Assessment of Water Quality around Selected Dams and Irrigation Projects in Nigeria

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Abstract

This study assesses quality of water sources within dams and 4 irrigation project (Gurara Irrigation Project, Bakolori Irrigation Project, Oyan Irrigation Project, and Isampou Irrigation Project) sites located in 4 river basins (Upper Niger, Sokoto-Rima, Ogun-Oshun, and Niger-Delta) across Nigeria. Water samples were collected in each of the 4 different locations and analysed at Kaduna Environmental Protection Authority (KEPA) Laboratory, using Atomic Absorption Spectrometer (AAS) among others, focusing on the concentration levels of key water parameters including physio-chemical, heavy metals, and microbial count. The two-way ANOVA was conducted for the laboratory results of all 7 heavy metals as a basis for understanding the impact of both location and heavy metal type on the concentration of heavy metals in the water. The outcome of the two-way ANOVA analysis reveals that there is no significant difference in the mineral contamination of Cu, Cr, Fe, Mg, Mn and Zn across all 4 locations. Only Ca appears to have recorded a significant divergence in the records from the 4 project sites. The result also reveals EC, Na and K with mean concentration values above permissible limit (APL) for irrigation standards as well as for drinking water set by the WHO (2012). The microbial counts for Total Coliform Count (TCC), Thermo Tolerant Count (TTC) and Bacterial Count in majority of the samples assessed were relatively high. Based on the result, the study recommends periodic water quality monitoring in the study areas with the view to early detections and treatment.

Keywords: Dams, Irrigation projects, water quality, River Basin Development Authorities (RBDAs), Nigeria

Introduction

Water quality is an important parameter touching on all aspect of ecosystems and human well-being including food production, economic development, ecosystem, health and biodiversity (Ayoade, 1988; UN Water, 2010). The utility of water is limited by its quality which makes water suitable or unsuitable for particular usage. Water quality from management perspective is defined by it desired end use. Consequently, water for recreation, fishing, drinking and habitat for aquatic organism required higher levels of purity. For this reason, water quality is taken on a broad definition as the physical, chemical and biological characteristic of water necessary to sustain desired water uses (UN/ECE, 1995). It is a measure of the condition of water relative to the requirement of one or more biotic species or to any human need or purpose. It is mostly used by reference to a set of standards against which compliance can be assessed. The most common standards to assess water quality relates to drinking water, safety of human contact and for the health of ecosystem. Thus, water quality is therefore, defined as water which is safe for drinking and appealing to all life on earth. This implies that the water should contain no chemical as radioactive substance that are harmful to the health of any life; the water must be free from disease causing organisms and stable in terms of corrosion (Nwankwo, 2012).

Water quality for irrigation purposes generally takes into account certain factors including the capacity of the crop or tolerance to salinity, sodium concentration and phytotoxic trace elements. The effect of salinity on the osmotic pressure in the unsaturated soil zone is one of the most important water quality considerations because this has an influence on the availability of water for plant consumption (Kadyampakeni; Appoh, & Barron, 2018, Adamu, 2013, Ayers & Wescot, 1985). Sodium in irrigation waters can adversely affect soil structure and reduce the rate at which water moves into and through soils. It is also a specific source of damage to fruits. Phytotoxic trace elements such as boron, heavy metals and pesticides may stunt the growth of plants or render the crop unfit for human consumption or other intended uses. All these point to the fact that poor quality water when used for irrigation tend to affect crops by causing accumulation of salts in the root zone, loss of permeability of the soil due to excess sodium or calcium leaching, or by containing pathogens or contaminants which are directly toxic to plants or to those consuming them (White, & Broadley, 2003).

Contaminants in irrigation water also render the soils unfit for agricultural production overtime if left unchecked. Even when the presence of pesticides or pathogenic organisms in irrigation water does not directly affect plant growth, it may potentially affect the acceptability of the agricultural product for sale or consumption. Giving the importance of water to human existence, it is pertinent to not only ensure it availability but also to ensure that quality is guarantee for desired usage. Therefore, it is important that a holistic and sustainable approach is adopted in the process of water resources development and management. Thus, in recent times, questions of sustainability contextual (the difference in environmental quality vis-à-vis physical developments) and measures put in place to mitigate or prevent further pollution has been growing, assuming even greater international and cross-disciplinary dimensions as the scale and ramifications of these issues escalate. These discussions are best reflected in the sustainable development goals (SDGs) and other relevant international sustainability instruments such as the Kyoto Protocol, the Clean Development Mechanism (CDM), the United Nations Framework Convention on Climate Change (UNFCCC), the World Bank Environmental and Social Guidelines, the International Standards Organisation (ISO) suite of Environmental Management Systems (EMS) just to mention a few (UN, 2015; UNDP, 2018; Tyoto Protocol, 1997 & UNFCCC, 1992)

