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José Papin Mehounou
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Rock Modéran Toklo
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Jacques K Fatombi
Laboratoire de Chimie de l'Eau et de l'Environnement (LCEE) de l'Ecole Normale Supérieure de Natitingou, Bénin

Antoine Sokènou Houngbo
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Serge Freddy Senou
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Nikita Topanou
Laboratoire de Chimie de l'Eau et de l'Environnement (LCEE) de l'Ecole Normale Supérieure de Natitingou, Bénin

Roger Gérard Josse
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Correspondence
Roger Gérard Josse
Laboratoire d'Analyses Physico-chimiques des Milieux Aquatiques (LAPMIA) de la Faculté des Sciences et Techniques (FAST) de l'Université d'Abomey-Calavi, UAC-Rép du Bénin

Chemical pollution of the waters and sediments of the Aplahoue agricultural production zone in Benin

José Papin Mehounou, Rock Modéran Toklo, Jacques K Fatombi, Antoine Sokènou Houngbo, Serge Freddy Senou, Nikita Topanou and Roger Gérard Josse

Abstract
Parameters such as Total Organic Carbon, nitrate ion, nitrite ion and metals were determined according to conventional methods of chemistry in our different laboratories. The following average concentrations were obtained in the waters: total organic carbon (5.44 mg / L at 12.59 mg / L); nitrate ion (12mg / L at 70mg / L); the nitrite ion (0.2 mg / L to 1.2 mg / L); ortho-phosphate (0.07 mg / L to 1.4 mg / L); Chromium (2µg / L at 15.21µg / L); Copper (2 µg / L at 5.6 µg / L); Arsenic (2.1 µg / L at 17.2 µg / L) and Cadmium (0.9 µg / L at 8.26 µg / L); Aluminum (8.67µg / L at 15µg / L); potassium (9.9 µg / L at 22.11 µg / L); Lead (1.35µg / L at 11.02µg / L). For sediments, the following assessment values were obtained after calculating the Enrichment Factor (EF) and the Geoaccumulation Index (I-geo): for EF (1.07 to 10.0), 56) and I-geo (2.22 to 8.70).

Keywords: Chemical pollution, waters, sediments, agricultural production

Introduction

Healthy water is necessary to life, hygiene, prevention of diarrhea and other waterborne diseases. Access to water is a constant concern of all times and places. Quite often when there is excess in the case of a flood or shortage in times of drought, water becomes a matter of life and death. In the past, we wondered about the microbiological characteristics of water, today we are worried not only about its microbiological quality but also about its physicochemical characteristics. According to FAO, 70% of all water is used in agriculture (H.Keddal, 2008) [11]. In agricultural areas, to increase their production, farmers used chemical fertilizers and pesticides whose residues made the water unfit for consumption. In Benin, Biaou *et al*. (2003) [2] and Pazou *et al*. (2006) [16] studied the contamination of environmental components by pesticides used in agricultural environments. However, these authors did not take into account the contamination of water, either by pesticide residues or by heavy metals. However, the contamination of water by toxic substances was closely linked to that of soil and sediments (Coats, 1991) [6], which has been observed by (Soulé Adam *et al*., 2010) [18] in the cotton zone of Gogounou, Kandi and Banikoara (Benin). Insufficient coverage of the drinking water distribution network leads some residents of Aplahoue to resort to surface and groundwater. This study aims to evaluate the metallic pollution of water and sediments in this agricultural production area in order to assess the contamination rate and the health risks.

Material and methods

Area of study and sampling

The Commune of Aplahoue is part of the department of Couffo, South -West of Benin. Covering an area of 915 km2, it is limited to the North-East by the Commune of Djidja, to the South by the Commune of Djakotomey, to the East by the Commune of Klouékanme and the Commune of Abomey, to the West by the Republic of Togo. A series of two water sampling and sediment sampling campaigns was conducted between August, and October, 2017. This period was chosen because it covers the early stages of application and the application of chemical fertilizers.

Physico-chemical analysis methods

Methodology: The flasks used for the samples were rinsed first with distilled water and then with the samples to be studied. Before the determination of the metals by the ICP, the samples were acidified beforehand (0.2 ml of concentrated nitric acid per 20 ml of water) then filtered with a 0.45 µm filter and which diameter is 25 mm.

Table 1: Summary of the physicochemical parameters measured and methods used

Parameterstudied	Devices and methods
Total OrganicCarbon	COT-meter analytic jéna multi N/C 2100S
Nitrite, Nitrate and Orthophosphate	Brand ion chromatograph Dionex ICS 3000
Metals	ICP
Sediments	Mineralizing Milestone Stard D. Microwave Digestone System

Enrichment Factor (EF).

