Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.6104

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (6):** 1420-1435 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Influence of the Use of Pesticides on the Quality of Water Resources in the Agboville Department (Southeast of Cote d'Ivoire)

Rodrigue Kotchi OROU[1*], Ernest Kouassi AHOUSSI[1], Yro Hyacinthe TIE[2], Germaine Adjoua TANOH [3], Drissa Tanina SORO[4] and Nagnin SORO[1]

[1]Laboratory of Sciences and Technology of Water and Environment, UFR of Earth Sciences and Mining Resources (UFR-STRM), Felix Houphouët-Boigny University of Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire

[2]Department of Environment and Risk Prevention, Ministry of Salubrity, Environment and Sustainable Development, 20 BP 650 Abidjan 20, Côte d'Ivoire.

[3]Laboratory of Soil Sciences, UFR of Earth Sciences and Mining Resources (UFR-STRM), Felix Houphouët-Boigny University of Cocody, 22 BP 582 Abidjan 22, Côte d'Ivoire

[4]Department of Environmental Sciences (DSE), Jean Lorougnon Guédé University, 02 BP 150 Daloa 02, Côte d'Ivoire

*Corresponding Author E-mail: orourodrigue@gmail.com

Received: 19.11.2017 | Revised: 22.12.2017 | Accepted: 27.12.2017

ABSTRACT

Farmers in the department of Agboville use pesticides to improve their agricultural yield without knowing their effects on the quality of water resources. The main objective of this study is to assess the level of contamination of surface water and groundwater through the use of pesticides in the department of Agboville. 24 samples of which 18 for surface water and 6 for groundwater were made during the dry season and the rainy season. The laboratory assay made it possible to obtain the concentrations of pesticide active ingredients in the water. Statistical analysis of hydrochemical data and indices of contamination are the different methods used to reach our objective. The order of abundance of the active ingredients detected in the sampled waters is glyphosate> glyphosate isopropylamine salt> deltamethrin> chlorpyrifos-ethyl> thiamethoxam> dichlorodiphenyltrichloroethane. Only glyphosate concentrations in the rainy season have an average greater than 0.1 µg / L while in the dry season it is less than 0.1 µg / L. DDT was not detected in the waters sampled in both seasons. The average values of the ICP (> 2) show that the water is of average quality and according to the average values of the IPA these waters are of good quality (> 0,5 µg / L). Surface water is more exposed to pesticide contamination than groundwater, and contamination is more severe in the rainy season than in the dry season.

Key words: *Farmers, Pesticides, Contamination, Water, Agboville.*

INTRODUCTION

Before the advent of phytosanitary products worldwide, cropping systems were designed to ensure the best compromise between phytosanitary risk and yield potential of crops[32].

Cite this article: OROU, K. R., AHOUSSI, K. E., TIE, H. Y.,TANOH, A. G., SORO, T. R. and SORO, N., Influence of the Use of Pesticides on the Quality of the Water Resources in the Department of Agboville (Southeast of Cote d'Ivoire, *Int. J. Pure App. Biosci.* **5(6):** 1420-1435 (2017). doi: http://dx.doi.org/10.18782/2320-7051.6104

Gradually, the acquisition of knowledge about the needs of a plant in mineral elements, the control of fertilization and the development of herbicides, insecticides and first synthetic fungicides have profoundly modified the culture systems[4]. Pesticides have been introduced on the world market to protect crops from pests and diseases, to secure or boost yields[3, 20]. The agricultural exploitation of the lands thus appears as an activity generating income for rural populations confronted with the rural exodus. But, alongside this important contribution to the economy of our countries in a world in recession, hovers the specter of an ecological disaster because the good behavior of these cultures requires the use of phytosanitary products. Agrochemicals are a source of environmental pollution[3,13] and have been implicated in the degradation of the quality of water resources[10,19]. Their use is done very often in disregard of health and environmental risks [14]. In France, agricultural pollution due to the use of fertilizers and pesticides is an important cause of degradation of the quality of water resources[9, 20]. In the United States and Quebec, plant protection products were detected in 86% of surface water samples[12, 7]. In Burkina Faso, [35, 31] have shown that water degradation is due to the use of agricultural inputs. In Benin, ecosystem disruption has been attributed to the use of pesticides in the cotton sector[1,22]. In Côte d'Ivoire, the work of [39] reported contamination of groundwater by pesticides in agricultural areas. Those of [40], have shown that the lagoon waters of Aghien and Potou are characterized by very high concentrations of pesticide active ingredients that make these waters unsuitable for the production of drinking water. In the Niéki Valley in south-eastern Côte d'Ivoire, analyzes of the various market gardeners (okra, vegetable cornet, spinach and eggplant) have shown that most of the elements found are pesticides of the pyretroid family and a plasticizer from the phthalate family[40]. In the study area, the area under cultivation has increased with production of food and cash crops. All the actors involved in these crops use phytosanitary products to either improve yields or protect them against pests. In addition, this area has great potential in terms of water resources that are crucial for both agricultural activities and the provision of drinking water to the population[27, 28]. In addition, in Azaguié, Agboville department, contamination of groundwater and food products by pesticides has been reported[39, 38]. This demonstrates that the region's water resources are not immune to contamination by plant protection products that are heavily used. It is important to note that a large proportion of the population living in rural agricultural areas is supplied with water from wells or rivers and that the quality of these waters is not monitored. Are agricultural activities in the department of Agboville likely to degrade the quality of water resources? Farmers in the department of Agboville use pesticides to improve their agricultural yield without knowing their effects on the quality of water resources. It is therefore necessary to make a more complete diagnosis on the quality of surface water and groundwater. This is the perspective of our study whose main objective is to assess the level of contamination of surface water and groundwater through the use of pesticides in the department of Agboville.

PRESENTATION OF THE STUDY AREA

Located in southeastern Côte d'Ivoire, between latitudes 5°35N and 6°15N, and longitudes 3°55W and 4°40W (Figure 1), the department of Agboville covers an area of approximately 3850 km^2 with a population of 292190 inhabitants [15].The population is mainly rural and its main activity is agriculture. Food crops, cocoa, rubber and oil palm are the main crops in the Agboville department. The geology of the study area consists of Birimian and Eburnian formations with associated metamorphosed halos[2]. The outcrops in the region are attributed to the Paleoproterozoic and define the Birimian deposit cycle. Their origin is essentially sedimentary[34,2]. The thickness of the alterites in the Agboville department varies on average between 4 and 53 m [2, 26]. Alterite aquifers are mainly captured by rural and urban populations using shallow

catch basins and wells up to 20 m deep. As a result, the water from these wells is highly exposed to pollution[2]. The second aquifer is that of fractures. Over the entire study area, these aquifers are intercepted by numerous boreholes and their existence is linked to the importance of open fractures. It provides significant freshwater and good quality reserves because of its protective screen capable of feeding large rural centers. The climate of the study area and its surroundings is transitional equatorial type with four (4) seasons in the year including two (2) rainy seasons (April to July and September to October) and two (2) dry seasons (November to March and August to September) [10]. This climate is conducive to agriculture. This climate is conducive to agriculture and to increase harvests, pesticides and fertilizers are used.