In Nigeria, the government's efforts toward development led to the establishment of River Basin development authority (RBDA) in 1976 domiciles in the federal ministry of water resources and environment. The 12 RBDAs were created with the purpose of harnessing both ground and surface water resources for the nation's development including irrigation agriculture, hydropower generation, provisions of public water supply amongst others. These led to the construction of dams that create reservoirs for storage and future distribution of water as an efficient way to manage water resources for human needs. Construction of dams in Nigeria has been on the rise in the past decade, to curb the rising demand for water (Oiganji, Onwuegbunam, Onwuegbunam, & Abok, 2019, ICOLD, 1999; Asmal, 2009).

Dams are structures built to retain water by forming a reservoir behind the structure. They are usually built across or near naturally flowing water to manage the water for human use (BDS, 2015). Every dam causes temporary or permanent submergence and in some cases the displacement of people and property (ICID, 2011). Though, dams are supposed to bring about development in areas of water supply, irrigation for agricultural purpose and the generation of hydro-electric power, but it has also created environmental and social challenges within and around communities where they are located. These challenges are aggravated by the increase in population and urbanisation which contribute to water demands and pollution (Oiganji, Onwuegbunam, Onwuegbunam, & Abok, 2019, Coboum & Segale, 2003; Ali, 2008). The pollutants usually find their way into water bodies through direct pumping, deliberate channelling, overland flow and inflow; this may lead to health related challenges (Odjugo & Konyeme, 2008; Toufeek & Korium, 2009). The health impact of dams to human health consist mainly of water related diseases including death, disability, illness and disorder are caused directly or indirectly by the conditions or change in the quality of any water (WHO, 2000).

The Nigerian government has developed the National Irrigation/Drainage Policy & Strategy (NIDPS) published in 2015 by the FMWR, and supported by the Food and Agriculture Organisation (FAO) of the United Nations. The NIDPS provides a synoptic background on the current status and contributions of irrigation to Nigeria's economy, eventually x-raying 7 broad emerging issues of population expansion, conflicts, low productivity and low return on investments, environmental imbalances, under-utilisation of water and land resources, low regulation capacity, and low user inclusiveness (Federal Ministry of Water Resources, 2015).

Given these policy provisions, guiding principles and implementation strategies, the NIDPS will be actively considered and incorporated into the irrigation components of these RBDAs. Considering the life span, scale and footprint of existing and proposed infrastructure for the various projects (irrigation of thousands of hectares of plantations, processing of farm yields, hydro-power generation, fisheries, municipal water usage) at the 4 RBDAs reviewed, it is instructive to also note the possibility of injecting various forms of pollutants into the environment from the range of envisaged activities across the focus RBDAs as production becomes highly rationalized through operational efficiency. This study is therefore, a response and contribution to this current sustainability discourse as it is set to determine the current water quality statuses around irrigation projects development at selected river basins across Nigeria, with the view to addressing water quality challenges for sustainable development

MATERIALS AND METHODS

Study Area

Locational Context

The 4 River Basin Development Authorities (RBDAs) under this study (Sokoto-Rima, Upper-Niger, Ogun-Oshun and Niger-Delta) comprise a vast expanse of land area covering about 13 States while the main projects investigated are located in 4 States across 3 of Nigeria's 6 geo-political zones (Figure 1). Table 1 show the study areas (project sites) where the water samples were taken. The areas of interest to this study include water sources within the vicinity of dams and irrigation project sites in the 4 RBDAs listed in Table 1. Of then 4 RBDAs covered under this study, the Niger-Delta RBDA is the only one without a dam because of the generally low-lying elevation of the region which is around 0m – 10m above sea level. It is also important to note that these projects and RBDAs are located in different geographical areas - north, south-west and south-south regions of Nigeria.