The enrichment factor provides the number of times an element is enriched relative to the abundance of that element in the reference material. The reference material used in this study was that defined by Wedepohl, 1995. The calculation of the EF was defined by the content of a contaminant element of the sample to the concentration of a relatively immobile considered element of this sample, compared with the same ratio found in the reference material (Average shale). Iron (Fe) has been chosen as the immobile element of reference for this calculation. This choice was based on the fact that iron is naturally present in the waters and sediments of the study area. In addition, it is one of the reference materials widely used in the literature (LIU W., ZHAO J, 2005) [13] and (FANG T. H, 2006) [10].

$$EF = \frac{[M]_{sample} / [Fe]_{sample}}{[M]_{RM} / [Fe]_{RM}}$$

Where: EF = enrichment factor; $[M]_{sample}$ = concentration of metal M in the sample;
$[Fe]_{sample}$= concentration of iron in the sample; $[M]_{RM}$ = concentration of metal M in the reference material and $[Fe]_{RM}$ = concentration of iron in the reference material.

Table 2: Enrichment factor assessment grid.

EF values	Appreciation according to (Acevedo-Figueroa *et al.*, 2008)
EF< 1	No enrichment
1 – 3	Low enrichment
3 – 5	Moderate enrichment
5 – 10	Moderate to strongenrichment
10 – 25	Strong enrichment
25 – 50	Very strong enrichment
FE > 50	Extreme enrichment

Geo-accumulation index (I-geo)

A second criterion for assessing the intensity of metallic pollution is the geo-accumulation index. This empirical index compares a given concentration to a value considered as a geochemical background.

$$I\text{-}geo = \log_2(Cn / 1,5Bn)$$

Where: I-geo = geo-accumulation index; log2 = base logarithm 2; n = item considered; C = concentration measured in the sample; B = geochemical background; 1.5 = exaggeration factor of the geochemical background, whose function is to take into account the natural fluctuations of the geochemical background.

Table 3: Geo-accumulation assessment grid (I-geo)

The values of I-geo	Appreciation according (Müller G, 1969) [14]
I-geo< 0	Without contamination
0 – 1	Without slight contamination
1 – 2	Moderate contamination
2 – 3	Moderate to severe contamination
3 – 4	High contamination
4 – 5	Strong to extreme contamination
I-geo> 5	Extreme contamination

Results and Discussion

Total organic carbon

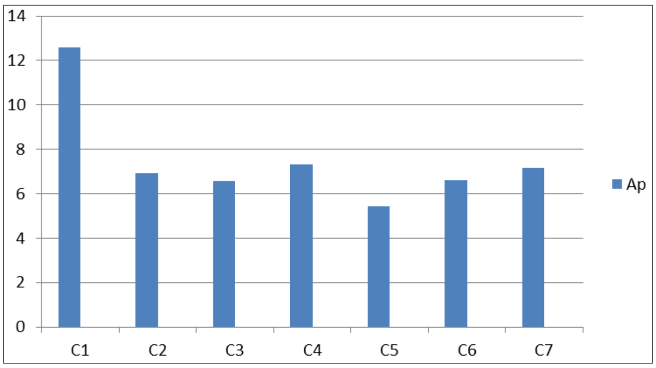

Fig 1: Total organic carbon content in water samples.

Total organic carbon TOC is one of the most important composite parameters in the assessment of organic water pollution. It represents the amount of organic matter expressed in carbon (mg / L). The average TOC values ranged from 5.44 mg / L to 12.59 mg / L at the Aplahoue site. Note that all the values obtained exceed the French standard of 2 mg / L for water intended for consumption. These values obtained result from the leaching of soils, agricultural, industrial and urban waste.

Ammonium ion

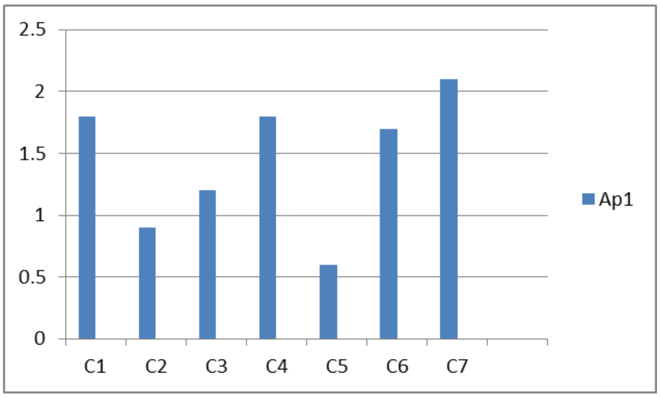

Fig 2: Spatial variation of ammonium ion concentrations in water samples.

