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Physicochemical Parameters of Three Water Bodies in Bakolori Irrigation Project, Zamfara State, North Western Nigeria

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Abstract

Some physicochemical parameters of water in main irrigation canals (MIC), earthen ponds (EP) & main drainage canals (MDC) of Bakolori Irrigation Project (BIP) were assessed from March 2012 to February 2013. Air temperature (AT), water temperature (WT), water depth (WD), water velocity (WV), transparency (T) & pH were measured in situ, while Total Dissolved Solids (TDS) was determined in a laboratory. The data collected were analysed on the bases of two seasons & five sub-seasons: Early dry (EDS); mid dry (MDS); late dry (LDS); Early rainy (ERS) and flood period (FPS). WT was highest (28.2±1.45°C) during LDS & lowest (18.94±1.39°C) during MDS, T was highest (52.1±2.48cm) in EP during LDS & lowest in MIC during ERS, WD was highest (3.9±0.26m) in MIC& lowest in EP both in MDS, pH was highest (7.7±0.22) & lowest (6.5±0.81) both in EP during LDS & MDS respectively, TDS was highest (88.0±7.5mg/l) in MDC during MDS & lowest (38.5±4.01mg/l) in EP during ERS. Results were compared with recommended water quality values for human consumption, aquatic life and fish production. It was concluded that the water bodies were safe with regards to the parameters investigated.

Keywords:
Bakolori, Physicochemical, Water, Nigeria

Introduction

Water is very important to aquatic organisms, for survival, nutrition, growth, excretion and reproduction (Boyd, 1979). Aquatic ecosystems are highly dynamic and subject to pollution which creates serious problems causing extensive damage to the environment and the living aquatic organisms (Martin and Hidayathulla, 2007). Good quality water availability is among the basic needs of living organisms and the quality of water for human consumption, aquatic life and for fish production depends on three major factors which interrelate to produce some specific quality parameters that make water to be either of good or bad qualities (Beadle, 1974). 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).

The Bakolori Irrigation Project (BIP) 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, forestry development as well as electricity power generation. There is paucity of information on water quality status of water bodies in irrigation systems of Nigeria and BIP in particular (FAO, 2004). Earthen ponds in BIP have not been assessed for water quality (USAID, 2010). The research was designed to examine some physicochemical parameters of main irrigation canals, earthen ponds and main drainage canals within the command area of BIP and compare them to recommended water quality values for human consumption, aquatic life and fish production.

Materials and Methods

Study Area

The BIP is located 110 km 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). 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). The mean annual rainfall is about 500mm (FAO, 2004) 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, 1993). The temperature ranges between 25^{0}C and 35^{0}C (FAO, 2004), and extreme heat is experienced before the rainfall (Yahaya, 2002).

