E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2022; 10(6): 101-107

www.fisheriesjournal.com
Received: 06-09-2022
Accepted: 19-10-2022

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Concentration of some heavy metals in main irrigation and drainage canals water of Bakolori irrigation project, Zamfara state, north western Nigeria

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DOI: https://doi.org/10.22271/fish.2022.v10.i6b.2753

Abstract
Concentration of Some heavy metals in main irrigation and drainage canals water of Bakolori Irrigation Project (BIP) were investigated from March 2019 to February 2020. Four sampling stations were systematically & randomly selected from the two canals respectively. 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 ($p<0.05$) 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 partially polluted by Cd, Cr and Pb, but reasonably safe with regards to other heavy metals investigated. The study recommends continuous assessment of the water bodies for heavy metals concentration and bioaccumulation studies on fishes caught from the canals, Bakolori Reservoir, Natu Lake as well as Sokoto and Bobo Rivers.

Keywords: Bakolori, heavy metal, canal water, irrigation, Nigeria

1. Introduction

Water bodies are prone to pollution which may negatively affect the environment and the living aquatic organisms (Martin and Hidayathulla, 2007) [17]. Heavy metals generally, enter aquatic environments through atmospheric deposition, erosion of geological matrix or due to anthropogenic activities 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) [19]. Fishes being one of the main aquatic organisms in the food chain may often accumulate large amounts of certain metals such as Fe, Zn, Pb, Cd, Cu and Mn which are common toxic pollutants for fish (Martin and Hidayathulla, 2007) [17]. Water bodies exhibit variation in their chemical composition with seasons (Aminu *et al.*, 2019) [4]. Fisheries can be integrated in irrigation systems, especially in major irrigation and drainage canals and water bodies established from residual irrigation water by the use of species with known preference for such water bodies (Nasim, 2004) [23]. However, these water bodies are sometimes characterized by elevated salinities and high concentrations of agrochemicals, hence the need for their water quality assessment (Petr and Mitrofanov 1998) [26].

Nigeria has vast expanse of fresh water bodies (Ita, 1993) [14] which are associated with factors that interrelate and constitute the favorable and unfavorable aquatic ecosystems, and collectively determine the suitability of the water for intended purposes (APHA, 2005) [5]. Inland fresh water bodies are prone to intensive anthropogenic activities due to agricultural and mining activities, sewage from municipal and industries (USEPA, 2016) [32]. Good quality water is necessary for living organisms and the quality of water for human consumption, aquatic life and for fish production depends on three factors which synergistically interrelate to produce some quality parameters that make the water of either good or bad qualities (Beadle, 1974) [6]. It is the web of physical, chemical and biological factors that constitute aquatic environment and influence the beneficial uses of water (Tchobanoglous and Schroeder, 1987) [29]. Water quality is defined as any physical, chemical and biological parameters of water which affect the survival, growth and reproduction of fish (Boyd, 1979) [7]. These parameters have ranges which fish can tolerate, below or above which can lead to stress, growth impairment or even mortality (Aminu *et al.*, 2018) [3]. Water quality assessment involves collecting water samples from water bodies for determining the status of some relevant parameters, which indicate the suitability of the water for purposes such as human consumption, aquatic life and fish production (Delince, 1992) [8].

Irrigation water bodies have elevated salinities and high concentrations of agrochemicals, such as fertilizers, insecticides, herbicides and pesticides, hence the need for their water quality assessment (Petr and Mitrofanov, 1998) [26]. Some of the problems in irrigation systems are poor or nil water quality assessment, which results in underutilization of the water for aquaculture developments (Nasim, 2004) [2].

The Bakolori Irrigation Project, according to (FAO, 2004 & USAID, 2010) [10, 31] 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) [31]. Since there is currently no available published information on the heavy metals concentration in water bodies of BIP including the 17 earthen ponds partly used for fish culture, this research has become very imperative, because it is important to investigate whether the water quality parameters of water bodies in BIP are within the acceptable range for human consumption, aquatic life and aquaculture development. The findings of this research may provide the basis for further studies and utilization of the water bodies in the BIP for aquaculture and other purposes.

Materials and Methods

Study area

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) [10]. 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) [10].

