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Biomonitoring of non – essential heavy metals concentrations in the Tono irrigation dam using mussel tissues

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Abstract: One of man's worst endeavour to augment sustainable industrial development of water bodies is non – essential, highly – persistent, bio-accumulative and extremely toxic heavy metals contamination. After over three decades of continuous excessive use of xenobiotic chemicals in farming around the Tono irrigation dam, an effective modus operandi of monitoring the non – essential heavy metals concentrations is of utmost interest; thus the hub of this research work. Accumulation of As, Cd, Cr, Hg, Ni, Pb and Sb in the tissues of bivalves, *Anodonta rugifera* mussels were studied at various different hydrographical sampling locations of the water body at Tono irrigation dam. These concentrations were in the range of 0.39-4.00, 0.39-3.72, 1.08-2.04, 0.73-14.65, 3.57-9.13, 0.10-11.91 and 0.11-1.47 respectively. The overall mean concentration values of these metals were in the order Ni > Hg > Pb > Cr > Cd > As > Sb.

Keywords: Irrigation Dams, Heavy Metals, AAS Analysis, Mussels, Toxicity

1. Introduction

It is an inescapable fact that inland water bodies are largely the life artery of many settlements in the Sahelian regions. These water bodies are appropriate starting point for the accomplishment of man's most fundamental needs and fruition of critical technological developments such as good drinking water systems, construction of dams for domestic and irrigational purposes, extraction of precious minerals, fishing and natural fertilization of agricultural lands, which consequently often lead to very high population and urbanization (industrialization) around this areas. For instance, in the Upper East Region of Ghana (one out of ten regions) alone, there are three irrigation dams as shown in Fig., 1 below [1], [2].

One of such inland water bodies of national importance is the Tono irrigation dam, which is located in the Upper East Region of Ghana. It is one of the largest Agricultural dams in West Africa that was constructed in the mid – 80s. In recent times, the dam has been reconstructed for the commercialization of various priority agricultural projects such as; aquaculture, improved rice variety production, tomatoes production, etc. Thus the economic importance of this dam cannot be overemphasized in the agricultural development of the nation as it also enables the cultivation of various nutritional green leafy vegetables all – year – around.

Nevertheless, in the wake of increased misuse of highly – subsidized pesticides and fertilizer application, indiscriminate small - scale mining for precious metals, an ever – increasing population around the dam, use of poisonous chemicals in fishing and other anthropogenic activities, the water body in the Tono dam is a source of chemical substances emission into agricultural lands. Among the myriad of varied organic and inorganic substances released into this aquatic ecosystem, heavy metals have received considerable attention due to their potential bioaccumulation in different aquatic species [3], [4], [5], [6]. Again, aside their unfortunate ability to easily bio-accumulate in aquatic ecosystems species, these metals are well recognized to be persistent, non – biodegradable, extremely toxic with their deleterious health effects even at lower concentration levels [7], [8].

