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Estimation of Surface Water Contamination by Pyrethroids and Glyphosate in the Kerou and Pehunco Cotton Growing Areas of Northeastern Benin

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Abstract With the use of pesticides in cotton production areas, environmental components, including water bodies intended for consumption, become exposed. The study aims to assess the level of contamination of water bodies by pyrethroids and glyphosate in the Kerou and Pehunco cotton-growing areas in Benin. To do this, through a sampling campaign, water samples were taken in triplicate, followed by analysis of nutrient salts on the one hand, and of pesticide active ingredients on the other, by spectrophotometry and chromatography. The nutrient salts NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, Cl^- and SO_4^{2-}, although globally in low levels, are more concentrated in the waters in agglomerations than in the cotton production zone. On the other hand, the water has very high levels of cypermethrin (18 mg/L), deltamethrin (41 mg/L) and glyphosate (11 mg/L) in the cotton-growing zone, sometimes quadrupling the pesticide levels in the urban areas, particularly in the areas of Gando-Baka, Marékpo and Pehunco-Gah. These results indicate that mineral salts in the Kérou and Pehunco plans have a dual origin, namely chemical fertilizers and, above all, animal droppings and other domestic discharges from the agglomerations. In addition, the pesticides come mainly from the dispersion in cotton growing areas with risks of gastric, nervous and dermal health problems. These results are an alert that should reorient agricultural policies in order to preserve the health of the population.

Keywords: *water bodies, mineral salts, pyrethroids, cotton crops, health*

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1. Introduction

Faced with the drastic decline in tropical soil fertility, large quantities of chemicals such as fertilizers, insecticides or herbicides are used in agriculture as plant growth regulators and to have better yields [1,2]. Similarly, [3] indicate that in conventional agriculture, chemical pesticides and genetically modified crops help to simplify work or achieve high yields. The danger associated with the use of these pesticides is that they are now detected in all environmental compartments: water (fresh and marine), air, soil [4]. Moreover, [5] has shown that precipitation contributes to the dispersion of these pesticides far from their source through the natural phenomena of water evaporation and condensation. Extreme climatic events are meteorological phenomena localized by the populations in Northern Benin in the form of floods or drought, heat wave and especially strong wind [6]. These data cumulated with the type of climate with a uni modal rainfall pattern of a long dry season and a long rainy season facilitate the rapid dispersion of pollutants emitted from cotton areas for deposition in surface water bodies. Thus, they end up in our food and in our bodies and cause several serious health damages. According to recent statistics, the annual number of cases of poisoning of children related to chemicals varies between 1 and 5 million, including several thousand fatal cases. However, developing countries that use only 25% of the pesticides produced in the world record 99% of the deaths due to these types of poisoning [7]. For [8], potential effects related to pesticide exposure in humans include poisoning of sensitive tissues, endocrine disruption, and elevated risks of birth defects and cancers.

In aquatic ecosystems, the situation seems more alarming because once released into these environments, pesticides and heavy metals become entangled in these ecosystems and contaminate fisheries resources [4]. Thus for decades, the pollution of aquatic ecosystems has become an international concern given its disturbing proportions over the past half century.

In Benin, in cotton production areas, farmers report cases of discomfort which include headaches, colds, skin rash, and fatigue after spraying pesticides [9]. Studies conducted in Benin have shown that calculations on the health risk indices (HRI) of the IRPeQ reveal that some active ingredients such as endosulfan, chlorpyrifos-ethyl and maneb present both acute and chronic risks. This is due to the toxicity of these chemicals [10]. Between 2012 and 2016 the commune of Kérou in northern Benin recorded two hundred and thirty-five (235) cases of intoxication, including fourteen (14) cases of death. These preliminary data, which provide information on the problem of pesticides on terrestrial biotopes, are not sufficient to identify the health and environmental risks to which the populations using surface water sources in the cotton-growing areas are exposed, or even the underlying causes of the high frequency of intoxication and death.

This study aims to (i) determine the levels of active ingredients of pesticides in surface waters (ii) evaluate the levels of nitrogen and phosphate nutrients and (iii) identify the health risks to which the populations of Kerou and Péhunco in northern Benin are exposed. In light of these questions, the following hypotheses are formulated: (i) significantly high levels of cypermethrins and deltamethrins are revealed in the surface water of the Kerou and Péhunco cotton zone (ii) high nitrate and phosphate levels are detected in water (iii) the use of surface water in this zone for consumption exposes the population to endocrine disorders.