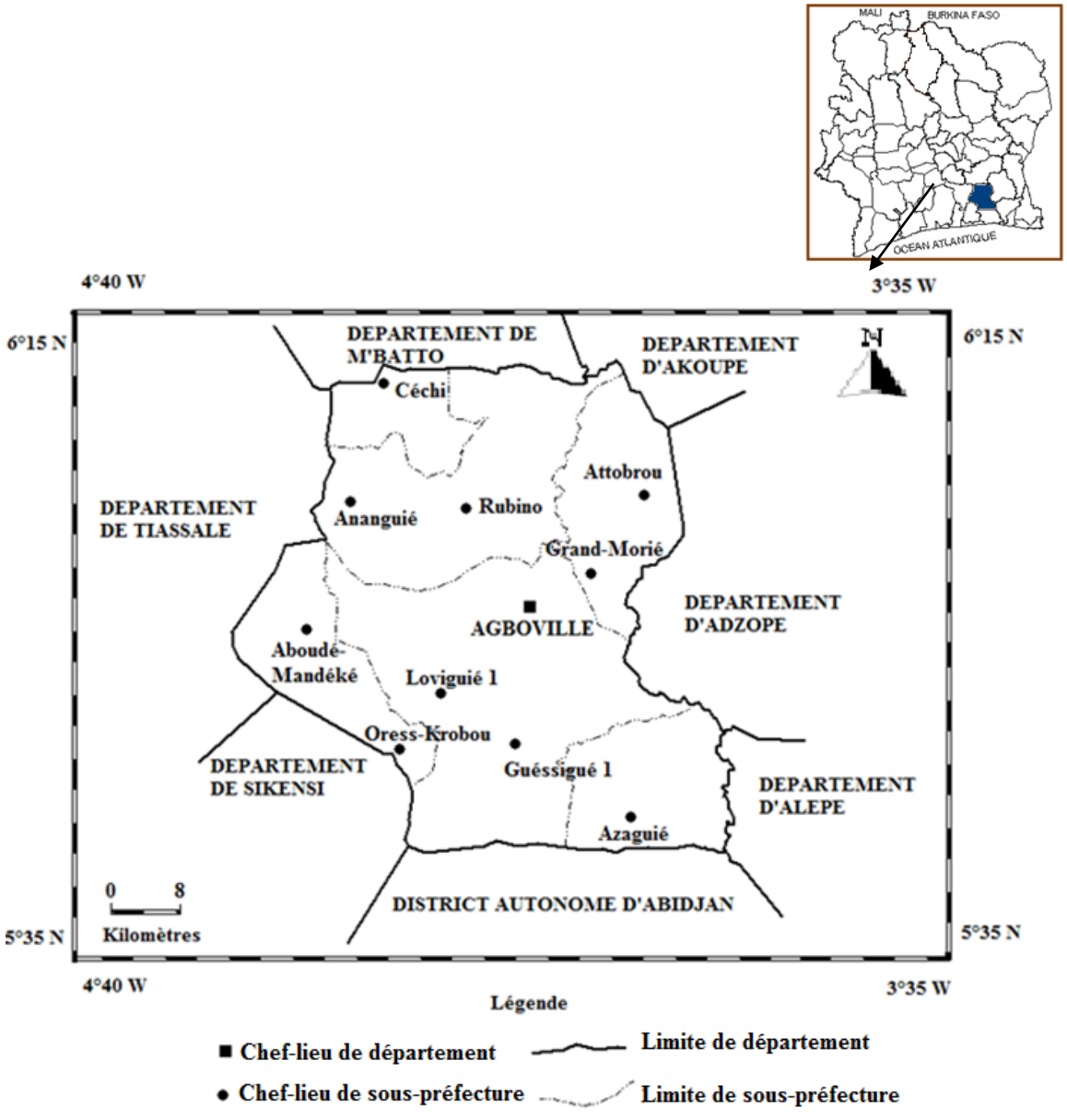

Fig. 1: Location of the study area

The term "pesticides" refers to "all substances (molecules) or products (formulations) that eliminate pests, whether they are used in the agricultural sector or in other applications" [4]. Insecticides, fungicides and herbicides are the most used pesticides in the study area (Figure 2). Farmers use fungicides to control fungi that affect the roots of rubber trees and cocoa trees. Insecticides are widely used in food crops and cocoa orchards.

Fig. 2: View of herbs in a cornfield after herbicide treatment in Azaguié

MATERIAL AND METHODS

II-1 Material and data

The material used consists essentially of cartographic and hydrochemical data. To carry out this study, topographic maps of the square degree of Abidjan, Dimbokro and Grand-Bassam at 1/200 000 scale were used to locate the water points and delimit the study area. The report of the analyzes of the active ingredients of the pesticides of the water samples taken constitute the hydrochemical data. Sampling was carried out on 18 surface water points and 6 wells in the Agboville department. Six (6) active ingredients were detected: glyphosate, glyphosate isopropylamine salt, dichloro diphenyl trichloroethane (DDT), chlorpyrifos-ethyl, deltamethrin and thiamethoxam. Glyphosate and glyphosate isopropylamine salt are active ingredients of herbicides; and DDT, chlorpyrifos-ethyl, deltamethrin and Thiamethoxam are active ingredients of insecticides.

II- 2 Methods

II-2-1 Sampling method

The sampling strategy adopted in our study is based on spatial coverage, the position of plantations in relation to water points and the age of plantations. The twenty-four (24) water points were selected based on the use of pesticides and crops grown. Water samples are collected and transferred to one (1) liter glass bottles previously washed and decontaminated [30]; and one (1) milliliter of hydrochloric acid is spilled to remove microorganisms in the sampled waters. . For well water and surface water, sampling is carried out using a bucket equipped with a bucket.

II-2-2 Method of analysis

As part of this study, the sampling campaigns were conducted following a hydrological cycle: rainy season (19 to 25 September 2014) and dry season (27 February to 04 March 2015). The active ingredients of pesticides were analyzed by the Central Environmental Laboratory of the Ivorian Center Anti-pollution (CIAPOL) according to gas chromatography coupled to a mass spectrometer. This method was used by [6, 40, 8]. The active ingredients of the pesticides were determined according to the method of extraction with C-18 cartridge followed by the gas chromatography assay coupled to a mass spectrometer. The principle of this method was to take 10 ml of the water sample and condition the octadecyl column (C-18) by passing 10 mL of methanol and 10 mL of deionized water. The entire sample taken was passed through the C-18 column prior to the drying of the absorbent. The drying of the cartridge was observed for 30 minutes. Pesticides retained on the column were eluted with 5 ml of methanol by soaking for 30 minutes. The extract is transferred into a conical glass vial for chromatography assay (HPLC). The standard solutions and the

samples were analyzed with a gas chromatograph equipped with a mass spectrometer, in ion-scanning mode. The pesticide concentrations in the sample are calculated by comparing the peak areas of the sample products with the surfaces obtained with standard solutions of known concentrations. The expression of the results is given by the following equation:

$$Cp = \frac{Sc \times Ce \times V2 \times Vf \times F}{Se \times Me \times V1}$$

Cp: concentration of the active ingredient (mg/L); **Sc**: peak area of the sample; **Se**: peak area of the standard; **Ce**: standard concentration (mg/L); **V1**: volume to be purified (L); **V2**: volume after purification (L); **Vf**: final volume (L); **Me**: volume of the sample (L); **F**: dilution factor.

II-2-3 Treatment methods

The calculation of contamination indices is the methodological approach of this study.

Method of calculating contamination indices

These methods describe the degree of water contamination. They are used in combination to assess the level of water contamination in the study area to control the negative effects of these waters on the population. These water quality indices are: the Pesticide Contamination Index (ICP) and the Pesticide Alteration Index (IAP).

• Pesticide Contamination Index (ICP)

"Pesticide quality" is a method that was implemented by [42] in 2005. This method is defined as follows: for each sites (water sampling point), the sum of the concentrations of the active ingredients or substances detected is calculated, then a score of 1 to 3 is assigned according to the sum concentrations of the active ingredients per sample. Finally, we calculate the average score obtained on all campaigns. The classification and quality-pesticide grade grid are summarized in Tables 1 and 2 respectively.

