International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Occurrence and Concentration of Pesticides in the Water and Tissues of Two Species of Fish from Lake Guessabo Surrounded by Agricultural Land (West, Côte d'Ivoire): Potential Risks for Humans and for Ecological Receptors

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Abstract: ***Guessabo lake is very importance for its ability to provide abundant fishery resources and to provide natural habitat for many aquatic species. However, its ecological balance is threatened by various pollutants generated by agricultural activities. The aim of this study is to assess the ecological risks and the presence of pesticides in surface water and in freshwater fish tissue by the QuEChERS method. Thus, the pesticide concentrations were compared to regulatory and toxicological values. The pesticides found mainly in terms of concentration and presence in water was aldicarb (10.40 µg/L), simazine (9.36 µg/L), desisopropylatrazine (1.37 µg/L), monolinuron (0.87µg/L) and parathion - methyl (0.75µg/L, chlorfenvinphos (0.84 µg/L), methabenzthiazuron (3.44 µg/L), metazachlor (1.55 µg/L), isoproturon (2.11 µg/L) and cyanazine (0.42 µg /L). The levels of these pesticides detected in the water are higher than the safety levels recommended for drinking water, which is a concern for the health of the local population since they use this resource for consumption in many camps. Pesticide residues were also found in muscle tissue from 14 of 22 fish (63.6%) analyzed. Aldicarb was most frequently quantified in the muscles of Chrysichthys nigrodigitatus and Oreochromis niloticus (55.5% and 63.63% of samples tested, respectively). Concentrations of pesticides in water compared to toxicological benchmarks and the high presence of pesticides in fish indicate likely harmful effects on populations of fish and other biota due to the presence of insecticides. In view of these findings, additional weight - of - evidence research is needed to prioritize the management of agricultural products and implement restoration measures to prevent several fish species from becoming endemic and threatened.***

Keywords: Pesticides, Ecological risk assessment, Lake water, Fish, Human health

1. Introduction

Lakes around the world are threatened by socio - economic activities that degrade environmental conditions by altering land and climate, thereby affecting hydrology and water quality (Jenny *et al*., 2020). Also, climate change is affecting the distribution of pesticide residues among the different environmental matrices while modifying their use (Harsimran and Harsh, 2014). Indeed, a decrease in pesticide residues on crops, due to climate change, is likely to lead to increased vulnerability to pests and diseases. As a result, the frequency and volume of pesticide application by farmers during the growing season will increase. Thus, the concentrations of residues detected could double in aquatic environments and in certain aquatic products (Bloomfield *et al*., 2006).

The result of this widespread pesticide contamination is its impact on the health of aquatic organisms or its accumulation in the edible tissues of fish (Andersson *et al*., 2014, Jacquin *et al*., 2019), with a probable risk for consumers. In fact, the biology and physiology of aquatic fauna depend mainly on the quality of the water in their habitat. Guessabolake is exposed to sources of pollution generated by agriculture and other socio - economic activities. As a result, this lake faces serious environmental problems caused by the high input of nutrients that accelerate the eutrophication process and pesticides that pose a potential threat to aquatic life and human health (Kouame et *al.*, 2019, Attoumgbre *et al.*, 2019). Attoumgbre *et al.* (2019) reported the proliferation of cyanobacteria and episodes of anoxia. This phenomenon led to the death of several fish (Oreochromis *niloticus*) indicating a progressive depletion of this hydrosystem. Moreover, freshwater fish in this part of the country is gaining the preference of many consumers, due to its low - fat content, mainly saturated fatty acids and cholesterol, compared to similar cuts of red meat. Therefore, precise estimation of the water quality level of Guessabolake is essential for human and economic development. Ultimately, the increased use of pesticides has an impact on the quality of surface water resources intended for drinking water and is likely to induce cellular damage in aquatic organisms (Jenny *et al*., 2020). Therefore, assessing the levels of pesticides in fish muscles becomes crucial for environmental and health sciences. Also, pesticides other than organochlorines are little studied in the muscles of fish. However, apart from this group of pesticides, others have the potential to modify functions essential to the survival of species. In fact, studies carried out by several authors have shown that the mixture of certain compounds such as organophosphates and carbamates had additive or synergistic neurotoxic effects on exposed fish (Wang *et al*., 2015). In addition, certain pesticides other than organochlorines reduced the growth of fish (Huynh *et al*., 2012). This shows that assessments of the quality of surface water resources without including aquatic organisms would be an underestimation of the real risks to aquatic species. Thus, the risk index RQ becomes essential for estimating the risk at different trophic levels and for the protection of aquatic ecosystems. In light of these concerns, the objectives of this work are: knowledge of the general patterns of presence and content of pesticide residues through the determination of pesticide residues in different compartments such as lake water and biota (tissues of fish), in order to assess the ecological and human risk. In addition, the comparison of pesticide contents with environmental quality guideline values (WQPS) provides relevant data for the restoration of the great lakes of Africa.

