Journal of Water Resource and Protection, 2014, 6, 1268-1275
Published Online October 2014 in SciRes. http://www.scirp.org/journal/jwarp
http://dx.doi.org/10.4236/jwarp.2014.614116

Scientific Research

Eco-Toxicological Approach as a Contribution to Integrated Water Management on Okpara Dam at Kpassa in Benin: Evaluation of Contamination of Fish and Surface Water by Organochlorine Pesticides

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Received 17 August 2014; revised 12 September 2014; accepted 5 October 2014

Abstract

The paper explores the degree of pollution of organochlorine pesticides in fish and water in the dam at Kpassa on a tributary of Okpara River that is pumped by Benin National Water agency (SONEB) in supplying drinking water to supply the city of Parakou. Doing so, fourteen parameters of organochlorine are analyzed. Most of obtain organoclorine concentration in water and fish below is indicated critical values. However, DDT and endrine concentration in water is slightly above legal tolerable values. Hexachlorobenen and dieldrine concentrations are three times higher than legal limit value while aldrine is ten times higher. However, heptachlore is double concentrated in fishery while aldrine (endrine, dieldrine aldrine, lindane, hexachloro-benzene, DDT) is found in

How to cite this paper: Fofana, R., Labintan, C., Mama, D., Kaki, C., Afouda, A. and Linsoussi, C. (2014) Eco-Toxicological Approach as a Contribution to Integrated Water Management on Okpara Dam at Kpassa in Benin: Evaluation of Contamination of Fish and Surface Water by Organochlorine Pesticides. *Journal of Water Resource and Protection*, **6**, 1268-1275.
http://dx.doi.org/10.4236/jwarp.2014.614116

the dam fish and surface water three times concentrated than tolerated value. These levels of concentrations result from the intensification of organoclorine pesticide used in agriculture especially in cotton production. These are caused by the chemical application accumulated in soil and through the food value chain system. Therefore, it is very important to extract sediment from the reservoir by dredging in oder to renew the ecosystem of the dam. To persistently manage the basin water resources, it is imperatively important to observe a significant behaviour changed from all stakeholders.

Keywords

Water Pollution, Organochlorines, Kpassa Dam, Nanon Basin, Integrated Water Resources Management

1. Introduction

When hydrogeological conditions are inadequate, water quality and environmental well-being become a real concern. This is the case in city of Parakou in the northern part of Benin specifically around the dam of Kpassa on Okpara River. The dam of Kpassa is supplied with streams of the Nanon basin located in a cotton production zone. The region agricultural production inputs are characterized by the extensive use of organochlorine pesticides fungicides and herbicides. These pesticides are from chlorine and they represent an important group of persistent organic pollutants.

The dam of Kpassa was built by Société Dahoméenne du Kénaf (Sodak) in 1969 on Nanon River, a tributary of Opkara River in Oueme basin. It was mainly used for cleaning Kenaf (*Hibiscus cannabinus* L.). In 1972, SODAK stopped producing. This induces at that moment shortage of drinking water supply to the city of Parakou, the third bigger town in Benin. This had increased the city supply vulnerability and groundwater became deficient. Thus, the government rehabilitated the infrastructure, which was assigned to Société Nationale des Eaux du Benin (SONEB), the city official drinking water supplying agency.

It is well established that the existence of a stream always attracts human settlements because of all services and advantages that water provides. Indeed, in addition to clean water supply, irrigation, watering and fishing are also increasing growing around the dam.

Nowadays, due to population growth and the increasing frequency of climate change in extreme events, that resource deserves a particular attention from all actors.

Indeed, the dam management stakeholders' workshops in 2008 and 2014 recommended the need of knowledge on water quality on that site. The first workshop was 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) to protect the dam. As a result of an advocacy process, sensitization and multi-actors dialogue, this first workshop took place at Parakou in December 2008. It aimed at sharing risks and findings in short, medium and long-term actions related to the dam water resources management. Five main points were discussed. This included the lack of knowledge or data on quantity and the quality of water resources; the development of invasive aquatic plants; the erosion in the catchment and at the downstream of the dam; the siltation and the increasing sediment level inside the reservoir; non-existence of a framework or actors organizations for the region an IWRM.

One of the principal recommendations from that workshop was to conduct studies to clarify the issue of water pollution in order to support decision making related to agriculture services in the basin and the human health protection.

Indeed, the dam sediment study was conducted by Fidel *et al*. [1] and they concluded that manganese and iron content in the dam was higher than the normal. This was in line with the finding of Zogo *et al*. [2]. In addition, high concentrations of phosphorus were also found in sediment [3].

