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Levels of some heavy metals in earthen ponds and concrete water storage reservoirs in Bakolori irrigation project, Zamfara state, North Western Nigeria

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Abstract
Levels of Some heavy metals in Earthen Ponds and numerous Concrete Water Storage Reservoirs (CWSRs) in Bakolori Irrigation Project (BIP) were investigated from March 2019 to February 2020. Four sampling stations were randomly selected from each of the two water body types. Water samples were collected monthly from the eight sampling stations and taken to the laboratory for analysis of Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn). The data collected were arranged on the bases of two seasons (dry & wet) and five sub-seasons, namely: Early dry (Oct - Dec); mid dry (Jan & Feb); late dry (March - May); Early rainy (June & July) and flood period (Aug & Sept), and subjected to T test analysis using Minitab statistical package. Results were compared with the water quality standards for Human consumption, aquatic life and fish production. Results showed that the water bodies were partly polluted by Cadmium, Chromium and Lead, but reasonably safe with regards to Copper, Manganese, Iron and Zinc. The study recommends continuous assessment of the water bodies for heavy metals concentration and bioaccumulation studies on fishes cultured and/or captured from the two water bodies.

Keywords: Ponds, water storage reservoirs, Bakolori, heavy metal, Nigeria

Introduction

Aquatic environment and its resident aquatic organisms are prone to pollution due to natural and human activities (Martin and Hidayathulla, 2007) [14]. Some of the toxic substances that cause pollution with high detrimental effects are heavy metals. These metals generally, enter aquatic environments through natural phenomenom, such as atmospheric deposition, erosion of geological matrix or due to anthropogenic causes such as; agricultural activities, industrial effluents, domestic sewage and mining wastes. These metals remain either in soluble or suspension form and are finally taken up by the organisms (Mason, 2002) [16]. Fishes being one of the main aquatic organisms in the food chain may often accumulate large amounts of these metals such as Fe, Zn, Pb, Cd, Cu and Mn which are common toxic pollutants for fish (Martin and Hidayathulla, 2007) [14]. The concentration of these metals and other chemicals in water is usually affected by many factors such as climate and seasons. According to Goldman and Horne (1983) [9] water bodies exhibit variation in their chemical composition with seasons. Aquaculture can be integrated in irrigation systems, especially in earthen ponds that can constructed across the irrigation and drainage canals and water bodies established for other irrigation and management purposes, such as concrete water storage reservoirs, this can be achieved by the use of species with known preference for such water bodies (Nasim, 2004) [20]. However, these water bodies are usually not assessed for their aquaculture suitability and human consumption. Hence the need for their water quality assessment (Petr and Mitrofanov 1998) [23].

Fresh water bodies are associated with certain factors that interrelate and constitute the favorable and unfavorable aquatic ecosystems, and collectively determine the suitability of the water for any intended purposes (Beadle, 1974) [3]. Inland fresh water bodies are prone to intensive anthropogenic activities due to agricultural and mining activities, sewage from municipal and industries (Moses, 1983) [19]. Therefore, these water bodies may contain some levels of agrochemicals, such as fertilizers, insecticides, herbicides and pesticides, hence the need for their water quality assessment (Aminu *et al*., 2018) [33]. But there is poor or nil water quality assessment of irrigation systems of Nigeria, resulting in underutilization of the water bodies for aquaculture developments (Nasim, 2004) [20].

The Bakolori Irrigation Project, according to (FAO, 2004 & USAID, 2010) [7, 28] is a multi-purpose dam and irrigation project designed to supply irrigation water to a net area of 23,000 hectares to boost food production, fisheries and livestock development, drinking water supply, among other things. There is paucity of information on water quality status of water bodies in irrigation systems of Nigeria and BIP in particular. Earthen fish ponds in BIP have not been assessed for water quality parameters (USAID, 2010) [28]. Since there is currently no available published information on the heavy metals' concentrations in the 17 earthen ponds used for fish culture, and the numerous concrete water storage reservoirs, this research has become very imperative, because it is important to investigate whether the heavy metals concentration of the earthen ponds and the CWSRs in BIP are within the acceptable range for human consumption, aquatic life and aquaculture. The findings of this research may provide the basis for further studies and utilization of the two water body types in the BIP for aquaculture and other purposes.

