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Eco-toxicological approach as a contribution to Integrated water Resources Management of Okpara dam at Kpassa in Benin; Toxic metals (Pb, Hg, As and Cd) assessment in Fishes (*Tilapia Guineensis)* and Freshwater

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Abstract

In this study, the concentrations of toxic metals (Pb, Hg, As and Cd) in fishes (Tilapia Guineensis) and freshwater from Okpara dam at kpassa near Parakou in Benin, were assessed using Atomic Absorption Spectrophotometer (AAS) method at the laboratory of IRGIB Africa, highly accredited. In water samples, the mean concentrations of Pb, Hg, Cd and As where 0.0174, 0.011, 0.00046 and 0.001respectively while the standard values are 0.05, 0.001, 0.005, and 0.05 respectively. As for fishes specimens, the observed mean concentrations for Pb, Hg and Cd were 0.039, 0.032 and 0.003 compared to 0.30, 0.50 and 0.050 mg/kg respectively as standard values. Here As were insignificant in analysed fishes. Results also show that concentrations in fish's specimen do not correlate with those in water. According to the background knowledge about contaminants, a part of metals carried from the catchment is adsorbed onto suspended particles and settles to the sediment. Also, the presence of metals in fishes confirms that metals were available in aquatic ecosystem. This is not surprising when we know that no system of management of solid and liquid waste in the watershed exit. Indeed, the study catchment belongs to farm area with chemical use and a quick urbanization zone. Okpara dam is vital for human health and environmental well-being in the basin. Overall results indicate that fish and freshwater from Okpara dam were slightly contaminated by toxic metals but concentrations did not exceed standers. However, intensive and regular studies are required for monitoring. Also, iinformation, education and communication education are very important for behaviour change by reparians in order to prevent levels of contaminations that would not be easy to address.

Keywords: IWRM, contamination, Pb, Hg, Cd, As, Okpara dam at Kpassa, pollution, bioaccumulation.

Introduction

When hydro geological conditions are inadequate, surface water is used for all needs. So that water quality and environmental well-being become a real concern. This is the case of Parakou; the third bigger town in the northern region of Benin where water service is based on Okpara Dam at Kpassa. The region is characterized by agricultural production area and quick urbanization area with lake of sanitation system.

It is well established that existence of a stream always attracts human settlement because of all services and advantages that water provides[1]. Indeed, in addition to clean water supply, irrigation, watering and fishing are also increasing around the dam. When considering the heavy metals concentration in water and fishes, the most important aspect is their toxicity to humans and the ecosystem interactions via food chain[2] Toxic metals are always worrying because of their toxicity and the effects of bioaccumulation that they could induce from a level to another level of food chain [3, 4].

Integrated Water Resources Management requires best knowledge on water quantity as well as water quality according to water management low in Benin « Low n°2010-44 of November 24th 2010 ».

Nowadays, due to increasing population and climate change, Okpara Dam merits a particular attention from all actors. Indeed, the dam management stakeholder's workshop in 2008 and in 2014 recommended the need of knowledge on water quality on that site. These workshops were initiated by Country Water Partnership of Benin. This organisation has been working with all stakeholders including national authorities, local communities and NGOs in a context of Integrated Water Resources Management (IWRM), for sustainability of water service via an advocacy process, sensitization and multi-actors dialogue. One of the principal recommendations from those workshops was the need of studies to clarify the issue of water pollution in order to support decision making related to ecosystem services in the basin and human health protection. Indeed, the sediment from the dam was studied and it comes out that Manganese and Iron content in the dam was higher than the normal[5]. In addition high concentrations of phosphorus were

also found in the sediment from Okapar dam[6]. Besides geological sources of pollution, human made pollutants affected water quality in that area: there is a need to address water quality issues throw analyses of certain chemicals parameters such as organ chlorine pesticides; Heavy metals (lead, cadmium and arsenic, mercury); and nitrates which could be palpable indicators of pollution.

The aim of this study is to determine heavy metals (lead, mercury, cadmium and arsenic) concentrations in water and fishes (Tilapia Guineensis) from Okpara dam at Kpassa as a tool for decision making.

Material and Methods

Study area: This study addresses Okpara dam located in the village of Kpassa. It is located in the Municipality of Tchaourou in Borgou region. It is at twelve kilometers from the city of Parakou on latitude 9°17'28.91'' N and longitude 2°44'13.90'' E on Google Earth.