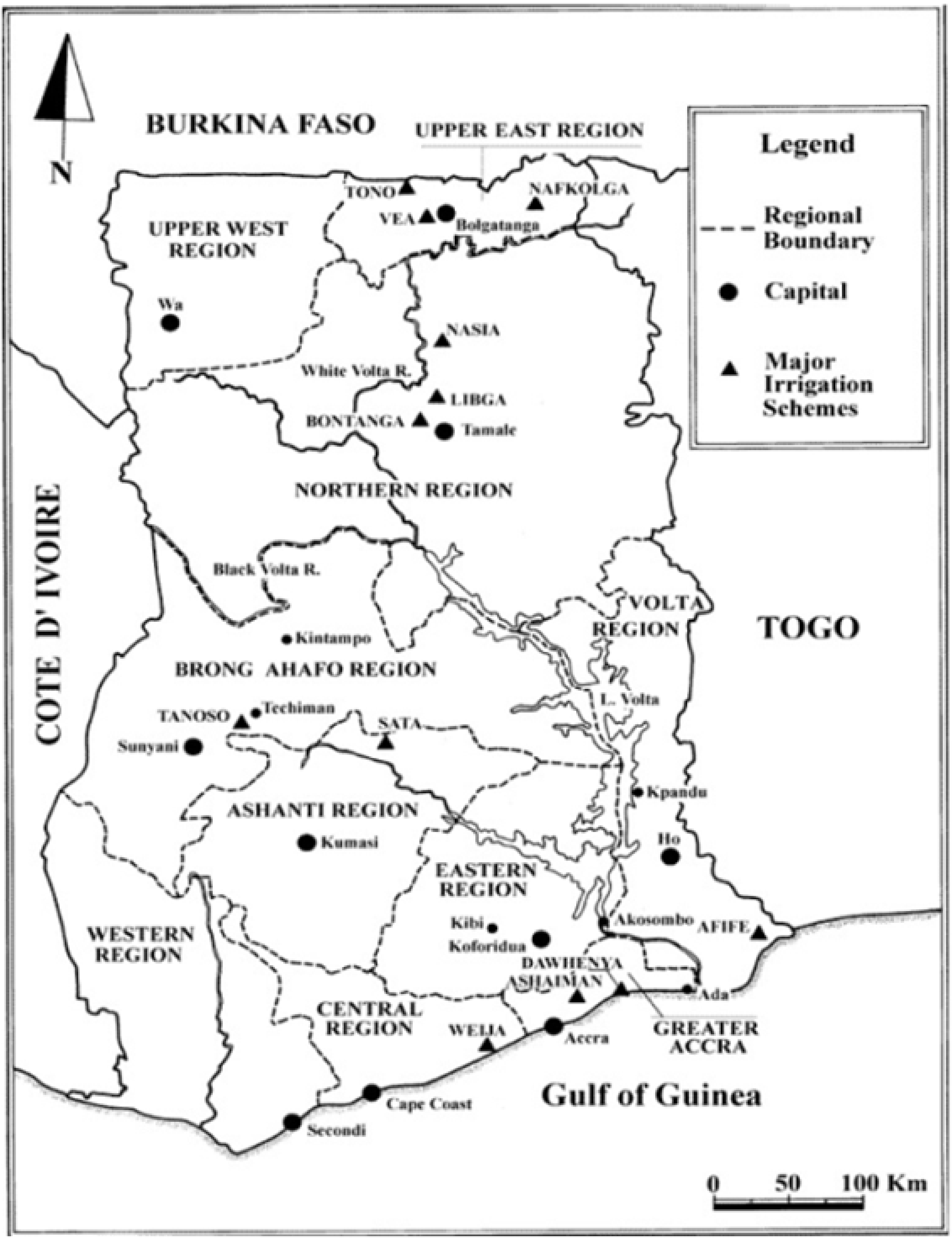

Fig 1. *Administrative regions and major irrigation schemes. Source: Ref [1]*

Therefore, suspension long – lived filter feeders, Mussels, with their unique capability-based accumulation of heavy metals and other toxins in their tissues were exclusively used in monitoring the concentration levels of non – essential heavy metals at the Tono irrigation scheme. Hence, the aim of the study was to qualitatively and quantitatively determine the concentration levels of various heavy metals in the Tono dam using Mussel (*Anodonta rugifera*) tissues as a bio – indicator of choice.

2. Materials and Methods

The study was conducted at the Tono irrigation dam situated at the South – Western part of Navrongo in the

Upper East Region of Ghana. This irrigation dam lies approximately between latitude 10°52' 11.67" North and longitude 1°08' 00.00" West [2]. Detail background of this study area is presented elsewhere [9]. Seven different hydrographical sampling points coded – named SP 1, SP 2, SP 3, SP 4, SP 5, SP 6, SP 7 and SP 8 were purposively selected around the irrigation dam with respect to successive major influences as shown in Fig., 2. SP 1 and SP 2 were located downstream.