2. Material and methods

2.1 Study area

Sassandra river is 650 km long; it originates in Guinea and crosses Ivory Coast from north to south and discharges into the sea at the level of the town of Sassandra, in a typically tropical climate. Guessabo lake located upstream of the Buyo dam on the river Sassandra constitutes the administrative border between the regions of Upper Sassandra and Guemon. The hydrological regime of the lake is influenced by rainfall and the closure of the Buyo Dam. Guessabo lake is bordered by forest with holes for agriculture, livestock and human settlements. Agricultural land is heavily fertilized and large quantities of pesticides (herbicides) are used to control weeds in the various crops. Guessabo lake with a depth that oscillates between 0.5m and 20m is located between latitudes 6 57’ and 7 2 ’N and longitudes 6 45’ and 6 46’W (figure 1).

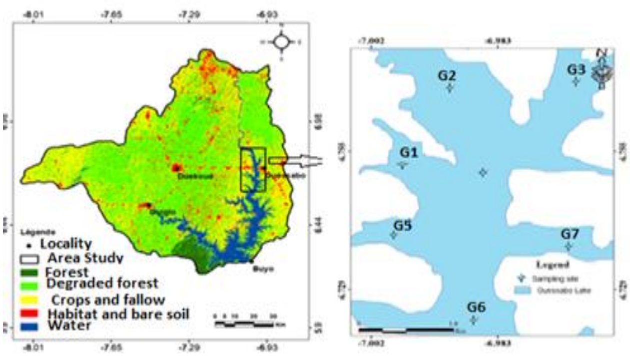


Figure 1: Location of the sampling area

2.2 Sample collection and analysis

Field samples (water) were taken at two different times: twice during the seed period and twice during the post - seedperiod. In order to assess the spatial variation in terms of contamination by pesticides, water samples were taken at seven stations on Guessabo lake (Fig.1): to the west, near the village of Dibobli, where there is cocoa, rubber, banana, corn and rice plantations (G1 and G5); to the east, near the sub - prefecture of Guessabo surrounded by few agricultural fields (G7); to the north, near the entrance canal to the river in its lake part also surrounded by agricultural land (G2 and G3); in the middle of a water column, a little far from agricultural fields (G4), and to the south surrounded by forest and plantations (G6). Water samples were collected in glass bottles (1.5 L) and immediately transferred to the laboratory for analysis. Samples were stored at 4 °C in the laboratory prior to analysis. Five hundred milliliters of water samples were filtered to remove floating or insoluble matter.

Concerning fish, medium and large pieces were collected at the landing stage from professional fishermen. A total of 22 individuals belonging to two species of fish were collected. The different fish species are distributed as follows: 11 Oreochromis *niloticus* and 11 Chrysichthys *nigrodigitatus*. These fish species are chosen because of their annual availability at the study site at the time of sampling, their prominent place in the diet of local residents and their different habitats and feeding strategies. The collected fish samples were transported to the laboratory in a cooler and classified according to the species. Then, the fish muscles were ground using a high - performance disperser (Ultraturrax). The optimum speed for finely crushing the cells without inducing potential losses of pesticides (degradation by too high heat) was applied for a temperature of 25 ° C. The wet weights were recorded and the fish samples were then stored in aluminum packaging, frozen in liquid nitrogen and then stored at - 18 ° C until analysis.

2.2. Extraction and analysis procedures

2.2.1 Analysis of pesticides in water

Very briefly, water samples were extracted by solid phase extraction (SPE) with the plastic cartridge containing octadecyl (C18) using a previously published procedure (Kouamé *et al*., 2020). The limits of detection (LOD) and quantification (LOQ) ranged from 0.003 to 0.1 µg / L and 0.009 to 0.35 µg / L, respectively, depending on the pesticide. The recoveries ranged from 48.50% to 70% and the accuracy was less than 20% for all pesticides.

2.2.2 Analysis of pesticide residues in fish muscles

QuEChERS extraction method developed by Lazartigues *et al*. (2013) is the one used in this work. It is a good means of extracting pesticides from complex matrices and provides high quality results with a minimum number of steps (Chatterjee *et al*., 2016). The method is based on two main steps: an extraction by salting out and a cleaning with hexane to eliminate the lipids.

The mixture of magnesium sulfate ($MgSO_4$) and sodium chloride (NaCl) allowed the separation of the aqueous and organic phases. The extraction quality depended on the sample homogenization step for this we maximized the exchange zone between the sample and the extraction solvent. This step was crucial to ensure better recoveries. Acetonitrile which has a great ability to easily separate from water with the addition of a mixture of adsorbents (primary and secondary amines (PSA), C18 and carbon black (GCB)) and $MgSO_4$ allowed purification and elimination of residual water.