2. Materials and Methods

2.1. Study Sites

The communes of Kerou and Pehunco are located in the northern of Benin, particularly in the northeastern part of the Atacora department. They are home to 178414 inhabitants [11]. They are located between the parallels 1°39' 51'' and 2°17' 18"of latitude- North on the one hand and the meridian 10°03'27" and 11°23' 46"of longitude-East on the other hand (Figure 1). Likewise, they enjoy a Sudano-Guinean type of climate, characterized by two seasons: a rainy season from mid-April to mid-October, and a dry season from mid-October to mid-April. The rainfall, favorable to Agriculture oscillates between 800 and 1,100 mm of rain per year and distributed over nearly 170 days [12]. The average temperature is 26°C with a maximum in February. The harmattan, a cold and dry wind, blows between November and mid-March and sometimes causes a thermal amplitude of more than 10°C [13]. The water points on the map were used as sampling stations.

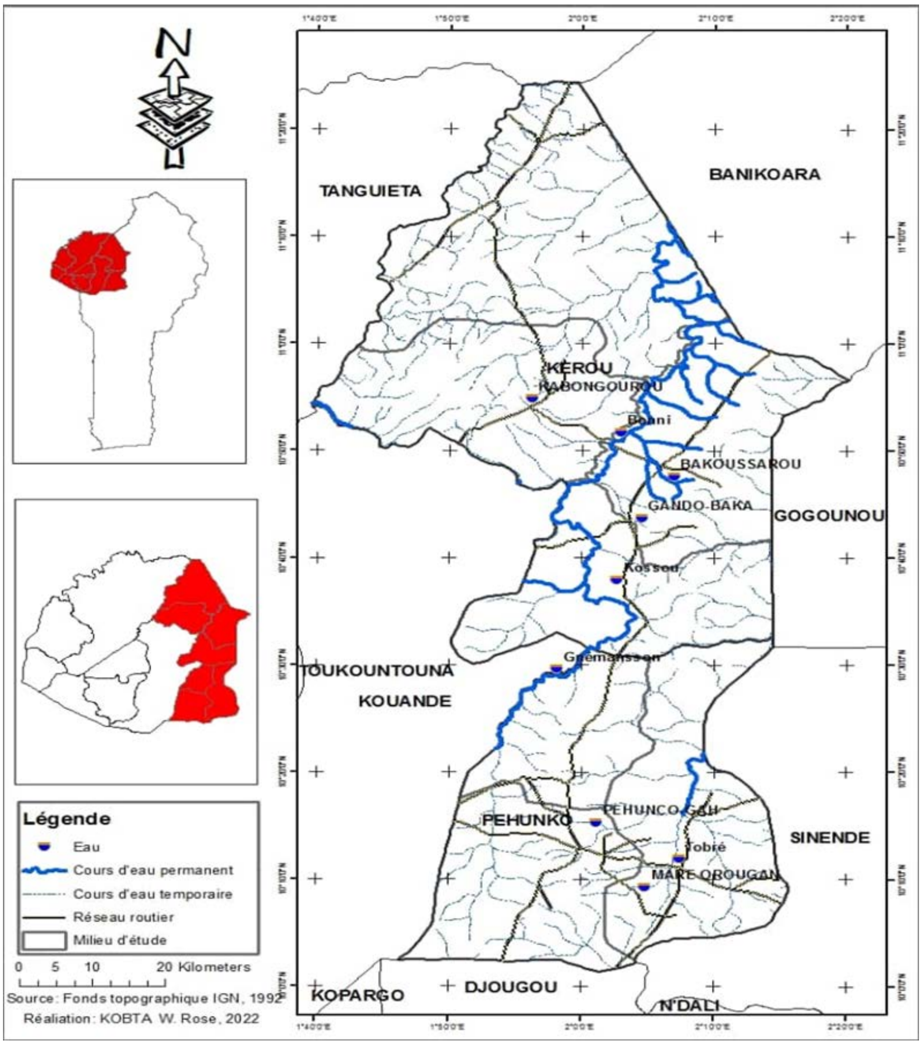


Figure 1. Spatial distribution of water sampling sites in the communes of Kerou and Péhunco (Source: Kobta, 2021)