Materials and Methods

Study area

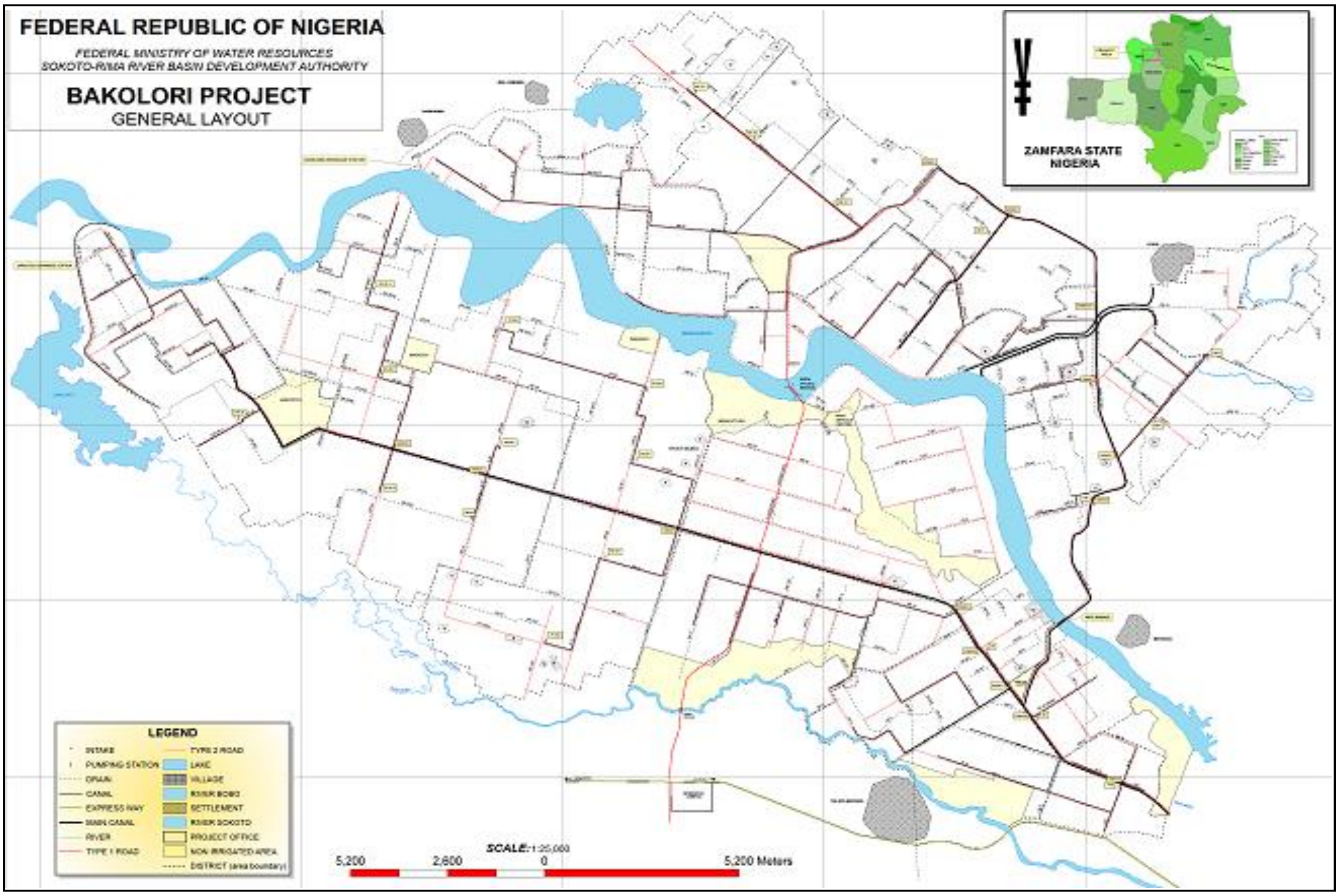

Fig 1: Map of BIP Showing its location in Zamfara State (USAID, 2010) [28]