Briefly, 5g of muscle thawed at 4 ° C was placed in a polypropylene centrifuge tube. Four milliliters of acetonitrile (containing 1% formic acid) was added. The addition of 1% formic acid to the extract was necessary to obtain better recoveries for some compounds. In addition, the addition of

Paper ID: SR21220001819 DOI: 10.21275/SR21220001819

formic acid helped stabilize the pesticides during extraction, as some pesticides were unstable in acetonitrile (metolachlor).

In this study, the very large group of diverse pesticides, in terms of physicochemical properties, analyzed in the multi - residue methods required monitoring of the pH during the extraction step. In fact, pH is an important factor when analyzing pH - dependent compounds (requiring specific isolation conditions) (chloroacetanamide) to minimize degradation of labile pesticides under alkaline or acidic conditions (Nortes - Méndez *et al.* ., 2016). The extraction protocol adopted in this work is that described by Lazartigues*et al.* (2013). The pesticide content was quantified by liquid chromatography coupled to a spectrometer (LC - MS/MS). The chromatographic separations were carried out using a Varian 1200L LC - MS/MS instrument equipped with a source of electrospray in positive mode and a triple quadrupole type analyzer. The method had a limit of quantification (LOQ) varying from 0.022 to 0.032 µg kg^{-1}.

2.3 Assessment of the potential risk to aquatic life and quality of the water resource

Risk quotients (RQs) were calculated for surface waters to assess potential risks to aquatic life. The concentrations of pesticides in surface water were compared with the guideline values for water quality (WQPS) set by CMME (2007) for the protection of freshwater species and with the maximum admissible values (MAV) defined by French legislation for the production of drinking water (JORF, 2017).

$$RQ = \frac{MC}{LC50} \times 1000$$

MC: Maximum measured concentration, LC50: Lowest value established in the literature for fish in water and 1000 is the corrective factor defined in the technical guidance document on risk assessment (EC, 2003) applied when only short - term data are available to ensure the susceptibility to harmful effects of the substances identified. When RQ <1, the occurrence of a toxic effect is very unlikely and if RQ> 1, the occurrence of a toxic effect cannot be excluded. Table 1 presents the properties of some frequently detected pesticides and their ecotoxic characteristics derived from short - term tests on daphnia and fish available in the literature.

Table 1: Properties of some pesticides detected above the detection limit in water samples and ecotoxicological benchmarks derived from short - term tests on daphnia and fish available in the literature (Johnson and Finley, 1980; Koshlukova and Reed, 2014, Bhawna and Reddy, 2016)

Pesticides	T1/2 surface water (days)	Solubility (mg L−1)	Log Koc (g/cm^3)	LogKow	48 h LC50 (mg. L^{-1}) Daphnia	96 h LC50 (mg L^{-1}) Fish
Aldicarb	30	4930 - 5290	36	1, 15	0, 41	0, 80
Simazine	221	6, 2	130	1, 74 - 2, 26	1, 1	0, 56
Atrazine	60 - 210	33	100	2, 75	50, 41	3, 1
Cyanazine	16	171	190	1, 8	-	17, 4
Parathion - methyl					0, 14	1, 09
Methabenzthiazuron		60	527	2, 64	-	15, 9
Monolinuron	22	740	271, 5	2, 2	0, 26	
Chlorfenvinphos		145	680	3, 8	0.0003	0.297

3. Results and Discussion

3.1 Results

3.1.1 Occurrence of pesticides in the waters of Lake Guessabo

Table 2present the concentrations of pesticides measured in water and fish. The detected pesticides were classified into four groups according to their spatial distributions (regular or irregular presence in sampling points) and their concentrations. The first group corresponds to pesticides found frequently with relatively high average concentrations. It consists of aldicarb (10.40 µg/L) and simazine (9.36 µg/L). These toxic and ecotoxic active substances banned in the European Union since 2003 are nevertheless approved and authorized in Côte d'Ivoire. The second group of active ingredients consists of desisopropylatrazine (1.37µg/L), monolinuron (0.87µg/L) and parathion - methyl (0.75µg/L). It is characterized by relatively high detection frequencies and rather low average concentrations. The third group is made up of molecules found with relatively low detection frequencies and which have more or less low average concentrations. This group includes chlorfenvinphos (0.84 µg/L), methabenzthiazuron (3.44 µg/L), metazachlor (1.55 µg/L), isoproturon (2.11 µg/L) and Cyanazine (0.42 µg/L). Pesticides irregularly detected are atrazine (0.46 µg / L), metobromuron (0.18 µg / L), metoxuron (3.47 µg / L), metolachlor (0.34 µg / L), metamitrone (0.6 µg / L), linuron (0.18 µg / L), propazine (0.68 µg / L), diuron (0.35 µg / L), terbuthylazine (0.77 µg / L) and crimidine (0.9 µg / L). Crimidine has been banned in Europe since 2004 because of its toxicity and ecotoxicity. Monolinuron, methabenzthiazuron and diuron are toxic and ecotoxic active substances banned in the European Union. They are not part of the phytosanitary products approved and authorized in Côte d'Ivoire. Spatial distribution of pesticides differs depending on the active substances. In addition, the G_2 and G_3 stations recorded more diversity of active ingredients than the other stations. Also, the low occurrence of pesticide detection returns to stations G_1, G_6 and G_7. Herbicides were the most detected.