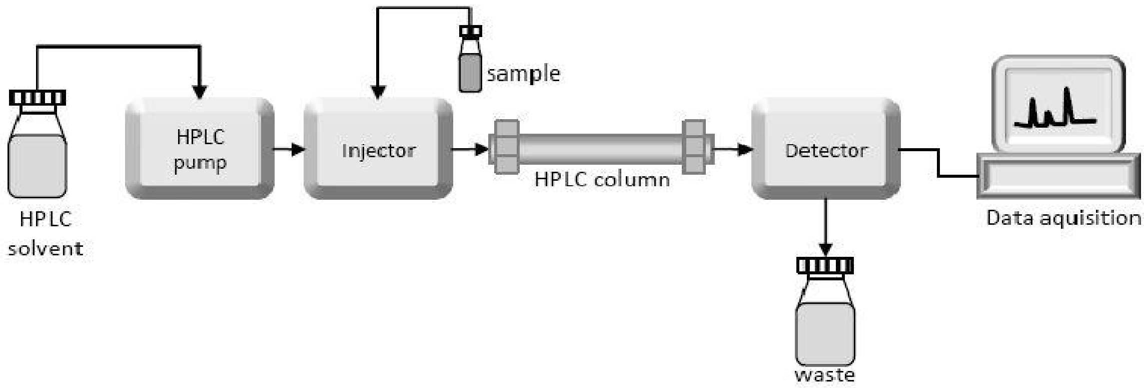


Figure 2. High performance liquid chromatography system (**Source:** Adanlokonon, 2019)

2.2. Method of Study

2.2.1. Identification of Sampling Sites and Water Sampling

The water bodies were identified according to their proximity to cotton farming areas (Fètèkou, Boni, Kossou, Tobré, Gnémasson) and other sources defined as controls located in agglomerations used for domestic purposes (Gando-Baka, Marékpo, Gouréfoungo, Péhunco-Gah and Maré Orougan) (Figure 2). At each sampling site, a transect, is made in the water body. On this transect three points are sampled, namely the edges of the two banks and the middle of the watercourse. The water is collected at 25 cm below the surface with the help of 2 liters weighted bottles. The three sub-samples of water thus obtained are intimately mixed in equal proportions to make a composite sample, 2 L of which is transferred to an amber bottle containing 25 mL of methanol. Once in the laboratory, the water samples were transferred to a refrigerator at 4°C and analyzed the next day for nutrient salts, cypermethrins, deltamethrins and glyphosates content.

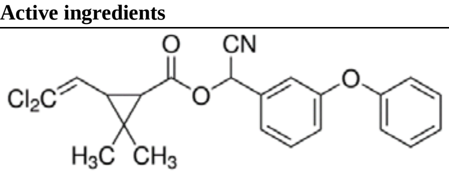
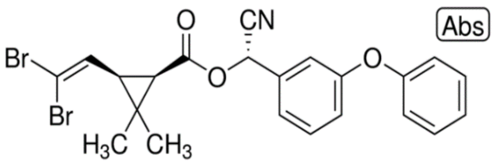
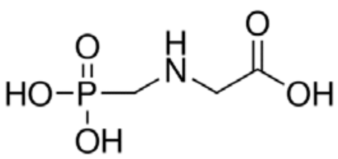
2.2.2. Analysis of Mineral Content and Active Ingredients of Pesticides

In situ, parameters such as dissolved oxygen, temperature, pH and electrical conductivity were measured [14]. Nutrient salts indicative of eutrophication and probably associated with fertilizer use in the fields were determined. These are nitrates, nitrites, ammonium, orthophosphates, sulfates and chlorides. Then the active ingredients of pesticides such as cypermethrins, deltamethrins and glyphosate were determined. Table 1 and Table 2 summarize the methods used to determine these parameters in the water. GPS coordinates were taken with GPS 60, GARMIN during the period of July 2021.

Table 1. Methods of measurement of physicochemical parameters of water

Monitored parameters	Materials and methods used	References
pH, Temperature, conductivity, TDS, salinity	In-situ measurement by a multi-parameter, pH, conductivity meter WTW340i	NF T 90-008 NF T 90-029
O_2 dissolved	In situ measurement by Potentiometry/electrochemical method	NFT EN 25814
NO_3^-	Colometry, method / reduction of cadmium	
NO_2^-	Colometry, diazotization method	NFT EN 26777
NH_4^+	Nessler's method	
N total	Nessler methods after mineralization	

Table 2. Determination methods for active ingredients of insecticides and herbicides

Active ingredients	Dosing method
  	Liquid chromatography coupled with mass spectrometry

2.2.3. Statistical Analysis of Collected Data

Statistical analysis and calculation of mean values and standard errors were performed with the "Statistical Analysis System" version 9.2 after verification of conditions of normality and homoscedasticity of variance. The mean values of the different water variables obtained in each village were compared with the Student Newman Keuls test at the 5% threshold [15]. Subsequently, Pearson correlation tests (r) were established between the variables measured in situ (pH, temperature, conductivity, and dissolved oxygen), nutrient salts (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, total P) and the levels of cypermethrins, deltamethrins and glyphosates.