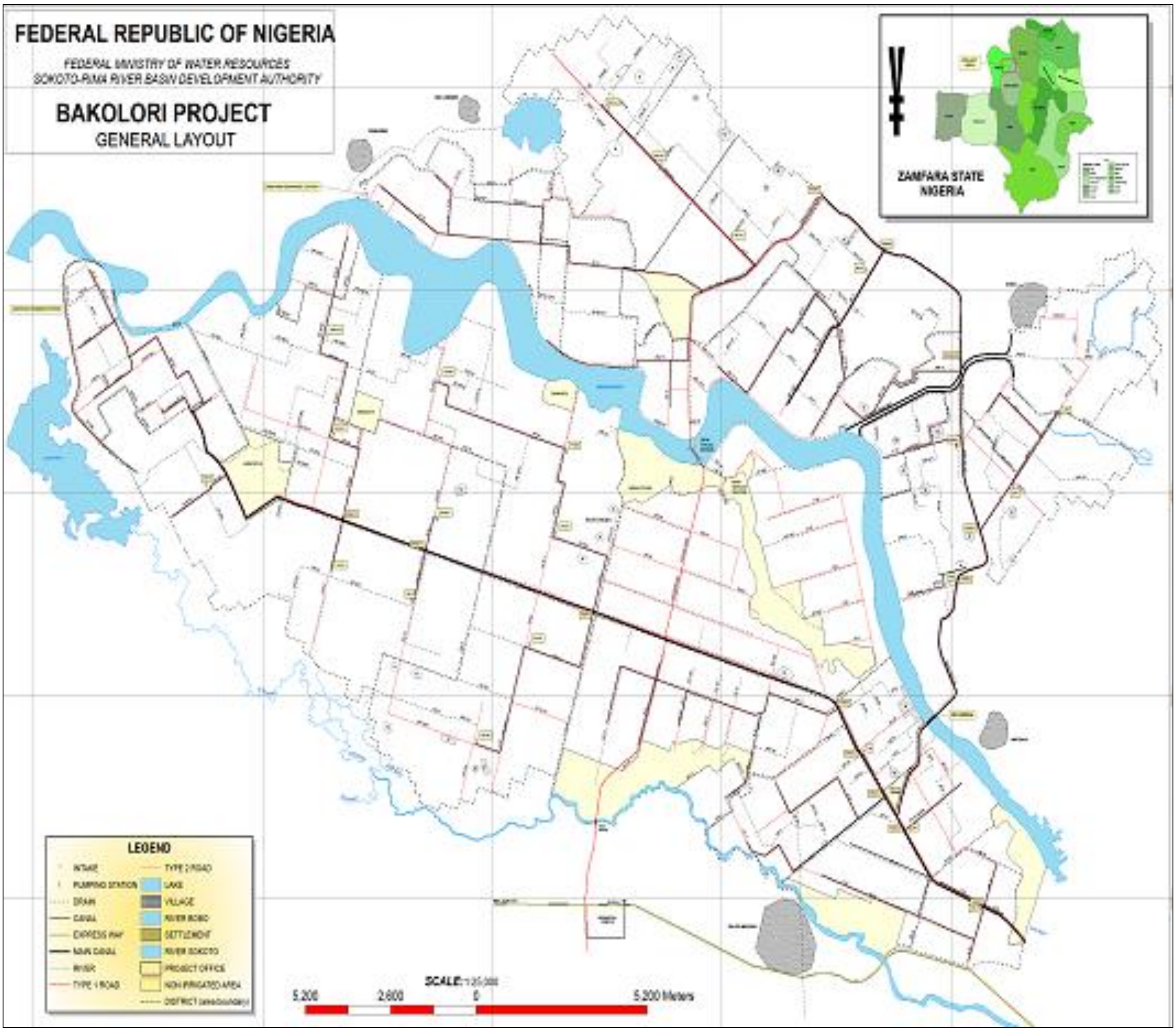

Fig 1: Map of Bakolori Irrigation Project Showing the Main Canals & its location in Zamfara State (USAID, 2010) [31]

