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STATE OF PLAY IN THE USE AND MANAGEMENT OF PESTICIDES AND RISK OF CONTAMINATION OF FISH PONDS IN AGRICULTURAL PRODUCTION AREAS IN CÔTE D'IVOIRE: CASE OF THE DEPARTMENTS OF AGBOVILLE AND SOUBRÉ

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Abstract: *A survey was carried out among 129 pesticide applicators of the departments of Agboville and Soubré, in order to identify the phytosanitary practices in field's treatment adjacent to a fish farm. It turns out that pesticide application is a male task. Among these pesticide applicators, 59.7% of those from Soubré are illiterate as compared to 12% of those from Agboville. Most applicators in both localities (64% in Agboville and 95% in Soubré) have no qualifications. Only 1.5% of them are wearing appropriate protective equipment when spraying. 50.7% and 9.7% of applicators of Agboville and Soubré respectively are dressed in partial equipment. Poor practices in the dosing and preparation of porridges, as well as the management of empty packs could expose fish farms to pesticide residues contamination; fields being treated virtually every month in the year. Among the pesticides listed, insecticides accounted for 47% followed by 44% herbicides. Growth regulators and fungicides represent 5% and 4% respectively. At the end of this survey, it appears that pesticides with toxic effects on human health and environment have been listed. Thiamethoxam and glyphosate are respectively the predominant insecticide and herbicide contaminants.*

Keywords*: survey, fish farms, thiamethoxam, glyphosate, health risks*.

1. Introduction

At the dawn of its independence, Côte d'Ivoire concentrated its economic development on agricultural sector **[1]**. Thanks to its important natural potentialities characterized by a favorable climate, fertile lands and important hydrological resources, a varied range of vegetal productions is available on Ivorian markets **[2]**. In response to the increase in consumption imposed by its growing population, adoption of the Master Plan for Agricultural Development 1992 – 2015 has promoted the use of plant protection products (fertilizers and pesticides) in agriculture **[3]**.

The use of pesticides in Ivorian agriculture is only recent, but has developed rapidly. Already in 1996, the amount of pesticides used was estimated at more than 128,000 tons **[4]**. Of course, the use of pesticides has significantly increased agricultural productions. But at the same time, they

have a negative influence on biodiversity and lead to health risks related to their exposure **[5, 6]**.

Some of these pesticides are indeed very remnant products; their half-life extending over several years in the order of ten years and beyond. In tropical countries as in the case of Côte d'Ivoire, they can degrade rapidly under action of ultraviolet radiation into derived products which are generally more toxic and more stable than the initial products **[7]**. Following a spread, the fraction of pesticides that reaches the ground, joins the groundwater by infiltration or surface water by runoff. And yet, the dangerousness of these products is well proven. They would be responsible for decreasing immunity **[8]**, of appearance of cognitive and neurodegenerative disorders **[9]**. Thus, use of agricultural pesticides is not without consequences on environment, health of farmers themselves and that of consumers. In Benin, in the department of Borgou, 37 deaths of people and 36 cases of severe intoxication were recorded following endosulfan poisoning between May and September 1999 **[10]**. In Côte d'Ivoire, according to the occupational health service of the hospital and university center of Yopougon (Abidjan), high clinical signs suggestive of organophosphorus and carbamate in many patients would have been detected **[11, 12]**. To this end, in the interest of public health, it is therefore imperative to identify the phytosanitary practices made on crops by Ivorian farmers.

The purpose of this study was to identify agricultural pesticides used in fields near fish farms, and the phytosanitary practices of applicators in Agboville and Soubré departments with the aim of making a prognosis of the state of environmental pollution and that of fishes from these farms.

2. Materials and methods

2-1. Presentation of the study areas

This study was carried out in the departments of Agboville and Soubré. Agboville department covers an area of 11,300 km^2 and is located 80 km from the Ivorian economic capital, Abidjan. Characterized by a dense and humid forest, this department is part of the southern forest of Côte d'Ivoire **[13]**. It has a very rugged terrain characterized by presence of many valleys and hills. The climate is subequatorial with two dry seasons and two rainy seasons all of unequal length. The average annual rainfall is 1400 MM of rain. Agboville is mainly irrigated from east to west by Agneby's river and has a ferralitic type soil. However, there are non-permanent rivers that can drought in dry season including rivers Abé, Bebasso, Gorké, Kavi, Mafou, Mé, M'brou and Séguié. The average annual temperature is around 25 °C, and economic activity is based on primary sector dominated by cocoa farming.

