

*Full Length Research Paper*

# Risk of workers exposure to pesticides during mixing/loading and supervision of the application in sugarcane cultivation in Burkina Faso

<sup>1</sup>OUEDRAOGO Richard, <sup>2</sup>TOE Adama Makoum, <sup>3</sup>ILBOUDO Sylvain, <sup>3</sup>GUISSOU Pierre Innocent

<sup>1</sup>Université de Ouagadougou - Laboratoire de Toxicologie, Environnement et Santé, Institut de Recherche en Sciences de la Santé – Direction régionale de l'Ouest

<sup>2</sup>Institut de Recherche en Sciences de la Santé – Direction régionale de l'Ouest

<sup>3</sup>Université de Ouagadougou - Laboratoire de Toxicologie, Environnement et Santé, Institut de Recherche en Sciences de la Santé

## Abstract

A risk assessment of worker exposure to pesticides in the case of sugarcane cultivation in Burkina Faso was conducted in 2011. This study was conducted at first by observation of workstations, investigation of the medical history, clinical somatic and biological examination of workers. Then, the United Kingdom Predictive Operator Exposure Model Version 7 (during only mixing/loading) and the Estimation of bystander and resident exposure Model (during application supervision) was used to quantify pesticide exposure intensity. This study involved eleven (11) workers, all male, responsible for mixing/loading and the supervision of the application of pesticides. The average age of the exposed workers was 53.1 years with 17.6 years of experience. Clinical and laboratory tests show pathology such as hypertension, diabetes and fluctuating values of biological and hematological parameters. The exposure estimate shows that the absorbed doses ranging from 0.28 to 3600 mg/day during mixing/loading, from 0.0011 to 0.8768 mg/kg/day during the supervision of application at 3 m and from 0.0001 to 0.0839 mg/kg/day during the supervision of application at 20 m of the application. Overall, the results of this study show that workers are exposed to pesticides. This exposure can be exacerbated by the long exposure time, insufficient protection and especially the general state of workers' health.

**Keywords:** Pesticide, Risk factor, Occupational exposure, People present, Sugarcane.

## INTRODUCTION

The use of pesticides for crop protection has become inevitable in developing countries. Indeed, the pressure

due to the presence of pests has cause loss of up to 30% of total production (Ministère de l'Economie et des Finances, 2011). Therefore, pesticides are used against pests.

### Abbreviations

SN-SOCUCO Nouvelle Société Sucrière de la Comoé  
CBC-Complete blood count  
AST-Aspartate aminotransferase  
ALT-Alanine aminotransferase  
UKPOEM-United Kingdom Predictive Operator Exposure Model  
PPE-Personal protective equipment  
AOEL- Acceptable operator exposure level  
RI-Risk index  
WH -World Health Organization

In modern agriculture, the intensification of production has resulted in the widespread use of pesticides. If these pesticides were effective against pests, they nevertheless present real dangers and at three levels:

- Toxicity to users in agriculture (Toe *et al.*, 2000; Toe *et al.*, 2002)
- Toxicity to the consumer due to the presence of toxic residues (Fournier and Bonderef, 1983).
- Pollution and environmental toxicology (Ramade, 1992; Toe *et al.*, 2004).

\*Corresponding author E-mail: richardoued@gmail.com;  
Tel : (+226) 766 566 56

On the health front, misuse of pesticides can

cause poisoning and/or diseases that can cause death (Ouedraogo *et al.*, 2011; Abhilash and Singh, 2009; Ouedraogo *et al.*, 2008; Prado-Lu, 2007; Toe *et al.*, 2002; Toe *et al.*, 2000). Indeed, pesticides are the cause of many chronic diseases and degenerative conditions such as cancer, Alzheimer's (Anger and Kintz, 2009; Multinigner, 2005). If the effects of acute poisoning are immediate and dramatic, those resulting from chronic exposure are insidious.

Among the factors that may influence or exacerbate pesticide poisoning, there is a lack of training and non-compliance with the precautions use of products (Ouedraogo *et al.*, 2011; Toe *et al.*, 2004; Toe *et al.*, 2002; Toe *et al.*, 2000).

In Burkina Faso, the production of sugarcane leads to the use of herbicide and insecticide for crop protection. On average, about 23 t of insecticides and a similar amount of herbicides are used each year on this culture.

