., Dike, D.O., Bede, O. (2012), Potentially harmful elements health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. *Chemistry Central Journal*, **6**:77.

Oyoo-Okoth, E., Admiraal, W., Osano, O., Manguya-Lusega, D., Ngure, V., Kraak, M.H.S., Victoria Chepkirui-Boit., Judith Makwali. (2012), Contribution of soil, water and food consumption to metal exposure of children from geological enriched environments in the coastal zone of Lake Victoria, Kenya. *International Journal of Hygiene and Environmental Health*; **216** (1): 8 – 16.

Reena Singh, Neetu Gautam, Anurag Mishra, and Rajiv Gupta (2011). Heavy metals and living systems: An overview. *Indian J Pharmacol*. 43(3): 246–253.

Ruchita Dixit, Wasiullah, Deepti Malaviya, Kuppusamy Pandiyan, Udai B. Singh, Asha Sahu, Renu Shukla, Bhanu P. Singh, Jai P. Rai, Pawan Kumar Sharma, Harshad Lade, and Diby Paul (2015). Bioremediation of Heavy Metals from Soil and Aquatic Environment: An Overview of Principles and Criteria of Fundamental Processes. S*ustainability 7*, 2189-2212; doi:10.3390/su7022189.

Szynkowska, M. I., Pawlaczyk, A, E. Wojciechowska, Sypniewski, S., Paryjczak, T. (2009).

Human Hair as a Biomarker in Assessing Exposure to Toxic Metals. *Polish J. of Environ. Stud*. Vol. 18, No. 6 (2009), 1151-1161

Teraoka, H., 1981, Chemical investigation of inorganic elements in human hair. Jpn. J. Hyg. 36, 712–717.

Uwah, E.I., Ndahi N.P., Ogugbuaja, V.O., (2009), Study of the levels of some agricultural pollutants in soils, and water leaf (*Talinum triangulare*) obtained in Maiduguri, Nigeria. *Journal of Applied Sciences in Environmental Sanitation.* 4 (2): 71 – 78.

Veronica Ngure, Theophilus Davies, Geoffrey Kinuthia, NoahSitati, Silvanus Shisia, and Elijah Oyoo-Okoth (2014). Concentration levels of potentially harmful elements from gold mining in Lake Victoria Region, Kenya: Environmental and health implications. *Journal of Geochemical Exploration*, Volume 144, Part C, September, Pages 511–516

Veronica Ngure, Noah Sitati, Silvanus Shisia, Geoffrey Kinuthia(2015). Assessment of Heavy Metals Pollution in Urban Soils and the Implications to Consumers Health. *Journal of Natural Sciences Research* www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.5, No.17.

Webb, J., Mainville, N., Mergler, D., Lucotte, M., Betancourt, O., Davidson, R., Cueva, E., Quizhpe, E. (2004), Mercury in fish-eating communities of the Andean Amazon, Napo River Valley, Ecuador. *EcoHealth 1* (Suppl. 2), 59-71.

Were, F.H., Njue, W., Murungi, J., Wanjau, R., (2008). Use of human nails as bioindicator of potentially harmful elements environmental exposure among school age children in Kenya. *Total Environ. Sci.* **393**, 376–384.