Ammonia nitrogen is one of the links in the complex nitrogen cycle in its original state. It is a gas soluble in water. It is a good indicator of pollution of watercourses by organic discharges of agricultural, domestic or industrial origin (Ben Abbou *et al.*, 2014) [1]. Note that all values obtained exceeded the WHO standard of 0.05 mg / L for water intended for human consumption. The highest average value was observed at point C7 and the lowest mean value at point C5. The non-standard values obtained were due to the application of fertilizers (NPK fertilizer and urea) based on nitrogen that were drained by runoff to watercourses.

Nitrate ions

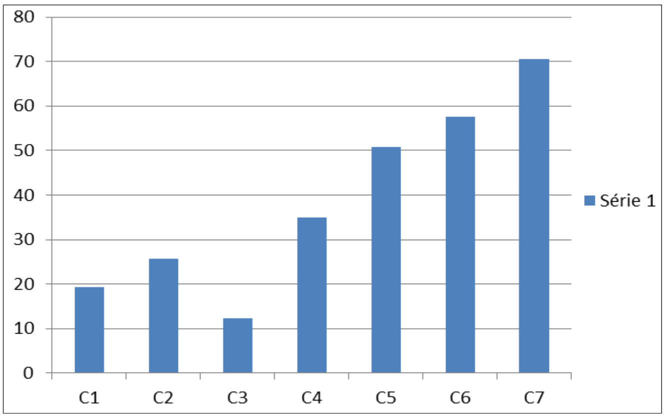

Fig 3: Spatial variation of different concentrations of nitrate ion in water samples

Nitrates are an important, indisputable marker of pollution. Figure 3 showed the different average values of the nitrate ion obtained during our sampling. Mean values ranged from 12 mg / L at C3 to 70 mg / L at C7. It was noted that points C5, C6 and C7 had a higher average value than the WHO standard of 50mg / L for water intended for human consumption. Although nitrates had no direct toxic effects except at high doses, they are readily converted by bacterial reduction into nitrites, the health effects of which would not be neutral (Elbouqadaoui *et al*., 2009) [9].

Nitrite ion

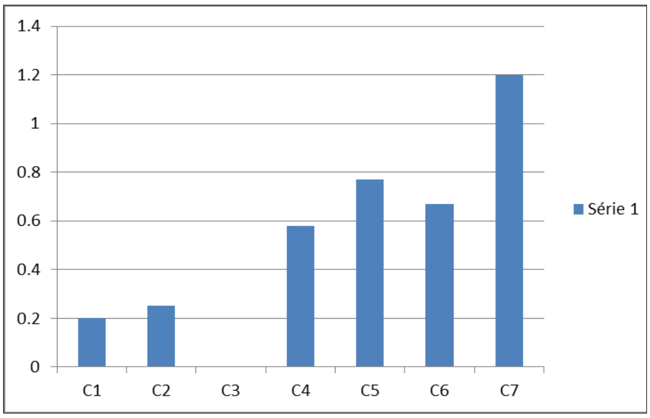

Fig 4: Nitrite ion content in the water samples analyzed.

The nitrite ion contents in the analyzed water samples were shown in FIG. 4. It is easy to see, on reading the results, that the points C4, C5, C6 and C7 had average values exceeding the French standard which is 0.5 mg / L for water intended for human consumption and that point C3 has a mean value lower than the limit value of detection. Note that the main source of nitrite contamination was the massive use of fertilizers in agriculture, followed by animal and human waste (Chartrand *et al*., 1999) [5], (Levallois and Phaneuf 1994, Quebec, 1997) [12].

Ortho-phosphate PO_4^{3-}

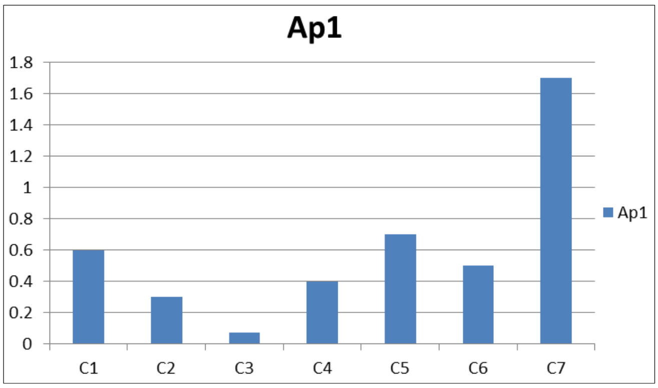

Fig 5: Concentration of ortho-phosphate ions in the water samples analyzed.

Orthophosphates are the predominant form of phosphorus available in soil or water (Bouderka Nouzha *et al*., 2016) [3]. There was a variation of 0.07 mg / L at point C3 to 1.7 mg / L at point C7, except for points C2, C3 and C4, all other points had an average concentration exceeding the WHO standard of 0.5mg / L for water intended for consumption. These non-standard values were due to the use of NPK fertilizers and organophosphorus in crop fields.