Bakolori Irrigation Project is located 110km southeast of Sokoto city (USAID, 2010), between latitude 12° 33'N to 12° 42'N and longitude 5° 57'E to 6° 07'E within the Sokoto River Basin (FAO, 2004). The localities of Talata Mafara, Maradum, and Bakura (all in Zamfara state) North-Western Nigeria hold all the 23,000 hectares of the project (FAO, 2004) [7]. Almost 65% (15,000 hectares) of the land was designed for sprinkler irrigation which is now abandoned, while gravity fed surface irrigation was designed for the remaining 35% (8,000 hectares) (USAID, 2010) [28]. The mean annual rainfall is about 500 mm (FAO, 2004) [7] which starts between April and June and ends around October when the dry season sets in, with an annual cold and dusty harmattan between November and February (Ita, 1993b) [11]. The temperature ranges between 25 °C – 35 °C (FAO, 2004) [7], and Extreme heat is experienced before the rainfall between March and April and may extend to late June or July with late rainfall (Yahaya, 2002) [32].

The components of the gravity fed system include: A 15 km-long concrete lined supply canal; Two concrete lined main canals totaling 45 km of length; Concrete lined secondary canals totaling 200 km of length; Tertiary canals (earthen) totaling 300 km of length, and Field ditches (earthen) totaling 400 km of length (FAO, 2004) [7]. There are several earthrn ponds and numerous concrete water storage reservoirs (CWSRs) across the scheme, which are used to store water when the fields are not in need of irrigation. They also serve as backup in case of emergency need of water when the upper fields are taking much of the water in the supply canal.

Sampling procedure

Eight (8) sampling stations denoted by numbers 1 to 8 were located within the study area.

- Station 1, 2, 3 and 4 were randomly selected from the Earthen Ponds in BIP
- Station 5, 6, 7 and 8 were randomly selected from the Concrete water storage Reservoirs (CWSR).

Collection of water samples

Water samples were collected from each of the sampling stations monthly. Each sample was replicated three times. A total of twenty-four (24) 500 ml capacity plastic bottles were used for sampling every 7th day of the month, for a period of 12 months (March 2019 to February 2020). A total of two hundred and eighty-eight (288) samples (500 ml each) were collected for the determination of the heavy metals' concentration.

As described by (Lind, 1979) [12], water sample bottles were rinsed with the water at the sampling stations and lowered into the water body to collect water samples from about 15cm depth below the water surface at each of the twelve sampling points. The bottles were screwed tightly and transported immediately to the laboratory for analysis.

Water analysis

Heavy metals were analyzed in the Chemical Laboratory of Faculty of Agriculture, Usmanu Danfodiyo University, Sokoto, Sokoto state, Nigeria.

Sample digestion

Fifty ml of water sample was measured in to a beaker and 10ml of concentrated Nitric acid was added, the solution was placed on a hot plate and heated to digest under fume cupboard until it evaporated half way. The solution was allowed to cool after which it was made to 50 ml with distilled water and then filtered with a filter paper. The filtrate was used for the determination of Cd, Cu, Cr, Fe, Mn, Pb and Zn (Udo and Ogunwale, 1986) [27] Atomic Absorption Spectrophotometer (BUCK scientific Model 210 VGP) instrument was used to detect the heavy metals. The concentration of heavy metals in water was expressed in mg/l.

Data analysis

The data collected were arranged and analyzed for differences in the two water bodies on the bases of two seasons (dry & wet) and five sub seasons, namely: Early dry (Oct - Dec); mid dry (Jan & Feb); late dry (March - May); Early rainy (June & July) and flood period (Aug & Sept). T test analysis using Minitab statistics computer software was used to analyze the data collected.

Results

Table 1 and 2 show the overall/seasonal and sub seasonal heavy metals mean levels respectively.