Table 1: Classification of concentrations of active ingredients [42]

Sum of concentrations	Note
< 250 ng/L	1
250 à 500 ng/L	2
> 500 ng/L	3

Table 2: Quality-Pesticide Grid [42]

Water quality	Very good	Good	Very bad
Average score per site (Quality-Pesticides)	1 – 1.5	1.5 - 2	2 - 3

• Pesticide Alteration Index (IAP)

The classification of pesticide active ingredients is by class of alteration (Table 3). These classes were defined according to the classes of the groundwater quality assessment system [21] and the WHO guideline values. These values are then compared to the recommended standards or reference values for drinking water, ie 0.1 µg/L for an active ingredient, and 0.5 µg/L for the total active ingredients in a well or drinking water treatment. sampled water[23,24,25]. Pesticide alteration is the sum of all pesticide active ingredients detected and quantified.

Table 3: Pesticide Alteration Degree Matrix[21]

Water quality	Very good	Good	Bad	Very bad
Alteration Pesticides (µg/L)	< 0.1	0.1 – 0.5	0.5 - 5	> 5

RESULTS AND DISCUSSION

III-1 Results

Statistical analysis of hydrochemical data

The elementary statistical parameters of the concentrations of active ingredients in all the water resources and those obtained in the two studied components (groundwater and surface water) are recorded respectively in Tables 4, 5 and 6.

Table 4: Basic statistics of the active substances detected in the water resources of the department of Agboville

		Rainy Season			Dry Season		
Active ingredients (µg / L)	**WHO Standard**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Glyphosate	0,1 µg/L	0	0.420	0.140	0	0.520	0.080
Glyphosate isopropylamine salt		0	0.280	0.070	0	0.300	0.040
DDT		0	0	0	0	0	0
Chlorpyrifos-ethyl		0	0.320	0.030	0	0.400	0.030
Deltamethrine		0	0.300	0.040	0	0.301	0.030
Thiamethoxam		0	0	0	0	0.110	0.005

Table 5: Statistics of active substances detected in the groundwater of the department of Agboville

		Rainy Season			Dry Season		
Active ingredients (µg / L)	**WHO Standard**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Glyphosate	0,1 µg/L	0	0.300	0.053	0	0.100	0.020
Glyphosate isopropylamine salt		0	0.090	0.020	0	0.050	0.010
DDT		0	0	0	0	0	0
Chlorpyrifos-ethyl		0	0.100	0.016	0	0.006	0.002
Deltamethrine		0	0.300	0.050	0	0.030	0.005
Thiamethoxam		0	0	0	0	0	0

Table 6: Statistics of active substances detected in surface waters of the department of Agboville

		Rainy Season			Dry Season		
Active ingredients (µg / L)	**WHO Standard**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Glyphosate	0,1 µg/L	0	0.420	0.174	0	0.52	0.107
Glyphosate isopropylamine salt		0	0.280	0.088	0	0.300	0.052
DDT		0	0	0	0	0	0
Chlorpyrifos-ethyl		0	0.320	0.037	0	0.400	0.043
Deltamethrine		0	0.200	0.036	0	0.301	0.041
Thiamethoxam		0	0	0	0	0.110	0.007

Glyphosate

Glyphosate values in the rainy season range from 0 to 0.420 µg/L, with an average of 0.140 µg/L (Table 4). However, in the dry season, they are between 0 and 0.520 µg/L, with an average of 0.080 µg/L (Table 4). In the rainy season, 45.83% of the points sampled have a concentration greater than 0.1 µg/L and in the dry season 29.14% have a concentration greater than 0.1 µg/L (Figure 3). These values show that glyphosate contamination is higher in the rainy season than in the dry season. Similarly, it is noted that the highest values are found in surface waters (Tables 5 and 6).

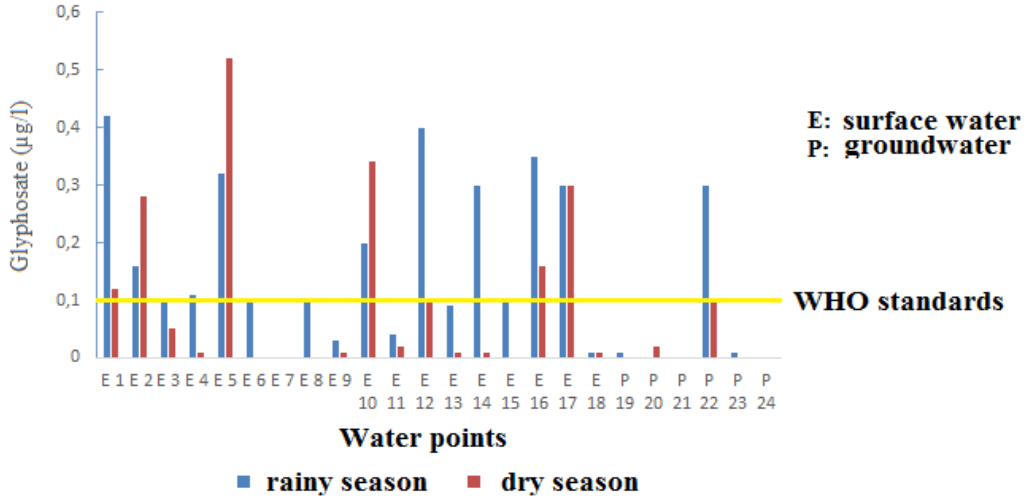

Fig. 3: Evolution of glyphosate in surface and groundwater of the department of Agboville

Glyphosate isopropylamine salt

Values of glyphosate isopropylamine salt in the rainy season range from 0 µg/L to 0.280 µg/L, with an average of 0.070 µg/L (Table 4). In the dry season, they are between 0 and 0.3 µg/L, with an average of 0.04 µg/L (Table 4). In the rainy season, 25% of the points sampled have a concentration greater than 0.1 µg/L and in the dry season 12.50% have a concentration greater than 0.1 µg/L (Figure 4). These values show that contamination with glyphosate isopropylamine salt is important in the rainy season rather than in the dry season. The highest values were observed in surface waters (Tables 5 and 6).

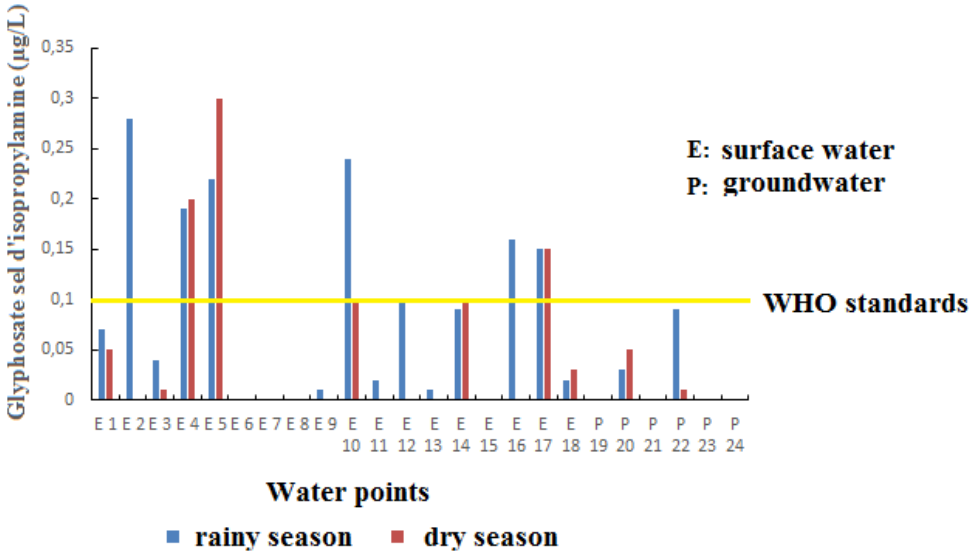

Fig. 4: Evolution of glyphosate isopropylamine salt in surface and groundwater of Agboville

Dichlorodiphenyltrichloroethane (DDT)

Dichlorodiphenyltrichloroethane (DDT) was not detected in the water sampled during the dry and rainy seasons (Table 4).