Soubré's department is located in the south-west of Côte d'Ivoire, 380 km from Abidjan and extends on 4779 km^2. The relief consists of vast plateaus surmounted by hills in places and a subequatorial climate type, characterized by a dry season and two rainy seasons of unequal length. The hydrographic network consists of permanent watercourses, the most important of which are Sassandra's river and its main tributaries, the Davo, Gôh, Lobo and N'zo. Soubré has a ferralitic type soil and has vegetation with enormous agricultural and forestry potential making the department one of the most important economic centers in the country. Economic activity is based on primary sector dominated by cocoa cultivation, and 70 % of the population is rural. Figure 1 present the map of the study areas.

Figure 1: Map of the study areas. Source: www.elevesmaitres-ci.com/archives/2014/09/12/30577917.html, modified by Gnagne Adou Blanchard

2-2. Choice of investigations sites

Survey was held in five villages or camps in each department. It was interested in pesticides applicators whose treated plantations are within one kilometer of a fish farm. In Agboville department, applicators concerned come from the villages of Kamabroux, Mucho, Offoriguié, Offoumpo and Oress-Krobou. In Soubré, they come from camps of Amarakro, Carrière, Djoutoubou, Kouakoudankro and Sayo. The choice of these sites was motivated by the fact that sales of fish from these fish farms was made at least once. The farming system in these two departments varies from semi-intensive to intensive.

2-3. Progress of the investigation

The survey was conducted with 129 planters and / or pesticide applicators from the two departments, of which 67 are from Agboville and 62 are from Soubré.

It was carried out using a questionnaire giving information on the type and qualifications of applicator, age range, periods of application, commercial names of the pesticides used, places of purchase, preparation of porridge, wearing of personal protective equipment (PPE), any

discomfort experienced by spraying suites and the management of empty packaging. The survey was conducted according to snowball method **[14]**. It consisted of interviewing owners and / or pesticide applicator of fields adjoining fish farm on a radius of about one kilometer, then to interview another following recommendation of the previous one. It is completed in a village when people recommended by the previous ones have already been interviewed in the radius considered. Farms observations were made during pesticide application. The survey lasted 27 days in Agboville from April 7 to June 11, 2017, and then 18 days in Soubré over the period from September 7 to September 26, 2017.

2-4. Data analysis

The survey data was entered using CS Pro version 6.3 software. Data were later taken to Excel 2010 for clearance, regulation and graphing. Stata version 14.2 software has been used for statistical processing. The Chi2 statistical binding test between variables was established at 5% threshold ($P < 0.05$).

3. Results

3-1. Gender and age range of applicators

The survey revealed that pesticides application in fields is a task almost exclusively male. The male gender represents 97% and 93.5% respectively in Agboville and Soubré. They are adults, most of whom are aged 31 to 40, followed by those aged 41 to 50. However, applicators over 50 are more abundant in Agboville than in Soubré (Figure 2).

3-2. Schooling level and qualification of applicators

While rate of applicators enrolled in Agboville is high and reaches 88% dominated by secondary level, that of Soubré is low with 40.3% whose primary level is dominant (Figure 3). The rate of qualified applicators is relatively low in both localities. This survey shows that 36% of applicators are qualified to apply phytosanitary products in Agboville, while 5% are concerned in Soubré. For more cases in both localities, application is made by the plots owners or entrusted to maneuvers, whose generally aren't qualified. These owners both applicators represent 59.4% and 90.3% in Agboville and Soubré respectively. Exception is made in Offoumpo's village where application is mainly entrusted to specialists trained to that task.

3-3. Spraying periods and wearing of PPE

Contrary to Soubré, pesticides are almost sprayed every month in the year in Agboville. However, insecticides and fungicides are preferentially sprayed in the months of January, August and December. As for herbicides, they are preferentially sprayed in February, March and April depending on the locality (Figures 4 & 5). Applicators interviewed don't have adequate PPE against pesticides. In Soubré, protection is almost non-existent and comes down to wearing ordinary boots and clothes, often torn. However, in camps of Amarakro, Kouakoudankro and Sayo some of them protect airways using a nose shield.