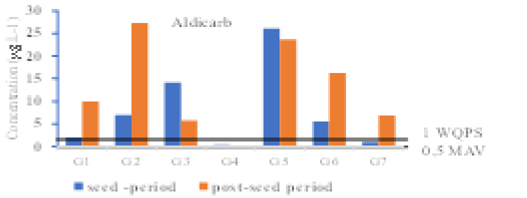
Paper ID: SR21220001819 DOI: 10.21275/SR21220001819

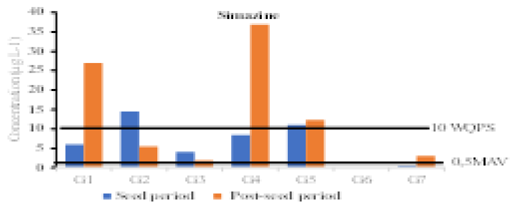
Table 2: Average concentrations in water (µg / L) by lake Guessabo study station corresponding to the 22 pesticides detected.

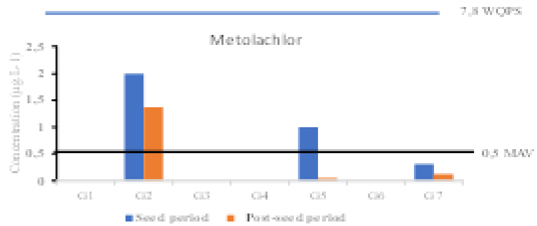
Pesticide	Stations						
	G1	G2	G3	G4	G5	G6	G7
Aldicarb	5, 98	17, 15	9, 84	0, 27	24, 82	10, 85	3, 9
Atrazine			1, 25	1, 91		0, 5	
DIA	2, 33	2, 12	0, 19	3, 7	0, 7	0, 45	0, 11
Chlortoluron		0, 31	7, 95	0, 3	0, 15		
Isoproturon		6, 81	1, 77		3, 57		2, 67
Monolinuron	0, 37		0, 87	4, 11	0, 13	0, 15	0, 5
Métobromuron		0, 17				0, 22	0, 9
Métoxuron			0, 48	10, 35		13, 51	
Métazachlor	0, 5	0, 43	4, 62	5, 35			
Métolachlor		1, 65			0, 53		0, 2
Méthabenzthiazuron		13, 12	9, 97	0, 5	0, 02	0, 5	
Métamitrone		1, 35	2, 86				
Simazine	16, 5	9, 97	2, 92	22, 73	11, 65		1, 77
Linuron		0, 06	1, 25				
Fénuron							
Parathion - méthyl	0, 07	2, 92	0, 12		1	0, 25	0, 48
Chlorfenvinphos		1, 78	0, 1		0, 5		0, 28
Propazine		0, 96	2, 7	0, 75			
Cyanazine		0, 55	1, 22	1	0, 16		
Diuron		0, 1			1, 9		0, 45
Terbuthylazine		0, 16	1, 35	0, 82			
Crimidine	0, 11	1	1, 35	2, 24	0, 10		

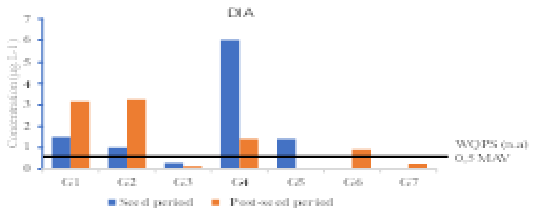
3.1.2 Comparison of pesticide concentrations in lake water with guideline values for water quality