3. Results

3.1. Dynamics of Physicochemical Parameters Measured in Situ in the Waters

Electrical conductivity provides a rough and comprehensive assessment of mineralization in the waters (Table 3). The surface waters examined show low values overall with a maximum of 103.12 µS/cm obtained in Gouréfoungo and a minimum of 34.74mg/L in Boni. These low values indicate low mineralization and therefore low nutrient content in the water. This is confirmed by the dissolved oxygen concentrations recorded, which for 70% of the sites explored were above 8 mg/L, indicating a low level of nutrients and low microbial activity that consumes oxygen. Thus, the recorded pH values reveal those of natural waters with values close to neutrality oscillating around 7, possibly indicating the possible presence of weak acids in the form of free CO_2 and weak bases in the form of HCO_3^-, which by their buffering capacity confer this pH to the water. The salinity of the waters of the localities remains low and does not exceed 0.04 ‰ for the most loaded waters with a minimum value of 0.001‰. In total, the variables measured in situ indicate a low disturbance environment susceptible to consumptive use.

3.2. Dynamics of Eutrophication Indicator Parameters

Nitrites, nitrates, ammonium ions and ortho-phosphates are among the indicators of the level of eutrophication of the water (Table 4). Ammonium levels range from 0.001 to 0.19 mg/L for the most heavily contaminated waters. These levels remain low compared to Beninese standards (0.5 mg/L) for drinking water. The localities of Maré Orougan, Gando Baka and Péhunco gah receive more nitrogenous nutrients than the other localities. In reality, there is an interaction between the levels of nitrogenous nutrients in the aquatic biotopes thanks to the bacteria that ensure their conversion into one or the other form. Thus, according to our work, nitrate levels are highest in the three preceding zones, as well as in zones such as Gando Baka, with values of 9 mg/L. On the other hand, the Tobré, Kossou, Fètèkou and Boni zones have the lowest levels, fluctuating around 1.5 mg/L. About 60% of the water sources have nitrate levels higher than 4.5 mg/L. These levels, although high, remain low and are 10 times lower than the standard accepted in drinking water, which is 45mg/L. With respect to nitrites, the water has low nitrite levels, with values ranging from 0.1 to 1.5 mg/L for the most contaminated water sources (Péhunco Gah). These values remain low and indicate a possible use of these waters for drinking purposes. The sources of these nitrogenous nutrients are multiple and can concern the mineral fertilizers used in the agricultural fields or even the organic waste which by decomposition and mineralization can be progressively concentrated in the surface water bodies. If the sources are of agricultural origin, the excessive accumulation of nutrient salts in water bodies after dispersion from farms is a sign of poor incorporation and assimilation in exports during harvesting. Apart from nitrogenous nutrients, ortho-phosphates are in high concentrations in the above-mentioned water bodies (1.7mg/L maximum), while the Boni, Fètèkou and Kossou areas have the lowest levels (0.2mg/L). This indicates a similarity in the sources of emission of these nitrogen and phosphate nutrients into the water, a source that is probably related to the chemical fertilizers used in the cotton farms, but which is also complementary to the livestock activities in the control zones, which discharge much more animal excrement rich in nutrient salts. In spite of the generally low levels of these nutrients, the remaining concerns relate to the continuous input of these nutrient salts, which may cause, among other things, problems of eutrophication, with its corollary of destroying the ecological balance. In addition, the chlorides and phosphates that were monitored in the water bodies have peaks of 7.5 and 6.5 mg/L on average in the Gouréfoungo and Marékpo areas. Overall, the level of contamination of surface water bodies with nitrogen and phosphate pollutants remains low, suggesting that these water sources can be used for drinking purposes. In this study, these nutrient salts showed concentrations 2 to 3 times lower in areas of high cotton production than in control areas. It appears that for cotton crops, the important exports of nutrients during harvesting reduce the loss of salts to the soil and contribute little to the contamination of water, whereas the control zones targeted are in agglomeration with various livestock breeding activities and probably contribute more nutritive salts, hence the high levels of mineral elements in the control zones.