Prior to give an employment authorization and to prevent the risk of poisoning pesticide users, firms are asked to provide a risk assessment of the exposure (Sahelian Pesticide Committee, 2000). Applicators' exposure has been documented for several situations (Toe *et al.*, 2012; Toe *et al.*, 2002; Toe *et al.*, 2000), both for people present (bystanders) when spraying pesticide and/or after is missing. Very few or no studies have been conducted in developing countries to document the issue and fill this gap.

In Burkina Faso, no study has been published on the applicator's exposure. However, a good knowledge of risk factors for poisoning, exposure and protection measures not only provides a basis for decision making but also sets directions for future studies to further prevent the risk of poisoning of operators and people present (bystanders) when using pesticides.

The objective of this study was to evaluate the risk of workers exposure to pesticides in the case of sugarcane cultivation in Burkina Faso.

## MATERIALS AND METHODS

### Study area

Sugarcane is an industrial crop grown by Nouvelle Société Sucrière de la Comoé (SN-SOCUCO) in Burkina Faso. SN-SOSUCO is a sugar food industrial unit. It is located in the administrative area of the Cascades in the province Comoé, south-west of Burkina Faso. Its geographical coordinates are located between 10°41 and 10°47 north latitude and 38°4 and 4°39 west longitude (Millogo *et al.*, 2004). The climate is Sudano-Sahelian. Average rainfall (31 years) is 1100 mm. The annual average temperature is about 27 °C (Millogo *et al.*, 2004). Sugarcane is grown on an area of about 3850 ha.

SN-SOSUCO is the second largest employer after the government of Burkina Faso, it employs around 900 permanent workers. In the campaign period, the number of seasonal and daily employees can reach 2000 (Millogo *et al.*, 2004).

### Study population

The study population consisted of warehouseman and workers responsible for the mixing/loading and the supervision of pesticide application (Photo 1). The choice of these workers is based on their frequency of exposure to pesticides and their seniority position of pesticide management. Eleven male workers were included in the study. These workers were enrolled after informed consent to the study.

### Methodology

The study was a descriptive cross-sectional study.

An observational survey of workstations was first conducted to collect information on pesticides used (formulations used, doses, treatment areas, application type, protective personal equipment used). Then, a questionnaire was administered to workers to collect data on individual characteristics (age, weight, hazard perception). Finally, workers were asked about their medical history and underwent a somatic clinical examination. Following this review, the workers have since undergone a biological examination (biochemistry and hematology).

### Hematological analysis

Hematology analysis involved a complete blood count (CBC). We used plastic tubes under vacuum with anticoagulant (K<sub>3</sub>EDTA) 5 mL Vacutainer brand syringes, a rubber tourniquet, and iodized alcohol and cotton wool for disinfection in blood samples. The analysis of samples required an automatic blood cell counter brand ABX diagnostics.

### Biochemical analysis

Biochemical analytes were transaminases (AST, ALT), creatinine, amylase and determination of baseline cholinesterase for workers involved in the use of organophosphates and carbamates. We used hemolysis tubes plastic dry vacuum 5 mL Vacutainer brand, syringes of 5 mL, a rubber tourniquet, the iodized alcohol and cotton wool for disinfection in blood samples. Analysis of samples required a centrifuge brand Funke Gerber, a spectrophotometer brand Hospitex Diagnostics, a spectrophotometer Lisa 300 PLUS,



a)



b)

**Photo 1a,b.** People present (bystander) during application of pesticides in cultivation of sugarcane in Burkina Faso



**Photo 2.** Operators handling pesticides without protective equipment

kits chemical reagents laboratories SOBIODA (TGP- monoreagent ALT, AST monoreagent - TGO) Spinreact (cholinesterase), Erba Mannheim (creatinine) and Cypress ( $\alpha$ -amylase).

**Assessment of worker exposure during mixing/loading**

The assessment of worker exposure during mixing/loading of the gruel was carried out using the spreadsheet United Kingdom Predictive Operator Exposure Model Version 7 (UK-POEM 7). The spreadsheet UK-POEM 7 has been developed by industry experts and the approval of the United Kingdom (European Food Safety Authority, 2008). This model

calculates the predicted dose of pesticide (in mg/kg bw) absorbed by the operator during mixing/loading of the gruel (Photo 2). The absorbed dose during mixing and loading is calculated from the following equations (Health and Safety Executive, 2013).