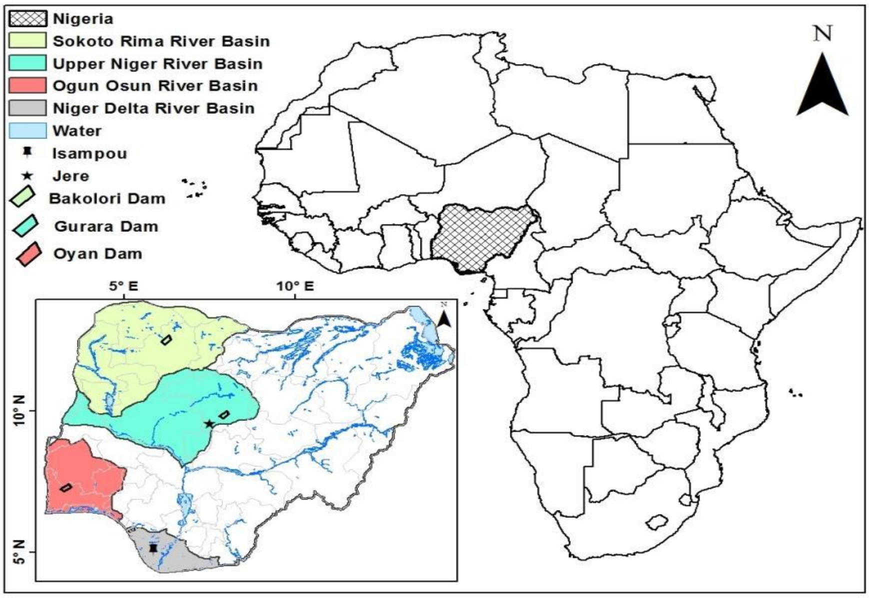

Figure 1: Location of the 4 pilot RBDAs within the context of Nigeria

Table 1: Dams & irrigation projects investigated in this study

S/N	RBDA	Dams/Projects	Size of Basin	Status	Period of Field work
1.	Sokoto-Rima River Basin (Zamfara State, North-West)	• Bakolori Irrigation Project	1592.163 km^2	No EIA study	10^{th}–17^{th} April 2019
2.	Upper Niger River Basin (Kaduna State, North-West)	• Gurara Irrigation Project; • Azara/Jere Irrigation Project	1226.385 km^2	EIA Study Report submitted in 2005	22^{nd}–29^{th} April 2019
3.	Ogun-Oshun River Basin (Ogun State, South-West)	• Oyan Dam	636.453 km^2	No EIA study	5^{th}-12^{th} May 2019
4.	Niger Delta River Basin (Bayelsa State, South-South)	• Isampou Rice Irrigation Project	298.908 km^2	EIA study Report submitted in 2001	12^{th}–19^{th} May 2019

Source: Authors' Fieldwork, 2019

2.1.2. Physico-Environmental Context

Given the varying locations across the country of the 4 RBDAs, there is obviously a clear diversity in climatic and physical conditions of the study locations. Generally, the climate in the southern part of Nigeria (within which 2 of the pilot RBDAs are located) fall within the tropical wet and dry Am by Koppen's classification in the wet-sub-humid agro-ecological zone of Nigeria, with an annual average rainfall range of between 2,000mm and 4,000mm; a short temperature range between a low of 26^0C and a high of 30^0C. For the 2 RBDAs in the northern part of Nigeria (Upper Niger and Sokoto-Rima), the climate generally falls within the tropical wet and dry Aw by Koppen's classification in the dry-sub-humid agro-ecological zone of Nigeria, with an annual average temperature ranging between 33.5^0C (high) and 20.1^0C (low); 980mm of rainfall. For both north and south, there is a clearly marked rainy and dry seasons with the south receiving more rainy days than the north. Similarly, the elevation between these RBDAs differ significantly as shown in Figure 2a (digital elevation model) and 2b (topography) with the least elevation expectedly recorded at the Niger Delta RBDA, and highest elevation recorded in the Sokoto-Rima RBDA. The vegetation in the south is mainly consisted of the mangrove forest (Niger Delta RBDA) and rain forest (Ogun-Oshun RBDA) while in the north, the vegetation is predominated by sudano-sahelian savannah (Sokoto-Rima RBDA) and tropical grassland and guinea savannah (Upper Niger RBDA).

The phenomenon of high runoff and a relatively high water table (often during rainy seasons) makes lands, like the fadama soils found along the drainage systems in the northern-based RBDAs (especially in and around cities and towns), prone to salinity/sodicity development. Regular monitoring of groundwater table fluctuation and irrigation water quality in the fadama lands is therefore, necessary in order to detect potential incidences of salinity hazards and proffer timely interventions including design and installation of surface or sub-surface drainage systems, adopting conjunctive use of surface and groundwater supplies for all-year-round urban agricultural productivity.