Chlorpyrifos-ethyl

The chlorpyrifos-ethyl content in the dry season is between 0 µg/L and 0.4 µg/L, with an average of 0.03 µg/L (Table 4). In the rainy season, they are between 0 and 0.32 µg/L, with an average of 0.04 µg/L (Table 4). In the rainy season, 12.5% of the points sampled have a concentration higher than 0.1 µg/L and in the dry season 8.33% have a concentration greater than 0.1 µg/L (Figure 5). These values show that this insecticide active ingredient is more present in water in the rainy season than in the dry season. The highest values were observed in surface waters (Tables 5 and 6).

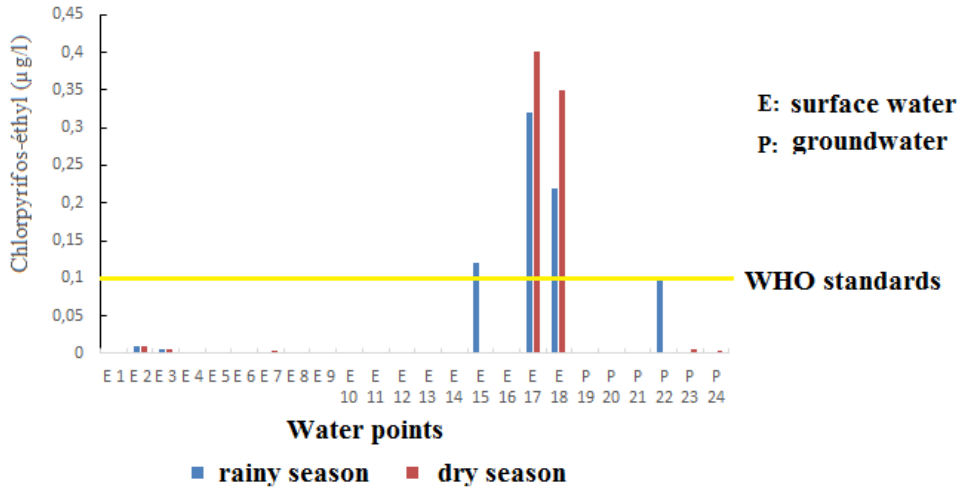

Fig. 5: Evolution of chlorpyrifos-ethyl in the surface and groundwaters of the department of Agboville

Deltamethrin

Values of deltamethrin in the rainy season range from 0 µg / L to 0.3 µg/L, with an average of 0.04 µg/L (Table 4). In the dry season, they are between 0 and 0.301 µg/L, with an average of 0.03 µg/L (Table 4). In the rainy season, 25% of the points sampled have a concentration greater than 0.1 µg/L and in the dry season 12.50% have a concentration greater than 0.1 µg/L (Figure 6). Deltamethrin is more present in the water sampled in the rainy season than in the dry season. The highest values were observed in the Offo N'po well at shallow depths during the rainy season and in the dry season in a surface water reservoir (Tables 5 and 6).

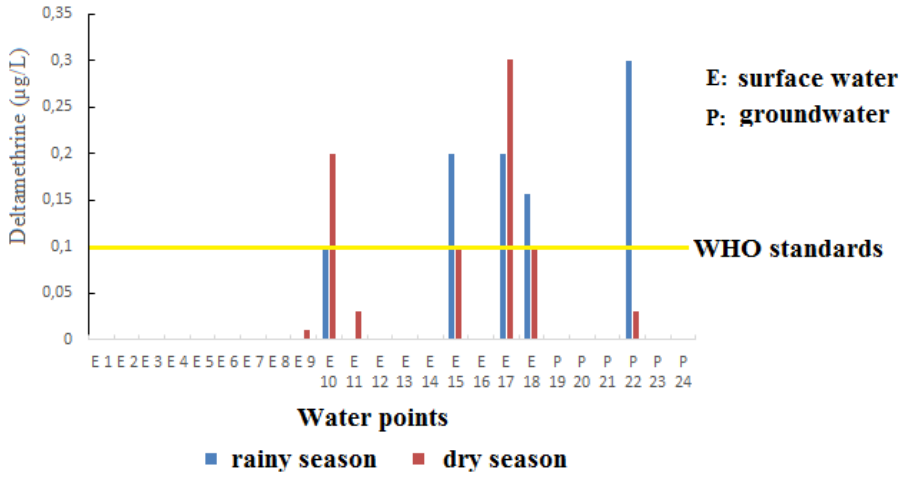

Fig. 6: Evolution of deltamethrin in surface and groundwater of Agboville department

Thiamethoxam

Thiamethoxam was not detected in the water sampled in the rainy season but in the dry season. The average value of thiamethoxam is 0.005 µg/L. Levels were detected only at two surface water points (0.01 µg / L and 0.11 µg / L). In the dry season, a single point has a concentration greater than 0.1 µg/L or 4.17%.

Glyphosate and glyphosate isopropylamine salt are the active ingredients of herbicides and have been detected in all crops. Deltamethrin, chlorpyrifos-ethyl, thiamethoxam and dichlorodiphenyltrichloroethane have been detected in cocoa and market garden plantations. If we consider the average values expressed in µg / L, the active ingredients have an order of abundance of type: glyphosate> glyphosate isopropylamine salt> deltamethrin> chlorpyrifos-ethyl>thiamethoxam> dichloro diphenyltrichloroethane. This order is the same

for both seasons. The sum of the active ingredients of each water point is represented by Figure 7. In the rainy season, the sum of the active ingredients of 5 water points is greater than 0.5 µg/L while in the dry season, there are only 3 water points whose sum of the active ingredients is greater than at 0.5 µg/L. Overall, surface water is more exposed to pesticide contamination than groundwater. However, this contamination is more marked in the rainy season than in the dry season.

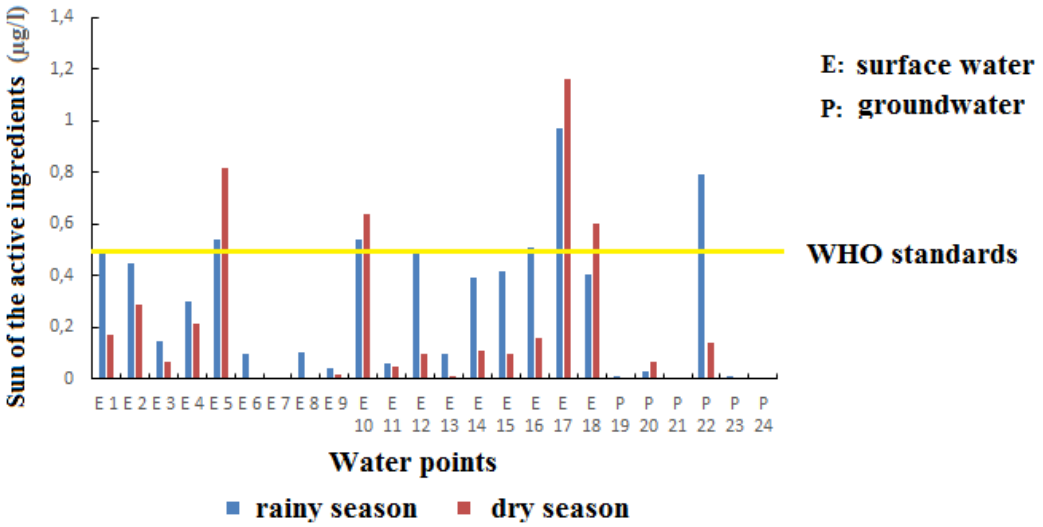

Fig. 7: Evolution of the sum of the active ingredients in the surface and underground waters of the Agboville department

Pesticide contamination indices

The results of the indices of water contamination by pesticides are recorded in Table 7. These indices made it possible to evaluate the level of water contamination by pesticides. The indices of surface water and groundwater contamination are reported in Tables 8 and 9, respectively.

