RISK ASSESSMENT FOR SMALL FARMERS EXPOSED TO PLANT PROTECTION PRODUCTS IN THE NIGER RIVER VALLEY

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ABSTRACT

Plant protection products play a very important role in agriculture. However, their misuse can have serious negative impacts both on human health and environment. A study was carried out to identify the plant protection products used in the Niger River valley and to observe the local pesticide management practices. Ten active substances were identified as the most used chemicals by farmers. Their toxicological properties were characterized and their respective Potential Dermal Exposures (PDE) was evaluated in order to assess the risk level for the local small growers. The UK Predictive Operator Exposure Model was used to quantify the PDE during mixing/loading and application according to the local practices. The survey shows that the most common active substances are organophosphate or pyrethroids insecticides. In addition, some other prohibited and counterfeit pesticides cocktails are also used. All active substances used in Niger River valley are highly toxic. When sprayed without personal protective equipment (PPE) they could induce significant harmful impacts on the human health after exposure. The predictive exposure levels vary from 0.0013 mg/kg bw/day to 0.4125 mg/kg bw/day, several times higher the Acceptable Operator Exposure Level (AOEL) for all actives substances. The survey also revealed that 76% of operators do not use any PPE during mixing/loading or spraying. Other bad practices observed in study area can increase the exposure of operators. Moreover, local consumers could also be exposed through intake of pesticide residues on harvested products.

Keywords: pesticides, risk assessment, UK-POEM, operators, Niger River valley

INTRODUCTION

According to the European Food Safety Authority (EFSA), plant protection products (PPP) are substances that are mainly used to keep crops healthy and prevent them against any pest (EFSA, 2014). These substances can be chemicals or micro-organisms (including viruses) that have action against pests or on plants, part of plants or plant products (EU-database). In agriculture, plant protection products have been used for a long time (Kim et al., 2015). But, they can have negative impacts on human health and environment (Marzouk et al., 2012; Uchendu et al., 2012; Awad et al., 2014). In this context, before an active ingredient can be used as a plant protection product in the European Union, it must be evaluated and approved by the European Commission (EC, 2009). Misuse of PPP can generate high

exposure of farmers (direct contact) and consumers (intake of pesticide residues) (Choi et al., 2006; William, 2013; Son et al., 2016).
In Niger, the river valley is an agricultural zone in which a significant activity of vegetables production develops. This activity plays a very important role because it contributes to food security of populations and to fight against poverty. Hence, it's viewed as an important cash crop, a source of additional financial resources. However, small growers, who have to cope with increasing pest and disease problems in their crops despite the intensive use of pesticides, have entered in a vicious circle of growing pest pressure and repeated pesticide applications leading to misuse, intoxications and resistance of pests. Mainly illiterate, the farmers in Niger River valley are not aware about the actual toxicity of PPP, potential health impacts and how they must be used (Illyassou et al., 2015).
For farmers, the main sources of exposure of plant protection products are direct contacts during handling (mixing and loading) and indirect contacts during spraying (MacFarlane et al., 2013; Wumbei, 2013; Richard et al., 2014). Detrimental effects on health can result from those exposures, resulting in severe intoxications or leading to chronic diseases such as Parkinson disease, cancers or Alzheimer's (Richard et al., 2014). Several methods and models have been used in recent years to estimate operator's exposure to plant protection products (Machera et al., 2003; GrobKopt et al., 2013; Toumi et al., 2016). Exposure assessment of operators is part of the risk assessment during registration of plant protection products in Europe according to Regulation N°1107/2009 (EFSA, 2014).
The objectives of this study were to collect at the field data on PPP used in the Niger River valley (Niamey and Tillabéri), to observe the local practices of growers and to evaluate accordingly the risk level after dermal exposure of small farmers to those plant protection products.

MATERIALS AND METHODS

Study area

This study took place in the Niger River valley (South-West of the Niger territory) (figure 1).