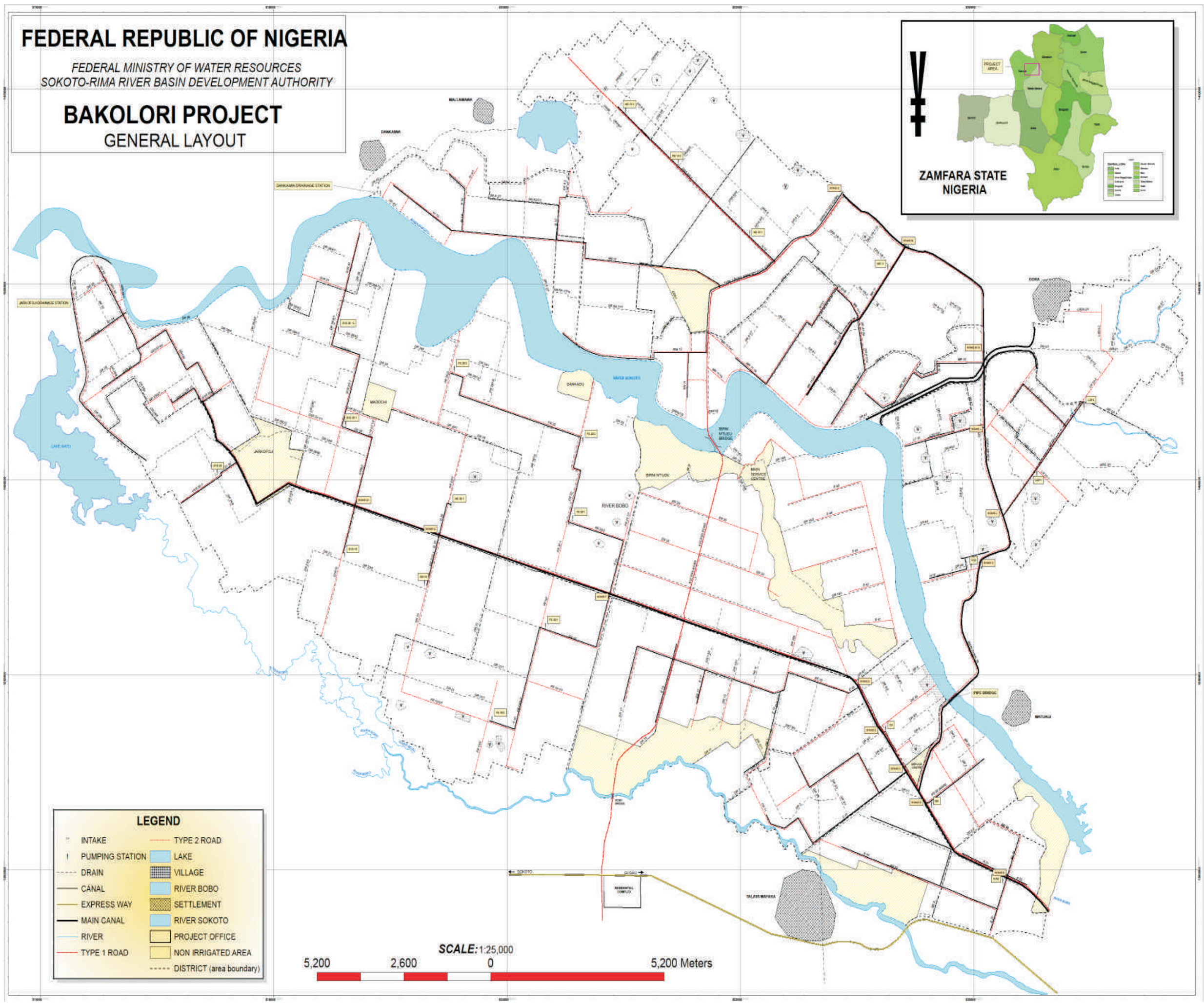

Figure 1: General Layout of Bakolori Irrigation Project
Source: USAID (2010)

The components of the gravity fed system include: A 15 km-long concrete lined supply canal; Two concrete lined main canals totalling 45 km of length; Concrete lined secondary canals totalling 200 km of length; Tertiary canals (earthen) totalling 300 km of length, and Field ditches (earthen) totalling 400 km of length (FAO, 2004).

Sampling Procedure

Twelve sampling stations denoted as A, B, C, D, E, F, G, H, I, J, K and L were located within the study area.

* Stations A,B,C and D were systematically located on the left main canal.
* Stations E,F,G and H were randomly selected from the 17 earthen ponds.
* Stations I,J,K and L were purposively located on the main drainage canals.

Collection of Water Samples and Water Analysis

Water samples were collected as described by (Lind, 1979), every 7th day of the month, for a period of 12 months (March 2012 to February 2013). Each sample was replicated three times. The bottles were screwed tightly and transported to the laboratory for analysis. Air and water temperatures were determined as described by Lind, (1979), water velocity and water depth were determined as described by Slingsby and Cook, (1986), transparency was measured using a Secchi disc as described by Delince (1992) and pH was measured using a Jenway Model 3015 pH meter as described by Stirling, (1985) at each sampling station every month. While TDS was determined using the water samples collected, in the Agric. Chemical Laboratory, Usmanu Danfodiyo University, Sokoto.

Results

The overall/seasonal and sub-seasonal mean parameters values are contained in Tables 1 and 2 respectively, while the trends of mean monthly values are shown in Figures 2 to8.