Table 7: Extreme Values of Water Resource Quality Indices

	October 2014 (rainy season)				March 2015 (dry season)			
Indices	**Min**	**Max**	Avg	**EC**	**Min**	**Max**	Avg	**EC**
ICP	1	3	1,71	0,81	1	3	1,54	0,71
IAP	0	0,97	0,30	0,28	0	1,16	0,2	0,30

Table 8: Extreme values of groundwater quality indices

	October 2014 (rainy season)				March 2015 (dry season)			
Indices	**Min**	**Max**	Avg	**EC**	**Min**	**Max**	Avg	**EC**
ICP	1	3	1,33	0,81	1	2	1,17	0,40
IAP	0	1,58	0,28	0,59	0	0,282	0,07	0,11

Table 9: Extreme values of surface water quality indices

	October 2014 (rainy season)				March 2015 (dry season)			
Indices	**Min**	**Max**	Avg	**EC**	**Min**	**Max**	Avg	**EC**
ICP	1	3	1,83	0,78	1	3	1,67	0,74
IAP	0	1,94	0,67	0,50	0	2,322	0,50	0,66

Min: minimum, **Max**: maximum, **Avg**: average, **EC**: standard deviation

Results of the Pesticide Contamination Index (IPC)

The ICP of the sampled waters ranges from 1 to 3, with an average value of 1.71 in the rainy season, and between 1 and 3, with an average value of 1.54 in the dry season (Table 7). The highest indices were observed during the rainy season in the subterranean and surface waters (Tables 8 and 9). In the rainy season, 60% of the waters sampled are of very good quality and 40% are of very poor quality compared to the Pesticide Contamination Index (Figure 8).

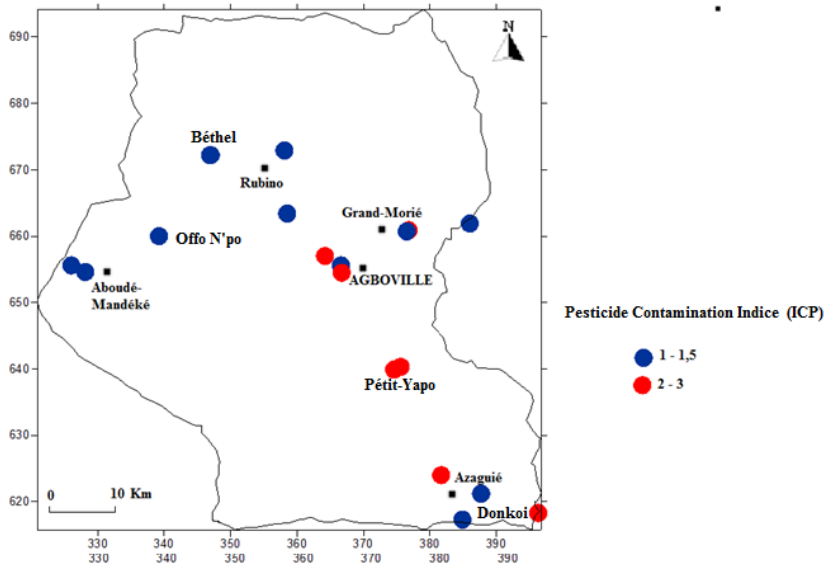

Fig. 8: Spatial distribution map of the Pesticide Contamination Indices (ICP) during the rainy season in the Agboville department

In the dry season, 50% of the waters are of very good quality, 20.83% of the waters are of good to average quality and 29.17% are of very poor quality according to the Pesticide Contamination Index (ICP) (Figure 9). Water contamination by pesticides is greater in the rainy season than in the dry season (Figure 10). The values of the ICP show that the waters sampled in the department of Agboville are generally of good quality.

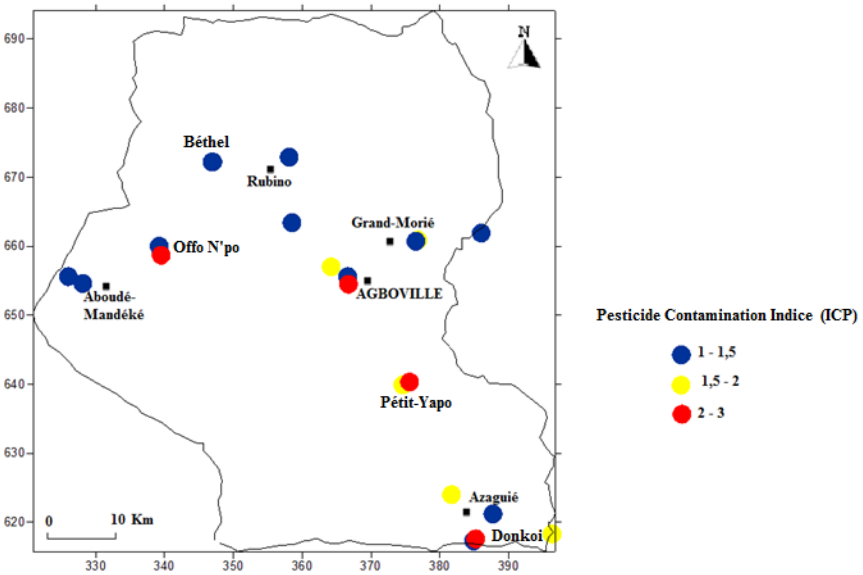

Fig. 9: Map of spatial distribution of Pesticide Contamination Indices (ICP) in the dry season in the department of Agboville

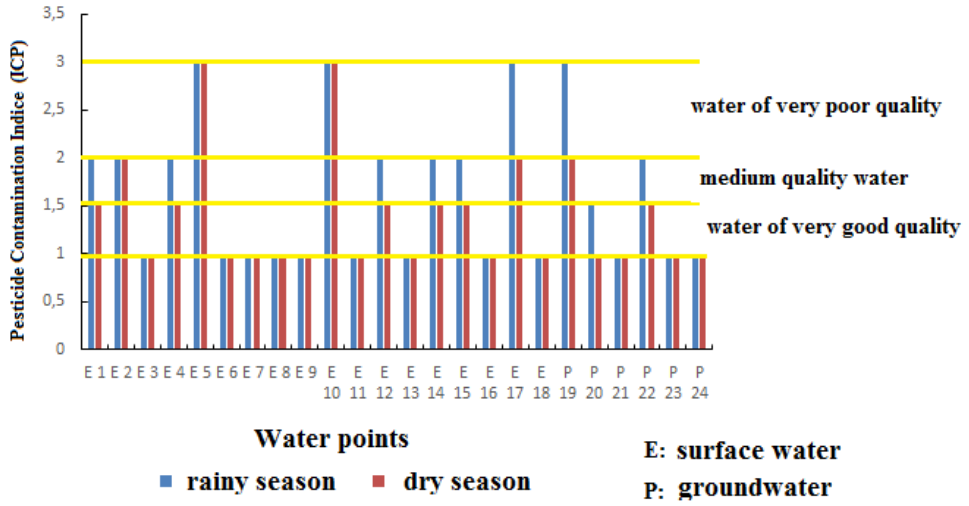

Fig. 10: Seasonal variation of the Pesticide Contamination Index (ICP) of surface and groundwater in the department of Agboville

Results of the Pesticide Alteration Index (IAP)

The IAP for the sampled waters ranges from 0 to 0.97 µg/L with an average value of 0.30 µg/L in the rainy season and from 0 to 1.16 µg/L, with a mean value of 0.2 µg/L in the dry season (Table 7). The highest indices were observed in surface waters (Tables 8 and 9). In the rainy season, 29.17% of the water is said to be of very good quality, 20.83% of the water is considered to be of good quality and 50% is of poor quality according to the Alteration Index Pesticides (Figure 11). In the dry season, 37.5% of the waters are of very good quality, 41.67% are of good quality and 20.83% are of poor quality according to the Index of Alteration Pesticides (Figure 12). Alteration of water by pesticides is greater in the rainy season than in the dry season (Figure 13). The IAP values indicate that the waters sampled in the Agboville department are of good quality.