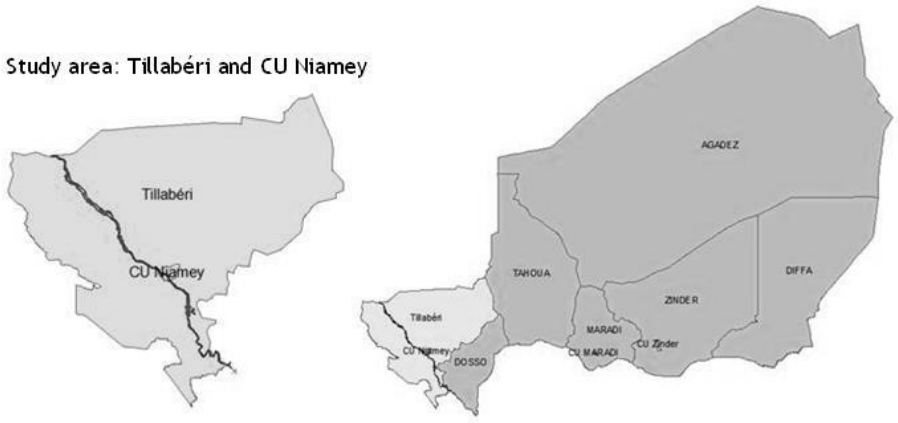

Figure 1: Study area in Niger (the Niger River valley)

The study area is located between 13°28' and 13°35' North latitude and 02°03' and 02°10' East longitude. In this region, the average annual temperature is about 29°C. The rainfall is highly irregular and variable, ranging from 400 mm to 600 mm. The winds are almost regular all the year with a speed higher than 3.5 m/s. In Niger River valley, the climate is characterized by a long dry season (from October to May) and a short wet season (from June to September). Soils located along the river are sandy-clayed soils with rather low organic matter content. Many vegetable productions are developing today along and surrounding the river valley.

Survey and collection of data

A previous general survey was carried out in the study area to have a better understanding of the population, an idea of the skills of farmers, a better knowledge of the local agricultural practices and finally to be able later to assess the risk for their health and for the environment. This first survey was completed by a deeper and closer investigation among a group of 55 local small scale growers selected randomly in the area surveyed. Interviews were conducted according to a questionnaire (about all aspects regarding plant protection products and their practices) and data were collected on the main following points:

- Characteristics of the farmers population (gender, education, …);
- Plant protection products used (name of the products, commercial formulations, active substances, size of the containers, type of closure, …);
- Current state of pesticide management practices (dosage/ha, average area sprayed/day, duration of work, type of sprayers, personal protective equipment, storage, …);
- Respect of basic hygiene rules and measures taken before, during and after application of the plant protection products.

Model used to assess the dermal exposure of farmers

The UK *Predictive Operator Exposure Model* (UK-POEM) was used to estimate the Potential Dermal Exposure (PDE, in mg/kg bw/day) according to the previously observed local practices. All parameters required in the model are presented in the table 1.

Table 1: Parameters used for the calculation of farmers' exposure

Parameters used in the UK-POEM Model	Details
Application method	Backpack sprayer (15 L tank)
Formulation type	Emulsifiable Concentrate (EC, solvent based formulation)
Dermal absorption from product	10% (default value used)
Dermal absorption from spray	10% (default value used)
Container	1 L, any closure
Work rate/day	1 hour
Duration of spraying	6 hours
PPE	None or gloves

The total predicted dose of exposure calculated by the model is the sum of both exposures, first during handling, mixing and loading (contact with product, mainly by hands) and later, during spraying (droplets of mixture received on the whole body). Dermal absorption is the main route of exposure; in accordance with the PPR (Plant Protection Products and their Residues) panel group of EFSA, a general default value of 10% was used for dermal absorption of all active substances (recommended, realistic value) to assess the risk for farmers working with pesticides in the Niger River valley. Calculations of the predictive exposure were repeated for two scenarios: without Personal Protection Equipment (PPE), which is the most frequent scenario in the Niger River valley, and with PPE (mainly gloves, sometimes worn by farmers).

Risk assessment

The risk for each plant protection product sprayed was characterized comparing the predicted exposure dose of active substance, expressed in mg/kg bw/day, with AOEL (Acceptable Operator Exposure Level). If the predicted exposure dose is lower than the AOEL value of the respective active substance, the risk of exposure can be considered as acceptable. On the contrary, when the AOEL value is exceeded, mitigation measures should be recommended to reduce the risk level.

Statistical analysis of data

All data collected during the survey (from the questionnaires) as well as the calculated total exposure values were analyzed using Origin version 6.0 and/or Excel 2007 software.

RESULTS

Plant protection products inventory

The survey has shown that 100% of the growers are using PPP (acaricides, fungicides, insecticides and herbicides) to prevent damage and protect their crops. A grand total of 57 commercial formulations were recorded during the survey: 48 (84%) insecticides, 4 fungicides and 4 herbicides. A total of 25 active substances were identified (table 2). For some PPP the nature of the formulation was not mentioned on the label and was considered as unknown.

