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Original Research Article

Determination of selected heavy metals contamination in water from downstream of the Volta Lake at Manya Krobo district in eastern region of Ghana

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The study was conducted to determine the contamination of seven heavy metals namely (Mn, Cu, Zn, Pb, Cr, Hg and Fe) in dam water used for irrigation and fishery in five communities (Atimpoku, Akuse, Small London, Kpong and Akosombo (control)) located along downstream of the Volta Lake and its health impacts on the inhabitants of Manya Krobo District of the Eastern Region in Ghana. This dam is a major source of drinking water for Akuse province population. A total of 100 water samples were collected from five different sites along the dam. The samples were analyzed for heavy metals using microwave-assisted acid digestion (Milestone ETOS 900) and Atomic Absorption Spectrometer (Varian AA 240FS). The maximum and minimum concentrations of Fe, Mn, Cu, Zn, Pb, Cr and Hg in the water were (0.453 – 0.0.224), (0.012 – 0.002), (0.004 – 0.003), (0.009 - 0.001), (0.101 – 0.053), (0.006 – 0.003) and (0.001) mg/L respectively. There were no significant differences (p>0.05) in heavy metal concentration between the various sites and the control. The mean concentrations of Mn, Cu, Zn, Cr and Hg were found to be within the WHO, Water Pollution Control Legislation (WPCL), Criterion of Irrigation Water (CIW) and US EPA permissible limits while Pb and Fe levels recorded were slightly higher.

Key words: Heavy metal concentration, microwave-assisted acid digestion, permissible limits, atomic absorption spectrophotometer

INTRODUCTION

The pollution of aquatic ecosystems by heavy metals is an important environmental problem, as heavy metals constitute some of the most hazardous substances that can bioaccumulate in various biotic systems. Water can be stressed with heavy metal load sourced from weathered soils/rocks, mining and metallurgical releases, industrial discharge, domestic sewage and non-point source runoff (El-Sayed et al., 2011; Censi et al., 2006; Adams, 2001). This may exert unsustainable demand on freshwater by aquatic microflora/microfauna, aquatic wild and humans who depend on such waters, and may be exposed to contamination by heavy metals and other contaminants and their deleterious consequences (Olatunyi and Osibanjo, 2012; Edorh, 2007).

Heavy metals include essential elements like, Zn, Cu, Cr and Mn as well as non-essential elements or toxic metals such as Cd, Pb, As and Hg. When the essential metals are present in trace concentrations, they tend to ensure physiological functions of living tissue and regulate many biochemical processes. However, at increased concentrations heavy metals exert a profound action on living matter, affecting the growth, metabolism and morphology of cells. Heavy metals are non-biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways (Ukpebor et al., 2005).

The levels of heavy metals such as Mn, Cr, Ni, Cu Zn and Pb in some inland rivers and dams in West Africa have been reported (Amoo et al., 2005; Wogu and Okaka, 2011; Olatunyi and Osibanjo, 2012; Ndela and Manohar, 2014).

In recent years, there has been a proliferation of rural

Table 1. Approved Standards of concentration of Heavy Metals in Water

Standard	Heavy metals load in water (mg/L)						
	Fe	Mn	Cu	Zn	Pb	Cr	Hg
WHO 2003 Guidelines	0.3	0.10	1.0	3.0	0.01	0.05	0.001
EPA 2002 Standard	0.3	0.02	1.3	2.0	0.05	0.05	0.001
CIW 1997 Standard	5	2	0.2	2	5	0.1	0.01
WPCL 2004 Standard	0.3	0.05	0.02	2	0.01	0.02	0.001

metal fabrication and agricultural industries along the Volta basin. Akuse, Atimpoku, Small London and Kpong are fishing communities along the river Volta whose inhabitants also produce crops such as rice, sugar cane, banana and vegetables for export. The application of sewage sludge, sewage water, pesticides and fertilizers to these agriculture lands may contribute to the accumulation of the heavy metals in top soil layers and their subsequent spreading to large areas of the estuary through surface run-off.

The aim of this work is to assess the levels of heavy metal (Mn, Cu, Zn, Cr, Hg and Fe) concentration in dam water of lower Volta basin which is the major source of water supply for irrigation, fishing, domestic and industrial purposes and ascertain whether or not the concentrations are within US EPA and WHO permissible limits for human consumption.