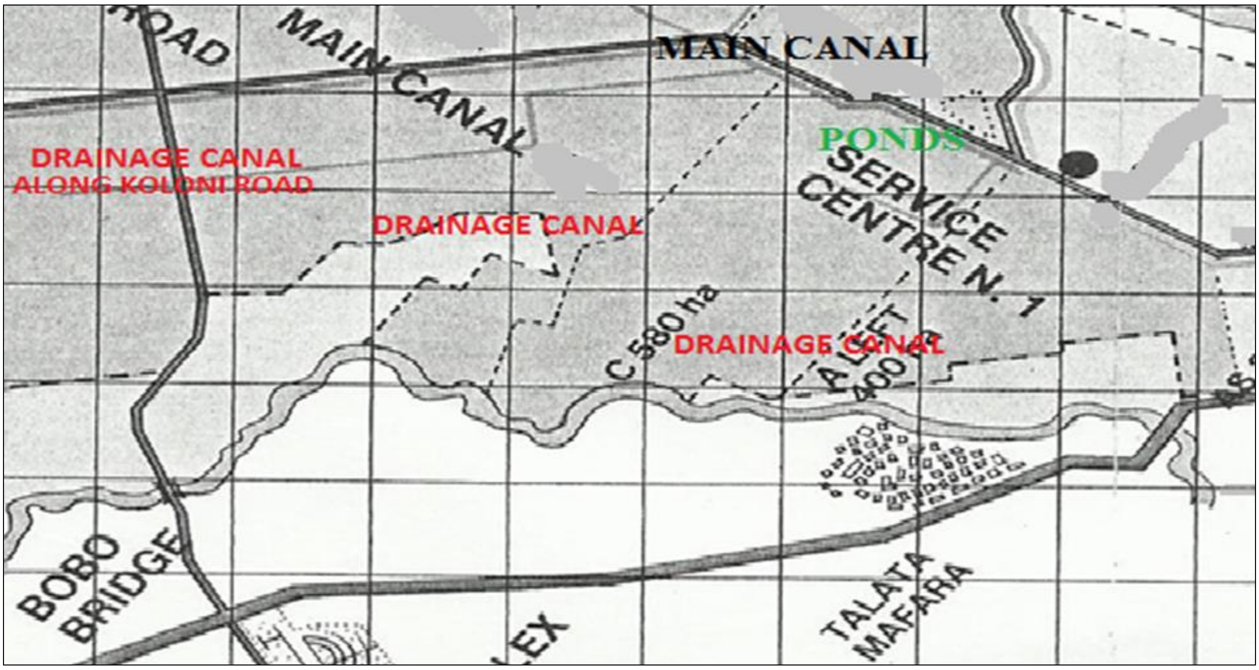

Fig 2: Map of the study area showing the locations of the Main Canals (FAO, 2004) [1].

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) [31]. The mean annual rainfall is about 500mm (FAO, 2004) [10] 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) [14]. The temperature ranges between 25^0C - 35^0C (FAO, 2004) [10], 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) [36].

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) [1].

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 systematically located on the main irrigation canals.
- Station 5, 6, 7 and 8 were purposively selected on the main drainage canals.

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) 500ml 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 (500ml each) were collected for the determination of the heavy metals' concentration.

As described by (APHA, 2005) [5], 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.

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 50ml 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) [30] 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 concentrations respectively.

Table 1: Mean Seasonal/Overall Mean Concentration of Some Heavy Metals in Main Irrigation & Drainage Canals Water of BIP, Zamfara State, North Western Nigeria

Parameter	Water Body	Dry Season	Wet Season	Overall Mean
Cadmium ion (mg/1)	Main Canal	0.12±0.05	0.06±0.02	0.09±0.05
	Drainage canal	0.12±0.08	0.06±0.04	0.10±0.07
Chromium ion (mg/1)	Main Canal	0.11±0.07	0.06±0.02[b]	0.09±0.06
	Drainage canal	0.11±0.09	0.07±0.03[a]	0.09±0.08
Copper ion (mg/1)	Main Canal	0.19±0.09	0.41±0.15	0.29 ±0.16
	Drainage Canal	0.23±0.19	0.39±0.15	0.28 0±.19
Iron ion (mg/1)	Main Canal	1.18±0.95[a]	1.46±0.39[a]	1.22+0.82[a]
	Drainage Canal	0.75±0.49[b]	1.34±0.39b	0.95 ±0.56[b]
Manganese (mg/1)	Main Canal	0.11±0.08	0.32±0.19	0.18±0.16
	Drainage Canal	0.10±0.08	0.30±0.19	0.17±0.15
Lead ion (mgt1)	Main Canal	0.23±0.08[a]	0.07±0.02	0.17±0.10[a]
	Drainage Canal	0.19±0.07[b]	0.09±0.03	0.15±0.09[b]
Zinc ion (mg/I)	Main Canal	0.45±0.19	0.48±0.14a	0.44±0.18
	Drainage Canal	0.45±0.19	0.46±0.21b	0.44±0.19