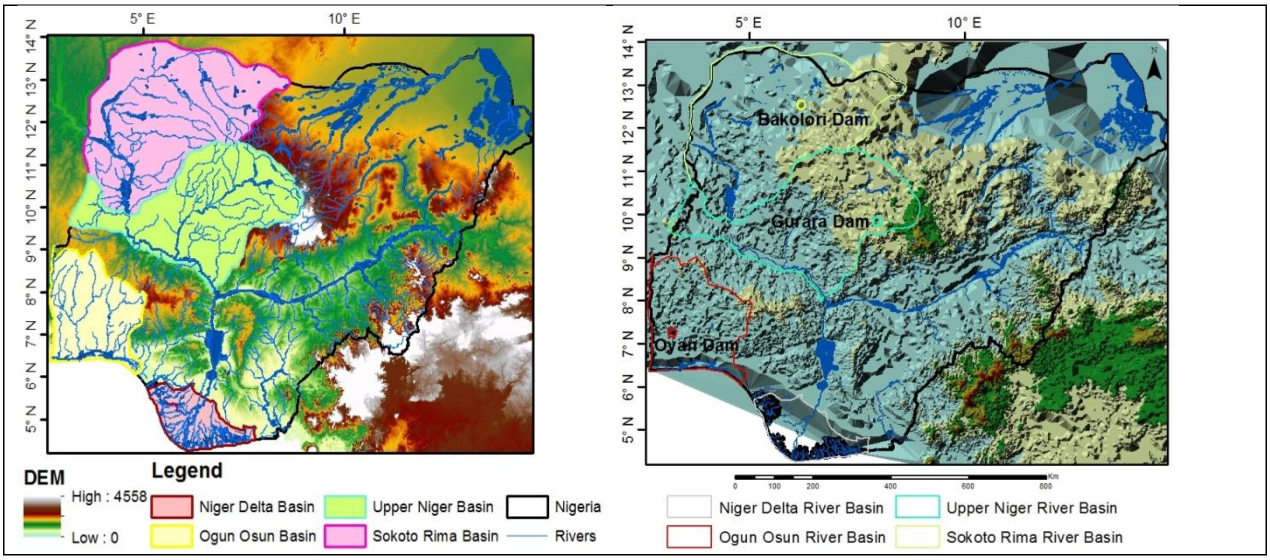

Figure 2: (a) Digital elevation model (DEM), and (b) topographic map of the 4 RBDAs under study

Socio-Economic Context

Within each of the 4 RBDAs, there are a number of large urban centres including Sokoto, Gusau, Birnin-Kebbi, Talata-Mafara, Dutsinma, Goronyo, for Sokoto-Rima RBDA; Kaduna, Minna, Zaria, Kontagora, Zungeru, Gwagwalada, Yaba, Abaji, for Upper Niger RBDA; Abeokuta, Iseyin, Ogbomosho, Itoikin, Sagamu, Ibadan, for Ogun-Oshun RBDA; and Port-Harcourt, Yenagoa, Warri, Asaba, for Niger Delta RBDA. These cities and towns play major commercial, trado-religious, industrial, administrative and educational roles within the context of Nigeria. Immigration, natural growth rate, administrative, educational and increasing commercial activities continue to increase the population and spatial size of these cities and towns. The current population of Nigeria was recently estimated at 201million growing at a 2.60% annual rate. Generally, Nigeria's national average population density is 267 inhabitants per km^2 (Oak Ridge National Laboratory, 2010) while a breakdown according to regions and States is presented in Figure 4. However, basin-specific population concentration is presented under the result section of each basin.

The major economic activities within the 4 named RBDAs include largely primary activities such as farming, animal husbandry, fishing, mining, and secondary activities such as buying and selling, agro-processing, and tertiary activities (mostly conducted in the urban centres) such as services (Ortserga, Kwaghsende, Dam, Kile, Ujoh, & Gyuse, 2019). By and large, the agricultural activities, fisheries, and animal husbandry are largely conducted on a non-commercial scale with limited technological input. These RBDAs comprise of different indigenous cultural groups including Hausa, Fulani, Yoruba, Nupe, Gbagyi, as well as other cultural groups who engage in seasonal occupations at specific projects within the RBDAs. Also, the land tenure system at the RBDAs vary with land ownership vested in the communities at all projects sites within Sokoto-Rima RBDA, while land ownership at Upper Niger, Ogun-Oshun and Niger Delta RBDAs projects sites is vested in the -FGN after due compensation.