In Agboville, however, the majority of applicators protect themselves from pesticides inhalation using a nose shield or gas mask, and/or contact with eyes using glasses. Only 1.5% protect themselves from inhalation, contact with eyes and body using a suit (Figure 6). At 5% threshold, a statistical link is established

between PPE's wearing and schooling level ($P<0.05$) (Table 1), and between PPE's wearing and the lack of qualification ($P < 0.05$) (Table 2).

3-4. Discomfort felt

79% and 77% of applicators of Agboville and Soubré respectively feel discomfort, of which itching, sneezing and skin irritation are the most common; sometimes, eyes irritation and cold. On the other hand, some admit not to feel effects (Figure 7). The null hypothesis of independence between the variables PPE's wearing and existence of discomfort is accepted at 5% threshold. There is no statistical link between these two variables ($P > 0.05$) (Table 3).

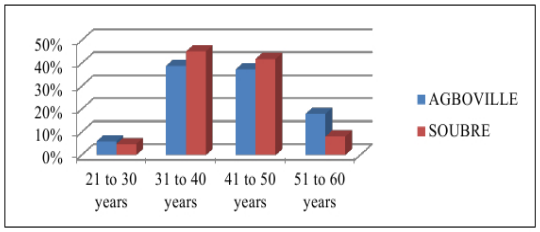

Figure 2: Applicators age's groups distribution by locality

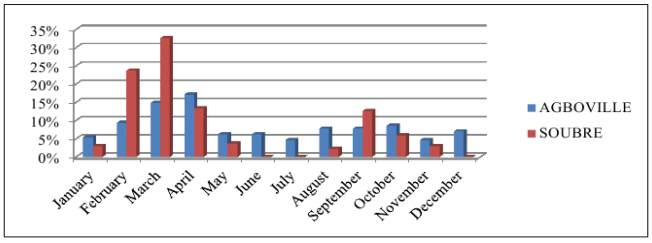

Figure 5: Herbicide spraying periods in the year by locality

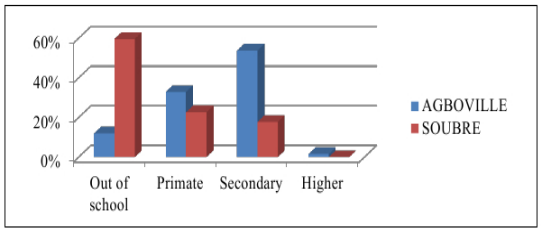

Figure 3: Applicators schooling level's distribution by locality

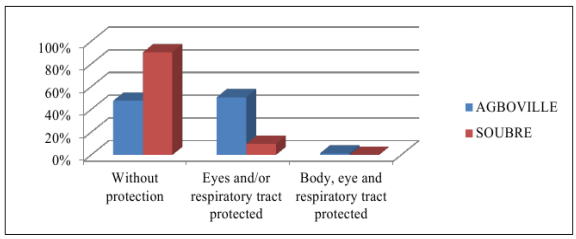

Figure 6: Wearing of personal protective equipment when spraying by locality

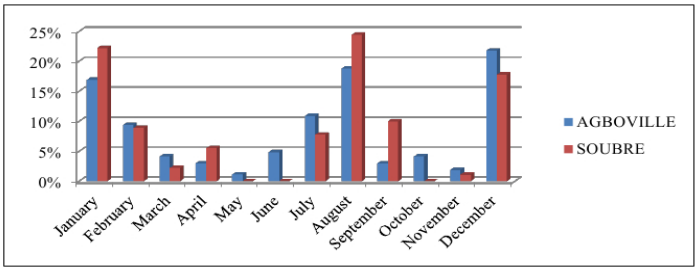

Figure 4: Insecticide and fungicide spraying periods in the year by locality

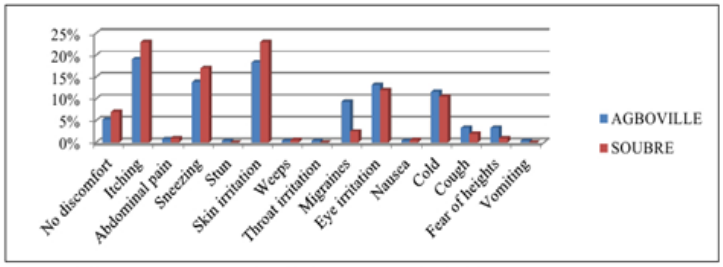

Figure 7: Distribution of discomfort felt following spraying by locality

3-5. Places of purchase pesticides and management of empty packaging

In both localities, 53.2% and 78.1% of Agboville and Soubré applicators respectively buy pesticides at local markets (Figure 8), where they are exposed without any protection from sun. A statistical link is established between choice of the places of purchase of pesticides and their cost and