Table 2: PPP and their active substances used in Niger River valley (Niamey and Tillabéri), listed according to their biological activities (formulation type: EC: Emulsifiable Concentrate - WP: Wettable Powder - G: Granules – SL: Liquid Solution)

Commercial name of the formulation	Active substances (as mentioned on the label)	Biological activity
Callifol	Dicofol	Acaricide
Acarius 18 EC	Abamectin	Insecticide
Actellic 50 EC	Pirimiphos-methyl	Insecticide
Attakan 144/200 EC	Cypermethrin/Imidacloprid	Insecticide

Batik	Bacillus thuringiensis	Insecticide (microbial)
Baygon	Carbosulfan	Insecticide
Bomec 18 EC	Abamectine	Insecticide
Caïman 19,2 EC	Emamectine-benzoate	Insecticide
Calthio	Thirame/Chlorpyriphos-ethyl	Insecticide
Capt88 16/72 EC	Acétamiprid/Cypermethrin	Insecticide
Clean-up 100 EC	Cypermethrin	Insecticide
Cruch 1000 EC	Dichlorvos	Insecticide
Curacon 500 EC	Profenofos	Insecticide
Cypercal 50 EC	Cypermethrine	Insecticide
Cyperforce 50 EC	Cypermethrine	Insecticide
Cypermethrin 10 EC	Cypermethrin	Insecticide
Cypra 100 EC	Cypermethrine	Insecticide
DDforce 1000 EC	Dichlorvos	Insecticide
Decis 25 EC	Deltamethrin	Insecticide
Deltacal 12,5 EC	Deltamethrin	Insecticide
Delvap super 1000 EC	Dichlorvos	Insecticide
Dursban 240 EC	Chlorpyriphos-ethyl	Insecticide
Ema 19,2 EC	Emamectine-benzoate	Insecticide
Emacot 19 EC	Emamectine-benzoate	Insecticide
Executor 1000 EC	Dichlorvos	Insecticide
Fiproforce 25 EC	Fipronil	Insecticide
Furadan 3G	Carbosulfan	Insecticide
Karate 25 EC	Lambda-cyhalothrin	Insecticide
Kartap 500 SP	Cartap	Insecticide
Karto super 25 EC	Lambda-cyhalothrin	Insecticide
Kombat 25 EC	Lambda-cyhalothrine	Insecticide
Kungfu 25 EC	Lambda-cyhalothrine	Insecticide
Lambda power 25 EC	Lambda-cyhalothrine	Insecticide
Laraforce 25 EC	Lambda-cyhalothrin	Insecticide
Malathion	Malathion	Insecticide
Methoate 400 EC	Dimethoate	Insecticide
Pacha 15/10 EC	Cyhalothrin/Acetamiprid	Insecticide
Perfect killer 20 EC	Chlorpyriphos-methyl	Insecticide
Polythrine 30/15 EC	Profenofos/Cyhalothrin	Insecticide
Pyrical 480 EC	Chlorpyriphos-ethyl	Insecticide
Reeva 25 EC	Lambda-cyhalothrin	Insecticide
Ridoff 1000 EC	Diclorvos	Insecticide
Rocket 20 EC	Chlorphyriphos-ethyl	Insecticide

Smash-super 50 EC	Cypermethrin	Insecticide
Super-plus	Cypermethrin/Dimethoate	Insecticide
Termex 480 EC	Chlorpyriphos	Insecticide
Termikill 20 EC	chlorpyriphos	Insecticide
Titan 25 EC	Acetamiprid	Insecticide
Viper 30/16 EC	Indoxacarbe/Acetamiprid	Insecticide
Coga 800 WP	Mancozeb	Fungicide
Dithane 800 WP	Mancozeb	Fungicide
Thioral WP	Thiram (TMTD)	Fungicide
Thirame P	Thiram (TMTD)	Fungicide
Calliherb SL	2,4-D	Herbicide
Herbiax 100 WP	Bensulfuron-methyl	Herbicide
Malik 108 EC	Haloxylfop-R-methyl	Herbicide
Samory 100 WP	Bensulfuron-methyl	Herbicide

Most of the PPP are EC formulations (solvent based, usually more toxic than SL, WP or granules). It also appears that a large number of different active substances are commonly sprayed by the farmers who have no information about their properties and the risk for their health. Only 25 formulations (44%) used are registered by the Sahelian Pesticides Committee (CSP) which is the unique office charged by the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) to regulate pesticides uses in its member states. But often they have been registered for a usage on cotton and are not appropriate for vegetables (at minimum, dosage and PHI should be reviewed before those PPP could be recommended). Many PPP sprayed are toxic insecticides which belong mainly to the organophosphate (28%), pyrethroid (12%) or neonicotonoid (8%) families (figure 2). Some products which are less toxic (e.g. Abamectin) or even nontoxic (e.g. Bacillus thuringiensis) could be better recommended to small farmers.