These sampling points were the reference sites for the broad water quality serving the irrigation system. SP 3 and SP 5 represented contamination from domestic animals and anthropogenic activities such as washing, processing of agricultural produce, extraction of gold etc. SP 4 and SP 6 were located upstream. These sites are strongly predisposed to leaching waters from abused pesticides and fertilizers applications in farm lands. Vehicular intrusions in the dam occurred between SP 7 and SP 8. Freshwater mussels, *Anodonta rugifera*, species were found to be the most dominant species in all the sampling points and thus were selected as a bio-indicator of choice for monitoring heavy metals concentration levels in the dam.

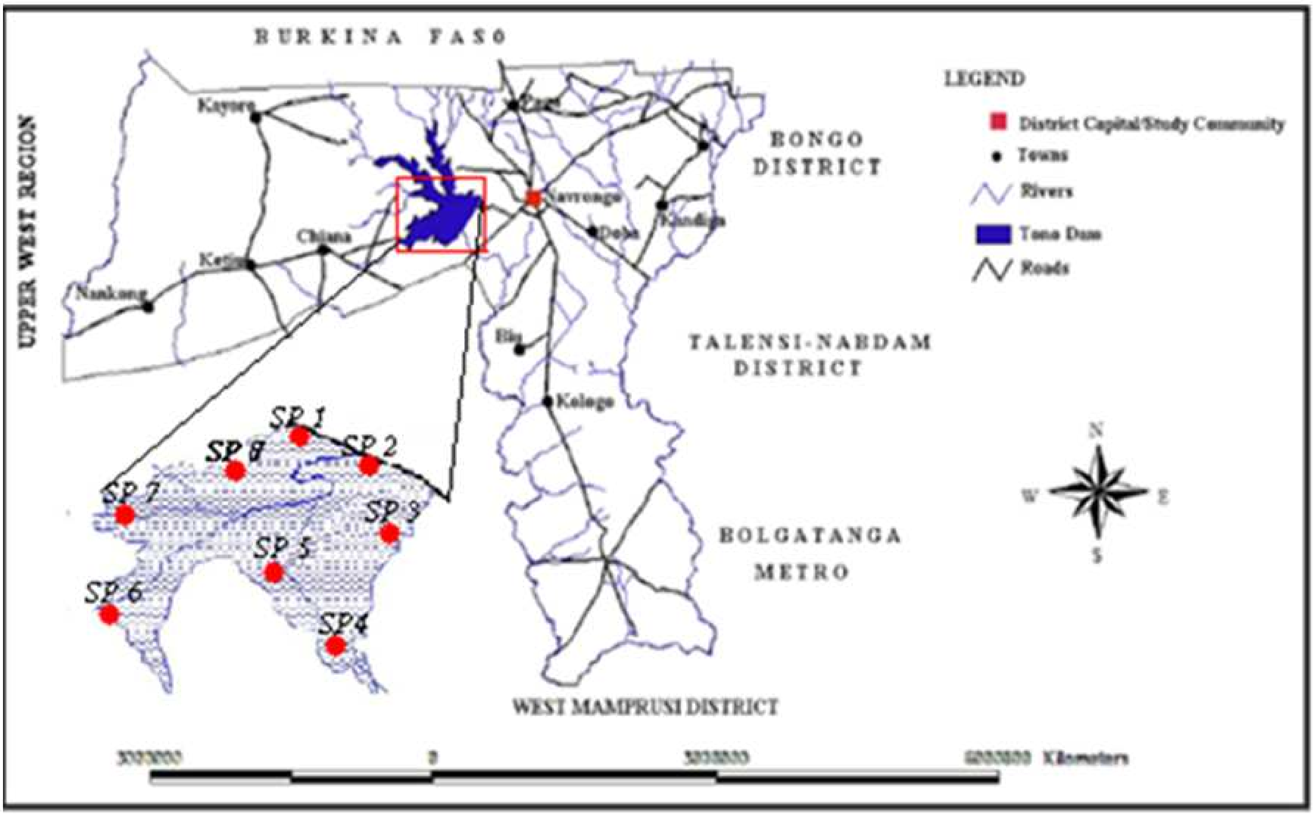

Fig 2: *Tono irrigation dam in the district context showing all sampling points.*