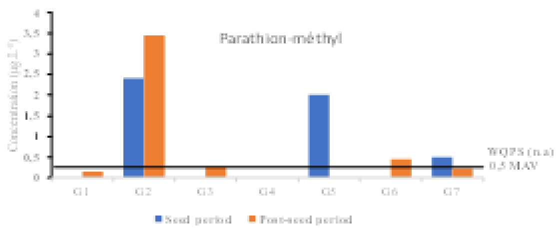
Fifty - seven percent (57%) of the pesticide concentrations recorded in the surface water samples are higher than the regulatory values defined by the French standard for surface water (MAC = 0.5 µg L^{-1} per single substance; Figure 2 and Figure 3). In addition, the concentrations of aldicarb recorded at stations G_1, G_2, G_3, G_5 and G_6 during the two periods as well as the concentrations of simazine recorded at stations G_1, G_4 and G_5 during the post - seed period and the atrazine in station G_4 during the seed period exceed the WQPS standard for the protection of freshwater species. Overall, the highest concentrations were measured during the seedling period. However, no significant difference between the contents of the seed and post - seed period was observed (p> 0.05). Also, in general, no pesticides are detected at station G6 during the post - seed period except for metoxuron.

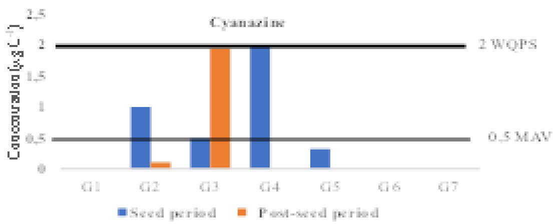












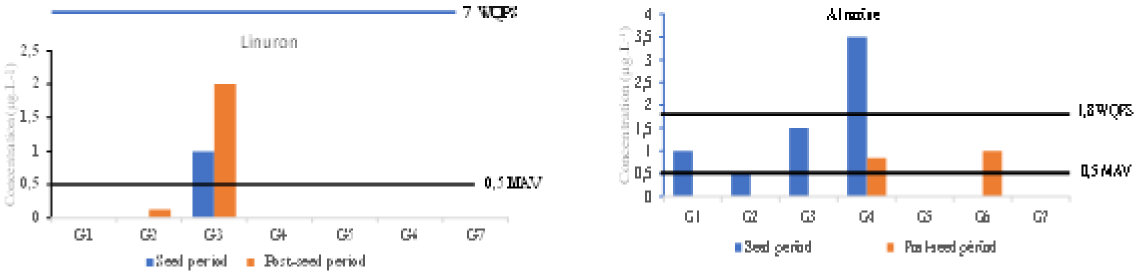


Figure 2: Concentrations (µg L $^{-1}$) of pesticides (aldicarb, metolachlor, simazine, deisopropylatrazine (DIA), atrazine, parathion - methyl, linuron and cyanazine) in the waters of Lake Guessabo depending on the sampling stations. MAV: Maximum admissible value (µg L $^{-1}$) in surface water according to the French standard. WQPS: Guide value for water quality (µg L $^{-1}$) set by Canadian Water Quality guidelines to protect freshwater aquatic life (CMME, 2007), n. a: guide value not available