proximity at the threshold of 5% ($P < 0.05$) (Table 4). Empty packs generally are mismanaged. There are left intact in fields after use (67% of cases in Agboville and 89% in Soubré). In other cases, there are reused for domestic use as a container for drinking water or palm wine called "bandji", but also for preservation of cooking ingredients such as salt (Figure 9). There is a statistical link between the management of empty packaging and qualification of applicators at the 5% threshold ($P < 0.05$) (Table 5).

3-6. Listed pesticides and their active ingredients

At end of the survey, 72 different pesticides were counted, 15 of which were unregistered, ie 20.8%. There are 47% of insecticides, 44% of herbicides, 5% of growth regulators and 4% of fungicides. Twelve insecticidal active ingredients have been identified, of which thiamethoxam is the most important, belonging to nicotinoids family (Figure 10). In herbicides, eleven active ingredients have been identified of which glyphosate is the most represented molecule (Figure 11). In fungicides, six active ingredients have been identified among which metalaxyl is predominant. In growth regulators Ethephon is predominant.

Table 1

Cross table and independent test of Chi2 between the variables PPE's wearing and Applicator Schooling Levels.

PPE's WEARING	SCHOOLING LEVEL				Total
	Unschooled	Primary	Secondary	Higher	
NO	40	26	22	0	88
YES	5	10	25	1	41
Total	45	36	47	1	129
Pearson chi2 (1) = 21.2173 Pr = 0.000					

Table 2

Cross table and independent test of Chi2 between the variables PPE's wearing and Applicator Qualifications.

PPE's WEARING	APPLICATOR QUALIFICATION		Total
	None	Qualified	
NO	81	7	88
YES	21	20	41
Total	102	27	129
Pearson chi2 (2) = 28.1686 Pr = 0.000			

Table 3

Cross table and independent test of Chi2 between the variables Protection Equipment and Discomfort Felt.

PROTECTION EQUIPMENT	DISCOMFORT		Total
	None	Presence	
Full equipment	0	1	1
None protection	21	67	88
Partial protection	7	33	40
Total	28	101	129
Pearson chi2 (3) = 0.9347 Pr = 0.627			

3-7. Preparation of porridge

During observations made when porridge is prepared, the dosage prescribed on packaging is not followed. It is usually done under the order of owner of plantation treated when applicator is a specialist. When this one is lacking, the dosage is arbitrary and depends on its judgement or a third person. Applicators sometimes make mixture of different pesticides. It concerns 21.7% and 17.7% of applicators of Agboville and Soubré respectively. While 65% of mixture consists of mixing several insecticides in Agboville, 70% of mixture made in Soubré concern several herbicides.