*For a liquid concentrate formulation:*

$$AD_{ml} = N_o \times H_{co} \times T_s \times C_{as} \times P_a / 10000 \quad \text{Equation 1}$$

With

$AD_{ml}$  : absorbed dose during mixing and loading (mg/day)

$N_o$  : number of operations by day

$H_{co}$  : hand contamination/operation (ml/day)

$T_s$  : transmission to skin (%)

$C_{as}$  : active substance concentration (mg/ml)

$P_a$  : percent absorbed (%)

*For a solid concentrate formulation:*

$$AD_{ml} = \frac{(H_{co} \times T_s \times P_a \times 10^{-1} + I_{exp} \times T_{rpe} \times 10)}{C_{as} \times 10^{-3}} \times d \times W_{rd} \times$$

Equation 2

With

$AD_{ml}$  : absorbed dose during mixing and loading (mg/day)

$H_{co}$  : hand contamination/operation (ml/day)

$T_s$  : transmission to skin (%)

$P_a$  : percent absorbed (%)

$I_{exp}$  : Inhalation exposure/kg a.s. (mg/kg)

$T_{rpe}$  : transmission through respiratory protective equipment (%)

$D$  : dose (kg/ha)

$W_{rd}$  : work rate/day (ha)

$C_{as}$  : active substance concentration (mg/g)

The predicted exposure of the operator, expressed in mg/kg bw/day is calculated from the absorbed dose relative to body weight of 63.4 kg by:

$$\text{Operator exposure} = AD_{ml} / O_{bw} \quad \text{Equation 3}$$

With

$AD_{ml}$  : absorbed dose during mixing and loading (mg/day)

$O_{bw}$  : operator body weight (kg)

For the exposure assessment, we considered the dermal absorption value from the database FOOTPRINT PPDB (Footprint, 2013). In case of missing data, a default value of 10% was taken into account the recommendations of the European Union (European Commission, 2004).

We considered four exposure scenarios:

Scenario 1: operators do not wear any personal protective equipment (PPE) during mixing and loading a backpack sprayer;

Scenario 2: operators wear gloves when handling liquid formulations and respirators for handling solid formulations during mixing of the gruel and loading a backpack sprayer;

Scenario 3: operators do not wear any personal protective equipment (PPE) during mixing of the gruel and loading a tractor mechanical pressure;

Scenario 4: operators wear gloves when handling liquid formulations and respirators for handling solid formulations during mixing of the gruel and loading a tractor mechanical pressure.

### **Assessment of worker exposure during the supervision of the application of pesticides (people present or bystanders)**

The model used is called "Estimation of bystander and residential exposure." It is a model used by the German phytosanitary legislation for the estimation of bystander exposure after pesticide application (Bundesinstitut für Risikobewertung, 2013a). The absorbed dose (mg/kg bw) during the supervision of the application of pesticides is calculated from equation (Bundesinstitut für Risikobewertung, 2013b):

$$SE_B = AR/BW \times [(D \times BSA \times DA) + (I^*_A \times A \times T \times IA)] \quad \text{Equation 4}$$

Where

SEB is the total systemic exposure (sum of the dermal exposure after application via spray drift and the inhalation exposure after application).

AR is the application rate (kg/ha)

D is the drift deposit for one application based on application technique and distance

BSA is the exposed body surface area

DA is the dermal absorption

BW is the body weight of present person.

$I^*_A$  is the specific inhalation absorption expressed in mg/kg a.s. (6 h)

A is the area treated

T is the exposure duration

IA is the inhalation absorption

The dose of pesticide that reaches a person present is calculated for supervision at 3 m (5 m for glyphosate) and at 20 m from the site of application.

### **Statistical analysis**

The data were coded, entered and analyzed on Epidata 3.1. For each pesticide, the total exposure [value] was divided by the acceptable operator exposure level (AOEL) to get a risk index (RI) values for the defined scenarios. Inspired by the work of Wumbei (2013), the risk index values were log transformed and the log value plotted into graphs to allow for an easy evaluation of the risk levels. If the predictive exposure in the models is lower than AOEL for the active substance, the use should be considered as acceptable.

## **RESULTS**

### **Pesticides used**

The study involved 12 pesticides (Table 1).

### **Socio-demographic profile of workers exposed**

Table 2 shows the socio-demographic characteristics of exposed workers.

Risk factors related to pesticide exposure are given in Table 3. The main symptoms reported by workers are disorders of the nervous system, digestive and respiratory systems.