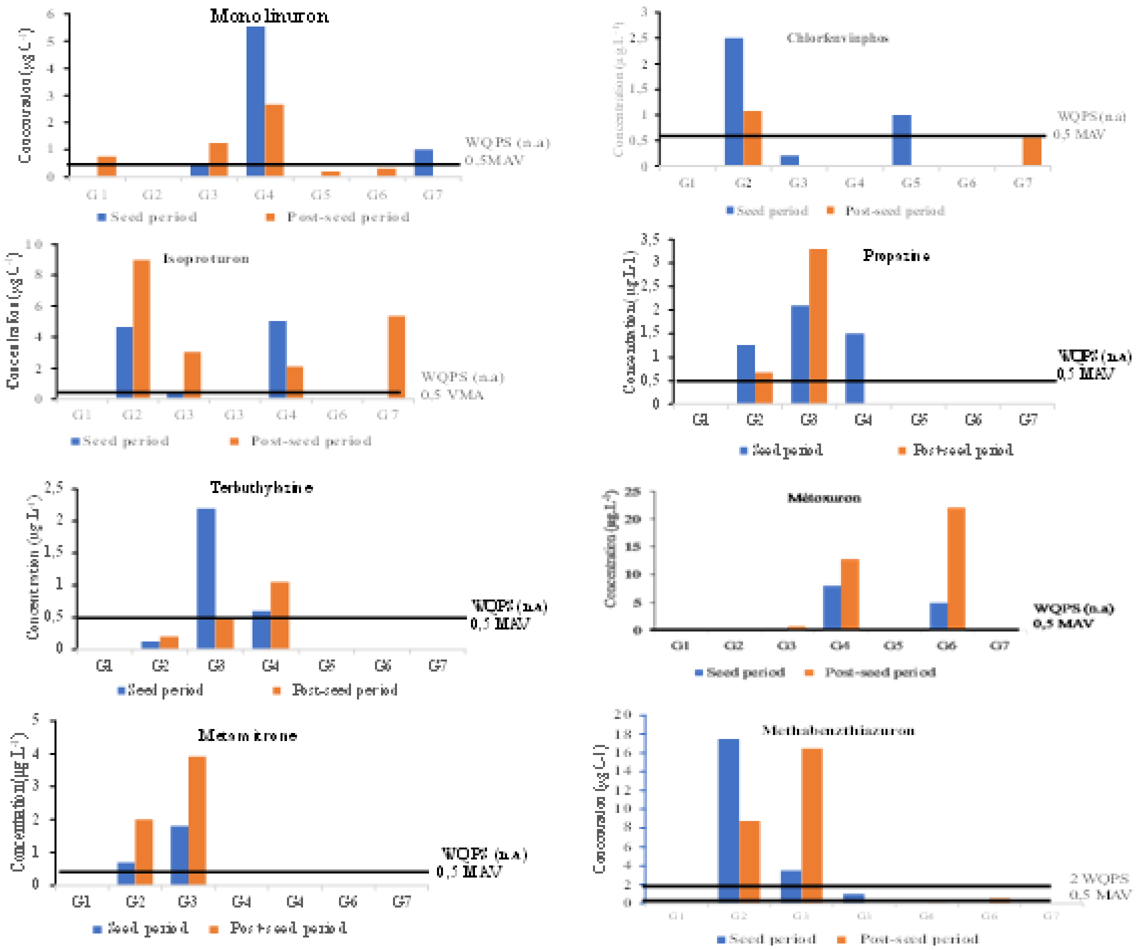


Figure 3: Concentrations (µg. L $^{-1}$) of pesticides (Monolinuron, Chlorfenvinphos, Propazine, Isoproturon, Terbuthylazine, Metoxuron, Methabenzthiazuron, Metamitrone) in the waters of Lake Guessabo depending on the sampling stations. VMA: Maximum admissible value (µg. L $^{-1}$) in surface water according to the French standard. WQPS: Guideline value for water quality (µg. L $^{-1}$) set by Canadian Water Quality guidelines to protect freshwater aquatic life (CMME, 2007). n. a: guide value not available

3.1.3 Pesticide residue content in the muscles of Chrysichthys*nigrodigitatus* and Oreochromis *niloticus* in Lake Guessabo

Pesticide residues were found in the muscle tissue of 14 of the 22 fish sampled (63.6%) in Lake Guessabo. Chemical analysis carried out on fish tissue showed accumulation of pesticides such as aldicarb, atrazine, isoproturon monolinuron, metazachlor metamitrone, simazine, fenuron, cyanazine and terbuthylazine in both species of fish (Fig.4). However overall, the highest concentrations were recorded in Chrysichthys *nigrodigitatus*. No significant difference was observed in the accumulation of pesticide residues found in the two species except for simazine. However, linuron and metoxuron were only detected in Chrysichthys *nigrodigitatus* while methabenzthiazuron was only detected in Oreochromis *niloticus*. Aldicarb was most frequently quantified in the muscles of Chrysichthys *nigrodigitatus* and Oreochromis *niloticus* (55.5% and 63.63% of samples tested, respectively). Most of the pesticides in the water have also been detected in fish. Only fenuron (a compound with high bioaccumulation potential, Kow = 3.162) was detected in fish without being in water.

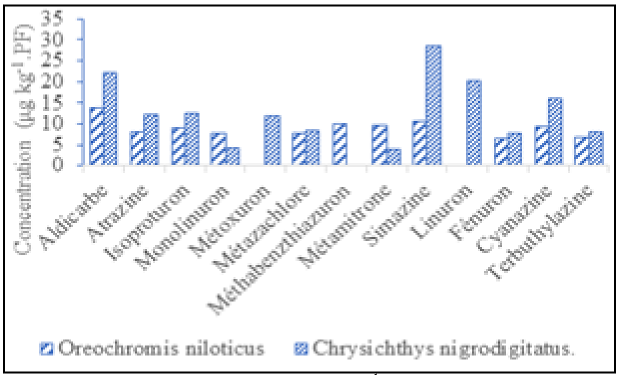


Figure 4: Concentrations (µg Kg^{-1}) of pesticide residues found in the tissues of Oreochromis niloticus and Chrysichthysnigrodigitatus

3.14 Assessment of potential risks to aquatic life

Figure 5 shows the risk threshold RQ equal to 1 for fish and daphnia in Guessabo Lake waters. Concerning fish, four pesticides largely exceed the RQ> 1. Moreover, all water samples except station G4 and station G6 respectively for aldicarb and simazine show RQ> 1. In addition, stations G1, G4 and G7 show that the risk threshold equal to 1 is also exceeded for monolinuron and clofenvinphos, which indicates potential risks for fish in Lake Guessabo. For daphnia, three pollutants (RQ> 1), mainly insecticides could have a serious effect at this trophic level.