3.3. Toxicity of Surface Waters by Insecticides and Herbicides

Cypermethrins, deltamethrins and glyphosate are active substances, some with insecticidal and others with herbicidal properties. Their presence in water indicates a dispersion from farms to water bodies. The results showed the presence of cypermethrin, deltamethrin and glyphosate in the 10 water points examined (Figure 2). These results revealed two groups of water, namely water containing high doses of pesticides (cotton zone) and water containing low doses. Cypermethrin levels are very high in the villages of Boni, Fètèkou, Tobré and Kossou, with average values around 16 µg/L, in contrast to the areas of Péhunco-Gah, Maré Orougan and Marékpo Gouréfoungo, where average values are four times lower than in the previous areas (about 4 µg/L). With respect to deltamethrin, the levels in the water points follow a similar pattern to cypermethrin in the same areas of Boni, Fètèkou, Tobré and Kossou, with average maximum levels of 30µg/L, 6 times higher than in the water of the villages of Péhunco-Gah, Maré Orougan, Marékpo and Gouréfoungo. This indicates a possible common origin of the sources of pollution of these waters by insecticides. In addition, glyphosate, a chemical herbicide, is highly concentrated in the same areas as the previous ones, with an average content of 8µg/L, and the areas of Péhunco-Gah, Marékpo and Maré Orougan confirm a minimal presence of active substances. Overall, the areas of pesticide concentration in the water coincide with areas of high cotton production.

3.4. Correlations between Nutrient Levels and Pesticide Concentrations in Water

Overall, the work revealed that areas with high pesticide concentrations, notably Boni, Fètèkou, Tobré and Kossou, had relatively low levels of minerals content in their waters, whereas waters with high pesticide concentrations (control area) had high levels of nutrient salts. Pearson's tests between mineral salts and pesticide active substances revealed significant correlations (Table 5). Thus ammonium, nitrate and phosphate concentrations were negatively and significantly correlated with cypermethrin levels with respective values of ($r = -0.618$; $p < 0.001$), ($r = -0.833$; $p < 0.001$) and ($r = -0.820$; $p < 0.001$) on the other hand salinity is positively and significantly correlated with cypermethrins ($r = 0.561$; $p < 0.001$). Similarly, these nutrient salts indicate negative and significant correlations with deltamethrins with respective values of ($r = -0.562$; $p < 0, 001$), ($r = -0.798$; $p < 0, 001$), ($r = -0.893$; $p < 0, 001$). Finally ammonium, nitrate and phosphate ions, chloride and sulfate show negative and significant correlations with glyphosate content in water. These data show that the sources of emission of pesticides and nutrient salts into water are identical and are therefore the chemical inputs used on farms. It also shows that waters with a high concentration of pesticides contain little nutrient salts and vice versa. Both chemical inputs are brought to the cotton crops in significant quantities, but the mineral fertilizers are used by the plant and exported through the crops, whereas the pesticides brought to the crops in large quantities are deposited, dispersed and leached into the air, water and soil after their activity on the crops.

Table 3. pH, Electrical Conductivity, Dissolved Oxygen and Salinity

Locations	pH	EC (µS/cm)	$O_{2\ (mg/L)}$	Salinity (‰)
Fetekou	7.52 ± 0.17a	93.34 ± 4.63ba	8.64 ± 0.39b	0.04 ± 0.005ba
Boni	7.08 ± 0.04b	34.74 ± 3.28e	8.50 ± 0.27b	0.01 ± 0.006bac
Kossou	7.54 ± 0.04a	97.39 ± 4.47ba	8.51 ± 0.14b	0.04 ± 0.01a
Tobré	7.55 ± 0.06a	63.70 ± 2.59c	8.66 ± 0.26b	0.03 ± 0.005bac
Guemassou	7.29 ± 0.08ba	26.92 ± 0.90e	8.67 ± 0.34b	0.02 ± 0.01bac
Gando Baka	7.03 ± 0.09b	66.40 ± 1.95c	9.32 ± 0.37ba	0.004 ± 0.0008c
Marekpo	7.29 ± 0.12ba	86.45 ± 4.54b	7.24 ± 0.54c	0.001 ± 0.0001c
Gourefoungo	7.03 ± 0.03b	103.42 ± 1.62a	6.83 ± 0.19c	0.004 ± 0.0008c
Pehunco-Gah	7.37 ± 0.15ba	48.90 ± 1.89d	10.16 ± 0.16a	0.01 ± 0.0008bc
Mare-Orougan	7.05 ± 0.03b	59.40 ± 1.77c	5.55 ± 0.28d	0.001 ± 0.00003c

Source: Results of data analysis, March 2021.

