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Pesticides Exposure: The Case of Workers on Growing Grapes in San Francisco Valley, Petrolina/Brazil

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Abstract

The objective of this work is to analyze the systems of application of pesticides used in harvesting grapes of the sub-medium San Francisco valley, in relation to the risks of occupational contamination. The manual, mechanized and semi mechanized systems of application, adopted by the grape growers of the city of Petrolina/PE, have been analyzed through a method of both quantitative and qualitative evaluation. In such a way, two production units were visited: a mid-sized company and another one from of the CODEVASF. Five simulations were carried out in four systems of pesticide application using the European entire body method. Pre-application processes, such as storage and dilution of pesticides, as well as post-application processes, including equipment maintenance, cleaning and storage of clothes used for the application process were also analyzed. The results show large differences in risk among the systems that were analyzed and better conditions offered by the agricultural company, which was seeking to obtain the certification process.

Keywords

Agricultural Work, Growing Grapes, Chemical Risk, Pesticides Exposure

1. Introduction

On the banks of the San Francisco River, in the northeastern Brazilian territory, the cities of Petrolina/PE and Juazeiro/BA became centers for growth and development during the 1960s. This was largely due to investments in irrigation, which currently supplies 80,000 ha of government subsidized land and 60,000 ha of privately farmed land. The region is home to the country's largest individually owned vineyards, with a combined 5000

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ha planted and 18,000 direct jobs. The land area used for growing domestic grapes grew 71.8% from 2620 ha to approximately 4500 ha during 1991 to 1995. This resulted in an overall production increase of 344%, or 32,000 tons [1].

Because of the large growth and widespread irrigation system, growers have adopted new technological methods for vineyard maintenance, one of them being the conventional use of chemical substances for pest and disease control. The combination of these and other technologies and the richness of the San Francisco river region have vastly expanded the reach of agricultural development. This has created new challenges for the growers, especially regarding crop damage resulting from pest proliferation and favorable disease conditions that have already caused significant losses when preventive measures are not used.

2. Methods for Measuring Dermal Exposure

Several methods have been developed to assess exposure to pesticides and comprehensive reviews are available [2]-[6].

According to Organisation for Economic Co-Operation and Development (OECD) [7], the methods for measuring dermal exposure are classified in:

a **Patch method**—The patch dosimeter acts as a barrier to entrap pesticide that would impact on the clothing or, if the patch is located beneath the clothing, would otherwise reach the skin. Therefore, the composition of the patch and its location on each body region should be considered based on the type of pesticide formulation handled, the application equipment used, and the crop.

b **Standard whole body dosimeter method**—The whole body dosimeter acts as a barrier to entrap pesticide that would otherwise contact the clothing or, in the case of an inner dosimeter, would penetrate through the clothing to the skin. The dosimeter should cover the body, including the arms and legs to the wrists and ankles, and should fit well enough to avoid interference with hand washing or other activities. It should be constructed of suitable absorbent materials, such as cotton or cotton/polyester undergarments, socks, trousers, long-sleeved shirts and coveralls. Garments made of non-absorbent materials may be unsuitable for certain types of formulation.

c **Variant of whole body (normal clothing)**—A variant of the whole body method is the normal clothing approach. This approach involves the use of clothing and underwear that represents what the workers would normally wear, as outer and inner dermal dosimeters.

d **The fluorescent tracer/video imaging method**—This method involves the incorporation of a fluorescent tracer in a pesticide formulation and subsequent visual and quantitative analysis using a video imaging method. This method reveals non-uniform patterns of exposure that escape detection by the patch method.

The OECD [7] lists the main advantages and limitations of the above methods for estimating dermal exposure (**Table 1**).

Heavy usage of pesticides and herbicides is common and increasing in the Brazilian fruit culture. There are two growing seasons per year and chemicals are usually applied 6 to 8 times per growing season. It is known that the toxicants used are harmful and can affect many different groups related to the vineyards: workers, neighbors, visitors, product consumers, and fishermen and others who rely on exposed water sources [8].

Table 1. Main advantages and limitations of the methods for estimating dermal exposure.