MATERIALS AND METHODS

Study Area

Kpong dam is the second hydroelectric dam built in Ghana over the Volta River. It is the downstream to the larger Akosombo dam. Kpong dam was constructed in 1981 to impound water level from the upstream side of river Volta during the period of excess supply. It has a top water level of about 450 m and 3 km long. The dam is located in northern part of Akuse town on latitude 6°7"12"N and 0°7"30"E in Ghana. Kpong dam receives its water from river Volta estuary at Atimpoku.

Sample collection and preparation

In all 100 water samples (20) from each of the five sites namely- Atimpoku, Akuse, Small London, Kpong and Akosombo (control site) respectively located along the downstream of the Volta Lake at Akosombo were collected between January and July 2012 from each study area. Before water sampling, all the glass bottles were cleaned and rinsed thoroughly with water to be analyzed. Water samples were collected from both sides and in the middle by lowering pre-cleaned plastic bottles into the bottom of the water body, 30 cm deep and allowed to over flow before withdrawing. Five sampling points of approximately 100 m away from each sample station were used for the sampling. The samples were stored in insulated iced chests at a temperature of about 4°C for analyses at the laboratory of Ghana Atomic Energy Commission (GAEC).

Digestion and Analysis of samples

Samples (≈ 5g) of water was weighed into a previously acid washed labeled 100 ml polytetraflouroethylene (PTFE) Teflon bombs. Six (6) ml of nitric acid (HNO_3, 65% w/v), 3 ml of hydrochloric acid (HCl, 35% w/v) and 0.25 ml of hydrogen peroxide (H_2O_2, 30% w/v) was added to each sample in a fume chamber. The samples were then loaded on the microwave carousel and the vessel caps secured tightly using a wrench. The complete assembly was microwave irradiated for 26 minutes using milestone microwave lab station ETHOS 900, INSTR: MLS-1200 MEGA and employing the microwave programme.

The teflon bombs were cooled in a water bath after digestion to reduce internal pressure and allowed for the volatilzed materials to re- stabilize. The digested sample was made up to 20 ml with double distilled water. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (Varian AA 240FS) in an acetylene-air flame equipped with a hydride Generator. The instrument settings and operational conditions were in accordance with the manufacturer's specifications. The instrument was calibrated with analytical grade standard metal solutions (1 mg/dm^3) in replicates.

RESULTS AND DISCUSSION

The mean concentrations (mg/L) of selected heavy metals assessed from the Volta Lake's water running through communities namely; Atimpoku, Akuse, Small London and Kpong with results also obtained from the control site at the main Akosombo dam site where less agricultural and industrial activities are carried out is shown on Table 1 below. However, the general trends in terms of ranges of concentration of each heavy metal in the water are shown in Figures 2 to 7.

Iron (Fe) and Lead (Pb)

The mean Fe levels in the Dam water at the four sampling sites ranged from 0.224 to 0.453 mg/L (Figure 1). The highest value of Fe (0.453 mg/L) was recorded at Akuse while the minimum Fe concentration of 0.224 mg/L was recorded at Small London. A site-by-site comparison of the data showed a significant difference (P<0.05) in the mean