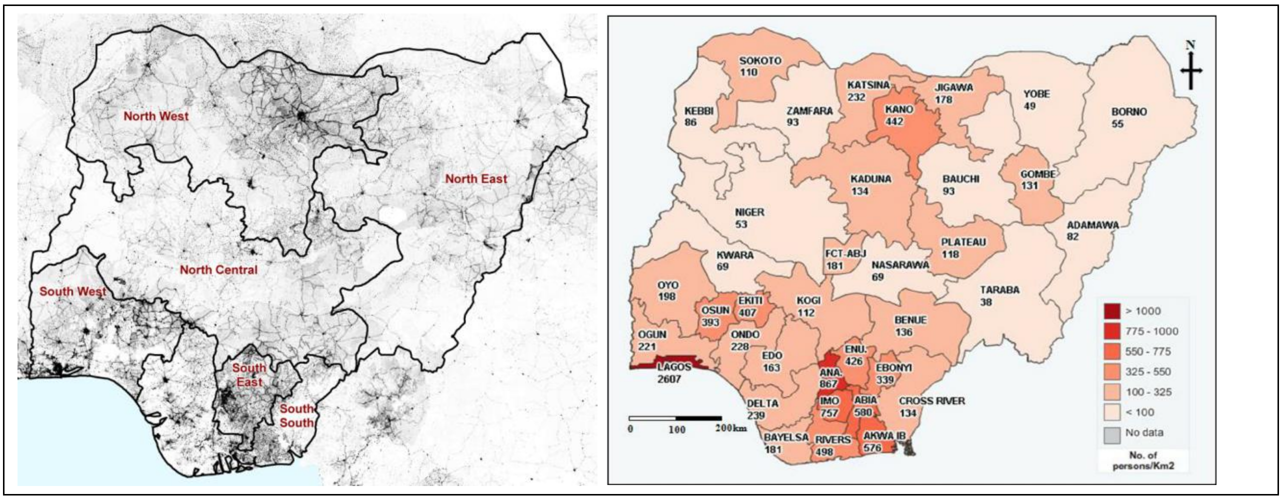

Figure 3: Population density by the 6 geo-political regions of Nigeria (Oak Ridge National Laboratory, 2010) and Population density per State (National Population Commission, 2006)

Methodology

A total of 10 water samples were collected at each of the 4 RBDAs dams/irrigation project sites from a combination of surface, and underground water sources, at different locations including the dam reservoir, main irrigation canal, creek/natural canal, hand-dug wells for irrigation, isolated ponds, boreholes and wells at host communities, river channels downstream of reservoir. The samples were collected during the rainy season except for the Sokoto-Rima basin located in the extreme north-west part of Nigeria where rains arrive later than April. Each of the water samples point was geo-referenced using hand-held GPS equipment, and subsequently mapped. These water samples were analysed at the Kaduna Environmental Protection Authority (KEPA) Laboratory in Kaduna State, using Atomic Absorption Spectrometer (AAS) among others, on 24 parameters (Table 2) which include physico-chemical, heavy metals and biological parameters. These parameters are selected by way of modification of the Irrigation Water Quality Tool (IWQT) proposed by Bortolini et al., (2018).

Table 2: Parameters tested in water sample at all 4 pilot RBDAs project sites

Category	**Parameters**
Physical/Chemical Parameters	pH, Electric Conductivity (Ec), Temperature, Dissolved Oxygen (TDO), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity, Total Hardness, Chemical Oxygen Demand (COD)
Heavy Metal	Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Copper, Chromium (Cr), Manganese (mn), Lead (Pb), Zinc (Zn), Iron (Fe)
Biological Parameters	Total Coliform Count, Faecal Coliform Count, Biochemical Oxygen Demand (BOD), Thermo Tolerant Coliform (or E.coli), Faecal Streptococcus, Clostridium Perfringens Spore

The results from laboratory and field analyses of various parameters were subjected to descriptive statistical analysis and two-wayanalysis of variance (ANOVA) to ascertain the statistical significance of the degree of variation between the results of the various locations of each sample type. Furthermore, the mean values of results generated from water sampling were compared to acceptable/prescribed/recommended levels and standards by WHO, FAO, Nigeria's Federal Ministry of Environment and other well-researched and documented sources in the literature.

Results and Discussions

The results of the water quality analysis in the study areas is presented and discussed under physico-chemical, heavy metals and microbial parameters of water in the study area. Irrigation water, irrespective of source, contains appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. In addition to the dissolved salts which have been the major problem for centuries, irrigation water carries substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). These substances may vary in a wide range, but mainly consist of dirt and suspended solids (SS) resulting into the emitters' blockages in micro-irrigation systems and bacteria populations and coliforms harmful to the humans and the animals. Basically, certain water elements have a higher potential to disrupt crop productivity. It is therefore, essential to understand the quantum of occurrence of these elements in water sources around irrigation project sites (Brady and Weil, 2002; Seid and Genanew, 2013).