Dermal Exposure Method	Main Advantages	Main Limitations
Patch	-Ease of analysis	-Assumes uniform deposition
Whole body	-No body region size or surface area correction necessary -Less time-consuming in the field	-Analysis may be more cumbersome -May be uncomfortable for operator
Variant of whole body	-Collects most pesticide not reaching skin -No extrapolation required for body surface area -Less time-consuming in the field	-Analysis may be more cumbersome
Dyes/video imaging	-Visual and quantitative analysis (conventionally or video imaging) -Measures exposure directly from skin (video imaging) -Useful for training operators	-Assumes equivalent clothing permeation by dye and pesticide

Source: Adapted from OECD ([7], p. 17).

According to Machera *et al.* [9], exposure to pesticides in farmers while using backpack sprayers mainly occurs through the dermal route represented more 99.0% of the total exposure among farmers applying pesticides with backpack sprayers. Thus, while studying exposure to pesticides in farmers using backpack sprayers, should aim to understand factors determining the level of exposure through dermal route.

In view of this reality, was evaluated the levels of exposure the pesticide appliers, by whole body methods, in the various methods of the spraying used in the Sao Francisco valley.

3. Materials and Methods

Two vineyard profiles were selected when determining units of study, taking into account levels of productivity.

- a medium-sized agricultural company that specialized in the growing of fresh fruits for export;
- local settler's farm, member of the Senator Nilo Coelho Irrigation Project, next to the San Francisco and Parnaiba Valley Development Corporation-CODEVASF.

Two different application systems used by the medium-sized company and three employees were chosen for exposure quantification tests. The first system involved an employee wearing backpack sprayer (model JACTO-20 L) with wands 50 cm in length using a type JA2 nozzle. The toxicant application was high-volume, covering the vines until it dripped from the leaves.

The second system involved a tractor-mounted electric system using a turbo-atomizer with a capacity of 400 L, model JACTO-ARBUS 400 L (**Figure 1**).

The local settler used two other application systems. Each one was tested for level of exposure with the cooperation of two of the settler's workers. The third system involved a worker equipped with a 50-cm-wide paint roller and an open 5l bucket with a handle. The roller is used to apply the cianamide hydrogen (Dormex) to the vine's stumps resulting from trimming (**Figure 2**).

The fourth system, known as *Capeta*, involved an air-pressure sprayer driven by a 1 Hp diesel engine and the same pump used by the ARBUS 400 L with a 200 L capacity (**Figure 3**). The contraption has pressure measurement and control devices and connections for two wands. The types of wands can vary depending on the product used and the purpose of the treatment. The entire contraption is mounted on an animal-powered wagon. One worker steers the animal and positions himself at a distance from the second worker who is manning the spray pistol, which is connected to the pump by a hose, and spraying the tops of the vines.

Figure 1. Simulation with turbo-atomizer.

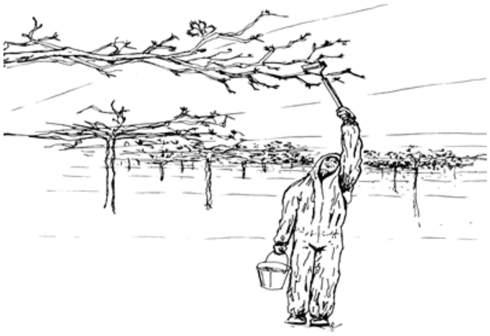

Figure 2. Simulation with paint roller.

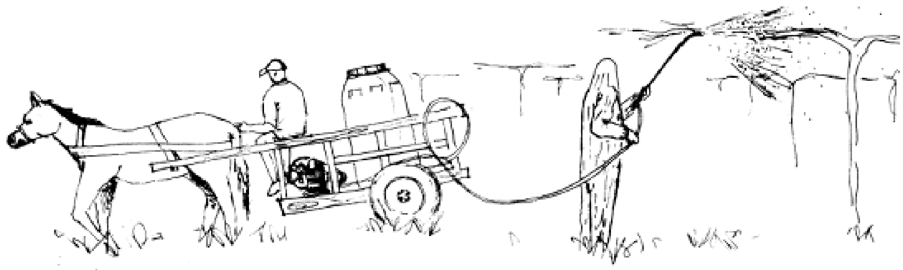

Figure 3. Simulation with equipment *Capeta* (side view).