In order to minimize the effects of differential concentration levels of metals due to bioaccumulation, Mussels (adult exemplars) of similar shell lengths from each sampling site were sampled. These mussels were sampled using laboratory stainless steel forceps and placed in polyethylene bags for transportation to the National Nuclear Research Institute (NNRI) of the Ghana Atomic Energy Commission (GAEC), Accra, Ghana for analysis.

All samples were thoroughly washed with distilled water before opening their hard shells (bivalves) to extract the tissues with a stainless-steel knife at the Commission. These tissues were homogenized with a high – speed stainless-steel bland blender and then further lyophilized using Christ Gamma 1-16 for 72 hours at – 30 °C and 0.370 mbar. Portions of these lyophilized samples were again grounded in a Retsch RS 100 vibratory disc mill into fine powder. About 0.5 g of each pulverized sampling point samples was weighed, mixed with 6 ml of 65% nitric acid and placed into each Teflon vessels. Approximately 1 ml of 30% of H_2O_2 was again added to each vessel and then shaken gently to form a homogeneous mixture before fitting these vessels into an ETHOS 900 microwaved digester for digestion. Triplicates of each sample were similarly prepared for digestion. To ensure complete digestion of all samples, the mixture was heated for about 25 minutes. After appropriate cooling, the digested residues were separately dissolved into various measuring cylinders containing double distilled water, filtered and then diluted to 20 ml using de-ionised water. These solutions were then analysed using a Flame Atomic Absorption Spectrophotometer model VARIAN AA 240 FS.

3. Results and Discussion

Unlike essential metals that are much needed for the normal physiological functions of humans, non – essential metals have no biological role. Regrettably, these non – essential heavy metals exhibit short tolerance levels at very low concentrations, toxic effects at moderate concentrations, serious health damage at high concentrations and most depressingly lethality at excessive concentrations, if detoxification is not immediately undertaken as shown in Fig., 3 [10].