The dam was built since 1969 on Nanon River which is a tributary of Opkara River in Ouémé basin. This dam drains an essential part of the water from Nanon catchment (2410 sq.Km), from latitude North 9°15' to 9°57 and longitude Est 2°35' to 3°05'. That catchment includes the communes of Nikki, Perere, N'Dali Tchaourou, Parakou and very small part of Bembereke as it is shown on the map (figure-1).

The catchment belongs to the Dahomeen bed-rock: it consists of a crystalline peneplain with hills with rocky outcrops of quartzite, gneiss, sand stone and laterite curasses. The topography of the land is moderate; the altitude of this area varies between 200 m and 450 m. The reservoir had about nine million cubic meters as maximum initial volume of water since 1975. It is mainly used for drinking water supply. Meanwhile, that water resource is more and more needed for irrigation as an adaptation to climate change since the land occupation is essentially by agricultural and cattle farm (80%) and weakly urbanized sector.

So, beside quantitative problem, actors should face the issue of water quality which is not the less regarding human activities in the catchment. Tilapia Guineensis is very common food item for reparians and it is the most represented in that type of ecological habitats. So, analyses were performed with Tilapia Guineensis.

Collected fishes weigh were between 106 g and 584 g and their length were 19 cm minimum and 38 cm. Specimens of Tilapia Guineensis were selected from captures at different places in the lake. In order to access the real risk on human health, the analysis stood on fish flesh.

Water samples were collected at deferent spots following the rules of the art[7]. Sampling collection were done under the supervision of IRGIB-Afrique Laboratory, so previous processing and ensure adequate packaging were implemented. All the samples were then kept cool for conservation before sending to the laboratory at Sike-Kondji.

Mineral analysis: The method of Atomic Absorption Spectrometry (AAS) with electro thermal atomization was used by IRGIB-AFRICA, an accredited laboratory where samples were analysed. That method is succinctly described below.

Principle: The method is based on the measurement by atomic absorption spectrometry with electrothermal atomization. Different sample aliquots were introduced into a graphite tube which can be heated to over 2800°C very quickly and in a controlled manner. The temperature increases gradually in order to dry samples and then induce the thermal decomposition of the matrix and thermal dissociation in free atoms. The atomic absorption spectrometry is based on the ability of free atoms to absorb light radiation. A light source emits specific light of an element. When the light beam passes through the cluster of atoms generated in the heated graphite furnace, light is selectively absorbed by the atoms of the selected element. The decrease in the intensity of light is measured using a detector with a specific wavelength.

Sample Preparation: For the determination of total metals, samples were acidified soon after collection by 65 % nitric acid until a pH of $\leq$ 2. The digestion step depends on handling conditions.

Equipment and materials: All glassware must be carefully cleaned before any assay of trace elements, rinsing with dilute nitric acid. (for ex. HNO 3 10%) and then several times with ultrapure water. there were flasks Beakers, pipettes, filter membranes of 0.45 µm nominal porosity, Tubes graphite with pyrolytic coating provided with platforms, and mainly, the Atomic Absorption Spectrometer equipped with an electrothermic apparatus of atomization, a hollow cathode lamp or an electrodeless discharge lamp suitable for the analyzed element, a device for automatic correction of the background noise, a computer display and an automated sample introduction, to deliver fixed volumes of up to 70 µl.

Reagents used: Ultrapure water (conductivity $\leq$ 0.1 S / cm). Hydrochloric acid 37% analytical grade. Nitric acid 65% analytical grade. Solutions mothers' multi-element or single, element traceable solutions are available. Certificate of Traceability provides all necessary data, such that the concentration of the elements presents, the uncertainty of the mother solution and shelf life of the solution. Modifying matrix, see the operating instructions of the device. Control Solution: This solution will be different traceable stock solutions. Reference materials: these materials (soil matrix preferably) should ideally be certified (MRC). Argon purity > 99.95 %.

Procedure: Calibration and preparation of standard solutions: use a minimum of 5 calibrations standards by uniformly