Physico-chemical parameters of water quality in the study areas

The results of the laboratory water analysis of this study showing the concentration levels of physico-chemical characteristics is presented in table 3 (see appendix 1). The information in table 3 show mean values for hardness, pH, COD, BOD, TDS, and TSS all occur below permissible limit (BPL) while EC, Na and K exhibit mean concentration values above permissible limit (APL) for irrigation standards as well as for drinking water set by the WHO (2012). Given that the mean value of sodium recorded is APL, the implication is that both soil and plants would be adversely affected as sodium once deposited from irrigation water, it becomes relatively impermeable to air and water (Husien et al., 2017). When crop roots are exposed to high sodium concentrations, it causes wilted foliage and stunted plant growth. This is because excessive salts in soil impede plants' uptake of water and cause plant tissues to become dry and discoloured. All water samples recorded pH values below 6.5, an indication of high acidic concentration. It is important to note that for EC, TDS, TSS, COD and BOD, the limit adopted is for irrigation purpose while all other limits are adopted for drinking water as provided by WHO (2012) guidelines for drinking water. This is considered relevant as it was observed during field work that most of the communities around these dams actually use reservoir water for drinking and other domestic uses. The EC levels are exceedingly high for both irrigation water and for drinking hence, posing the risk of affecting other nutrient occurrence in the soil and uptake by plants (Signore, Serio, Santamaria, 2016, Samarakoon, Weerasinghe, & Weerakkody, 2006).

Heavy Metals

Heavy metals are basically non-degradable elements that are harmful to human, plant and animal populations. Their occurrence is largely associated with anthropogenic activities including certain agricultural practices such as use of certain synthetic fertilisers, pesticides and herbicides. The result of the laboratory analysis of heavy metals in water sources in the study areas is presented in table 4 (see Appendix 2). The information in table 4 shows that concentration levels of heavy metals from water samples in the study areas varies. Ca, Fe, Mg, and Zn concentration levels were found to be above permissible limit (APL) in all the irrigations sites; Mn concentration level was found to be APL at Gurara & Azara/Jere, Bakolori and Oyan irrigation sites only; Cu and Cr was also APL at Isampou irrigation sites. Meanwhile Pb was not found in any of the irrigation sites in the study areas despite the rate of mining and associated lead poisoning prevalent in Zamfara State. The permissible limits adopted for heavy metals are those prescribed by WHO (2012) guidelines for drinking water. The excessively high concentration of these heavy metals which are non-degradable, toxic and can be consumed by locals either through raw water intake, fish or farm produce has serious health concerns. For instance, it has been reported that excess calcium makes the kidneys work harder to filter it. This can cause excessive thirst and frequent urination. Too much calcium in the blood weakens the bones, create kidney stones, and interfere with how the heart and brain work (https://www.mayoclinic.org/diseases-conditions/hypercalcemia/symptoms-causes/syc-20355523#:~:text=Excess%20calcium).

In plants, White & Broadley (2003) reported that when excessive Ca is present in the rhizosphere solution, plants may suffer Ca toxicity. This may prevent the germination of seeds and reduce plant growth rates. Implication of high concentration of iron (Fe) in water content when consumed overtime leads to an overload which can cause/induced diabetes, hemochromatosis, stomach problems, and nausea. It can also damage the liver, pancreas, and heart. Gladis, & Xiufu (2023) reports that irrigation water with iron levels above 0.1 ppm may cause clogging of drip irrigation emitters and above 0.3 ppm may lead to iron rust stains, and discoloration on foliage plants in overhead irrigation applications. These levels are generally below the levels that cause toxicities in plant tissue except when iron levels exceed 4 ppm or when the root medium pH is below 5.5

Microbial Count

Microbial count indicates how many microorganisms such as bacteria; viruses and protozoans are present in water samples. Monitoring the total bacteria count is necessary, because the number of microorganisms shouldn't exceed certain guide values. The result of microbial analysis of water samples in the study areas is presented in table 5 (see Appendix 3). The microbial count analyses as presented in table 5 revealed that the Faecal coliform, Faecal Streptococus and Clostridium Perfringens Spore were not present in all the samples across the study areas. However, there were relatively high microbial counts for Total Coliform Count (TCC), Thermo Tolerant Count (TTC) and Bacterial Count in majority of the samples assessed.

The result reveals that at Gurara & Azara/Jere Irrigation sites Sample H records the highest TCC, Sample E records the highest aerobic and anaerobic bacterial count. At Bakolori Irrigation Project sites, microbial & bacterial contents of the sample I, G, F & C were essentially high. Since most of the communities around these irrigation/dam project sites were seen using these water sources for human consumption, they are at risk of contracting/suffering from water-borne related illnesses with common symptoms including gastrointestinal upset and general flu-like symptoms such as fever, abdominal cramps, and diarrhea.