### **Clinical examination of workers**

Professionals from two specific backgrounds may be related to pesticide exposure: these are accidents (n=2) and cases of chronic ocular irritation by contact with chemicals (n=2). Some workers became bloated after exposure to pesticides and work accidents were identified as the cause of the inhalation. Medical history

**Table 1.** Characteristics of pesticides used on sugarcane cultivation in Burkina Faso

Pesticides	Concentration	Type	WHO hazard class	Type of application
Metribuzin	643 g/kg	Herbicide	II	Tractor mechanical pressure
Chlorimuron-ethyl	107 g/kg	Herbicide	III	Tractor mechanical pressure
Pendimethalin	500 g/L	Herbicide	II	Tractor mechanical pressure
Acetochlor	900 g/L	Herbicide	III	Tractor mechanical pressure
Diuron	800 g/kg	Herbicide	III	Tractor mechanical pressure/backpack sprayer
Glyphosate	360 g/L	Herbicide	III	Tractor mechanical pressure/backpack sprayer
2,4-MCPA	400 g/L	Herbicide	II	Backpack sprayer
Trichlopyr	480 g/L	Herbicide	II	Backpack sprayer
Pichlorame	240 g/L	Herbicide	U	Backpack sprayer
Carbofuran	100 g/kg	Nematicide	Ib	-
MSMA	720 g/L	Herbicide	III	Backpack sprayer
Terbufos	150 g/kg	Nematicide	Ia	Tractor mechanical pressure

**Table 2.** sociodemographic characteristics of exposed workers

Characteristics	Minimum	Mean ± SE	Maximum
Height (cm)	165,0	173,3 ± 06,9	185,0
Weight (kg)	58,0	63,4 ± 10,1	81,0
Age (year)	45,0	53,1 ± 03,1	57,0
Experience (year)	1,0	17,6 ± 10,3	30,0
Length of service (year)	26,0	32,8 ± 02,5	35,0

**Table 3.** Risk factors related to the exposure of workers

Risk Factors	Frequency (%)
No personal protective equipment	82
No training received	55
No allocation soap	100
More than two reported symptoms consistent with pesticide poisoning in general	36
Less than two or no reported symptoms consistent with pesticide poisoning in general	64
Education less than high school	73
No recognition of the risks involved in the use of pesticides	9
Have you had an accident when handling pesticides	9
Dissatisfaction with personal protective equipment provided	73

and clinical examinations of exposed workers are shown in Table 4. The clinical examination of workers showed that 6 out of 11 were at risk when using pesticides.

**Biological examination of workers**

Three workers had a hypertransaminasemie. The results of amylase showed that all workers had normal values. The results of serum creatinine showed that five workers had hyper-creatinine.

The hematocrit values were normal in all workers. A decrease in white blood cells, red, hemoglobin, platelet and erythrocyte sedimentation rate was observed in

respectively 5, 4, 3, 1 and 3 worker. Elevated basophils, lymphocytes and erythrocytes sedimentation rate was observed respectively at 1, 3 and 1 workers. Three workers showed decreased monocyte and erythrocyte sedimentation rate.

The average value of cholinesterase was 4068.087 ± 1025.612 IU/L. The lowest value was 1860 IU/L and the highest value was 6122 IU/L.

**Assessment of worker exposure during mixing/loading**

Operators are exposed to most formulations with or

**Table 4.** Medical history and clinical examination of workers exposed to pesticides

Background/exams	Workers											
	1	2	3	4	5	6	7	8	9	10	11	
<i>Medical history</i>												
Hypertension												X
Diabetes					X							
Cervical trauma (accident of the highway)												
Hydrocele treatment									X			
None	X	X	X	X								
<i>Clinical examination</i>												
Reducible hernia inguinoscrotal right		X										
Increased intensity of the heart beat			X									
Epigastric tenderness				X								
Knowledge of diabetes treatment					X							
Deforming deviation of post traumatic neck by accident on the highway						X						
Trend hypertension									X			
Overweight									X			
Lumbago		X										
None	X											

without protective equipment, depending on the scenario considered (Figures 1 and 2).

#### **Assessment of workers exposure during the supervision of the application of pesticides (people present or bystanders)**

Workers are also exposed to most formulations during the supervision of the application with or without protective equipment, depending on the scenario considered (Table 5).