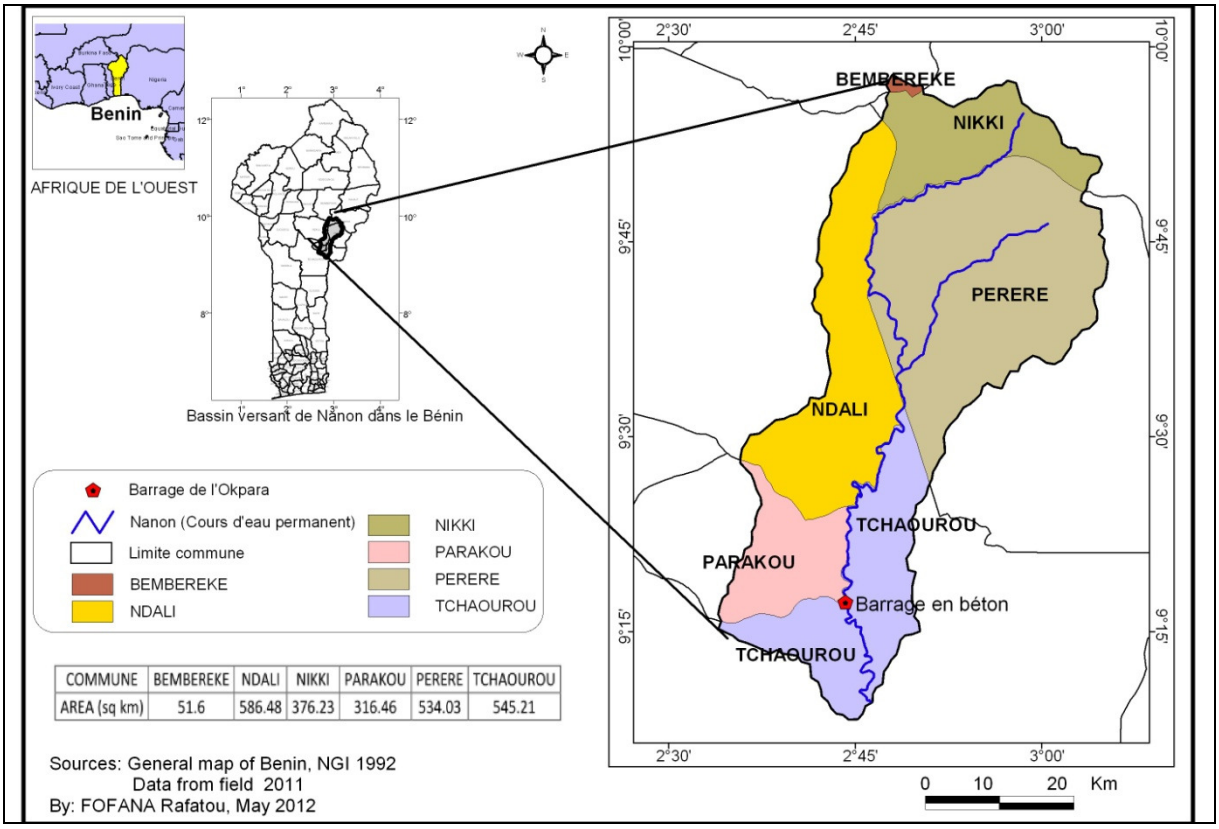

Figure- 1

Carte de Situation géographique du barrage de l'Okpara Collection of Samples and sample treatment: By using fish-trap, it was possible to check off seven species of fish such us Malapterurus electricus, Chrysichtys nigrodigitatus, Sarotherodon melanoteron, Tilapia Guineensis, Clarias gariepinus, irvineia voltae, and Pelvicachromis humilis

distributed in the range of measurement and in accordance with the instruction manual of the device. Checking the calibration with control solutions: pass control before each analysis and all 10 measures. Concentration values should not deviate from the limits on control charts. Otherwise, identify potential problems, fix and repeat the calibration.

Analysis of samples: the blank and the samples were analyzed as described in the manual of the device, in particular experimental conditions recommended to carry out the analysis. Analysis of MRC MRC analysis as an unknown sample.

Statistical Analysis: Parametric and non-parametric two samples test (t-test or mann-withney test) was used to test the milieu effect on the parameters. So the parameter values were compared between fish and water. Moreover, each mean value of parameters was compared to the standard value according to the specific milieu (fish or water milieu) to test if the observed mean values are different to the related standard values.

Results and Discussion

Heavy metal concentrations in fish: The Concentration of Pb, Me, Cd and As in *Tilapia Guineensis* at Kpassa is presented in table-1. Results lead to very low mean values of all assessed parameters compared to standards contained in table-3. Even maximum concentrations registered in specimen are very low.

Table- 1
Concentration of heavy metals in fishes from Okpara dam at Kpassa

Variable	Obs	Mean	Std. Dev.	Min	Max
Pb	30	.045881	.0027084	.038	.055
Hg	30	.0317655	.0016156	.027	.036
Cd	30	.001	0	.001	.001
Ac	30	.0033476	.0002771	.0026	.0041

Source; Made by author from STATA11 results

Heavy metals concentration in water: Analysis of table-2 reveals that the concentration of Pb, Me, Cd and As in water were below the acceptable toxic level. Limited values figured in table-3.