Statistical Analysis

The two-way ANOVA was conducted for the laboratory results of all 7 heavy metals as a basis for understanding the impact of both location and heavy metal type on the concentration of heavy metals in the water. The outcome of the two-way ANOVA (Figure 4, Table 3 and Table 4) analysis reveals that there is no significant difference in the mineral contamination of Cu, Cr, Fe, Mg, Mn and Zn across all 4 locations. Only Ca appears to have recorded a significant divergence in the records from the 4 project sites. The summary of the ANOVA results between all 7 metals and between all 4 locations is one of the following:

Sig = 1: No significant difference (at the 0.05 level) in concentration of heavy metals between locations and interaction between heavy metal types. In practical terms, this suggests a uniform pattern across locations or metals with no special variations as observed in Table 3 for Bakolori & Gurara, Oyan & Bakolori, and Isampou & Bakolori.

Sig = 0: A statistically significant (at the 0.05 level) effect in heavy metals concentration, suggesting meaningful differences in heavy metal concentration either across locations, types of metals, or specific location-metal combinations (interaction) as recorded in Table 3 for Oyan & Gurara, Isampou & Gurara, and Isampou & Oyan.

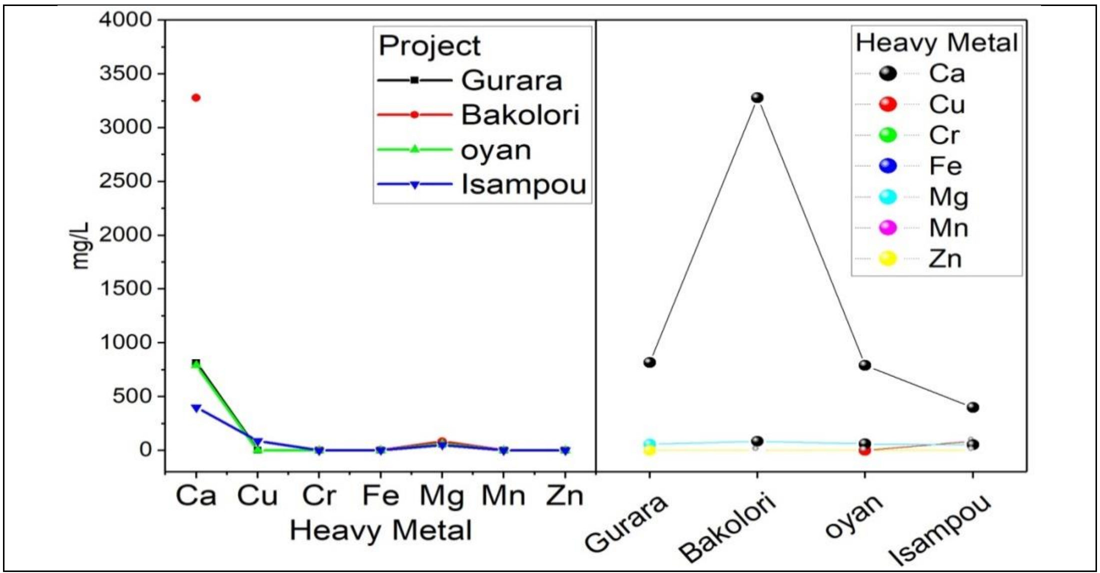

Figure 4: The two-way ANOVA for heavy metals in all project sites

Table 3: Statistical Analysis between Project Sites

Project Sites	MeanDiff	SEM	q Value	Prob	Alpha	Sig	LCL	UCL
Bakolori & Gurara	470.9024	85.95643	7.74761	6.54E-07	0.05	1	248.4913	693.3134
Oyan & Gurara	-8.25218	81.13927	0.14383	0.99962	0.05	0	-218.199	201.6945
Oyan & Bakolori	-479.155	85.1137	7.96143	3.02E-07	0.05	1	-699.385	-258.924
Isampou & Gurara	-52.9972	81.13927	0.92371	0.91436	0.05	0	-262.944	156.9495
Isampou & Bakolori	-523.9	85.1137	8.7049	1.30E-08	0.05	1	-744.13	-303.669
Isampou & Oyan	-44.745	80.24597	0.78856	0.9444	0.05	0	-252.38	162.8903

Table 4 also reveals a series of significance levels (at 0.05) in the interaction between the 7 heavy metals analysed in this study.