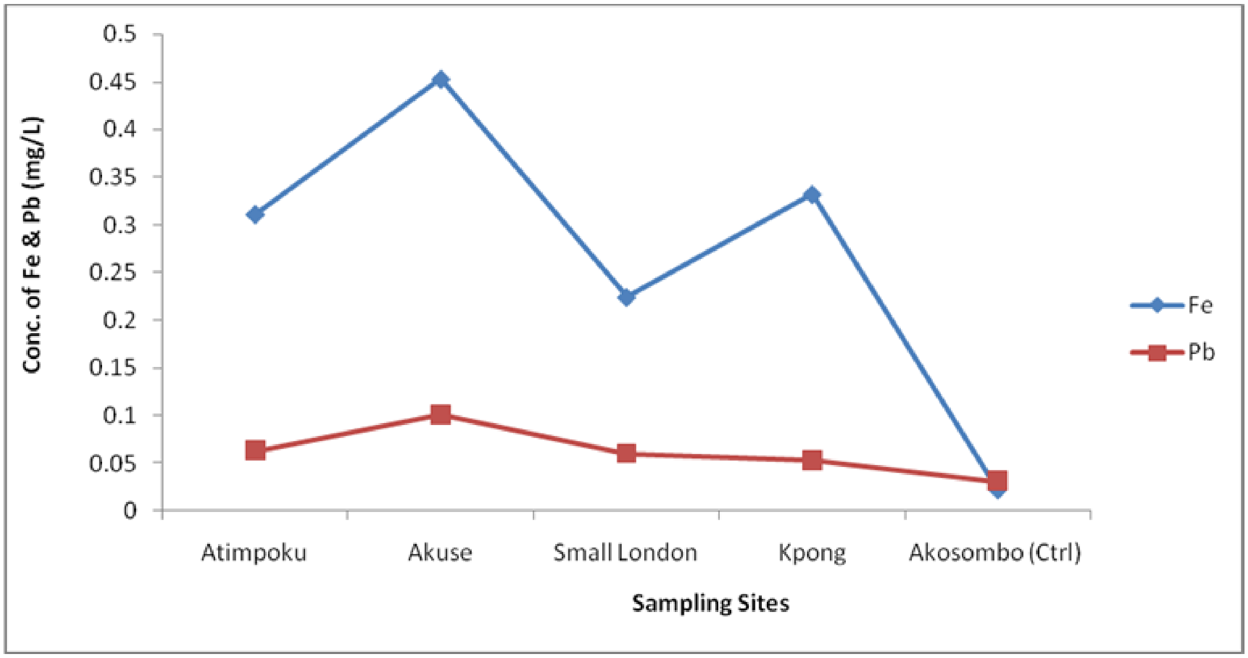

Figure 1: Mean concentration of Fe and Pb at the four sites and control

Fe concentration of water samples. The mean concentrations of Fe from all the four sampling sites were higher than that of the control site at Akosombo. However, the data showed that the grand mean Fe concentration of 0.33 mg/L at the four sites was slightly above the permissible limit of 0.3 mg/L for WHO, EPA and WPCL but below that of CIW (WHO, 2003).

The mean Pb concentrations of water at the four sampling sites ranged from 0.053 to 0.101 mg/L; the highest value was observed at Akuse whilst the lowest value was recorded at Kpong (Figure 1). The mean values obtained at the four sites were above that recorded at Akosombo, the control site. The mean Pb concentration obtained at the four sites were above the permissible limits of 0.05 mg/L, 0.05 mg/L and 0.01 mg/L respectively for WHO, EPA and WPCL Guideline/ Standard values. However, the Pb concentrations were below the specified value of 5 mg/L for CIW at all the sampling sites. The site-by-site comparison showed no significant differences ($P>0.05$) between the means.

Manganese (Mn) and Copper (Cu)

The mean Mn concentration of Dam water ranged from 0.002 - 0.012 mg/L; the highest value was observed at Atimpoku while the lowest concentration was recorded at Small London (Figure 2). The grand mean Mn concentration at the four sites was 0.007 mg/L which was less than the value recoded at Akosombo, the control site. Statistically, there was a significant differences ($P<0.05$) in mean Mn concentration between the four sites. However, the mean Mn concentration from all the sites were within the permissible limit of WHO, EPA, CIW and WPCL (Table 1).

The mean Cu concentrations recorded at the four sampling sites were the same (Figure 2). The mean values were lower than that obtained at the control site. There was no significant difference ($P>0.05$) in the Cu concentration in water from all the sites. The Cu content of water at all the sampling sites were lower than the permissible limits of WHO, EPA, CIW and WPCL.

Zinc (Zn), Chromium (Cr) and Mercury (Hg)

The concentration of Zn in the water at the four sites ranged from 0.001 mg/L - 0.009 mg/L (Figure 3). The highest value was recorded at Akuse and Kpong while the lowest was observed at Atimpoku and Small London sites. Zinc concentrations of water samples from Atimpoku and Small London were lower than values recorded at Akosombo, the control site. No significant differences ($P>0.05$) was observed in site-by-site Zn concentrations of the water samples. The data indicated that Zn concentration of the water samples were below the permissible limit of 3.0 mg/L reported by WHO, EPA, CIW and WPCL.

The mean concentrations of Cr were the same at the four sampling sites and with no significant differences ($P> 0.05$) observed between the means (Figure 3). The Cr levels recorded in the study area were below the permissible limits of 0.05 mg/L for WHO and EPA, 0.1 mg/L, and 0.02 mg/L, for CIW and WPCL respectively. The mean values of Cr obtained at the sites were higher than that recorded at Akosombo, the control site.