Practices of plant protection products use and management

In the safe use of plant protection products, personal experience plays a very important role. According to the results of the survey, the great majority (67%) of growers are familiar with PPP with an average experience of more than twenty years (figure 3).

This study showed that the most used equipment by growers for application is the backpack sprayer (60%). Unfortunately some others (40%) also used devices such as tree branches and plastic bottles with holes. In fact, they used the materials described by RECA (*Réseau National des Chambres d'Agriculture du Niger*) showed in picture 1 (RECA, 2013). This explains why, according to our observations, the exact dosage required was never respected by farmers at mixing and loading. They just estimate roughly the necessary quantity of products after a first test.

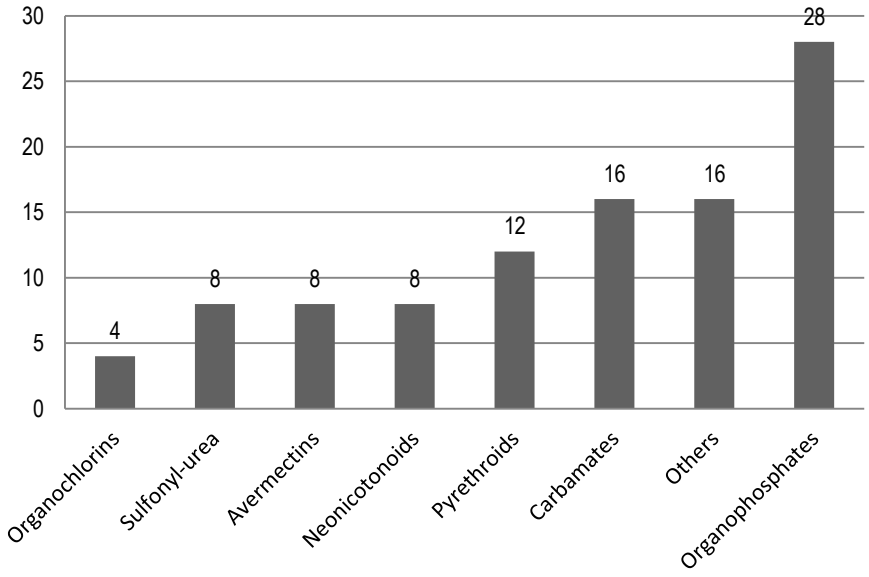

Figure 2: Percentage of active substances in the various chemical families (in %)
Others**:** Nereistoxin; Aryloxyphenoxy-propionate; Phenylpyrazoline; Microbial.

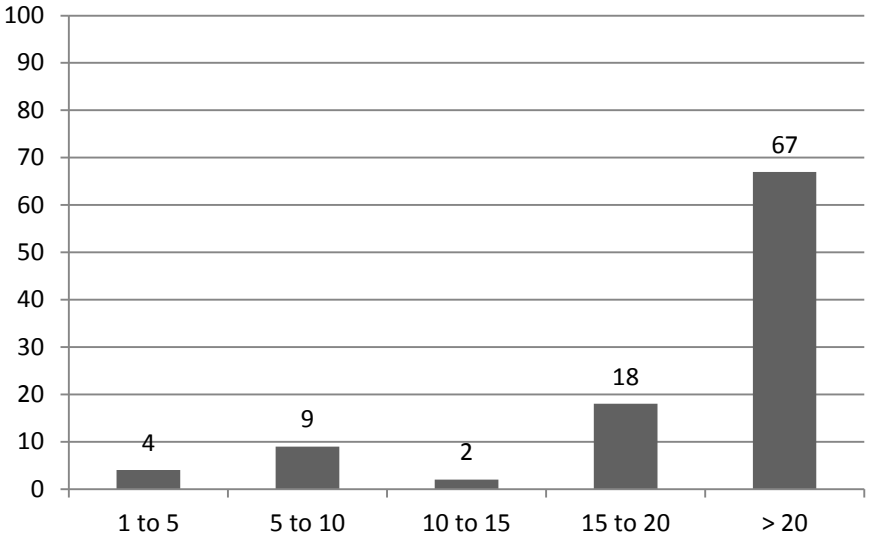

Figure 3: Year of experience of farmers in the use of PPPs (in %)

Photo 1: Measuring equipment used by farmers in Niger (Source: RECA, 2013)

76% of the growers don't use any PPE (Personal Protective Equipment) during mixing/loading and spraying (photos 2 and 3). In our survey, only 5% of the farmers wear a full protective equipment (figure 4). With regard to hygiene practices, more than 90% of farmers wash only their hands after spraying.