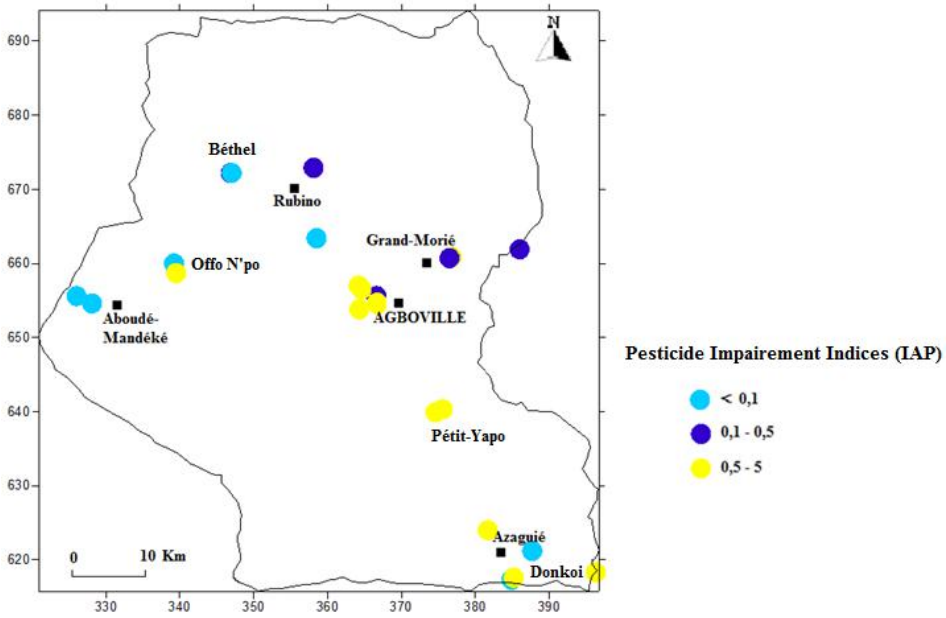

Fig. 11: Spatial distribution map of Pesticide Impairment Indices (IAP) during the rainy season in the Agboville department

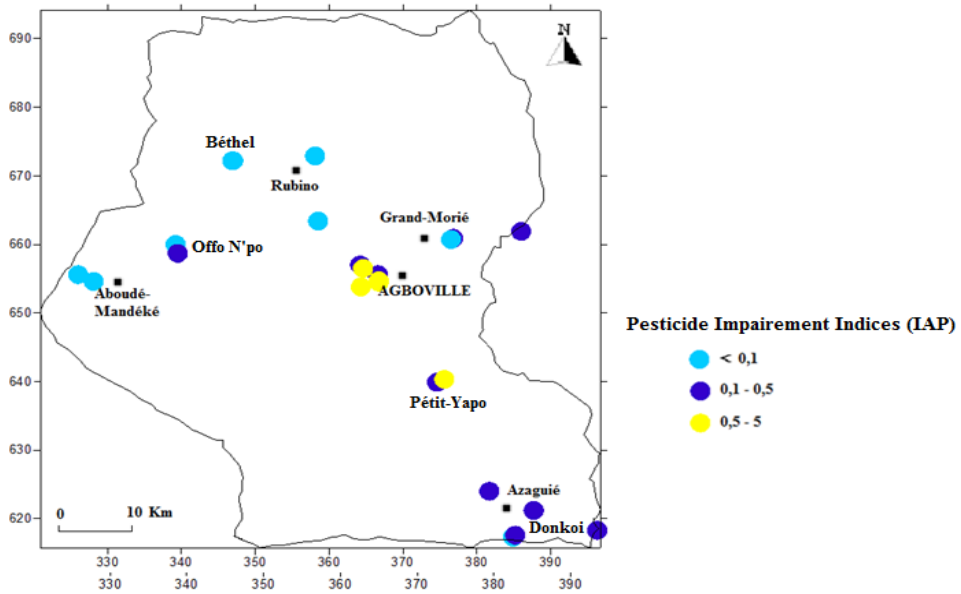

Fig. 12: Spatial distribution map of Pesticide Alteration Indices (IAP) in the dry season in the Agboville department

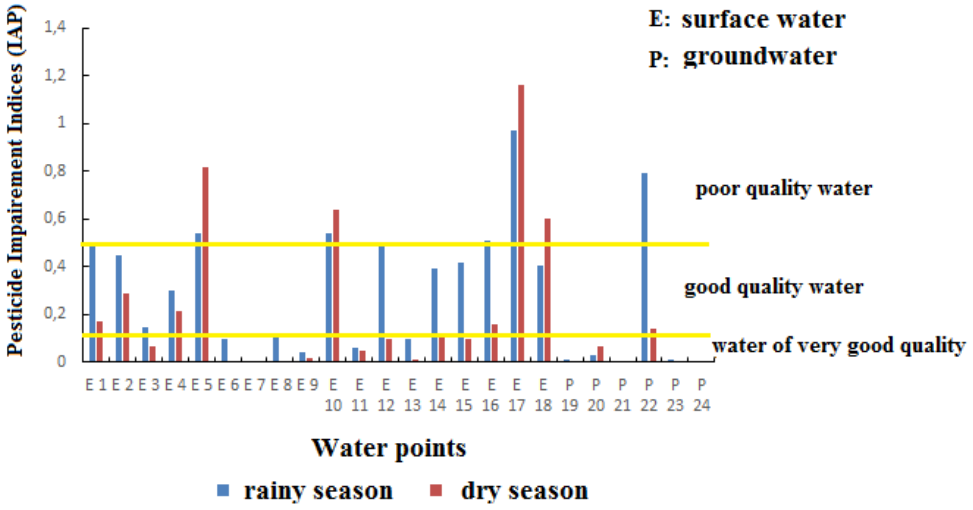

Fig. 13: Seasonal variation of the Pesticide Alteration Index (IAP) of surface and groundwater in the department of Agboville