Table 1: Mean Seasonal/Overall Mean Concentration of Some Heavy Metals in Earthen Ponds & Concrete Water Storage Reservoirs in BIP, Zamfara State, North Western Nigeria

Parameter	Water Body	Dry Season	Wet Season	Overall Mean
Cadmium ion (mg/1)	Pond	0.09±0.04^{b}	0.05±0.02	0.08±0.04^{b}
	CWSRs	0.10 ±0.03^{a}	0.06±0.04	0.10 ±0.02^{a}
Chromium ion (mg/I)	Pond	0.10±0.08	0.05±0.03^{b}	0.09±0.07
	CWSRs	0 11±0 09	0. 07±0 03^{a}	0.09±0.08
Copper ion (mg/1)	Pond	0.23 ±0.16	0.42±0.14	0.31±0.18
	CWSRs	0.23 ±0.19	0.39±0.15	0.28 0±19
Iron ion (mg/1)	Pond	1.17 ±0.89^{a}	1.34±0.48	1.23 ±0.78^{a}
	CWSRs	0.75±0.49^{b}	1.34±0.49	0.95 ±0.56^{b}
Manganese (mg/1)	Pond	0.11±0.05	0.30±0.14	0.17±0.13
	CWSRs	0.10±0.08	0.30±0.19	0.17±0.15
Lead ion (mg/I)	Pond	0.21 ±0.06^{a}	0.07±0.02	0.16±0.09
	CWSRs	0.19±0.07^{b}	0.09±0.03	0.15±0.09
Zinc ion (mg 1)	Pond	0.47±0.20	0.54±0.19^{a}	0.50±0.20^{a}
	CWSRs	0.46±0.13	0.46±0.21^{b}	0.44±0.19^{b}

Values are means ± standard deviations

Means in a column with superscripts are significantly different (*p*<0.05)

Table 2: Mean Sub-Seasonal Concentrations of Some Heavy Metals in Earthen Ponds & Concrete Water Storage Reservoirs in Bakolori Irrigation Project, Zamfara State, North Western Nigeria

Parameter	Water Body	Sub season				
		Late Dry (Mar-May) 2019	Early Rainy (June-July)	Flood (Aug-Sept)	Early Dry (Oct-Dec)	Mid Dry (Jan -Feb) 2020
Cadmium (mg/l)	Pond	0.11±0.03^{b}	0.05±0.01^{b}	0.04±0.01	0.08±0.04	0.07±0.02
	CWSRs	0.14±0.07^{a}	0.07±0.02^{a}	0.04±0.01	0.07±0.04	0.07±0.02
Chromium (mg/l)	Pond	0.18±0.03	0.07±0.03	0.04±0.01^{b}	0.05±0.03	0.03±0.01^{b}
	CWSRs	0.19±0.08	0.07±0.03	0.05±0.02^{a}	0.05±0.04	0.04±0.01^{a}
Copper (mg/l)	Pond	0.41±0.10^{a}	0.34±0.12^{a}	0.51±0.09	0.11±0.05^{b}	0.11±0.01
	CWSRs	0.30±0.05^{b}	0.30±0.10^{b}	0.48±0.13	0.22±0.28^{a}	0.10±0.03
Iron (mg/l)	Pond	1.47±0.31^{a}	1.51±0.55^{a}	1.16±0. 30^{b}	0.56±0.19^{a}	0.43±0.10^{a}
	CWSRs	1.34±0.15^{b}	0.97±0.29^{b}	1.50±0.34^{a}	0.43±0.26^{b}	0.30±0.06^{b}
Manganese (mg/l)	Pond	0.15±0.04^{b}	0.18±0.07^{a}	0.39±0.09^{b}	0.06±0.02	0.07±0.01
	CWSRs	0.17±0.08^{a}	0.13±0.06^{b}	0.45±0.11^{a}	0.06±0.02	0.06±0.02
Lead (mg/l)	Pond	0.18±0.05^{a}	0.07±0.02	0.05±0.02	0.26±0.04	0.25±0.04^{a}
	CWSRs	0.15±0.03^{b}	0.07±0.02	0.06±0.14	0.24±0.07	0.17±0.03^{b}
Zinc (mg/l)	Pond	0.61±0.09	0.64±0.19^{a}	0.43±0.13^{a}	0.45±0.22^{a}	0.31±0.06
	CWSRs	0.62±0.08	0.44±0.13^{b}	0.34±0.10^{b}	0.40±0.21^{b}	0.31±0.11