## **DISCUSSION**

Toxicological classes of pesticides show that 2,4-MCPA, metribuzin, pendimethalin and trichlopyr belong to the class II of the WHO (moderately hazardous). Acetochlor, diuron, glyphosate and chlorimuron-ethyl belong to Class III of the WHO (slightly hazardous) while pichlorame belongs to the class U WHO (unlikely to present acute hazard) (Table I) (World Health Organization, 2010).

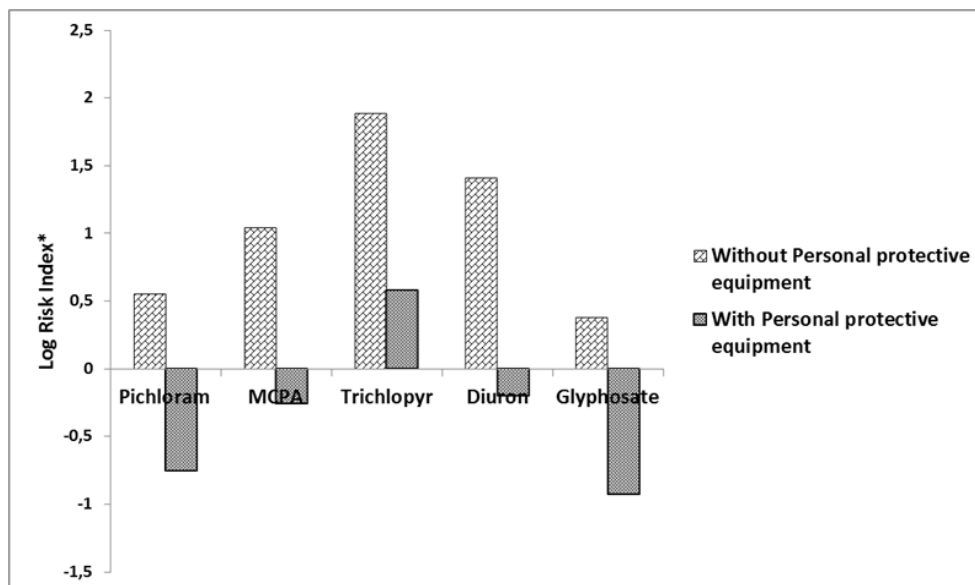
Compared to the conditions of use, acetochlor, diuron, glyphosate and chlorimuron-ethyl are very dangerous and should be used by trained applicators respecting routine precautions. Metribuzin, 2,4-MCPA, pendimethalin and trichlopyr are moderately dangerous, and should be used by trained and monitored applicators

who strictly follow the prescribed precautions (World Health Organization, 2010). According to WHO, the formulations of class II should be avoided if possible in developing countries (World Health Organization, 2010).

The majority of exposed workers were aged (53.1 years on average). However it is recognized that the functional capacity of vital organs such as the kidneys decreases with age, hence the increased risk to the health of workers (Pope, 2010; Klaasen, 2007). Workers have an average experience of 17.6 years at their workstation. This is very significant and indicates chronic exposure of these workers (Konradsen, 2007). Authors such as Ouedraogo *et al.* (2009) found that operators with long experience do not necessarily set a good example. By contrast, this experience can be a source of caution because workers have more or less been seeing cases of acute poisoning, or a risk factor because of repeated exposure to pesticides. According Toe *et al.* (2013), the operators applying pesticides without PPE do so on the pretext that there is no risk in the use of pesticides. But the trend is that even when operators are using a partial EPI there inevitably is a high risk among pesticide applicators exposure (Toe *et al.*, 2013; Przybylska, 2004).