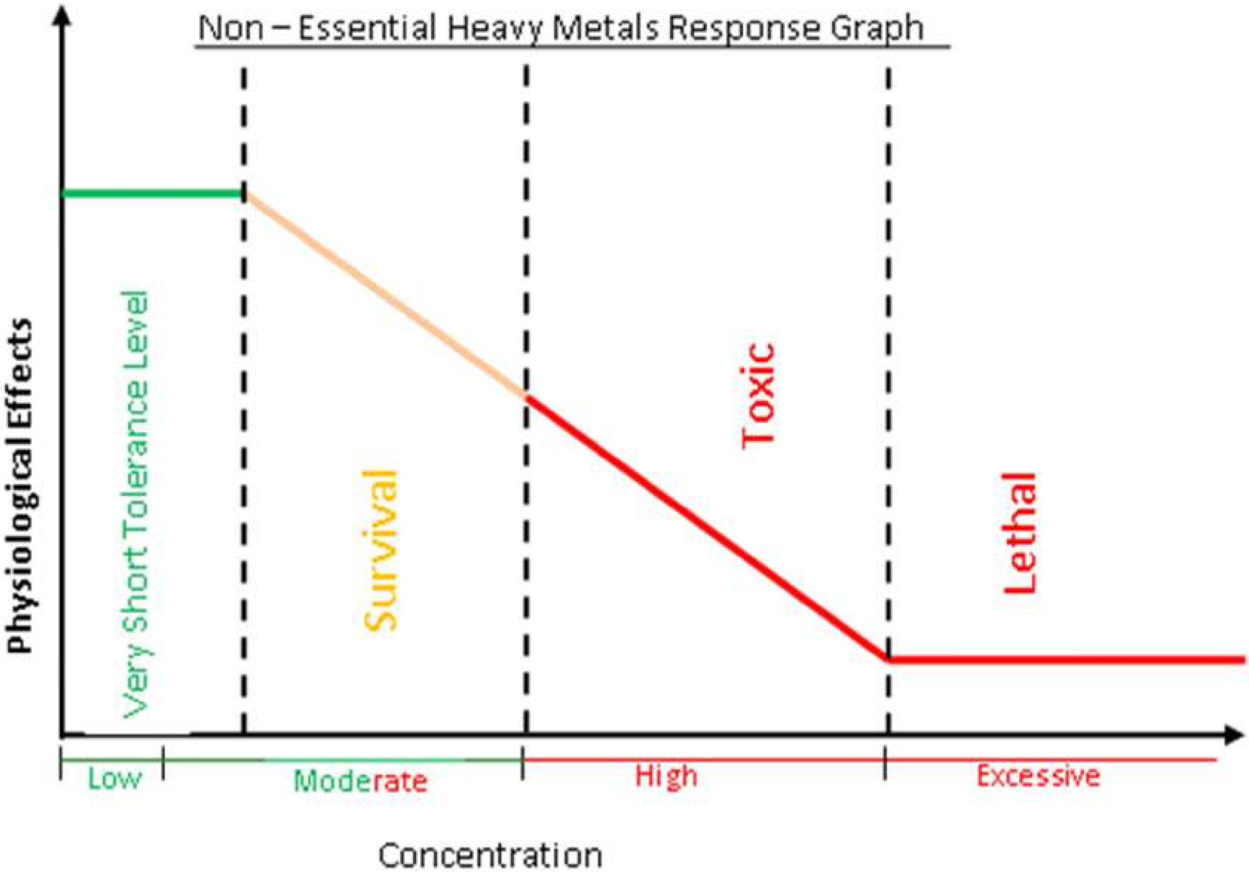

Fig 3: *A Schematic diagram depicting non – essential heavy metals dose – response graph*

Therefore, Mussels' tissues, which have been used as biological indicators in many field monitoring programs because of their cosmopolitan distribution, ability to concentrate many different contaminants and particularly their relatively long – lived filter feeding habitats, were used in this work [11]. The unique features of Mussels as an aquatic bio – indicator of choice over other species and the preferred used of bio – indicators over conventional techniques have been well documented by Naimo, in [12] and Jovic in [13].

The mean concentrations of seven (7) different non – essential heavy metals in *Anodonta rugifera* species tissues are presented in Table 1. An evaluation of Table 1 shows that the concentrations of most metals in the same water body differed significantly at the various hydrographical sampling points. For better appreciation of these differences and for easy comparative analysis, a pictorial histographic 3 – D representation was drawn based on Table 1 as shown in Fig. 4. One plausible explanation for these discrepancies is that, there are different sources for heavy metals contamination around the dam [14]. Other factors that could contribute significantly to these variations include; (1) varying physicochemical parameters at each hydrographical point, (2) environmental conditions such as fluctuating temperatures, salinity, pH, water conductivity etc., and (3) differential effluent discharge or contamination at each hydrographic point.

It should be worth – noting that; Pb, Hg and Ni were the dominant metals in most of the sampling points. The concentration of Pb recorded highest concentration level (11.91±1.68 ppm) at SP 7, lowest concentration level (0.10±0.01 ppm) at SP 6 and below Instrument Detection Limit (IDL) at SP 4 and SP 5. According to Soylak in [15], the Instrument Detection Limit (IDL) is defined as the concentration corresponding to three times the standard deviation of 10 blanks. Symptoms of exposure and toxicity to these metals include; abdominal pain, convulsions, hypertension, renal dysfunction, loss of appetite, fatigue, and sleeplessness. Other symptoms are hallucinations, headache, numbness, arthritis and vertigo [16].