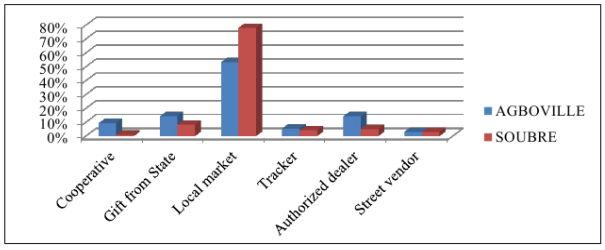

Figure 8: Places of purchase pesticide products by locality

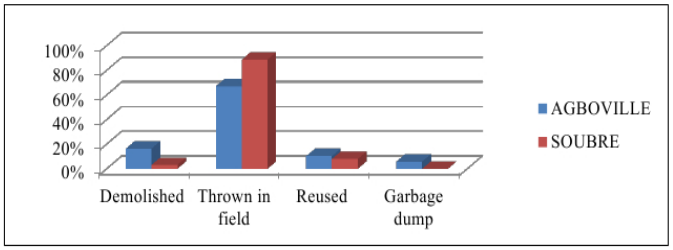

Figure 9: Management of empty packaging by locality

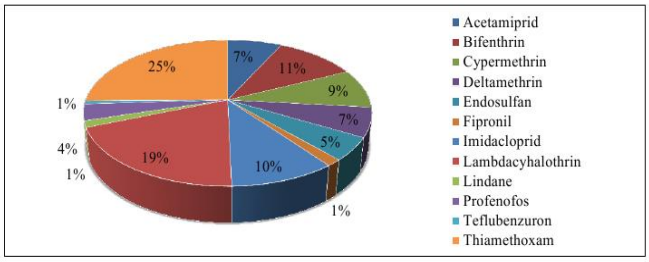

Figure 10: Active ingredients of insecticides listed

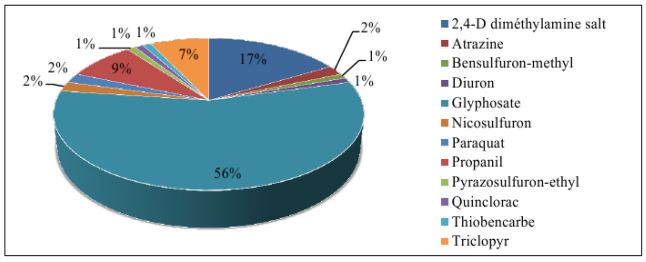

Figure 11: Active ingredients of herbicides listed

Table 4

Cross table and independent test of Chi2 between the variables Places of Purchase Pesticides and the Reasons of that choice.

PLACES OF PURCHASE PESTICIDES	REASONS FOR CHOOSING THIS PLACE						Total
	Effectiveness	Lower cost	No expense	Payment condition facilitated	Proximity	Quality	
Authorized seller	1	1	0	1	0	20	23
Cooperative	0	0	0	12	1	0	13
Gift of State	1	1	22	0	2	0	26
Local market	21	61	4	6	41	9	142
Street vendor	1	1	0	3	1	1	7
Tracker	0	0	0	7	2	2	11
Total	24	64	26	29	47	32	222
Pearson chi2 (4) = 378.9245 Pr = 0.000							

Table 5

Cross table and independent test of Chi2 between the variables Management of Empty Packs and Applicator's Qualification.

MANAGEMENT OF EMPTY PACKS	APPLICATOR QUALIFICATION?		Total
	None	Qualified	
Demolished and buried	4	9	13
Garbage dump	4	0	4
Reused	11	1	12
Thrown into fields	83	17	100
Total	102	27	129
Pearson chi2 (5) = 21.4686 Pr = 0.000			

4. Discussion

The survey showed that use of phytosanitary in both study localities for harvests optimization, is almost systematic as meant by several authors of other countries **[15, 16, 17, 18]**. According to some interviewees, this situation is due to lack of manpower. Application is an almost masculine task, as was also reported by **[19]** in Yamoussoukro market gardeners. These applicators are all adults aged 21 to 60 ; with the age group 31 to 40 being the majority. In Soubré, the majority of pesticides applicators are illiterate (60%), as are those in Morocco for the health protection of spearmint **[20]**. In Agboville, most of them are literate (87%), and 54% of them have reached secondary level. The few women pesticides applicators surveyed are all market gardeners and illiterate. According to those women, they would have learned phytosanitary application by initiation with their husbands as Muliele et al **[21]** pointed out, but also to ensure the survival and that of their family, because they would be either divorced or widowed. Despite the high proportion of literate applicators in Agboville, rate of qualified in phytosanitary application is low; it's even more so in Soubré. This observation is consistent with that made by Muliele et al **[21]**. This could explain bad practices observed in pesticides use as underlined by several authors **[22, 23, 24]**. Indeed, certainly literate applicators could be ignorant of good phytosanitary practices. According to some respondents, solicitation of specialist applicators is expensive, while pesticides and machines are sold over-the-counter. These bad practices refer in particular to the wearing of PPE, misuse of pesticides, their origin, the various mixtures made, management of empty packaging and precautions to be taken for any surrounding watercourse.