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 Main Irrigation & Drainage Canals Water of 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)	Main Canal	0.11±0.06[b]	0.06±0.01	0.05±0.01	0.10±0.04[a]	0.14±0.02[a]
	Drainage canal	0.14±0.07[a]	0.07±0.02	0.04±0.01	0.07±0.04[b]	0.07±0.02[b]
Chromium mg/l)	Main Canal	0.16±0.05[b]	0.05±0.02[b]	0.04±0.01	0.05±0.02	0.06±0.01[a]
	Drainage canal	0.19±0.08[a]	0.07±0.03[a]	0.05±0.02	0.05±0.04	0.04±0.01[b]
Copper (mg/l)	Main Canal	0.27±0.06	0.33±0.16	0.48±0.10	0.11±0.04[b]	0.10±0.02
	Drainage canal	0.30±0.05	0.30±0.10	0.48±0.13	0.22±0.28[a]	0.10±0.03
Iron (mg/l)	Main Canal	1.40±0.22	1.36±0.43[a]	1.56±0.33	0.30±0.11[b]	0.31±0.09
	Drainage canal	1.34±0.15	0.97±0.29[b]	1.50±0.34	0.43±0.26[a]	0.30±0.06
Manganese (mg/l)	Main Canal	0.17±0.08	0.14±0.07	0.48±0.09	0.06±0.02	0.07±0.02
	Drainage canal	0.17±0.08	0.13±0.06	0.45±0.11	0.06±0.02	0.06±0.02
Lead (mg/l)	Main Canal	0.12±0.04[b]	0.06±0.01	0.06±0.02	0.26±0.06	0.29±0.02[a]
	Drainage canal	0.15±0.03[a]	0.07±0.02	0.06±0.14	0.24±0.07	0.17±0.03[b]
Zinc (mg/l)	Main Canal	0.57±0.08[b]	0.51±0.05[a]	0.38±0.16[a]	0.36±0.25[b]	0.30±0.10
	Drainage canal	0.62±0.08[a]	0.44±0.13[b]	0.34±0.10[b]	0.40±0.21[a]	0.31±0.11

Values are Means ± standard deviations
Means in a column with superscripts are significantly different ($p<0.05$)

Discussion

Cadmium (Cd)

Data analysis revealed that the differences between the two water bodies in the overall mean, wet season and dry season mean values were insignificant (Table 1). Sub seasonal Cadmium mean values of the two water bodies were generally lowest in flood sub season. However, the highest mean value for Main Canal water was recorded in mid dry sub season, while that of Drainage Canal water was recorded in late dry sub season (Table 2). The highest seasonal and sub seasonal mean cadmium levels recorded in the drainage canal during the dry season (Table 1) and corresponding late dry sub season (Table 2) could be due to mine drainage (Mason, 1992) [18] 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) [16] used in the irrigation fields which drain in the drainage canals. 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) [13] 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 0.33mg/l reported for Kanji Lake (Mbagwu, 2000) [20] and 0.35±0.05 mg/l in Dadin Kowa Reservoir in Gombe state (Ovie *et al.*, 2000) [24]. The values are however, higher than 0.003 mg/l being the water quality standard for drinking water (WHO, 1993) [35] and 0.02 mg/l for fish production in African inland water bodies (Lioyd, 1992) [16]. Main canal and pond water values are lower than the 0.1 mg/l standard for aquatic life (Roberts, 1978) [27], while drainage canal overall mean value is comparable to it.

Chromium (Cr)

The highest seasonal and sub seasonal mean chromium levels in the canals water of BIP recorded in the drainage canal during the dry season (Table 1) and corresponding late dry sub season (Table 2) could be due to mine drainage (Mason, 1992) as a result of mining activities around the BIP area. It could also be due to leaching of phosphate fertilizers (Lioyd, 1992) [16] used in the irrigation fields which drain in the drainage canals. 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±0.07mg/l, 0.24±0.01 mg/l and 0.2 mg/l in Kware Lake, Lugu Dam and Goronyo Reservoir (Wapdiyel, 2002) [34]. 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) [13]. Overall mean Chromium values in the present study are higher than the water quality standard of 0.05mg/l for drinking water (WHO, 1993) [35] and 0.03mg/l for fresh water bodies (DPR, 1991) [9].

Copper (Cu)

The highest seasonal and sub seasonal mean copper levels in water bodies of BIP recorded during the wet season (Table 1) and corresponding flood sub season (Table 2) could be due to mine activities (Lioyd, 1992) [16] in the catchment areas of the Bakolori Reservoir from which the is sourced, and agricultural activities (Lioyd, 1992) [16] and runoff sediments containing heavy metals due to land disturbances resulting from developmental activities. The lowest levels recorded in the main canal 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 canal 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) [21] and 0.21±0.07 mg/l in stream/river of zamfara reserve (Ipinjolou and Argungu, 1998) [13]. The values are also lower than 1mg/l recommended for drinking water (WHO, 1993) [35] and 5 mg/l favourable for aquatic life (Vizeau, 1989) [33].