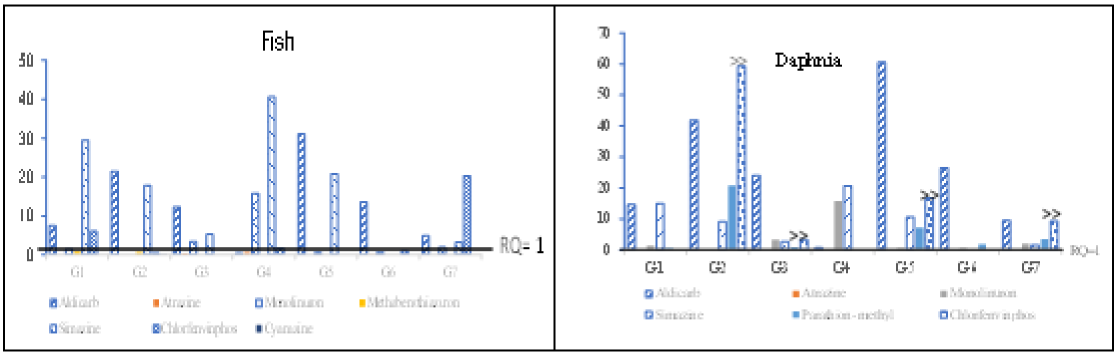


Figure 5: Risk quotient (RQ) in the waters of Lake Guessabo for fish on the left and for daphnia on the right at the level of the various stations for life in an aquatic environment. >> indicates that the represented value is divided by 100

3.2 Discussion

The spatial distribution of pesticides along Guessabo lake could be linked to land use. Pesticide concentrations were moderately high throughout most of the lake. G2 and G3 stations are globally more contaminated by pesticides than other stations. These stations are surrounded by crops of cereals, cocoa and rubber trees and receive a high load of pesticides due to the intensive agricultural activities that are carried out upstream. Stations G1 and G5 are also surrounded by agricultural land with less intensity due to its proximity to the village Dibobli, but also the existence of a large buffer zone consisting of macrophytes and bushy grasses, between farmland and these sampling stations, could contribute to the retention of agrochemicals.

Regarding the occurrence of pesticides, aldicarb has the frequency of detection and relatively higher concentrations than others pesticides detected. This pesticide is used as a soil treatment to protect a wide variety of agricultural products against pests, including a wide variety of insects, nematodes and aphids. Also, this strong presence of aldicarb in water is partly due to its physicochemical properties as well as its popularity with farmers (Weber et al., 2004, Kouame *et al*., 2020). In addition, the high concentrations of aldicarb during the two periods could be linked to the treatments of the cocoa trees in the interval between the two cocoa seasons. The regularity of the spatial distribution of certain pesticides suggests a permanent or frequent use of these compounds in the immediate environment of Guessabo lake and / or due to intensive fishing and navigation activities which contribute to the mixing of lake waters.

Overall, the highest concentrations were measured during the seedling period corresponding to the intensive period of field work with the use of herbicides. Herbicides are applied at the start of the season, either before or shortly after the emergence of the crop plant (corn, rice, etc.) to combat weeds that compete with young plants. During this period, the fields are relatively bare. During rainy episodes, the vegetation is not sufficient to limit surface runoff, the herbicides can easily be washed into the nearby stream. In addition, during both periods, a cocktail of pesticides (organophosphate, triazine, carbamate and chloroacetamide) was commonly found in water samples.

These cocktails, although formed mainly from herbicides, contain organophosphates able of inhibiting the activity of acetylcholinesterase. Also, they have the potential to act on organs that may be essential for species survival (Wang *et al*., 2015). Aldicarb and simazine have been detected with values that exceed the WQPS standard for the protection of freshwater species. Simazine is likely to affect photosynthesis in microalgae while causing its reduction in aquatic ecosystems (Booij *et al.*, 2015). In addition, the work of Bhawna and Reddy (2016) showed that parathion - methyl was toxic to Tilapia fish and that toxic effects depend on both exposure time and concentration. This toxicity manifests itself by reducing the protein, glucose and glycogen content of the liver of fish with a sub - lethal concentration of 1.02 mg / L due to the use of carbohydrates for energy production. which leads to a decrease in the amount of oxygen that the blood distributes to the tissues (hypoxia).

The low half - life pesticides detected with high concentrations in this watercourse suggest that these pesticides, although not authorized in the Republic of Côte d'Ivoire are used by a roundabout route such as transferring into containers approved pesticides and authorized.