Table 1: Mean seasonal and overall mean values of some physicochemical parameters of three water bodies of Bakolori Irrigation Project, Zamfara State, North Western Nigeria

Parameter	Water Body	Dry Season	Wet Season	Overall Mean
Air Temp (°C)	Main Canal	27.8± 4.4	28.7± 3.3	**27.5 ±4.2**
	Pond	27.6 ±4.7	27.9 ±2.1	**27.7 ± 4.0**
	Drainage canal	28.6 ±5.6	28.1 ±2.2	**28.7 ±4.8**
	Mean	**27.8± 4.9**	**28.3 ±2.6**	
Water Temp (°C)	Main Canal	24.8 ±3.7	26.1± 1.8	**25.2 ±3.3**
	Pond	25.3 ±3.8	26.2 ±1.6	**25.6 ±3.3**
	Drainage canal	25.6 ±4.3	26.7 ±1.5	**26.0±3.6**
Transparency (cm)	Main Canal	12.6 ±6.5[b]	5.8 ±1.5[c]	**10.1 ±6.2[c]**
	Pond	39.9 ±17.8[a]	43.4± 6.5[a]	**41.3 ±14.5[a]**
	Drainage Canal	12.6± 5.7[b]	12.8± 10.8[b]	**12.6 ±7.7[b]**
Velocity (m/s)	Main Canal	0.61± 0.18[a]	0.24± 0.07[b]	**0.48± 0.18[a]**
	Drainage Canal	0.19± 0.10[b]	0.48± 0.15[a]	**0.29± 0.18[b]**
Depth (m)	Main Canal	2.98± 1.03[a]	3.00± 0.64[a]	**2.98± 0.91[a]**
	Pond	0.91± 0.53[c]	1.50 ±0.30[b]	**1.11± 0.54[c]**
	Drainage Canal	1.24± 0.77[b]	1.74± 0.97[b]	**1.40 ±0.87[b]**
pH	Main Canal	6.7 ± 0.88	6.5 ± 1.01	**6.7 ± 0.94[a]**
	Pond	6.7 ± 1.16	6.5 ± 0.99	**6.5 ± 1.11b**
	Drainage canal	6.6 ± 1.04	6.6 ± 0.74	**6.6 ± 0.95[ab]**
TDS (mg/l)	Main Canal	53.2 ±9.6[c]	49.2± 5.6[b]	**52.1± 9.5[c]**
	Pond	64.1 ±11.2[b]	45.3 ±6.3[c]	**57.0 ±10.5[b]**
	Drainage Canal	69.0 ±13.2[a]	61.1 ±7.2[a]	**67.6 ±8.3[a]**

Values are Means ± standard deviations

Means in a column with same superscript were not significantly different (P>0.05)

Table 2: Subseasonal mean values of some physicochemical parameters of three water Bodies in BIP