Table 1: *Concentration levels of non – essential Heavy metals (ppm) in Anodonta rugifera mussels tissues collected at various hydrographic points at Tono irrigation dam.*

Sampling Points	As	Cd	Cr	Hg	Ni	Pb	Sb
SP 1	IDL	0.63±0.08	2.03±0.35	2.66±0.38	7.19±1.21	4.17±1.69	IDL
SP 2	0.39±0.02	1.81±0.15	IDL	3.00±0.41	IDL	3.92±1.74	0.11±0.01
SP 3	1.69±0.04	3.72±0.77	IDL	2.19±0.30	9.13±1.74	2.54±0.91	IDL
SP 4	3.70±0.81	0.39±0.04	2.04±0.41	14.65±2.03	6.18±1.30	IDL	1.47±0.28
SP 5	IDL	IDL	1.33±0.20	1.98±0.51	10.3±1.9	IDL	0.90±0.01
SP 6	4.00±0.83	1.00±0.51	1.91±0.31	12.78±2.00	3.57±0.90	0.10±0.01	IDL
SP 7	2.31±0.48	1.18±0.07	2.01±0.03	IDL	5.0±0.4	11.91±1.68	0.50±0.02
SP 8	1.97±0.36	0.96±0.01	1.08±0.03	0.73±0.01	IDL	13.50±1.77	0.30±0.01
Mean Value	**0.76**	**1.21**	**1.30**	**4.75**	**5.17**	**4.52**	**0.41**