Table 4. Eutrophication indicators parameters

Locations	NH_4^+ (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)
Fètèkou	0.001 ± 0.0006d	2.54 ± 0.04g	0.58 ± 0.07cd	1.20 ± 0.11d	1.07 ± 0.06d	0.31 ± 0.02d
Boni	0.02 ± 0.003d	2.05 ± 0.05g	0.63 ± 0.02cd	1.06 ± 0.08d	2.06 ± 0.04c	0.28 ± 0.01d
Kossou	0.001 ± 0.0003d	3.06 ± 0.04f	0.45 ± 0.06d	1.30 ± 0.05d	1.06 ± 0.02d	0.33 ± 0.03d
Tobré	0.01 ± 0.003d	1.16 ± 0.04h	1.05 ± 0.02b	0.90 ± 0.06d	1.01 ± 0.01d	0.51 ± 0.01d
Gnémasson	0.02 ± 0.005d	4.83 ± 0.16d	0.56 ± 0.04cd	0.60 ± 0.05d	2.00 ± 0.08c	0.23 ± 0.02d
Gando Baka	0.01 ± 0.001d	8.24 ± 0.15a	0.16 ± 0.01e	4.83 ± 0.53b	3.44 ± 0.38b	1.45 ± 0.12b
Marékpo	0.01 ± 0.0008d	4.27 ± 0.18e	0.92 ± 0.08cb	3.47 ± 0.27c	5.93 ± 0.10a	1.89 ± 0.05a
Gouré-foungo	0.21 ± 0.01a	6.21 ± 0.17c	0.84 ± 0.03cb	7.22 ± 0.39a	2.52 ± 0.29c	1.54 ± 0.14b
Péhunco-Gah	0.12 ± 0.005c	5.04 ± 0.03d	1.41 ± 0.22a	5.20 ± 0.18b	2.24 ± 0.15c	1.22 ± 0.12c
Maré-Orougan	0.19 ± 0.01b	7.48 ± 0.40b	0.88 ± 0.03cb	2.87 ± 0.07c	3.49 ± 0.27b	1.12 ± 0.06c
Standards Beninese (drinking water)	0,5	45	3,2	250	500	-
Standard WHO (drinking water)	-	50	3	250	250	-

Source: Results of data analysis, March 2022.