The concentrations measured in the water of the lake are higher than the regulatory values defined by the French standard for surface water (JORF, 2007) indicating a probable risk for the populations living around the lake and who use this water either for consumption or food preparation. Also, the pesticides which were detected with high concentrations in the environmental matrix, were mainly found in the muscles of fish. Indeed, the impact of pesticides on fish is closely related to the characteristics of the contaminants (Kow, environmental persistence and mobility) and the intensity of pesticide use in agriculture (Ernst *et al.*, 2018). Consequently, the high environmental levels can explain the high concentrations found in certain fish. On the other hand, the half - lives of some relatively larger molecules could partly justify their relatively high content in fish muscles although their content in the environmental matrix is low (Lazartigues *et al.*, 2013). Indeed, according to the OECD, the main criterion of accumulation is logP> 3, which means that there is no tendency to accumulate (OECD, 2008) for several of them (logP<3). Therefore, other factors, relating to fish and the ionizable characteristics of the compounds could justify these levels (Pico *et al.*, 2019). In fact, the fish studied are demersal or benthopelagic. As a result, they live more or less on the bottom and find part of their food in muddy bottoms composed mainly of organic detritus, invertebrates and periphyton, which could also be sources of pesticides (Belenguer*et al.*, 2014). However, our results are poor compared to other authors in the literature who have looked for organochlorines in the flesh of the same fish species. Indeed, this difference would be due to the low capacity of bioaccumulation in muscle for these compounds compared to organochlorine pesticides. Similar results were recorded in Oreochromis *niloticus* by Jonsson et al. (2019). Also, pesticide residues were found at low levels (0.89 µg. kg^{-1}PF on average) in fish from freshwater streams by Belenguer *et al*. (2014) in the Júcar river in Spain and by Ernst et al (2018) in the large rivers of South America (Uruguay and Negro). Our results are superior to those reported by Lazartigues (2010) which indicates for isoproturon and metazachlor respective average levels of 0.75 and 0.13 µg. kg^{-1} PF in the muscles of Oreochromis *niloticus*. On the other hand, they are lower than those of Chatterjee et al (2016) who reported parathion - methyl values between 66.11 and 70.88 µg. kg^{-1}PF. According to Tucker et al (2003), the low levels of accumulation in fish tissues and the rapid elimination of these indicate that organic herbicides do not tend to accumulate in fish. Fenuron (a compound with high bioaccumulation potential, Kow = 3.162) was detected in fish at high concentrations in Guessabo lake without being detected in water. This result is explained by its low persistence in water and indicates repeated use in agriculture in the study area (Belenguer*et al.*, 2014). Overall, Chrysichthys *nigrodigitatus* concentrated more pesticides than Oreochromis *niloticus*, although this difference was not significant. The difference in contamination between these two species in the same stream is believed to be due to efficient metabolism of these compounds from one fish to the other. Also, Chrysichthys*nigrodigitatus*has an omnivorous diet. Thus, we hypothesize that its position in the food chain could explain this high level of concentration compared to the other species. On the other hand, the fact that Chrysichthys*nigrodigitatus* bioconcentrates more pesticide than Oreochromis *niloticus* is in part due to the high percentage of lipids in its body compared to the other (Sancho *et al.*, 1998). Also, bottom - feeding Chrysichthys*nigrodigitatus* can accumulate concentrations of contaminants through direct contact with contaminated sediment or by feeding on organisms living in sediments (USEPA 2000). Concerning the risk linked to the ingestion of contaminated fish in Guessabo lake, two levels of risk could arise. These are ecological and human risks associated with the transfer of contaminants through food. The high presence of pesticides in fish suggests potentially serious effects on populations of fish and another biota.

4. Conclusion

The aim of this study was to know the general patterns of presence and content of pesticide residues through the determination of pesticide residues in different compartments such as lake water and biota (fish tissues) in order to assess ecological and human risk. The results showed a particularly diverse contamination profile, with strong disparities between agricultural periods. Also, the concentrations measured in surface water compared to the reference values indicate potential risks for living organisms in the water column. The sums of the average concentrations of the phytosanitary products sought are well above the EU standard of 0.5 µg / L for drinking water and of 2 µg / L for water intended for the production of drinking water. In addition, the accumulation of pesticide residues in fish species is likely to pose a risk to humans and also to large predators during their lifetime. However, this risk should be qualified in view of the fact that although the Codex Alimentarius recommends analysis only of the edible part of the fish, it currently does not provide for a maximum reference limit for several types of freshwater fish. In addition, this research is necessary to draw the attention of local residents to compliance with the rules prescribed by good agricultural use practices (frequencies, quantities applied, storage conditions, methods of disposal of packaging, approved pesticides) of pesticides in order to propose effective restoration actions at the basin scale.

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