Heavy metals in water samples

Table 4: Different concentrations of metals in water samples in µg / L

	C1	C2	C3	C4	C5	C6	C7
K	11,11	11,11	9,9	9,9	20,35	11,11	22,11
Al	10	10,88	8,67	12,45	10,12	11,24	15,89
As	5,5	12,2	2,1	6,75	12,56	11,2	17,2
Ni	2,4	1,9	2,01	4,5	3,4	3,4	6,5
Cu	2,1	2	-	3,1	4,02	2,35	5,6
Cr	3,5	10,11	2	5,6	8,9	7,22	15,21
Zn	-	-	-	-	-	-	-
Pb	3,25	3,05	1,35	5,6	7	5,80	11,02
Mn	-	-	-	-	-	-	-
Cd	2,3	3,1	0,9	5,1	7,2	6,2	8,26

Cadmium, considered to be toxic, is generally present in the environment at a very low concentration but can increase very rapidly with human activities (WHO, 2018). Cadmium ranges from 0.9µg / L at C3 to 8.26µg / L at C7. Note that 42% of the samples had a value higher than the WHO standard of 5µg / L. These high values were due to the use of chemical fertilizers used in agricultural production fields. The concentration of Arsenic varies from 2.1µg / L at C3 to 17.2µg / L at C7. We noted that points C5, C6 and C7 had values exceeding the WHO standard of 10µg / L for drinking water (WHO / FAO, 2001) [15]. From the comparison of the results with the AFNOR standard and the WHO standard, it was concluded that no chromium content exceeded these standards, which were 50 µg / L. Except for point C3, which had a value below the limit of detection for copper, all the other points had contents exceeding the French standard of 2 µg / L for water intended for human consumption. The values obtained for Copper resulted from the leaching of rocks and the application of chemical pesticides and fertilizers used by growers in the fields of production. Only point C7 had a lead concentration higher than the WHO standard of 10µg / L for drinking water. The presence of lead in the waters was due to an agricultural practice using chemical fertilizers and pesticides.

Comparison indexes

Enrichment Factor (EF)

The table below showed the different values of the enrichment factor.

Table 5: Value of the Enrichment Factor (EF)

	S1	S2	S3	S4
Al	3,23	5,82	8,35	8,66
As	2,18	3,08	3,98	4,92
Cd	1,07	2,29	2,74	3,11
Cr	1,61	3,56	5,68	6,17
Cu	4,45	6,77	6,98	7,59
K	2,08	5,54	8,89	9,37
Zn	3,07	5,42	9,91	10,56
Mn	1,52	2,43	2,97	3,51
Ni	3,34	5,27	7,33	6,33
Pb	4,32	6,55	8,63	9,31

The EF varied according to the different sampling points for the different metals studied; the lowest value obtained for FE is 1.07, which corresponded to a low enrichment (Cadmium) at station S1 and the highest value 10.56 corresponded to a moderate to high enrichment (Zinc) at station S3. From the analysis of the table it appeared that the anthropogenic contribution of the metals studied in the sediments increased from the first station S1 to the last station S4. The extreme values obtained at the S4 station were justified by its location (middle of the production fields).

The Geo-accumulation Index (I-geo)

The table below showed the different values of the Geo-accumulation Index.

Table 6: Geo-accumulation index value (I-geo)

	S1	S2	S3	S4
Al	3,80	4,58	5,04	5,09
As	2,24	3,10	3,98	4,28
Cd	2,22	3,42	3,08	4,05
Cr	2,97	4,52	4	4,80
Cu	3,39	4,80	4,79	5,40
K	3,17	4,52	5,14	8,70
Zn	3,74	4,48	5,29	5,35
Mn	2,45	3	3,09	3,30
Ni	3,53	4,90	4,40	5,39
Pb	3,23	4,14	4,71	5,03

As the EF, I-geo also varied according to the stations. Note that the smallest value has been observed at the level of the first station (2.22 for Cadmium corresponding to a moderate to high contamination) and the largest value at the fourth station (8.70 for potassium representing extreme contamination). The results obtained for the calculation of I-geo showed that there was a significant anthropogenic contribution, especially of certain metals such as: Al, Cu, K, Zn, Ni, and Pb. Note that the presence of these metals could be due to an agricultural practice using chemical inputs including fungicides (Deluisa *et al*., 1996) [7], (Bourrelier and Berthelin, 1998) [4], (Soulé Adam *et al.*, 2010) [18]

Conclusion

Analysis of water and sediment from the area of agricultural production in Aplahoue showed pollution due to chemical fertilizers and pesticides, which varies from one point to another. The C7 was more polluted than other areas; because its position was more favorable to a point and diffused pollution. It should be noted that the values outside standard obtained for the various parameters came from pesticides and chemical fertilizers. By a comparison of the levels of metal in water and sediments, it can be concluded that water pollution came from that of sediments.

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