Table- 2
Concentration of heavy metals in dam's water

Variable	Obs	Mean	Std. Dev.	Min	Max
Pb	30	.0155889	.0052875	.01	.038
Hg	30	.0141696	.0005842	.012	.016
Cd	30	.001	0	.001	-
Ac	30	.0005621	.0000939	.0003	.0009

Source; Made by author from STATA11 results

Table-3
Standard values of assessed parameters

	Pb	Hg	As	Cd
In Water (ref : decret n°2001-094 du 20 fevrier 2001)				
Limite /standards value (mg/l)	0,05	0,001	0,05	0,005
In Fish (ref: arrete 2005 n°3069/MAEP/D-CAB/SGM/DHR/DP/SA du 02 November 2005).				
Limite value / Standards (mg/kg)	0,30	0,50	Unknown	0,050

Source: Made by author from STATA11 results

Analysis of table-3 reveals that there is significantly negative correlation between the concentration of Hg and Cd in water and fishery species. Increase of those concentrations in the lake corresponds to their reduction in fish. This may be explained by the capacity of fish species to eliminate the toxicology rate.
Over all, according to national standards, the results showed that the level of the concentrations for Pb, Me, Cd in fish is lower than limited values [8], as well as in water [9].

Discussion: Previous researches have already led to classify the reservoir at kpassa (Okpara dam) as a hyper-eutrophic one[10]. The agrochemical management support in the basin is mainly through cotton cultivation phytosanitary treatments programs[11; 12]. The application of pesticides in the region farming system is fraudulently extend to other cropping systems especially in gardening. Moreover, the pesticides distributions are managed by informal sector which offering unauthorized products to farmers. Trace metals found in fish and freshwater in Okpara dam is juste a consequence of all this environmental conditions that contribute to increase ecosystem and human health vulnerability[13-15].

Unfortunately, some farmers who found a way to buy them from other countries illegally continued to use diverse related products, cheaper than authorised products[16, 17].

Although these concentrations were below acceptable toxic level, with regards to the behaviour of those toxic metals in the environment such as omnipresence, accumulation throw food chain [17]; some protection measures are required for sustainable water service. However, decision makers should be awarded for measures to take because even low-level exposure to these metals, if it is chronic, can have serious health implications. Because there is not degrade or destroy heavy metals, they are not decomposed and accumulate in human body; they concentrated in the liver, kidney, brain, and skeletal keratinized tissues such as hair and nails. Exposure to heavy metals has been linked to disorders development, various cancers, kidney and even reached, in some cases, death[18,19]. However, the provision of health and safety training will improve the level of

Table- 4
Correlation analysis of heavy metal concentration between Fish and Water in okpara dam

Regress V_1 Pb, Me, As, Cd						
Number of obs	60					
F(3,56)	1640.55		**Source**	**ss**	**df**	**Ms**
Prob>F	0.0000		Model	14.8312458	3	4.9437461
R-squared	0.9887		Résidual	0.16875417	56	0.00301347
Adj R-squared	0.9887		Total	15	59	0.25423729
Root MSE	0.0549					
V1	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% conf.interval]**	
Pb	-0.9527878	1.859715	-0.51	0.610	-4.678244	2.772668
Me	-30.14838	4.480174	-6.73	0.000	-39.12325	-21.17352
As	dropped					
Cd	-154.1522	31.94235	-4.83	0.000	-218.1404	-90.16399
_cons	2.523064	0.0504188	50.04	0.000	2.422063	2.624065

Awareness and understanding of reparians towards adequate issues [17, 19].

Henceforth, all water actors should be aware that the first step for river water quality management is collecting information on changes of water quality in dimensions of time and place and also determination of major sources of pollutants [15]. Yet the most importing thing remains actors' awareness for behaviour change [20].

Conclusion

This study provides initial data on the concentrations of toxic metals (Pb, Me, Cd and As) in the water and fish of the stopping of Okpara to Kpassa.The obtained concentration as well in water as in fish is much lower than the standards values. But it is the proof that the water body serves as the receptor for domestic or industrial wastes as well as runoff from agricultural lands where fertilizers and other agrochemicals are frequently used. Although results does not reflect directly any risk neither for human being nor for the ecosystem, we must fear an evolution of these figures if fitting management measures of solid and liquid wastes are not implemented everywhere in the affected catchment. It is necessary to monitor rigorously different parameters in order of prevent any impoverishment of that resource. Also, metals are recognized for their effect accumulation through the food chain. There is therefore the need to undertake research to assess that phenomenon in the basin. After all, education and public awareness are essential to control pollution.

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