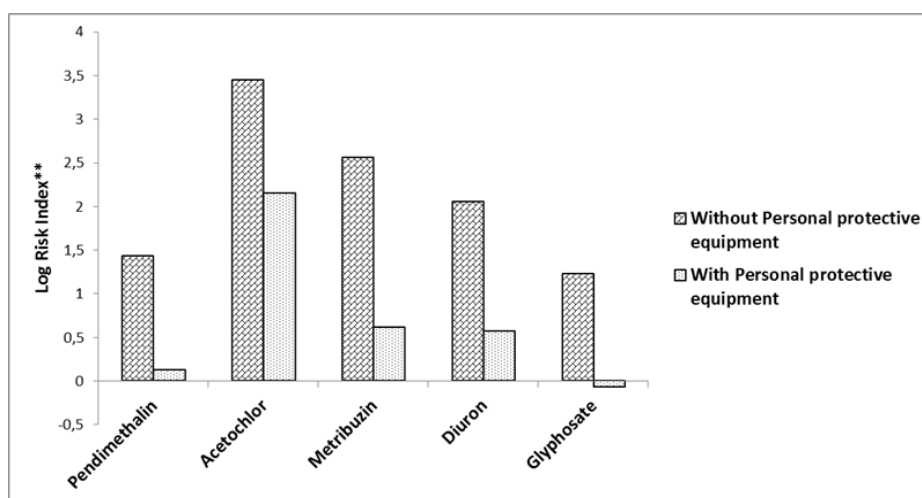
The educational level of workers is very low. Indeed, 73% of them have a lower level of secondary school education. This could be a handicap in the implementation of a program of reduction of health risks (Toe *et al.*, 2013; Sougnabe *et al.*, 2010).

Clinical and biological examinations of workers show



\*The risk is acceptable when LogRI are lower than 0.

**Figure 1.** Results of the evaluation of the workers exposure during mixing and loading of the gruel (Operators using a backpack sprayer)



\*\*The risk is acceptable when LogRI are lower than 0.

**Figure 2.** Results of the evaluation of the workers exposure during mixing and loading of the gruel (Operators using a tractor mechanical pressure)

**Table 5.** Results of the evaluation of the workers exposure during the supervision of the application

Pesticide	Absorbed dose (mg/kg/j) at 3 m	Absorbed dose (mg/kg/j) at 20 m	% AOEL at 3 m	% AOEL at 20 m
Pendimethalin	0.0978	0.0097	41.77	04.12
Acetochlor	0.8768	0.0839	4383.75	419.25
Diuron	0.0147	0.0012	209.59	17.18
Pichloram	0.0063	0.0005	2.10	0.15
Metribuzin	0.5013	0.0476	2506.69	238.12
Trichlopyr	0.0227	0.0016	45.46	03.30
MCPA	0.0013	0.0001	03.36	0.31
Glyphosate*	0.0011	0.0003	0.53	0.15

\* The absorbed dose of pesticide and the percent of AOEL were calculated for supervision at 5 m from the site of application.

a vulnerability of workers in the event of exposure to pesticides. The biological examination shows a decrease in hemoglobin, which indicates a diagnosis of anemia while low platelets (thrombocytopenia) indicates a risk of bleeding. The determination of cholinesterase in exposed workers showed that they had an average base rate lower than normal. This symptom is not a sign of acute intoxication as defined by WHO as an acute intoxication inhibition rate less than 50% of baseline.

In general, individual sensitivities related to age and general health could be due to worsening of pesticide poisoning.

The quantification models show that workers are exposed to pesticides through different routes (oral, dermal and/or pulmonary). The pesticide levels can reach between 0.28 mg/day and 3600 mg/day during mixing. This implies that they are exposed to most formulations with or without personal protective equipment and according to exposure scenarios. This exposure is greatly reduced when operators wear all their protective equipments (Ouedraogo, 2010; Gomgnimbou *et al.*, 2009; Nganoah, 2009; Yanke, 2009). Therefore, protective measures must be taken to reduce the exposure of workers (Lundehn *et al.*, 1992). In a study of worker exposure to captan, Lebailly *et al.* (2003) showed that the parameters used to quantify occupational exposure to pesticides are most commonly treated area and/or the time taken to perform the treatment. They add that other parameters such as the amount of pesticide handled and the type of protective equipment may be particularly interesting.

The results of the assessment of workers exposure during supervision of pesticide application show that the exposure limit value is exceeded in the case of supervision of the application of acetochlor (4384% and 419% respectively at 3 and 20 m), diuron (210 % at 3 m) and in the case of metribuzin (238% and 2507%, respectively 3 and 20 m). The maximum exposure (0.88 mg/kg/day) occurred in a worker applying acetochlor at 3 m.

## CONCLUSION

The results of the study show that workers are exposed to pesticides. This exposure can lead to health effects. These effects may be exacerbated by the long exposure time, insufficient safeguards and especially their overall health.

Laboratory tests show that workers have risk factors for health (including hyper creatinine). These risks could be reduced if mitigating measures such as wearing PPE and limiting exposure time were taken. These measures would decrease the pesticide load on the workers and consequently reduce the risks. The simple measure of wearing the personal protective equipment is recommended.

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