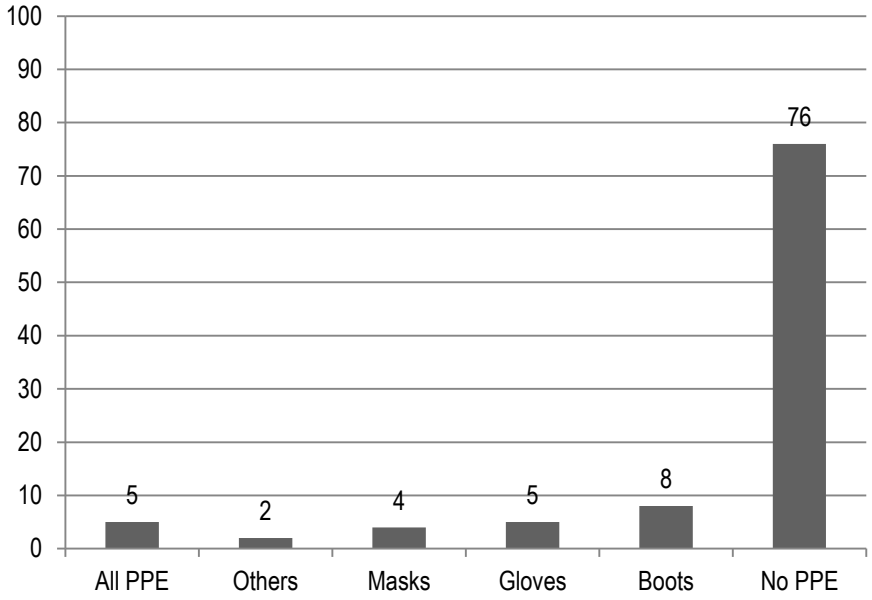

Figure 4: Personal Protection Equipment used by farmers (in %)

Photo 2: Mixing/loading without PPE

Photo 3: Spraying without PPE

Risk assessment

The UK-POEM model has been used to assess the potential exposure of farmers, working as usual (see table 1). Two scenarios, with and without PPE, were considered. Assessment was limited to active substances whose doses per hectare were recorded and to EC formulations. In total, the predicted exposure values during mixing/loading and spraying were assessed for 10 active substances. The toxicological values of each active substance were obtained through JMPR, Agrimex, EFSA and EU-Pesticides database and reported in table 3. Finally, the risk for farmers'health was determined for a dermal absorption of 10% compared to the respective AOEL (Acceptable Operator Exposure Level) of each active ingredient.

Table 3: Toxicology properties characterization of active ingredients their concentration and dose (AOEL: Acceptable Operator Exposure Level; LD_{50}: Lethal Dose 50; NA: Not available)

Active substance	LD_{50} (dermal) mg/kg.bw	AOEL mg/kg bw/day	Concentration in the PPP (g/L)	Dose (l/ha)
Abamectin	>2000	0.0025	18	1.0
Acetmiprid	>2000	0.07	25	0.5
Chlorpyrifos-ethyl	1250-2000	0.001	480	1.5
Cypermethrin	>2000	0.06	100	0.5
Deltamethrin	>2000	0.0075	25	1.0
Dichlorvos	75	0.0005	1000	0.5
Dimethoate	>2000	0.001	400	0.55
Emamectin-benzoate	> 1754	0.0003	19.2	0.5
Lambda-cyhalothrin	632-696	0.00065	25	0.4
Profenofos	3300	NA	500	1.5

The results given by the model are listed in the following tables 4 and 5.

Exposure without protection

Table 4 shows the potential dermal exposure values of operators during mixing, loading and spraying without protection compared with the AOEL.