Iron (Fe)

The significantly (p<0.05) highest seasonal and sub seasonal mean Iron levels in water bodies of BIP recorded in the main canal 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) [28] in the catchment areas of upstream part of Sokoto River and Bakolori Reservoir which is the main source of the main canal water. The lowest seasonal and sub seasonal mean Iron levels in the water bodies were recorded in the drainage canal water 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 0.07 mg/l and 2.07 mg/l found in Zamfara reserve (Ipinjolu and Argungu, 1998) [13], but lower than 13.18±1.67 mg/l, 15.08±0.18 mg/l reported for Lugu Dam and Goronyo Reservoir (Wapdeiyel, 2002) [34]. However, with the exception of early dry and mid dry sub seasonal values (Table 2) of main canal water and mid dry value of drainage canal water 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) [11]. Also, with the exception of early dry and mid dry sub seasonal values (Table 2) of the three water bodies and dry season and overall mean values of drainage canal 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) [35].

Manganese (Mn)

The highest seasonal and sub seasonal mean Manganese levels in water bodies of BIP recorded in the main canal 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) [28] in the catchment areas of upstream part of Sokoto River and Bakolori Reservoir which is the main source of the main canal water. The lowest seasonal and sub seasonal mean Manganese levels in the water bodies were recorded in the drainage canal water during the dry season (Table 1) and corresponding mid dry subseason (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) [13], but generally lower than 2.12±0.13 mg/l in Lugu Dam (Wapdeiyel, 2002) [34], 0.5 mg/l recommended for drinking water (WHO, 1993) [35] and 1mg/l acceptable for aquatic life and fish production (Boyd, 1979) [7].

Lead (Pb)

The significantly (p<0.05) highest seasonal and sub seasonal mean lead level in water bodies of BIP recorded in the main canal water during the dry season (Table 1) and corresponding mid 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) [16] 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) [34], but generally lower than the reported values of 4.04mg/l and 4.05mg/l for Lugu Dam and Goronyo Reservoir respectively (Wapdeiyel, 2002) [34] 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 0.01mg/l for aquatic life (FEPA, 2003) [11], 0.05 mg/l for fish production (DPR, 1991) [9] and 0.01 mg/l recommended by WHO (1993) [35] for drinking water.

Zinc (Zn)

The significantly (p<0.05) highest seasonal mean zinc levels in water bodies of BIP recorded in the Main Irrigation Canal water during the wet season (Table 1) could be due to mine activities (Lioyd, 1992) 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) [16] 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 lowest levels recorded in the main canal 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 canal 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±0.01mg/l to 10.14±0.11 mg/l in Zamfara reserve (Ipinjolu and Argungu, 1998) [35], but slightly higher than 0.21±0.04mg/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) [34]. The values are however lower than the water quality standard of 5 mg/l recommended for drinking water (WHO, 1993) [35] but higher than 0.03 mg/l for fish and other aquatic organisms (Vizeau, 1989) [33].

Conclusion

This study revealed the levels of some heavy metals' concentration in two water bodies in Bakolori Irrigation Project. Season, nature of the water bodies, mining and agricultural activities, in and around the studied area and the catchment areas of Bakolori Reservoir may have accounted for most of the variability in the concentration of the studied heavy metas.

The heavy metals with the highest values in the dry season were Cd, Cr and Pb in both the Main Irrigation and Main Drainage canals water. Those with high levels in the wet season are Cu, Fe, Mn & Zn in both canals water.

Main canal water had highest values of Fe (in both dry and wet season), Mn (dry season, wet season and overall mean) and Pb (dry season and overall mean). While, Drainage canal water had highest values of Cu (dry season), Pb (wet season) and Cd (all in dry season and overall mean) Cr (all in both the two seasons and overall mean).

The concentrations of some heavy metals in the two canals are not very safe for human consumption, aquatic life and fish production; these are Cadmium, Chromium, Lead (except in wet season and the corresponding early rainy and flood sub seasons) and Iron (except in early dry and mid dry sub seasons). It is therefore concluded that the Main Irrigation Canal and Main Drainage Canal water of Bakolori Irrigation Project in Zamfara State, North Western Nigeria is of reasonable water quality status for human consumption, aquatic life and fish production in terms of Copper, Manganese and Zinc ion, but of poor water quality status or partly polluted in terms of Cadmium, Chromium, lead (in dry season) and Iron (in wet season and late dry sub season).

Recommendations

The findings of this study provide baseline information for subsequent 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 water quality/pollution status of water bodies in and around the BIP especially 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 witnessed severally during the sample collection.
3. Studies should be conducted to determine the anthropogenic activities on the catchment areas of the tributaries of the Bakolori Reservoir.
4. Studies should be conducted to monitor the release in to the water bodies and impact of agrochemicals, such as fertilizers, insecticides, herbicides and pesticides to the water quality parameters, human consumption and aquatic life.

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