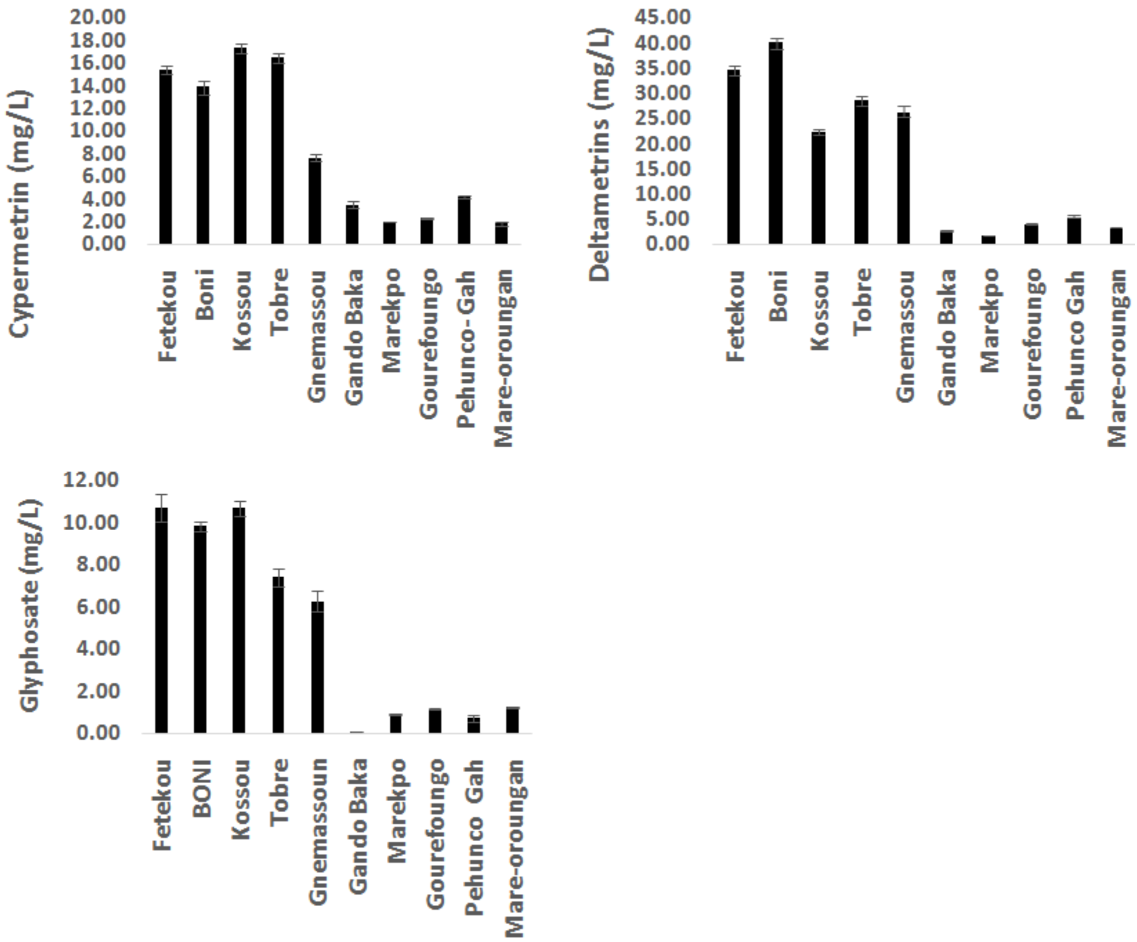


Figure 2. Cypermethrin, deltamethrin and glyphosate content in water (Source: Results of data analysis, March 2022)

Table 5. Pearson correlation test between nutrient content, chemical and physical parameters and the active matter of pesticide

	pH	CE	O_2	Salinity	NH_4^+	NO_3^-	NO_2^-	Cl^-	SO_4^{2-}	PO_4^{3-}	Cypermetrin	Deltamethrin
EC	0.202ns											
O_2	0.289ns	-0.273ns										
Salinity	0.552*	0.116ns	0.357ns									
NH_4^+	-0.461*	0.120ns	-0.530**	-0.513**								
NO_3^-	-0.590**	0.005ns	-0.266ns	-0.606***	0.540**							
NO_2^-	0.028ns	-0.112ns	-0.011ns	-0.128ns	0.433*	-0.170ns						
Cl^-	-0.453*	0.336ns	-0.134ns	-0.588**	0.659***	0.654***	0.234ns					
SO_4^{2-}	-0.364*	0.065ns	-0.396*	-0.649***	0.176ns	0.514**	0.059ns	0.408*				
PO_4^{3-}	-0.398*	0.329ns	-0.300ns	-0.680***	0.451ns	0.616***	0.225ns	0.817***	0.791***			
Cypermethrin	0.561**	0.045ns	0.344ns	0.780***	-0.618***	-0.833***	-0.192ns	-0.7***	-0.759***	-0.820***		
Deltamethrin	0.359ns	-0.265ns	0.302ns	0.663***	-0.562**	-0.798***	-0.202ns	-0.789***	-0.683***	-0.893***	0.867***	
Glyphosate	0.506**	0.008ns	0.239ns	0.760***	-0.578**	-0.796***	-0.286ns	-0.789***	-0.701***	-0.880***	0.935***	0.924***

ns: not significant; *: highly significant ($p<0.05$) **: highly significant ($p<0.01$); ***: very highly significant $p<0.001$.
Source: Results of data analysis, March 2022.