Table 4: Exposure values without PPE

Active substance	Potential Dermal Exposure (mg/kg bw/day)	AOEL (mg/kg bw/day)	% AOEL
Abamectin	0.011	0.0025	440
Acetmiprid	0.013	0.07	19
Chlorpyrifos-ethyl	0.396	0.001	39600
Cypermethrin	0.055	0.06	92
Deltamethrin	0.016	0.0075	214
Dichlorvos	0.556	0.0005	111200
Dimethoate	0.226	0.001	22600
Emamectin-benzoate	0.010	0.0003	3334
Lambda-cyhalothrin	0.013	0.00065	2000
Profenofos	0.384	-	-

Exposure with full protection

Table 5 shows the potential dermal exposure values of operators during mixing, loading and spraying with full protection compared to the AOEL.

Table 5: Exposure values with full protection

Active substance	Potential Dermal Exposure (mg/kg bw/day)	AOEL (mg/kg bw/day)	% AOEL
Abamectin	0.002	0.0025	80
Acetmiprid	0.002	0.07	3
Chlorpyrifos-ethyl	0.095	0.001	9500
Cypermethrin	0.009	0.06	15
Deltamethrin	0.003	0.0075	40
Dichlorvos	0.096	0.0005	19200
Dimethoate	0.040	0.001	4000
Emamectin-benzoate	0.001	0.0003	334
Lambda-cyhalothrin	0.002	0.00065	308
Profenofos	0.099	-	-

DISCUSSION

According to the survey, a large number of different plant protection products (56 commercial formulations) were used. The most active substances used in the Niger River valley are organophosphate and pyrethroids insecticides (82.45%). However, some other prohibited and counterfeit formulations cocktails are also used by producers. The used of banned formulations could be an important factor contributing to health risk (Mansour, 2004; Ahouangninou et al., 2011; Toe et al., 2013; Toumi et al., 2016).

The majority of the vegetable growers using plant protection products in the Niger River valley seemed to be experimented (67%). Nevertheless, the idea that the length time in using plant protection products confers some experience was not observed. For example, only five percent (5%) of the surveyed growers wear personal protective equipment. A similar result was observed in the study of the Food and Agriculture Organization in Burkina Faso (FAO, 2010). In the study of Toe et al. published in 2013, the majority of the farmers using pesticides was relatively young and had between 10 and 30 years' experience (Toe et al., 2013).

Regarding spraying equipment, in addition a significant part of farmers (about 40%) are still using unsuitable equipment (tree branches and bottles of water) that can generate high level of exposure. Ahouangninou et al. (2011) and Doumbia et al. (2009) respectively found in their studies that 30% and more than 26% of farmers use inadequate equipment such as tree branches for pesticides application in Benin and Ivory Coast. The unsuitable materials used for dosage are also a factor that can increase the exposure of operators and the risk for consumers. This practice linked to the illiteracy of growers was also observed in many other studies and countries, like Ivory Coast, Senegal and Togo (Cissé et al., 2003; Traoré et al., 2006; Kanda et al., 2009; Ngom et al., 2013).

The exposure of operators to plant protection products varies with the conditions of their use, in particular the availability of personal protective equipment (PPE). In term of PPE, 76% of growers don't use any PPE during mixing, loading and spraying. This practice could also be a significant threat to human health (Cissé et al., 2003).

In order to estimate the exposure level, some parameters such as application method, PPP formulation and concentration, PPE, dose and application volume were used in the UK-POEM model in accordance with the local practices (Kim et al., 2016; Richard et al., 2014). The results show that farmers could be highly exposed to plant protection products in the Niger River valley. Indeed, the estimated exposure levels exceed several times higher the acceptable operator exposure level (AOEL) for the two scenarios. The Potential Dermal Exposure (PDE) values vary between 0.010 mg/kg bw/day to 0.556 mg/kg bw/day during mixing, loading and spraying when growers work without PPE. The risk of exposure can be greatly reduced if farmers wear complete personal protective equipment. Here again, PPE plays a very significant role in reducing of operators' exposure to plant protection products (Toe et al., 2013; Wumbei, 2013, Richard et al., 2014).

CONCLUSION

In conclusion, the use of plant protection products can plays a very important role in agriculture conditions of Niger River valley without their misuse. The results of this study reveal that farmers had practices that increase exposure to pesticides formulations. Most farmers were not aware about pesticides hazard and risk due to

inappropriate practices and poor pesticide management. For ten of the active substances commonly used in the study area, operator exposure values exceed their respective acceptable exposure level (AOEL). To reduce the exposure of operators to plant protection products, sensitization of farmers to better practices is suggested. Therefore, there is an important need to improve investigations in the Niger River valley to be able to assess potential risks both on consumers health and environment.

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