In related development, further studies suggested various measures to reduce the concentration of manganese and iron in the dam's water [4]. Besides, these geological sources of pollution, man-made pollutants affected water quality in the dam's area. The area is located in Borgou region and characterized by the cotton cultivation system. Cotton is attractive at the political level in Benin; therefore, the government offers many facilities to farmers such as the pest management support in reducing insect negative impact on cotton cultivation. The pest management support is mainly through the cotton cultivation phytosanitary treatments programs [5] while biological treatments are inexistent. The application of pesticides in the region farming system is also extend to other cropping systems especially in gardening. Moreover, the pesticide distribution is managed by an informal sector which offers unauthorized products to farmers. For pesticides end users, despite their training and sensitization, pesticides are managed with a lot of risks (treatments without protection, treatment applications by children, combinations of food crops and cotton, pesticide storage in bedrooms, reuse of empties. This inadequate use of pesticides increased ecosystem and human health vulnerability [6] [7].

The organochlorine pesticides were recommended in Benin in the 1960s (DDT, lindane, dieldrin, heptachlor, etc.) and 1999-2007 (endosulfan) since they are effective against many insects. Other countries have been experiencing organochlorine pesticides since 1940 but due to the concentration in the environment these chemicals have been baned. Unfortunately, some farmers who found a way to buy them from other countries illegally continued to use diverse related products, cheaper than authorised products [8] [9].

As a researcher involved in the process of integrated water management on the catchment, we undertake to address water quality issues through analyses of such chemical parameters as organochlorine pesticides which can be palpable indicators of pollution in the dam.

2. Data and Methods

2.1. Study Area

The reservoir at the village of Kpassa on Nanon river a tributary of Okpara river in Ouémé basin is a lake located in the Municipality of Tchaourou in Borgou region, at twelve kilometres from the city of Parakou.

The dam which delimits this reservoir is built with clay since 1969. It drains an essential part of the water from Nanon catchment which stretched away on 2410 sq.Km between latitudes 9˚00'N and 9˚80'N and longitudes 2˚31'E and 3˚08'E. The reservoir initially contained about five million cubic meters in 1975. It is mainly used for drinking water supply. Due to increasing population and the siltation or sediment filling the reservoir, water will drastically shorten in a close future. The water depth now varies between 1.5 meters and 8.5 meters. Meanwhile, that water resource is increasingly coveted for irrigation as an adaptation to climate change since the land occupation is essentially by agricultural and cattle farm (80%) and weakly by urbanized areas [10].

The basin related to the dam belongs to the "Socle Dahoméen" bed-rock: it consists of a crystalline peneplain with hills with rocky outcrops of quartzite, gneiss, sandstone and lateritic cuirasses. The topography of the land is moderate. Altitude of this area varies between 200 m and 450 m.

That catchment includes the communes of Nikki Perere, N'Dali Tchaourou, Parakou and a little part of Bembereke as it is shown on the map (**Figure 1**).