Parameter	Water Body	Subseason				
		Late Dry (Mar-May) 2012	Early Rainy (June July)	Flood (Aug-Sept)	Early Dry (Oct Dec)	Mid Dry (Jan Feb) 2013
Air Temp (°C)	Main Canal	30.8±4.17	29.1± 4.14	27.7±1.89	27.9± 1.90	21.0± 1.5
	Pond	30.8±4.31	28.5±2.19	27.5±2.03	27.6±1.87	21.1± 1.8
	Drainage canal	31.7±4.78	27.8±2.39	28.3±1.99	28.5±2.00	21.3±1.17
	Grand mean	**31.3±4.39^a**	**28.5±2.88^b**	**28.1±2.23^b**	**28.8±1.79^b**	**21.1±1.17^c**
Water Temp (°C)	Main Canal	26.5±2.82^b	25.6±1.65^{ab}	26.3±1.90	25.4±1.22^b	18.94±1.39
	Pond	27.8±2.20^a	26.1±1.41^a	26.2±1.74	26.6±1.39^a	19.4±0.92
	Drainage canal	28.2±1.45a	24.7±0.95^b	26.6±1.46	26.8±2.65^a	19.2±1.06
Transparency (cm)	Main Canal	5.9±0.37^c	5.4±1.18^b	6.1±1.74^c	14.6±4.32^c	20.2±0.95^a
	Pond	52.1±2.48^a	43.0±7.95^a	43.7±4.91^a	27.7±18.23^a	-
	Drainage canal	7.8±0.99^b	6.2±1.49^b	19.3±12.13^b	18.0±5.63^b	11.6±1.03^b
Velocity (m/s)	Main Canal	0.3±0.01^a	0.3±0.04^a	0.17±0.02^b	1.2±0.94^a	0.2 ±0.06^a
	Drainage canal	0.10±0.09^b	0.10±0.09^b	0.8±0.33^a	0.4±0.23^b	0.14±0.11^b
Depth (m)	Main Canal	3.1±0.15^a	3.1±0.13^a	2.9±0.91^a	1.9± 1.22^a	3.9±0.26^a
	Pond	1.4±0.15^b	1.7±0.11^b	1.2±0.15^c	0.8± 0.28^c	0.2±0.05^c
	Drainage canal	1.5±0.09^b	1.2±0.49^c	2.2±1.05^b	1.4 ±0.99^b	0.4±0.16^b
pH	Main Canal	7.5±0.23	7.0±1.02^a	6.7±0.53	6.7± 0.67	6.6 ±0.16
	Pond	7.7±0.22	6.7±1.15^b	6.8±0.55	6.8 ±0.92	6.5± 0.81
	Drainage canal	7.6±0.17	6.8±0.86^b	6.6±0.16	6.7 ±0.40	6.6±0.46
TDS(mg/l)	Main Canal	40.6±5.04^b	47.9±5.06^b	56.14±7.01^b	79.10±11.0^a	47.5±3.70^c
	Pond	47.3±6.10^a	38.5±4.01^c	52.05±7.03^c	59.3±5.11^c	80.5±9.4^b
	Drainage canal	47.6±5.4^a	63±10.01^a	59.5±08.2^a	66.8±7.07^b	88.0±7.5^a

Values are Means ± standard deviations.
Means in a column with same superscript were not significantly different (P>0.05)

Discussion

The highest AT in the LDS (Table 2) could be due to hot weather of the subseason, while the lowest in the MDS could be due to the cold dry season (Abohweyere, 1990). The lowest WT of the three water bodies during the MDS were below the recommended temperature range of 25ºC to 35ºC for aquatic life (Charkroff, 1976), but very close to the optimum (20ºC to 25ºC) required for a tropical fish, *Cyprinus carpio* (Charkroff, 1976). Moreover, with the exception of the MDS, all the subseasonal (Table 2), seasonal and overall mean values (Table 1) of WT were within the recommended temperature range for aquatic life (Charkroff, 1976) and 25ºC to 32ºC for fish production (Boyd, 1979). The highest WT in the LDS could be due to hot weather, resulting from high solar radiation and reduced cloud cover (Golterman, 1975) while the lowest in MDS could be due to the influence of the cold dry season (Abohweyere, 1990). This agrees with the findings of Onaji *et al*. (2005) and Abubakar *et al*. (2013) who recorded highest WT in LDS and lowest in MDS in Kware Lake and Sokoto Rima River system respectively in North-Western Nigeria. WT was generally lower than the air temperature throughout the study period; this could be due to low specific heat capacity of the water bodies (Dupree and Hunner, 1984).

The low transparency (highest turbidity) of the MIC water could be due to suspended particulate matter, from surface runoff that entered the Bakolori Reservoir that feeds the canals, which might have contained organic and inorganic matters that rendered the water less transparent (Boyd, 1979) and the highest value in MDS could be due to high concentration of calcium and sodium ions, causing coagulation of aggregates and sedimentation of suspended particulate matters (Delince, 1992). Lowest Pond water value in EDS could be due to the increase in the phytoplankton biomass, which impacted characteristic greenish colour (Delince, 1992). It was however highest in LDS, possibly due to settling of suspended particulate matter in the water fed from the MIC in that subseason, since the ponds were stagnant or due to high concentration of calcium and sodium ions which caused coagulation of aggregates (Delince, 1992). The lowest value of MDC water in ERS could be partly due to the presence of phytoplankton and residual water from the irrigated fields containing loosen soil particles (Okayi *et al.,* 2001), while the highest in FPS could be due to the settling of the suspended particulate matter and lack of inflow of residual water from the fields, because it was during the FPS that rice grown in the fields were mostly harvested. Most seasonal and overall mean values of MIC & MDC (Table 1) were below the recommended Secchi Disk reading of (30-60cm) for fish production (Boyd, 1979). But MDC turbidity was due to both phytoplankton and suspended particulate matter including loose soil from irrigated agricultural fields (Okayi *et al.,* 2001). Moreover, fishes such as Tilapia and Clarias spp. were seen during the water sample collection; therefore, fish can survive there despite the low transparency. Pond Transparency values were within the recommended for fish production (Boyd, 1979).