*IDL = below Instrument Detection Limit

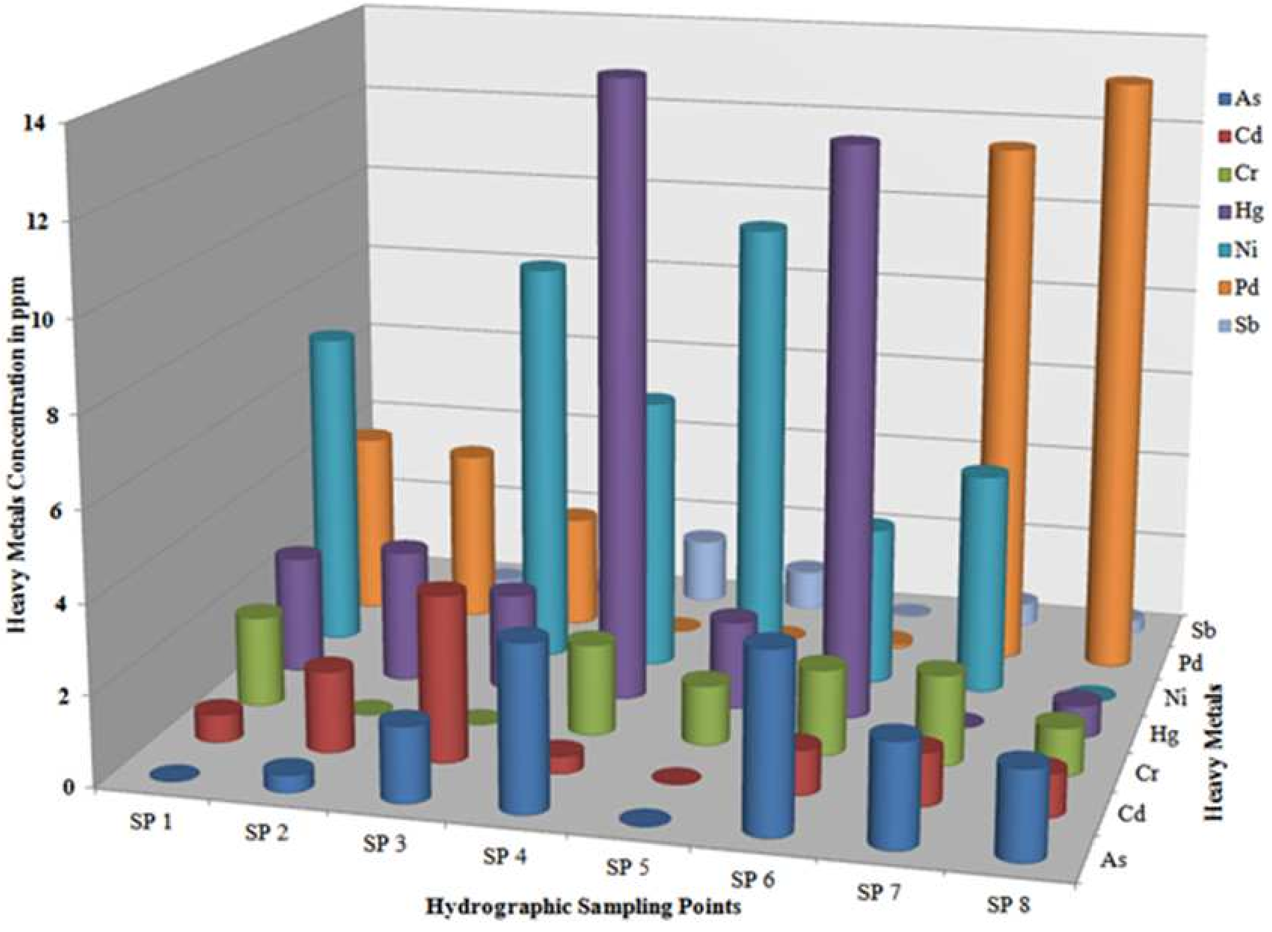

Fig 4: *Concentrations of non – essential heavy metals in all sampling points.*

The average levels of Hg ranged from 0.73 ppm to 14.65 ppm at SP 8 and SP 4 respectively. Higher values Hg at SP 4 and SP 6 suggest the preferential use of this metal in the extraction of gold around these sampling points. It can therefore be claimed that, the concentration of Hg contamination is mostly from anthropogenic sources. Mercury in the form of its methyl compounds is specifically the most toxic of the heavy metals [13]. Excessive exposure to Mercury causes; Inflammation of mouth and gums, swelling of salivary glands, excessive flow of saliva, loosening of teeth, kidney damage, muscle tremors, jerky gait, spasms of extremities; personality changes, discouragement, depression, irritability, nervousness, dementia and loss of motor coordination among others [17].

Ni was found in abundance in most of the sampling points in this study. The toxicity of Nickel and its compounds are not yet well known, however, they are well-recognized carcinogens [18].

Other heavy metals of extreme toxicity under certain conditions even at low levels include; Cd, As, Cr and Sb, thus necessitating regular monitoring of sensitive aquatic environments [19]. The highest concentration levels of these elements are 3.72±0.77 ppm, 4.00±0.81 ppm, 2.04±0.41 ppm and 1.47±0.28 ppm respectively. Intake of high levels of Cd is linked to vomiting and diarrhea, stomach pains, renal dysfunctioning, sugar in urine etc. Cr causes Asthma, kidney failure, discoloration of teeth, inflammation of skin, dizziness, intense thirst, abdominal pain, vomiting, shock and sometimes death may occur due to the presence of urea in blood [18]. Similarly, Arsenic (As) and Sb are also classified as extremely toxic metals. Aside Hg, all the elements are well within values reported by Jovic in [13].

4. Conclusion

This research work directly confirms the substantial presence of non – essential heavy metals in the dam. Their concentration levels were however, found to be varied at the various sampling points. The toxicological implications on human health of exposure to these non – essential heavy metals were discussed. Therefore, due to the persistence and accumulating abilities of heavy metals, their presences are warning signals. Consequently, precautionary measures such as the enactment and or enforcement of appropriate legislature and bye – laws for regulating activities around the dam, should be taken in other to curtail or minimise their contamination levels.

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