The concentrations of Hg obtained were the same (0.001

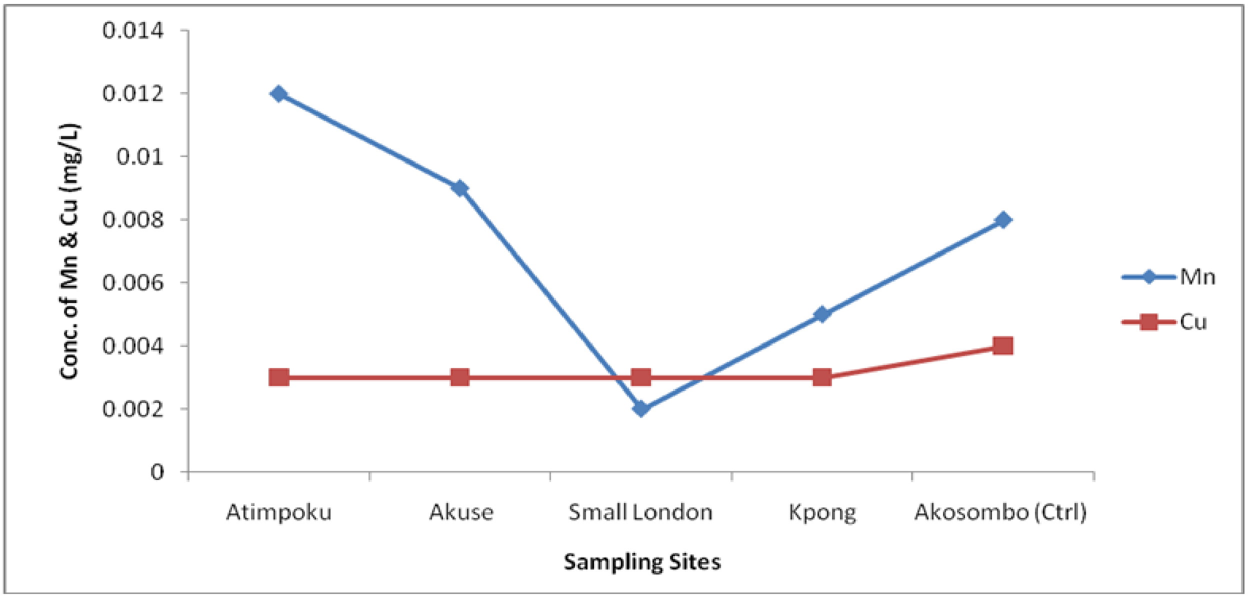

Figure 2: Mean concentration Mn and Cu at the four sites and control

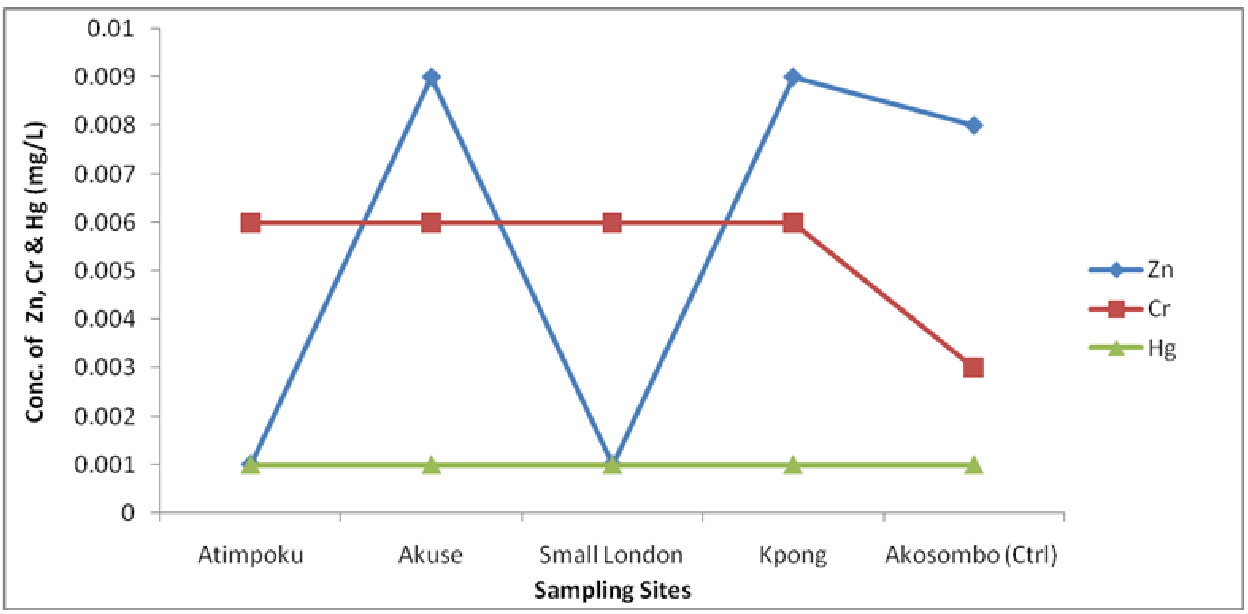

Figure 3: Mean concentration of Zn, Cr and Hg at the four sites and control

mg/L) at the four sampling sites and control (Figure 3). There was no significant differences (P > 0.05) between the sites monitored. The grand mean concentrations of Hg in the study area was comparatively below the recommended Guideline/standard values of 0.001 mg/L for WHO, EPA and WPCL and 0.01 mg/L for CIW respectively.

DISCUSSION

The essence of monitoring the concentration of these trace metals in the water body was to ascertain its pollution levels and significance in terms of health and ecological impacts for sustainable aquatic resources management in Ghana. The results on resident distribution of heavy metals, particularly, Fe, Mn, Cu, Zn, Pb, Cr and Hg at various locations in the five water sampling sites along the Akosombo Dam are shown in (Figures 1, 2 and 3).

Iron (Fe) is an integral part of many proteins and enzymes that maintain good health (IOM, 2001). Fe concentration from the five sampling sites including control site was in the order of Akuse (0.453 mg/L) > Kpong (0.332

mg/L) > Atimpoku (0.311 mg/L) > Small London (0.224 mg/L) > Akosombo (control site) (0.022 mg/L) (Figure 1). The results obtained at Akuse, Kpong and Small London were above the WHO, EPA and WPCL but less than CIW maximum permissible limit of iron. The most critical level was recorded at Akuse when compared to other sites. Deficiency of iron limits oxygen delivery to cells, resulting in fatigue, poor work performance, and decreased immunity. Additionally, it can result in toxicity, rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness and even death (Bhaskaram, 2001; Corbett, 1995). The main sources of iron comprise natural geological sources, industrial wastes, domestic and industrial discharge by-products and that; excess iron could further influence the presence of bacteria in the dam water, stain clothes and imparts bitter taste when present in suspended form as Fe^{2+} or Fe^{3+} (Ansari et al., 2004). The higher mean level of Fe recorded at Akuse