Table 4: Statistical Analysis between different heavy metals

Heavy Metals	MeanDiff	SEM	q Value	Prob	Alpha	Sig	LCL	UCL
Cu Ca	-1293.05	114.66098	15.94837	2.73E-09	0.05	1	-1634.06	-952.044
Cr Ca	-1322.14	111.64306	16.74795	1.27E-09	0.05	1	-1654.18	-990.108
Cr Cu	-29.0882	119.75949	0.3435	0.99998	0.05	0	-385.262	327.0854
Fe Ca	-1320.65	106.15544	17.5938	0	0.05	1	-1636.36	-1004.93
Fe Cu	-27.5929	114.66098	0.34033	0.99998	0.05	0	-368.603	313.4173
Fe Cr	1.49528	111.64306	0.01894	1	0.05	0	-330.539	333.53
Mg Ca	-1259.12	106.15544	16.77417	1.22E-09	0.05	1	-1574.84	-943.409
Mg Cu	33.93097	114.66098	0.4185	0.99994	0.05	0	-307.079	374.9412
Mg Cr	63.01919	111.64306	0.79828	0.9977	0.05	0	-269.016	395.0539
Mg Fe	61.52391	106.15544	0.81963	0.99733	0.05	0	-254.19	377.2381
Mn Ca	-1322.02	106.15544	17.61214	0	0.05	1	-1637.74	-1006.31
Mn Cu	-28.9694	114.66098	0.35731	0.99998	0.05	0	-369.98	312.0408
Mn Cr	0.11878	111.64306	0.0015	1	0.05	0	-331.916	332.1535
Mn Fe	-1.3765	106.15544	0.01834	1	0.05	0	-317.091	314.3377
Mn Mg	-62.9004	106.15544	0.83797	0.99699	0.05	0	-378.615	252.8137

Zn	Ca	-1322.02	106.15544	17.6121	0	0.05	1	-1637.74	-1006.31
Zn	Cu	-28.9667	114.66098	0.35727	0.99998	0.05	0	-369.977	312.0435
Zn	Cr	0.12149	111.64306	0.00154	1	0.05	0	-331.913	332.1562
Zn	Fe	-1.37379	106.15544	0.0183	1	0.05	0	-317.088	314.3404
Zn	Mg	-62.8977	106.15544	0.83793	0.99699	0.05	0	-378.612	252.8165
Zn	Mn	0.00271	106.15544	3.61E-05	1	0.05	0	-315.711	315.7169

Source: Authors' Analysis 2019

The key benefit of the two-way ANOVA for this study is the capacity to identify interaction effects, where the concentration of each heavy metal might vary depending on the location. For instance, certain metals might be more concentrated in industrial areas, while others might be more prevalent near agricultural sites. Similarly, an interaction effect would indicate that the concentration of a specific metal depends on the location, providing insights into localized contamination sources or environmental conditions.

Conclusion and Recommendations

The outcome of this study serves to advance the importance of assessing environmental impacts from bio-physical component, as well as measurement and intervention to relevant criteria/conditions, particularly as the resolution of central global issues of sustainability actually reside at the local level, an agglomeration of local efforts (such as this study) would, in turn, produce regional, then global effect. Additionally, the study bears in mind the many cases recorded elsewhere in Nigeria where the local/host environments bore (and continue to bear) disproportionate environmental degradation, social and health risks as completed projects agglomerate population while environmental quality (and its capacity to support them) continually decline due to the absence of an initial and subsequent periodic risks assessment of this nature.

For this study, it is crucial to assess the water quality given that environmental impact assessment (EIA) studies were not conducted for 2 of the projects (Bakolori Irrigation Project and the Oyan Dam Irrigation Project). For the Gurara Irrigation Project and Azara/Jere Irrigation Project (in Upper-Niger RBDA) and the Isampou Rice Irrigation Project (in Niger-Delta RBDA), the EIA studies were conducted in 2005 and 2001, respectively with no follow-up environmental audit almost 20 years after the EIA study was carried out. For this purpose, the study recommends periodic water quality monitoring in the study areas. To this effect, water samples should be collected from various sources of underground (hand-dug wells, tube wells, boreholes/artesian wells) and surface water (rivers, reservoirs, streams, ponds, springs) in the study areas quarterly with the view of regular assessment in relation to the WHO water standard for irrigation and domestic purposes. All water quality parameters (physical, chemical, heavy metals, and biological) should be monitored vis-à-vis the intended/existing usage as a major step towards promoting well-being of the communities around these projects and those consuming the projects from these projects sites.

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