DISCUSSION

The main source of pollution of groundwater and surface water in the region can be attributed to the use of herbicides and insecticides in palm groves, vegetable gardens, banana plantations (banana or plantain), rice paddies and rubber plantations. High levels of herbicide active ingredients have been detected in rubber and rice plantations. As for the high levels of active ingredients of insecticides, they have been observed in market gardeners. The concentrations of the active ingredients observed around these water points show the extent of the influence of the use of pesticides on the quality of these water resources. Glyphosate and glyphosate isopropylamine salt are the active ingredients of herbicides that have been detected in all crops. Deltamethrin, chlorpyrifos-ethyl and thiamethoxam have been detected in waters in or near cocoa plantations and vegetable gardens. The active ingredients have an order of abundance of the type: glyphosate> glyphosate isopropylamine salt> deltamethrin> chlorpyrifos-ethyl> thiamethoxam> dichloro diphenyltrichloroethane. This order of

abundance suggests a misuse and often uncontrolled use of herbicides despite restrictions of use. The presence of glyphosate and glyphosate isopropylamine salt in crops may be explained by the frequent and excessive use of these active ingredients for the control of weeds. Glyphosate is characterized by rapid degradation in the environment as it has a half-life (DT50) of 100 days in the environment [37, 5]. The presence of glyphosate in water reflects not only a high use of these products but also the proximity of plantations and sometimes the very low level of development of water points. This same observation was made by [39] in four (4) agricultural regions (Abidjan, Buyo, Grand-Lahou and Yamoussoukro) on organophosphorus pesticides with high concentrations. However, according to this work, the active ingredients of herbicides such as simazine, diuron and ametrine used in rubber and oil palm plantations have been detected with concentrations of less than 0.1 µg/L and reflect their low usage right now. The presence of glyphosate isopropylamine salt in the sampled waters means that the counter-band on plant protection products is important in the area. This active ingredient comes mainly from a herbicide not approved by the Ministry of Agriculture [18]. This counterfeit is due to the high cost of pesticides in the approved stores compared to small traders. They also participate in unfair competition to the detriment of authorized sellers. the same observations were made by [11] in Côte d'Ivoire, by [16, 17] in Togo, where most gardeners prefer to obtain pesticides from unauthorized resellers. Deltamethrin, chlorpyrifos-ethyl and thiamethoxam were detected in cocoa plantations and market gardens and had low concentrations. Deltamethrin is characterized by a low DT50 that is 50 days [37, 5]. DT50 values are widely used to estimate the persistence of these active substances in nature. The higher the DT50, the more slowly the active ingredient degrades in the environment [33]. Deltamethrin is the third most abundant active ingredient in the studied waters, which means the massive use of insecticides such as DECIS 12.5 EC for several crops such as cocoa, market gardening and food crops. In the study area, vegetable crops are very diverse and occupy medium areas where several types of vegetables are grown on the same areas. For this reason, the insecticides used are also very varied and large quantities are sometimes used. This is the case specifically in the town of Agboville (Angoh road, Castle district and RAN) and in the village of Petit Yapo where are exploited rice and vegetable crops. These crops have many phytosanitary problems and receive very intensive chemical treatments, including the frequent use of deltamethrins and chlorpyrifos-ethyls for market gardeners, herbicides for rice. These observations are justified by the highest ICP and IAP for these four (4) water points. Dichlorodiphenyltrichloroethane was not detected in all water points sampled as this active ingredient is banned for agricultural purposes worldwide [36, 41, 29] and Côte d'Ivoire [18] for several years. This absence to date could be on the one hand linked to the respect of the laws and regulations in force for the use of pesticides by the farmers in the department of Agboville and on the other hand to the use of DDT by certain micro-organisms. organisms for their metabolism because DDT has a slow degradation in the environment. An inter-season comparison shows that water contamination is more marked in the rainy season than in the dry season when the sum of the active ingredients of 5 water points is greater than 0.5 µg / L, while in the dry season it is There are only 3 water points where the sum of the active ingredients is greater than 0.5 µg / L. The differences in concentration would be due to two factors. The first factor would be rainfall runoff from insecticide-treated plants and leaching of agricultural soils treated with herbicides. The second factor would be the remobilization of the active substance molecules accumulated in the sediments, which occur at degrees along the slope of the site on the one hand, and the frequency of pesticide use on the other hand. An inter-water comparison shows that surface water is more contaminated by pesticides than

groundwater. This finding could be explained by wind action and runoff. Surface water is exposed to ambient air. Indeed, when spraying plantations, the air is contaminated and loaded with pesticide particles. These particles eventually end up in the water of dams, farm ponds and uncovered wells nearby or within plantations. This observation is similar to that of [40] in the case of the Aghien and Potou lagoons in southern Côte d'Ivoire. However, the presence of pesticide active ingredients in groundwater that are naturally of good quality because the passage of surface water and precipitation through the unsaturated zone normally rids them of the active ingredients, can be explained by several phenomena leading to contamination of well water. The shallow depth of the wells (less than 4 m), the poor development of wells and the proximity of plantations are all factors that may explain their presence in groundwater. These observations are similar to those of [39] which states that the presence of pesticides in groundwater is due to the shallowness of wells (less than 3 meters), the leaching of agricultural soils and the proximity plantations.

CONCLUSION

This study evaluated the level of contamination of water resources in the Agboville department by pesticides. The sampling method, the statistical analysis, the calculation of the contamination indices and the field health surveys made it possible to reach our objective. Overall, the level of contamination is low and the assessment is based on calculated indices. Herbicides are used more than insecticides and are used in all crops. Contamination is important in the rainy season during the dry season and surface water is the most contaminated. Glyphosate and glyphosate isopropylamine salt are the active ingredients of herbicides and have been detected in all crops. Deltamethrin, chlorpyrifos-ethyl, thiamethoxam and dichlorodiphenyltrichloroethane have been detected in cocoa and market garden plantations.

REFERENCES

1. Agbohessi P. T., Toko I. I. Et Kestemont P. État des lieux de la contamination des écosystèmes aquatiques par les pesticides organochlorés dans le Bassin cotonnier béninois, *Cah Agric*, **21:** N°1, 46-56 (2012).
2. Ahoussi K. E. Evaluation quantitative et qualitative des ressources en eau dans le Sud de la Côte d'Ivoire. Application de l'hydrochimie et des isotopes de l'environnement à l'étude des aquifères continus et discontinus de la région d'Abidjan-Agboville. Thèse de Doctorat Unique, Université de Cocody, Côte d'Ivoire, 270 (2008).
3. Allsop M., Huxdorff C., Johnston P., Santillo D. et Thompson K Santé : les pesticides sèment le trouble. Laboratoires de recherches de Greenpeace, 54 (2015).
4. Aubertot J.-N., Barbier J.-M., Carpentier A., Gril J.-J., Guichard L., Lucas P., Savary S., Voltz M. E. et Savini S. R. Pesticides, agriculture et environnement Réduire l'utilisation des pesticides et en limiter les impacts environnementaux, INRA et CEMAGREF (France) : 64 (2005).
5. Benoit P. Sols et pollution des eaux par les pesticides, Sols et pesticides - Journées Connaissances des Sols Poitou-Charentes, 27 (2007).
6. Bouchonnet S. et Libong D. Le couplage chromatographie en phase gazeuse-spectrométrie de masse. Département de Chimie, Laboratoire des Mécanismes Réactionnels de l'Ecole Polytechnique de l'Université Paris-Saclay, 24 (2014).
7. Carrier A. Le glyphosate : pas si inoffensif que ça! Ministère de l'Agriculture, Pêcheries et Alimentation du Québec – Chaudière-Appalaches, 33 (2013).
8. Centre d'Expertise en Analyse Environnementale du Québec Détermination des hydrocarbures aromatiques polycycliques : dosage par chromatographie en phase gazeuse couplée à un spectromètre de masse. MA. 400 – HAP 1.1, Rév. 4, Ministère du

Développement durable, de l'Environnement et de la Lutte contre les changements climatiques, 21 (2016).