compared to the other sites could be attributed to the greater number small-scale industrial activity which takes place in the town. The relatively higher mean Fe levels recorded at the sampling sites compared to WHO, EPA and WPCL maximum permissible limit may have implications on the quality of water for drinking, irrigation and fishery development.

The Pb concentrations in the various water sources in order of Akuse (0.101 mg/L) > Atimpoku (0.063 mg/L) > Small London (0.060 mg/L) > Kpong (0.053 mg/L) > Akosombo (Control site) (0.053 mg/L) were generally above the specific guidelines and standards of the WHO, EPA and WPCL. Lead is a toxic metal with no metabolic benefits to human and aquatic biota and could cause permanent damage to the health of both children and adults. Adults and children who drink water containing Pb in excess could experience kidney problems or high blood pressure and delays in their physical or mental development respectively (ACGIH, 2010; Newman and Unger, 2003). This probably buttresses the positive impacts of water resources monitoring and protection from the amalgamated efforts of responsible Government institutions mandated to control anthropogenic releases of lead into the water resources from main sources such as human and animal excreta, agricultural run-off containing phosphatic fertilizers, household sewages and mechanic workshops especially battery chargers.

The order of Mn concentration at all the sampling sites showed that levels detected at Atimpoku (0.012 mg/L) > Akuse (0.009 mg/L) > Akosombo (control site) (0.008 mg/L) > Kpong (0.005 mg/L) > Small London (0.002 mg/L) respectively and all the sites recorded comparatively lower Mn values than WHO, EPA, WPCL and CIW guidelines/standards (Figure 2). The accumulation of Mn in living organism has the potential of reaching toxic levels in human whereby victims manifest dullness, weak muscles, headaches and insomnia. However, the relatively lower Mn levels detected in the water than the recognized standards may be due to the influence of domestic wastes, natural geological mineral rock and industrial wastes discharge into the water body. Manganese pollution may also arise from the leachate of incinerated refuse containing the metal (WHO, 1981).