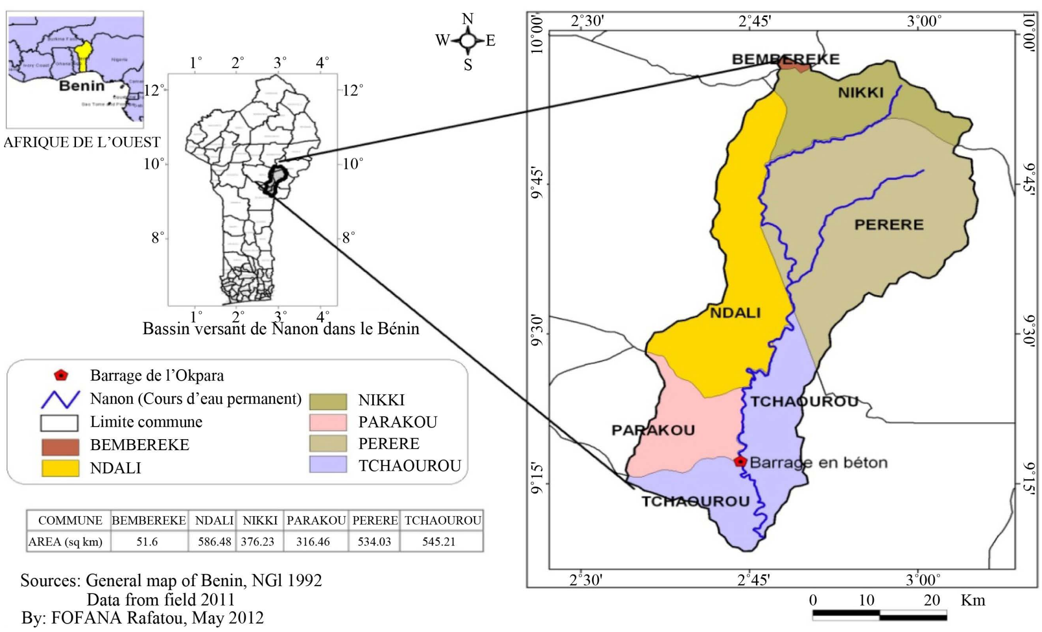

Figure 1. Location of the dam at Kpassa and extent of the Nanon catchment.

2.2. Sample

By using fish-trap, it was possible to check off seven species of fish (*Malapterurus electricus*, *Chrysichtys nigrodigitatus*, *Sarotherodon melanoteron*, *Tilapia guineensis*, *Clarias gariepinus*, *irvineia voltae*, *Pelvicach romis humilis*) assessed into five families: *cichlidae* were numerous with three species. Other families (*Malapteruridae*, *Claridae*, *Schilbeidae* and *Bagridae*) were represented by only one species.

Analyses were performed on *Tilapia guineensis* the most represented species that is also the most consumed in the study area.

30 samples of fish (*Tilapia guineensis*) were captured at different places in the lake (**Figure 1**).

30 samples of water are also drawn in the similar conditions.

Sampling collection was done under the supervision of Laboratoire IRGIB-Afrique which started the previous processing and ensures adequate packaging and conservation before sending the sample to the laboratory at Sike-Kondji.

2.3. Principle

The method is based on the measurement by atomic absorption spectrometry with electro thermal atomization. Aliquots separate sample are introduced into a graphite tube (there are several types) which can be heated to over 2800˚C very quickly and in a controlled manner. The temperature increase helps overcome by drying, thermal decomposition of the matrix and the thermal dissociation into free atoms. The atomic absorption spectrometry is based on the ability of free atoms absorb light radiation. A light source emits specific light of one element. When the light beam passes through the cloud 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 at a specific wavelength. Some fluids may contain large amounts of substances that may affect the results. High chloride concentrations can lead to poor results, as the volatility of many elements is increased and may result in loss of elements to be determined during the pyrolysis. The matrix effects may be overcome by optimizing the temperature program, the use of tubes and platform with pyrolytic coating, the use of chemical modifiers, the standard additions technique and the use of a correction background noise.

2.4. Packaging and Storage of the Sample

The pre-processing steps and sample preservation depend on the type of metal (dissolved or particulate total) sought. If samples are not analyzed directly, they are kept in the refrigerator. Before analysis, the samples will be at room temperature. Samples can be preserved, stabilized for a month.

Sample preparation and ultratraces of des pesticides analysis by gas chromatography (GC).

Residue analyses of OCPs in waters and fishes by developing analytical procedure continue to be an active area of research in recent years [11].

Yet trace analysis of OCPs in water and fishes is usually performed by gas chromatography (GC) because of their hydrophobicity and persistence, OCPs accumulate in fishes where they are likely to be bio-accumulated for many years [12].

That method of gas chromatography is used by IRGIB laboratory where samples were analyzed. It is described in four steps including three preparatory steps that are shown below.

2.5. Method of OCPs Extraction by Gas Chromatography

1) Protocol of test glass cleaning.

a) Rinse each glass a hot water many times; b) Soak them in the nitric acid 2% (HNO3) especially in the night; c) Rinse again with hot water; d) Rinse with in the distilled water without detergent; e) Rinse tow times with acetone et deux fois avec du DCM; f) Use DCM diluted at 5% pour deactivates all surface in glass; g) Rinse two times in DCM 10% to eliminate trace that may have escaped from the previous washing; h) let test-glass stay inside the furnace for 6 h à 325˚C; i) Rinse two times with acetone and two times with hexane before.

2) Material (glasses).

Graduated Test-tube and phial of 100 ml, Bulb of 250 ml for decanting, Round bottom bulb 125 ml, Very small test-tube par GC (polyéthylène) rinsed with hexane, Tube of 15 ml for centrifuging.

3) Standard solution.

Standard solutions (75 to 550 pg/ml) should be prepared by accurate weighing, dissolved in acetone and stocked inside a freezer −30˚C protected from light and wash with à hexane;

Standard solutions for work (5 ug/ml) prepared by appropriated dilution from the stock of cyclohexane conserved inside a fridge (4˚C) (polyéthylène) rinsed with hexane.