9. Debenest T. . Caractérisation de l'impact des pollutions agricoles sur les diatomées benthiques. Thèse de Doctorat, Université Bordeaux 1, France, 251 (2007).
10. Dembele O. Logiques et stratégies de développement urbain comparées à Abengourou, Agboville et Bonoua. Thèse de Doctorat, 3è cycle de Géographie, Université de Cocody, 666 (1989).
11. Doumbia M. et Kwadjo K. E. Pratiques d'utilisation et de gestion des pesticides par les maraîchers en Côte d'Ivoire : Cas de la ville d'Abidjan et deux de ses banlieues (Dabou et Anyama). *J. Appl. Biosci.,* **18:** 992-1002 (2009).
12. Giroux I. et Pelletier L. Présence de pesticides dans l'eau au Québec : bilan dans quatre cours d'eau de zones en culture de maïs et de soya en 2008, 2009 et 2010. Ministère du Développement Durable, de l'Environnement et des Parcs, Québec, Direction du suivi de l'état de l'environnement, 46 (2012).
13. Gnago J. A., Danho M., Agneroh T. A., Fofana I. K. and Kohou A. G. Efficacité des extraits de neem (Azadirachta indica) et de papayer (Carica papaya) dans la lutte contre les insectes ravageurs du gombo (Abelmoschus esculentus) et du chou (Brassica oleracea) en Côte d'Ivoire. *Int. J. Biol. Chem. Sci.,* **4(4):** 953-966 (2010).
14. Institut de la Formation en Médecine Tropicale Insecticides & Pesticides, 26 (2007).
15. Institut National de la Statistique. Recensement Général de la Population et de l'Habitat : résultats globaux, 22 (2014).
16. Kanda M. Agriculture maraîchère au Togo : analyse systémique et environnementale. Thèse Doctorat., Université de Lomé, Togo, 150 (2010).
17. Kanda M., Akpavi S., Wala K., Batawila K. et Akpagana K. (2014). Apparition d'un commerce informel de produits phytosanitaires dans le sud-ouest du Togo. *European Scientific Journal,* **10:** N°.6, 271-283.
18. Kouame K. L., Akamou F., Kouassi N. G. et Ouedraogo S. . Catalogue phytosanitaire de la Côte d'Ivoire. Direction de la Protection des Végétaux, du Contrôle et de la Qualité. 98 (2011).
19. Laurent F. Agriculture et pollution de l'eau : modélisation des processus et analyse des dynamiques territoriales. Habilitation à Diriger des Recherches, Sciences de l'environnement à l'Université du Maine, France, 205 (2012).
20. Marcus V. et Simon O. Les pollutions par les engrais azotés et les produits phytosanitaires : coûts et solutions, Collection « Études & documents » du Service de l'Économie, de l'Évaluation et de l'Intégration du Développement Durable du Commissariat Général au Développement Durable n° 136, 26 (2015).
21. Ministère de l'Ecologie et du Développement Durable et Agences de l'Eau Système d'évaluation de la qualité de l'eau des cours d'eau (SEQ-Eau), grilles d'évaluation seq-eau (version 2), 40 (2003).
22. Monkiedje A., Njine T., Tamatcho B. and Demanou J. Assessment of the acute toxic effects of the fungicide Ridomil plus 72 on aquatic organisms and soil micro-organisms. *Environmental Toxicology* **15:** 65-70 (2000).
23. OMS L'utilisation des pesticides en agriculture et ses conséquences pour la santé publique. Genève : OMS, 1991, 145 p., 200 ref. bibl.- O.M.S., CH-1211, GENEVE 27 SUISSE (1991).
24. OMS Guidelines for drinking water quality, vol.1, Recommendations (2nd edn.), Geneva, WHO, 1993, 130 (2008).
25. OMS Guidelines for Drinkingwater Quality, 4 th éd., 518 (2011).
26. Orou K. R. Influence de l'utilisation des engrais NPK sur la qualité des eaux souterraines dans les zones agricoles en milieu Soudano-Guinéen : Cas du département d'Agboville (Sud-Est de la Côte d'Ivoire), Mémoire DEA, Université Cocody-Abidjan, Côte d'Ivoire. 68 (2008).

27. Orou K. R., Soro G., Soro T. D., Fossou N. M. R. Onetie Z. O., Ahoussi K. E. et Soro N. Variation saisonnière de la qualité physico-chimique des eaux souterraines des aquifères d'altérites du département d'Agboville (Sud-Est de la Côte d'Ivoire). *European Scientific Journal,* **12:** N°.17, 81- 100 (2016a).
28. Orou K. R., Soro G., Soro T. D., Traore A., Fossou N. M. R. et Soro N. Aptitudes à l'agriculture des eaux souterraines du département d'Agboville (Sud-Est de la Côte d'Ivoire). *European Scientific Journal,* **12:** No. 21, 213-240 (2016b).
29. Paranjape K., Gowariker V., Krishnamurthy V. N. et Gowariker S. The pesticide encyclopedia, Center for Agriculture and Biosciences International, 725 (2014).
30. Rodier J., L'analyse de l'eau: Eaux naturelles, eaux résiduaires, eaux de mer, Ed. Dunod, 8ème Edition, Paris, 1383 (1996).
31. Rosillon F., Savadogo B., Kabore A., Bado-Sama H. and Dianou D. Attemps to answer on the origin of the high nitrates concentrations in groundwaters of the Sourou valley in Burkina Faso. *Journal of Water Resource and Protection,* **4:** 663-673 (2012).
32. Sabbagh C. et Menthiere N. Pesticides, agriculture et environnement : Réduire l'utilisation des pesticides et en limiter les impacts environnementaux, Expertise scientifique collective, INRA CEMAGREF (France), 68 (2005).
33. Schrack D., Coquil X., Ortar A. et Benoit M. Rémanence des pesticides dans les eaux issues de parcelles agricoles récemment converties à l'Agriculture Biologique. Innovations Agronomiques N° 4, 259-268 (2009).
34. Tapsoba-Sy A. Contribution à l'étude géologique et hydrogéologique de la région de Dabou (Sud de la Côte d'Ivoire): Hydrochimie, isotopie et indice cationique de vieillissement des eaux souterraines. Thèse de Doctorat 3è cycle, Université Nationale de Côte d'Ivoire, 200 (1995).
35. Tapsoba K. H. et Bonzi-Coulibaly L. Y. Production cotonnière et pollution des eaux par les pesticides au Burkina Faso. *J. Soc. Ouest-Afr. Chim.* N°21. 87-93 (2006).
36. Tomlin C. D. S. The Pesticide Manual, 11e éd., British Crop Protection Council, Farnham, Surrey, UK, 1606 (1997).
37. Tomlin C. D. S. The Pesticide Manual, 12e éd., British Crop Protection Council (BCPC), Farnham, Surrey, UK, 1250 (2000).
38. Toure N., Kouadio K. P., Yoboue K. E. et Yao-Kouame A. Évaluation des métaux traces, pesticides et plastifiants dans les produits maraichers (gombo, corète potagère, épinard et aubergine) dans la vallée du Niéki, sud-est de la Côte d'Ivoire. *European Scientific Journal*,**11:** N°.33, 183-196 (2015).
39. Traore S. K., Mamadou K., Dembele A., Lafrance P., Mazellier P. et Houenou P.Contamination de l'eau souterraine par les pesticides en régions agricoles en Côte d'Ivoire (Centre, Sud et Sud-Ouest). *Rev. Ivoir. Sci. Technol.,* **8:** 157-170 (2006).
40. Traore A., Ahoussi K. E., Aka N., Traore A. et Soro N. Niveau de contamination par les pesticides des eaux des lagunes Aghien et Potou (Sud-Est de la Côte d'Ivoire), *International Journal of Pure & Applied Bioscience,* **3:** N°4, pp. 312-322 (2015).
41. Vennetier P. Cadre de vie urbain et problèmes de l'eau en Afrique noire. Annales de géographie, **97:** N°540, 171-194 (1988).
42. Vioget P. et Strawczynski A. Pesticides dans les cours d'eau vaudois en 2002, 2003 et 2004. Service des Eaux, des Sols et Assainissement du Département de la sécurité et de l'environnement de Lausanne en Suisse, 8 (2005).