Lower concentrations of Cu ranging from 0.004 to 0.003 mg/L were similarly observed at all the sampling sites when compared with WHO, EPA, WPCL and CIW guidelines/standards (Figure 2). The levels observed may be attributed mostly to anthropogenic activities such artisanal fishing and discharge of domestic wastes; metal plating and leaching from minerals and negligible concentrations. The potential for Mn accumulation and toxicity in individuals living at the communities studied, is therefore not a major source of worry considering the current quality of the water resources of the Akosombo Dam and its environs for conjunctive benefits.

The lower Cu levels detected in the water resources probably revealed little or insignificant pollution trend from industrial activities from upstream due to proper protection of the lake from negative anthropogenic factors and ecological sustenance interventions adopted or implemented by the water resources development directorate and sectors under Government of Ghana such as the EPA, Water Research Institute and Water Resources Commission and the Volta River Authority.

Zinc which is often found naturally in water from industrial wastes, metal plating and plumbing is an essential nutrient in the diet of man because it acts as a catalytic or structural component in many enzymes that are involved in energy metabolism and in transcription and translation of RNA, determining the outcome of pregnancies and supporting neurobehavioral development on a positive note (Hotz et al., 2003). Conversely, very high concentrations of Zn compounds are corrosive and irritating to the skin, eye, mucous membrane and digestive tract causing nausea, vomiting and special types of dermatitis known as “zinc pox” (Lagadic et al., 2000). However, the mean Zn concentrations detected were below the specified guidelines or standards and may not manifest the associative toxicity symptoms stated on the humans who utilize the water resources in the short run.

While some forms of chromium are non-toxic, and may actually be trace nutrients for animals and humans, hexavalent chromium (Cr^{6+}) is more soluble in water and highly toxic even at low concentrations. It is easily absorbed in the human body and can produce various toxic effects within cells including irritating to eyes, skin and mucous membranes and can cause damage to the kidneys and liver (ATSDR, 2008). Mean Cr concentration of 0.006 mg/L recorded at the four sites; Atimpoku, Akuse, Small London and Kpong together with the control site at Akosombo (0.003 mg/L) (Figure 3) were below the recommended specific guideline or standards of the WHO, EPA and WPCL.

A higher concentration of Hg is noted to cause neurological and psychological symptoms, such as tremor, changes in personality, restlessness, anxiety, sleep disturbance and depression (Zahir et al., 2005). However, equal Hg concentrations of 0.001 mg/L, detected from all the water body locations were within the specified acceptable guideline and standards and could not pose significant negative health impacts on the users of the water resources at the time of this study.

CONCLUSIONS

Analysis of the risk level associated with the use of water from the dam for drinking, irrigation or fisheries by humans revealed that the concentration of Mn, Cu, Zn, Cr and Hg found in water were within permissible limits using various reference guides/standards.

Iron (Fe) and Pb revealed slightly higher levels at Atimpoku, Akuse, Small London and Kpong than the specific guidelines/standards even though it could not be linked to any significant negative health impact when the levels in the water were compared to the toxicity limits for manifestation of specific symptoms of human diseases caused by higher heavy metal traces in the water. Possible reason for traces of the metals in water resources could be anthropogenic activities such as agricultural discharge containing residual of pesticides and fertilizers, domestic wastewater, human and animal excreta and fishery waste discharge from upstream into the dam water sources. The increased levels of heavy metals in the water resource which is used for drinking and fishing activities could lead to great harm to humans and animals if effective monitoring of the water quality is not approached through the amalgamation of efforts by obligated state institutions through partnerships with the adjoining communities and the private sector.

RECOMMENDATIONS

The various unavoidable anthropogenic activities which lead to addition of heavy metals into the water bodies studied must be monitored, regulated on continuous basis or stopped. Activities which can be stopped without predisposing humans to severe negative impacts to safeguard the productivity of the water resources should be considered as such.

Water from the dam should be carefully monitored at regular intervals by testing it for additional microbial and physico-chemical characteristics of ecological importance.

There is the need for local research and academic institutions to assess the specific functions and contributions of corporate Governmental and Non-governmental organizations that support the protection and management of the water resources and come out with recommendations to integrate their efforts into public-private partnership strategies for intermediate and long term sustainable development action plans.

Further research should be conducted in aspects of non invasive pollution monitoring for the heavy metals using harvested fish samples that can bioaccumulate these metals in their bodies.

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