The lowest WD in EDS could be due to lack of water released from the reservoir during the subseason, because the irrigation fields were being prepared ahead of the next dry season production. The reverse was the case in LDS when the water level was highest because the irrigation activities were in full operation. The lowest Pond WD in MDS is likely because the ponds are partially drained for harvesting towards the end of the year in EDS and refilled with water in LDS for stocking. Hence it is very likely that the ponds are either shallow or empty during the MDS. The highest WD in ERS is however expected, because, the ponds are usually filled with water from the MIC in LDS prior to stocking and subsequently, replenished by residual water from the surrounding irrigated fields. The minimum WD of MDC in EDS could be due to the fact that there was no residual water from the irrigated fields as they were mostly harvested and the next cultivation was yet to commence. While the maximum WD recorded in the FPS could be due to runoff water from the irrigated fields and the environs. Mean depth of EP and MDC water were within the recommended range of 1 to 1.5m for fish production (Boyd, 1979).

The lowest WV of MIC in FPS could be due to lack of water released from the reservoir while harvesting. The highest value in EDS was due to high water released from the reservoir in October for management purposes as most plots were harvested and the canals were emptied and dried in November. The lowest WV for MDC in LDS and ERS might have been due to absence of, or little residual water from the irrigated lands. The highest value in FPS could be due to runoff from the irrigated lands which normally drain into the drainage canals.

Highest pH values of the three water bodies in LDS may be due to the presence of basic ions like potassium, Nitrate, phosphate, etc, in the water bodies. The values were within the range of 6.5-8 recommended for fish production in fresh water (Delince, 1992). The lowest pH in MDS could be due to decay of organic matter and suspension of sediment (Wade and Anadu, 1987). These are below the optimum levels but are however above the pH value of 4 considered dangerous to most fish (Delince, 1992). The LDS and ERS and seasonal values are within the recommended water quality standard of 6.5-9.2 for drinking water (WHO, 1993), 6.5 to 9 for fish production (Boyd, 1979) and 6-9 for aquatic life in fresh water (Roberts, 1978), while the values of EDS, MDS and FPS were slightly below the range.

The highest TDS value for MIC in EDS could be due to concentration of dissolved minerals caused by evaporation, seepage and least amount of water in the canal during the subseason (Table 2), because, most fields were being prepared for the next dry season operation. The highest TDS in EP and MDC water during MDS could be due to least amount of water in that subseason, because, there was no release of water from the reservoir. The lowest TDS of the water bodies in the corresponding subseasons could be attributed to the large amount of water they contained in the respective subseasons which might have diluted the dissolved solid content (Golterman, 1975). The values recorded in the present study (Tables 1 & 2) were below the 100mg/l water quality standard for aquatic life (Vizeau, 1989), 500mg/l for drinking water (FEPA, 2003) and 71.53±30.44mg/l of Kware Lake (Onaji *et al.,* 2005), but higher than 0.47±0.2mg/l reported for Sokoto-Rima River system (Abubakar *et al.,* 2013).

Conclusion

The study revealed the levels of some physicochemical parameters of three water bodies in BIP. Season, nature of the water bodies (especially for transparency & velocity), 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 parameters. The parameters were mostly within the acceptable levels for drinking water, aquatic life and fish production. It is therefore concluded that the Ponds, Main Irrigation Canals and Main Drainage Canals waters of BIP are of reasonable water quality for human consumption, aquatic life and fish production in terms of the physicochemical parameters studied.

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