Values are Means ± standard deviations

Means in a column with superscripts are significantly different (*p*<0.05)

Discussion

Cadmium (Cd)

T test analysis revealed that the differences in the overall mean and dry season mean values of cadmium in ponds and the CWSR were significant (*p*<0.05) but insignificant in wet season, and Seasonal Cadmium mean levels were generally lower in wet season than in dry season (Table 1).

Sub seasonal Cadmium mean levels of the two water bodies were generally lowest in flood sub season. The sub seasonal Cadmium mean values for the water bodies were significant (*p*<0.05) throughout the five sub seasons (Table 2).

The significantly (*p*<0.05) higher seasonal and sub seasonal mean cadmium levels in the CWSRs recorded during the dry season (Table 1) and corresponding late dry sub season (Table

2) could be due to mine drainage (Mason, 1992) [15] as a result of mining activities around Maradun and other villages whose streams are tributaries of Sokoto River which was dammed to create Bakolori reservoir from which BIP water bodies get their main water especially during the dry season. It could also be due to leaching from geological deposits of zinc ores and phosphate fertilizers (Lioyd, 1992) [13] used in the catchment farm lands. The lowest values recorded in pond water during the wet season (Table 1) and corresponding flood sub season (Table 2) could be due to dilution by rainfall and runoff water in wet season. This observation is in line with that of Ipinjolu and Argungu (1998) [10] who found concentration of these metals to be higher in dry season and lower in wet season in Zamfara Reserve. The overall mean values (Table 1) for the three water bodies are lower than 0.33 mg/l reported for Kanji Lake (Mbagwu, 2000) [17] and 0.35±0.05 mg/l in Dadin Kowa Reservoir in Gombe state (Ovie *et al*., 2000) [21]. The values are however, higher than 0.003 mg/l being the water quality standard for drinking water (WHO, 1993) [31] and 0.02mg/l for fish production in African inland water bodies (Lioyd, 1992) [13]. With the exception of dry season and corresponding late dry sub season values of CWSRs cadmium values which are were around 0.1 mg/l, all the cadmium levels recorded for both pond and CWSRs water were lower than the 0.1mg/l standard for aquatic life (Roberts, 1978) [24].

Chromium (Cr)

The highest seasonal and sub seasonal mean chromium levels recorded in the CWSRs during the dry season (Table 1) and corresponding late dry sub season (Table 2) could be due to drainage from mining sites (Mason, 1992) [15] as a result of mining activities around the BIP area. It could also be due to leaching of phosphate fertilizers (Lioyd, 1992) [13] used for crop cultivation in the agricultural lands in the catchment areas of the Bakolori Reservoir, which is the main source of the water in BIP. The lowest values recorded during the wet season (Table 1) and corresponding flood sub season (Table 2) could be due to dilution by rainfall and runoff water in wet season. The overall mean, seasonal and sub seasonal mean chromium levels in the present study were lower than 0.19±0.07 mg/l, 0.24±0.01 mg/l and 0.2 mg/l in Kware Lake, Lugu Dam and Goronyo Reservoir. The values were however, within the range of 0.02±0.01 mg/l to 0.21±0.07 mg/l in rivers of Zamfara reserve (Ipinjolu and Argungu, 1998) [10]. Overall mean Chromium values in the present study are higher than the water quality standard of 0.05 mg/l for drinking water (WHO, 1993) [31] and 0.03 mg/l for fresh water bodies (DPR, 1991) [6].