4. Discussion

4.1. Dynamics of Nutrient Salts in Waters

The work revealed levels of mineral salts such as nitrites, nitrates, ammonium and ortho-phosphates in all the water bodies explored, but these levels remain below the norm for drinking water in Benin. The pH measured is neutral in all the water points explored and compatible with Beninese and WHO standards, which range from 6.5 to 8.5. These values are still lower than those of [16], who worked on rainwater storage tanks. The work of [17] on groundwater showed rather acidic pH values revealing that the pH of the water varies depending on the origin of the water source. The water sources explored in the present work are surface water sources with low conductivities whose maximum of 103 µS/cm indicates low mineralization of the water revealed by mineral salt contents including ammonium (0,21 ± 0,01) mg/L, nitrates (8,24 ± 0,15) mg/L, nitrites (1,41 ± 0,22) mg/L, chlorides (7,22 ± 0,39) mg/L, ortho-phosphates (1,89± 0,05) mg/L, sulphates (5,93 ± 0,10) mg/L lower than those of the waters intended for consumption. [18] (decree n° 2001- 094) and those found by [19] Saizonou et *al*, 2015; [16] in rainwater storage; as well as that of [20] Dansou et *al*., 2015 who evaluated well water in Benin. This low mineralization can be explained by the nature of the waters of the studied sites less polluted compared to the agricultural area investigated by [19] Saizonou et *al*. 2015 who revealed a concentration in surface waters of agricultural areas in the Sota in Benin, a nitrate content approaching 180mg/L. Although low, these mineral elements are of concern as to the consequences of their continuous input into the environment by agricultural and livestock activities.

4.2. Pesticides in Water and Health and Environmental Risks

In our work, areas with high cotton production showed high pyrethroid and glyphosate levels compared to population clustering and less cultivated control areas. Cypermethrins and deltamethrins are insecticides used especially in cotton and vegetable fields for chemical pest control [20,21,22,23,24]. Average levels are high in the cotton regions for Cypermethrins (16 µg/L), deltamethrins (30µg/L) and glyphosate (8 µg/L) and the control areas have relatively low levels. [25] mentioned the effect of runoff water that can carry pesticides into aquatic environments and the wind that carries them to other plots, to pastures, to human settlements. In addition, [26] estimates that during the application of pesticides, not all particles are deposited on the crop and that about 70% fall on the ground and can therefore contaminate surface water. [27] had slightly lower results than ours when measuring pesticides in the Agbado River (central part of the country) with regard to pyrethroids but similar with regard to Glyphosate. This difference would have two origins, namely the techniques of detection and analysis and especially the water body prospected which differs from ours. In Canadian groundwater sources, values ranging from 2 to 9 µg/L were detected for glyphosate, a value similar to our results, while slightly lower pyrethroid levels (3.09ng/L) compared to our work were detected in these waters [28]. Furthermore, in the drinking water production areas and in the cotton belt of Gogounou and Banikoara, [29] found levels in sediments 10 times higher than ours. This is justified by the fact that pesticide deposition occurs through the formation of various complexes in sediments after a stay in water or after the death of organisms that have bio accumulated these pesticides [30,31]. [32] and [33] explained the presence of pesticides in water through four pathways, namely spray drift, leaching through the soil, runoff and finally accidental spillage. Sequenced testing from the field, in air, and in runoff showed that runoff was the priority transport component for active ingredients such as endosulfan, hexachlorocyclohexane, acetamiprid, lambda-cyhalothrin, profenofos, or cypermethrin to aquatic ecosystems [28]. Several health impacts have been identified as a result of exposure to pyrethroids, including deltamethrins, which result from the action of carbon tetrabromide on cypermethrins [29]. This is because of their neurotoxicity, hepatotoxicity, nephrotoxicity, cardiotoxicity, pneumotoxicity, reprotoxicity and immunotoxicity [29]. Thus, due to the intensive use of pesticides, different aquatic ecosystems are contaminated by residues [8,30,31,32,34] recommend for Northern Benin, a reduction of pesticide doses for a reasoned control in cotton production. Indeed in aquatic ecosystems, these pesticides are incorporated into trophic chains from phytoplankton through macroinvertebrates [35] to fish [36] corroborating the work of [37] who revealed the hypersensitivity of diatoms to a combination of pesticides in aquatic mesocosm. [22] reported contamination of source waters following cabbage cultivation in Senegal with Lambda-cyhalothrin levels at thresholds of 3.93µg/L. These globally low levels compared to WHO and Benin standards are certainly warning signals for an integrated control reducing chemical pesticides to the detriment of biological control reducing the contamination of aquatic ecosystems.

5. Conclusion

At the end of this study, with regard to the hypotheses, it appears that:

- Areas with high cotton production showed high pyrethroid and glyphosate levels compared to population clustering and less cultivated control areas.

- Mineral salts such as nitrites, nitrates, ammonium and ortho-phosphates in all the water bodies explored remained below of the norm for drinking water in Benin

- The pesticides come mainly from the dispersion in cotton growing areas with risks of gastric, nervous and dermal health problems.

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Conflict of Interests

The authors declare that they have no conflict of interest.

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