4) Extraction by gas chromatography.

a) Hashed and homogenized fish sample; b) 15 g of aliquot in a glass and missed with 50 mL of dichloromethane (DCM) leave at a centrifuge for 2; c) Add 50 g of anhydrous sodium sulphate to the mixture and leave again at centrifuge for a min d) Wait 2 min and then filter through Bûchner funnel and filter again through a watt man paper with anhydrous sodium sulphate; e) Evaporate the solvent at dry in an rotary evaporator (35˚C - 40˚C); f) Collect the dry residue and add 5 ml of cyclohexane; g) In a phial of 2 ml with 50 µl of standard solution (20 mg/L); 1 ml) add 1ml of that solution and then reach the final 2 ml with cyclohexane.

3. Results and Discussion

Analyse of the concentration of organo-clorines in fishes captured in the dam at kpassa reveal a relatively higher concentration of Heptachlore; Endosulfan *α*, *β*, suif; Hexachloro-benzene (BHC); chlordane; Epoxyde d' heptachlore; Endrine aldéhyde in fishery in comparison with the standard (normes). This is illustrated respectively by **Table 1** and **Table 2**.

However, analysis of the effect between the concentration of pesticides in water and fish reveal that only aldrine, hexacloro-benzene and *β*-BHC concentration are significantly correlated. This means that the intensity of pollution from these 3 pesticides sources will contributed to fishery pollution. Therefore, an increased of the concentration of in these respective organo-clorine in Dam water will obviously contribute to increased of their respective concentration in fish present in the dam. This is illustrated by **Table 3**. The conclusion made is based on student test, p value and R2 which respectively satisfied the condition $|t| > 2$, $p < 0.05$ and $R2 > 0.50$.

However, according to national standards [14], to limit the evolution of organochlorines pesticides in water and food, it is very important for riparian and all stakeholders to well understand the principle of organochlorine pesticides. It is a way toguide their behaviour at the basin level in order to reduce the evolution of chemicals concentrations in the lake. Irrigation and cotton production are the main causes of pollution by organochlorine pesticides. They can be attached to soil for years. They can also be transported in the air over long distances;

Table 1. Results from organochlorine pesticides fishes captured in the lace at Kpassa (Okpara).

Organochlorine components	Observation	Mean	Std. Dev.	Min	Max	Standard
Heptachlore	30	0.035816	0.006953	0.016	0.058	0.020
Methoxy-chlore	30	0.002	0	0.002	0.002	
Endosulfan *α*, *β*, suif	30	0.002532	0.000448	0.001	0.002778	0.010
Hexachloro-benzene (BHC)	30	0.123673	0.022486	0.03	0.16	0.020
Aldrine + Dieldrine	30	0.056502	0.005388	0.044	0.069	0.020
chlordane	30	0.002973	0.000756	0	0.004	0.010
lindane	30	0.094351	0.019451	0.02	0.16	
Epoxyde d'heptachlore	30	0.030664	0.005122	0.009	0.042	0.020
α-BHC	30	0.018611	0.001719	0.01	0.02	
β-BHC	30	0.017221	0.003439	0	0.02	
Δ-BHC	30	0.018611	0.001719	0.01	0.02	
DDE	30	0.003741	0.000973	0	0.006	
DDT	30	0.027221	0.006805	0	0.04	
Dichloro-biphenyl	30	0.047221	0.008596	0.01	0.06	
Endrine aldéhyde	30	0.013995	0.002136	0.004	0.018	0.01
Initial weigth (g)	30	285.1429	74.26858	106	584	

Sources: Made by authors using STATA.11 [13].

Table 2. Results of organochlorine pesticides analysis in surface water of the dam at Kpassa on Okpara.

Organochlorine components	Observations	Mean	Std. Dev.	Min	Max	Standard (µg/L)
Heptachlore	30	0.016018	0.00092	0.014	0.02	
Aldrine	30	0.055956	0.003349	0.04	0.06	0.01
Methoxy-chlore	30	0.002	0	0.002	0.002	
Endosulfan	30	0.002	0	0.002	0.002	0.005
Hexachloro-benzene	30	0.060845	0.008371	0.04	0.1	0.03
dieldrine	30	0.028044	0.004091	0.02	0.04	0.01
chlordane	30	0.005388	0.000979	0.002	0.008	
lindane	30	0.048044	0.004091	0.04	0.06	0.004
Epoxyde d'heptachlore	30	0.02088	0.001013	0.018	0.024	
Endrine	30	0.005596	0.000335	0.004	0.006	0.005
α-BHC	30	0.049037	0.004127	0.04	0.06	0.01
β-BHC	30	0.036889	0.005551	0.02	0.06	0.01
Δ-BHC	30	0.055956	0.003349	0.04	0.06	0.01
DDT + DDE + DDD	30	0.0376	0.002201	0.03	0.04	0.03
Dichloro-biphenyl	30	0.078578	0.017469	0.03	0.14	
Endrine aldéhyde	30	0.015209	0.000411	0.014	0.016	