Copper (Cu)

The significantly ($p<0.05$) high seasonal and sub seasonal mean copper levels in recorded in earthen ponds of BIP during the wet season (Table 1) and corresponding flood sub season (Table 2) could be due to mine activities (Lioyd, 1992) [13] in the catchment areas of the Bakolori Reservoir from which the water is sourced, and agricultural activities (Lioyd, 1992) [13] and runoff sediments containing heavy metals due to land disturbances resulting from developmental activities. The lowest levels recorded in the CWSRs during the dry season (Table 1) and the corresponding mid-dry sub season (Table 2) could be due to dilution as a result of high water levels in the supply canal that supplies CWSRs during the dry season (Table 1) and mid dry sub season (Table 2). All the sub seasonal, seasonal and overall mean copper values recorded in the present study are lower than 1.11mg/l reported for Kainj Lake (Mbagwu, and Adeniyi, 1994) [18] and 0.21±0.07 mg/l in stream/river of Zamfara Reserve (Ipinjolou and Argungu, 1998) [10]. The values are also lower than 1mg/l recommended for drinking water (WHO, 1993) [31] and 5 mg/l favorable for aquatic life (Vizeau, 1989) [29].

Iron (Fe)

The significantly ($p<0.05$) high seasonal and sub seasonal mean Iron levels recorded in the earthen Ponds during the wet season (Table 1) and corresponding early rainy sub season (Table 2) could be due to weathering of basement rocks, erosion of soils and drainage from agricultural lands (Tait, 1981) [25] in the catchment areas of upstream part of Sokoto River and Bakolori Reservoir which is the main source of the water supplied to the ponds. The lower seasonal and lowest sub seasonal mean Iron levels were recorded in the CWSRs during the dry season (Table 1) and corresponding mid dry sub season (Table 2). All the sub seasonal, seasonal and overall mean Iron values recorded in the present study are within the minimum and maximum values of 0.07mg/l and 2.07 mg/l found in Zamfara reserve (Ipinjolu and Argungu, 1998), but lower than 13.18±1.67 mg/l, 15.08±0.18 mg/l reported for Lugu Dam and Goronyo Reservoir (Wapdeiyel, 2002) [30]. However, with the exception of mid dry sub seasonal value (Table 2) of CWSRs, all the sub seasonal, seasonal and overall mean values in the present study are higher than the 0.3 mg/l recommended for aquatic life (FEPA, 2003) [8]. Also, with the exception of early dry and mid dry sub seasonal values (Table 2) of the two water bodies and dry season and overall mean values of CWSRs water, all the sub seasonal, seasonal and overall mean values of iron in the present study are higher than 1 mg/l recommended for drinking water (WHO, 1993) [31].

Manganese (Mn)

The higher seasonal and highest sub seasonal mean Manganese levels recorded in CWSRs water during the wet season (Table 1) and corresponding flood sub season (Table 2) could be due to weathering of basement rocks, erosion of soils and drainage from agricultural lands (Tait, 1981) [25] in the catchment areas of upstream part of Sokoto River and Bakolori Reservoir which is the main source of the main canal water feeding the CWSRs. The lower seasonal and lowest sub seasonal mean Manganese were recorded in both the pond and CWSRs water during the dry season (Table 1) and corresponding early dry sub season in both the two water bodies (Table 2). Manganese values in the present study are with the exception of dry season, early dry and mid dry sub seasonal values higher than 0.15±0.08 mg/l reported for rivers of Zamfara (Ipinjolu and Argungu, 1998) [10], but generally lower than 2.12±0.13 mg/l in Lugu Dam (Wapdeiyel, 2002) [30], 0.5 mg/l recommended for drinking water (WHO, 1993) [31] and 1 mg/l acceptable for aquatic life and fish production (Boyd, 1979) [4].