In Agboville, 48% of applicators give little interest to wearing of PPE ; as for Soubré, 90% are concerned. Similar observation is made by Doumbia and Kwadjo **[25]** among market gardeners in Abidjan and two of its suburbs. Some applicators with no education level or qualification interviewed, not wearing any protection during spraying, claim to be immune to pesticides that would then be ineffective on them. This same remark was made by Toe et al **[26]** in Burkina Faso among the cotton producers of the Hauts-Bassins, the Cascades and the Boucle of the Mohoun. Logically, this attitude of ignoring the wearing of protective equipment should be at the origin of listed discomforts, as well as numerous cases of intoxication and deaths that would have occured in camps as some respondents have indicated. These discomforts have also been observed by

Sonchieu et al **[27]** among bread sellers from Bamenda in Cameroon. And yet, results of our study show that being dressed in PPE does not induce absence of discomfort. This situation could be explained by the fact that applicators considered to be equipped with protection during spraying, are dressed only in partial and inadequate equipment such as use of nose shield instead of the gas mask and / or wearing ordinary clothes instead of the suit. In addition, only 1.5% of applicators interviewed confessed to detaining and wearing full protective equipment when spraying. The source of pesticides is also a source of concern. Pesticides are usually bought in local markets exposed to sun, as it is the case with tomato producers in Burkina Faso **[22]**. This could explain use of unapproved and unauthorized products in Côte d'Ivoire, as indicated by Doumbia and Kwadjo **[25]**. Also, according to some interviewees aware of using unauthorized products, there would cost less compared to those authorized.

Phytosanitary practices in our two study localities concerning dosage of porridges, mixtures of different pesticides and management of empty containers could have a negative impact on environment. In fact, the dosages carried out are generally beyond the requirements in the case of insecticides and herbicides. Concerning the case of insecticides, it is thought that overdose is due to resistance of insect pests to cocoa, which is dominant crop, and also to gardeners. This result is supported by the work of Gnankine et al **[28]**. According to these authors, overdose of pesticides by tomato producers in Burkina Faso is related to its pest resistance (*H. armigera* and *B. tabaci*) to insecticides. This situation could also explain the mixtures of pesticides carried out, with intention of producing a more effective porridge on these pests.

Observations made in farm environment have revealed mismanagement of empty packaging. There are either reused for drinking or abandoned in fields as shown by Eddaya et al **[20]**. However, good phytosanitary practices would advise that there be demolished and buried. These practices could prove damaging for the water environment.

From results of work of Keddal and N'dri **[29]** and Mawussi et al **[16]**, water resources represent the catchment area for a surge of pesticides residues. Given that investigation concerned plantations located in the vicinity of fishponds, it would therefore be likely to assume that by runoff or infiltration, pesticides residues could reach these ponds and then accumulate in fish; spraying being carried out almost every month. Studies have shown such contamination in surface water **[30]**, groundwater **[31]** and fish **[32, 33, 34]**. For this purpose, since lambdacyhalothrin, thiamethoxam and glyphosate are the predominantly identified pesticide active ingredients; consumption of fish from fish farms could constitute a risk for the health of populations. This is also the case of endosulfan of which the toxic effects are well known.

Indeed, lambdacyhalothrin dissipates rapidly in water due to its adsorption on particles and aquatic organisms **[35]**. It is extremely toxic to many aquatic organisms; hence its ban in China **[36]**. Works have shown the involvement of pyrethroids in coronary artery desease in Chinese population **[37]**. Similarly, tests in rats, mice and rabbits revealed neurotoxic effects of lambdacyhalothrin **[38]** and decrease of body weight **[39]**. Other tests in mice fed thiamethoxam for 18 months at concentration of 500 to 2,500 ppm, have shown that one of its metabolites CGA330050, would be responsible for liver tumors **[40]**. As for glyphosate, it has

been classified as a probably carcinogenic substance for human by the International Agency for Research on Cancer **[41]**. The results of De Roos et al **[42]**, have shown that glyphosate would be involved in the prevalence of myeloma or Kahler's disease, a type of cancer that affects plasma cells. Several authors have also shown other effects of pesticides including decline in intellectual abilities and intelligence level in children **[43]**, the onset of type 2 diabetes **[44]** or disorders of reproduction **[45]**.

5. Conclusion

Faced with the challenge of food security, the use of pesticides has won over Ivorian agriculture. However, poor pesticides use could expose population to risk related to consumption of food, especially fish from fish farms adjacent to plantations undergoing pesticides treatments. In view of continuing this work, it is planned to carry out qualitative analyses for the detection of pesticides residues in fish from fish farms, in order to assess their level of contamination.

6. Acknowledgement

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