Sources: Made by authors using STATA.11.

Table 3. Results of Correlation between organochlorine pesticides concentration in surface water and fishery of the study area. Number of obs = 60, Pseudo R2 = 0.9966.

y1	Coef.	Std. Err.	t	p > t	95% Conf.	Interval
Heptachlore	5.921637	5.712366	1.04	0.305	−5.563844	17.40712
Aldrine	14.26146	6.018301	2.37	0.022	2.160854	26.36207
Endosulfan	1.657955	2.945423	0.56	0.576	−4.264215	7.580125
Hexachloro-benzene	5.3886	2.085737	−2.58	0.013	−9.582257	−1.19495
dieldrine	−7.91355	8.929184	−0.89	0.38	−25.86687	10.03978
chlordane	−1.30459	3.169409	−0.41	0.682	−7.677114	5.067935
lindane	−3.41232	8.729988	−0.39	0.698	−20.96513	14.1405
β-BHC	19.38133	7.802382	2.48	0.017	3.693587	35.06907
Δ-BHC	−7.27033	5.919586	−1.23	0.225	−19.17246	4.631794
Dichloro-biphenyl	3.476438	1.880966	1.85	0.071	−0.3054978	7.258374
Endrine aldéhyde	−0.00019	0.000409	−0.45	0.651	−0.0010093	0.000637
_cons	1.243286	0.363495	3.42	0.001	0.5124307	1.974142

Sources: Made by Authors using STATA.11.

those chemicals persiste in the environment even in places where there are no human inhabitant. In aquatic systems, organochlorine pesticides are attached to sediment in the water and then accumulate in fish. Most of them are persistent organic pollutants (also known as POP) and accumulate in the food chain. Because of their toxicity and persistence in the environment, several organochlorine pesticides are subject to prohibition in Benin and at international level to reduce and/or eliminate their release into the environment. As such, they are subject to international controls.

Moreover, because these chemicals are fat soluble, they are found in higher concentrations in fatty foods.

Generally food is the main source of exposure to organochlorine pesticides, mainly by eating fatty foods of animal origin (such as milk, dairy products, fish, and meat). Minor sources of exposure for the general population are contaminated drinking water and air. You may have been exposed in the past when applying or handling pesticides. The infants may be exposed to these chemicals through breast milk and the foetus can be exposed in uterus via the placenta. Workers may be exposed to organochlorine chemicals during manufacture or application of these chemicals.

Generally, the digestive tract is the main route of exposure and are then preferably stored in fat. According to the substances they are more or less well absorbed by the skin or respiratory tract. Generally, they accumulate in the body over time. According to the substances they can be excreted in the urine or stool. These stored in body fat pesticides can be remobilized in the blood during fasting or in breast milk during lactation.

Organochlorines have a wide range of acute and chronic hearth effects, including cancer, neurological damage, birth defects and endocrine disruption. Effects on nervous, immune and hormone metabolism systems have been reported. Some of them have resulted in the case of occupational exposures and allergic skin problems.

4. Conclusions

This investigation provides characterization data on pop concentration about Okpara dam. Results show that some of the studied organochlorines (Endrine, dieldrine aldrine, lindane, hexachloro-benzene, DDT and its degradation products) have a high concentration although they are legally limited in four years. That situation depends on the persistent character of the pollutants. It is mentioned that people have been illegally using them. Previous researches have already led to classify the reservoir at Kpassa (Okpara) as a hypereutrophic one.

The most importing thing remains actors' awareness for the behaviour change. The reservoir dredged by ORIO new project can also be a way to renew water quality and life in that ecosystem. That will certainly influence the well-being of the ecosystem, especially that of inhabitants in such a sensitive case.

Acknowledgements

This study is achieved with the financial support from the Netherlands Embassy. We thank Mr. Adeke at "Direction des Pêches" and Prof. Ahyi of IRGIB-Africa for their large contributions.

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