Lead (Pb)

The higher seasonal and highest sub seasonal mean lead level in water bodies of BIP recorded in the Pond water during the dry season (Table 1) and corresponding early dry sub season (Table 2) could be due to weathering of lead ores and rocks, diffused inputs of lead from the use of petrol and lead batteries in vehicles (Liyod, 1992) [13] around the water body and its source or mining operations taking place in some villages around the catchment areas of Bakolori Reservoir. The lowest values during the wet season and the corresponding flood sub season could be due to its low solubility and dilution resulting from rainfall and runoff water in the wet season and the flood sub season. With the exception of wet season and the corresponding early rainy and flood sub seasonal values, most of the sub seasonal (Table 2), seasonal and overall mean values (Table 1) of lead in BIP during the present study are comparable with what was reported for Kware Lake (Wapdeiyel, 2002) [30], but generally lower than the reported values of 4.04 mg/l and 4.05 mg/l for Lugu Dam and Goronyo Reservoir respectively (Wapdeiyel, 2002) [30] and a range of 0.69±0.64 to 3.47±0.16 in Sokoto Rima River system at Argungu Fishing Festival site in North Western Nigeria (Abubakar *et al*., 2012) [1]. The recorded values in this study are generally higher than the water quality standard of 0.01 mg/l for aquatic life (FEPA, 2003) [8], 0.05 mg/l for fish production (DPR, 1991) [6] and 0.01 mg/l recommended by WHO (1993) [31] for drinking water.

Zinc (Zn)

The significantly (p<0.05) higher seasonal and highest sub seasonal mean zinc levels recorded in the Pond water during the wet season (Table 1) and early-dry sub season (Table 2) could be due to mine activities (Lioyd, 1992) [13] in the catchment areas of the Bakolori reservoir from which the bakolori Reservoir water come from. It can also be due to agricultural activities (Lioyd, 1992) [13] in the surrounding water sheds that drain in to the reservoir, and/or runoff sediments containing heavy metals due to land disturbances resulting from road construction. The lower level recorded in the CWSRs during the dry season (Table 1) and the corresponding mid-dry sub season in both the two water bodies (Table 2) could be due to dilution as a result of high water levels in supply canals during the dry season (Table 1) and mid dry sub season (Table 2). All the sub seasonal, seasonal and overall mean Zinc values recorded in the present study are within the range of 0.05±0.01 mg/l to 10.14±0.11 mg/l in Zamfara reserve (Ipinjolu and Argungu, 1998) [10], but slightly higher than 0.21±0.04 mg/l, 0.2±0.02 mg/l and 0.20±0.00 mg/l reported for Kware Lake, Lugu Dam and Goronyo Reservoir respectively (Wapdeiyel, 2002) [30]. The values are however lower than the water quality standard of 5mg/l recommended for drinking water (WHO, 1993) [31] but higher than 0.03mg/l for fish and other aquatic organisms (Vizeau, 1989) [29].

Conclusion

This study revealed the levels of some heavy metals' concentration in earthen ponds and CWSRs in Bakolori Irrigation Project. Season, mining and agricultural activities, in BIP and its catchment areas could have contributed to most of the variability in the levels of the studied heavy metals.

The heavy metals with the highest values in the dry season were Cd, Cr and Pb in both earthen ponds and CWSRs water. Those with high levels in the wet season are Cu, Fe, Mn & Zn in both water bodies.

The dry season levels of Cadmium, Chromium and Lead in the earthen ponds and CWSRs water of BIP were partly unsafe for human consumption, aquatic life and fish production. It is hence concluded that the earthen ponds and CWSRs water of Bakolori Irrigation Project in Zamfara State, North Western Nigeria is of poor water quality with regards to Cadmium, Chromium and lead. But the water is reasonably safe for human consumption, aquatic life and fish production in terms of Iron, Copper, Manganese and Zinc.

Recommendations

The findings of this research provide baseline information for further monitoring of water quality status of water bodies in Bakolori Irrigation Project for human consumption, aquatic life and fish production. The study recommends the following:

1. Continuous monitoring and assessment of heavy metals concentration of tributaries of both upstream and downstream of Sokoto River, Bakolori Reservoir and Bobo River.
2. The reported illegal mining activities in parts of Maradun and Zamfara State in general should be controlled by the relevant authorities, because it could be responsible for the high heavy metals concentration in the water bodies. This is to avert possible health hazard to aquatic life and human population especially the farmers, laborers and herds men who use water from these water bodies for drinking and food processing, as observed severally during the study.
3. Studies should be conducted to determine the anthropogenic activities on the catchment areas of the tributaries of the Bakolori Reservoir.

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