In order to maintain the fidelity of the test simulations, the test subjects must be workers who are familiar with the handling of the toxicants and able to perform the necessary routine tasks. The simulations differed from a real scenario in two ways: the toxicants were replaced with "artificial coloring" and the worker's protective clothing was replaced with an especially absorbent suit that included a hood and gloves. After the dusting, the suit is cut into standard parts (**Figure 4**) using the European method developed by the United Kingdom's Ministry of Agriculture, Food, and Fishing's Central Science Laboratory for laboratory analysis [10]. Extraction of the coloring was done with a 10% acetone solution and the concentration of the mock-pesticide was performed using a spectrophotometer. The Spectrometer used was a Perkin Elmer LS 50-B at an excitation wavelength of 660 nm and integration's time of 1.0 s.

The decision to use the same standards as those of the European Community was due mainly to the fact the European markets are the main target of the grapes from the Sao Francisco valley. A secondary motivation was the level of precision possible when using this method since it takes into accounts the whole body, rendering extrapolations needed by other methods dependent on localized droplet collectors unnecessary. In this way, the contamination risk can be evaluated based on the toxicity of the product and the level of exposure the worker faces [11] (**Figure 4**).

Toxicology can determine various parameters indicative of the toxicity of the products. For measuring the risk of chronic contamination occurrence, we used the non-observable effect level (NOEL) and the ingestion daily allowance (IDA). These measure acceptable daily levels of exposure, dermal or oral, that do not result in serious illness for humans.

The quantitative analysis of contamination risks seeks to compare the quantity absorbed during exposure (QAE) and the human tolerance limits determined by toxicology. We use DL_{50} for cases of acute contamination and NOEL for chronic contamination. To determine the QAE, it is accepted that 10% of the exposed dermal (ED) surface area and 100% of the exposed respiratory (ER) surface area are absorbent. When direct estimation is not possible, ER can be considered to be 1% of the ED. Therefore, QAE can be defined as 11% of the ED and risks can be calculating as follows:

Acute contamination

$$\%DT = \frac{0.11 \times ED \times FS}{DL50 \times P} \quad (1)$$

Chronic contamination

$$MS = \frac{NOEL \times P}{0.11 \times ED \times FS} \quad (2)$$

where, "%*DT*" is a percentage for the total dose, "*P*" is the body weight of the worker (it is common to use 70 kg as the average weight of an adult male, "FS" is the safety factor, and "*MS*" is the safety margin. The security factor is necessary as an adjustment to take into account that the results from toxicology are estimates based on results with non-human subjects. These adopted factors vary considerably between authors, which points to a weakness in this method when trying to reach absolute conclusions. Therefore, the merit of this study is to objectively compare the safety of distinct situations and not determine that a given situation is safe or unsafe. The values for FS used in our calculations were 10 for %*DT* and 100 for MS.

The criteria used to interpret the value of MS and to classify safe work conditions, as a function of MS, according to Machado Neto [11], was the following:

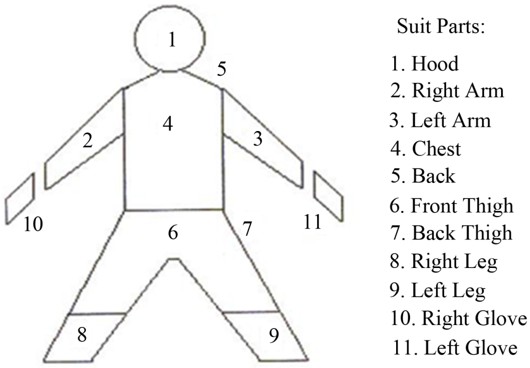

Figure 4. Cut the garment according to the body parts analyzed.

- If MS > 1, then the work condition is considered to be safe, that is, the level of exposure is tolerable and the risk acceptable, because the amount absorbed multiplied by the safety factor is less than the acceptable exposure (NOEL × 70 kg), or the limit index value (LIV);
- If MS < 1, then the work condition is considered unsafe, with the level of exposure and risk being unacceptable, because QAE × FS is larger than the acceptable exposure (NOEL × 70 kg).

The determination of safe work time (SWT) and exposure control need (ECN) for unsafe work conditions (MS < 1) can also be used in management strategies dealing with pesticides risks. The calculation of SWT can be used as a safety measure to control occupational exposure in pesticide use. The calculation of ECN permits the selection of a more appropriate safety measure, for each working condition [12].

4. Results and Discussion

The results of all the simulations are synthesized in **Table 2**, where it is observed that method with the highest exposure potential was that using the *Capeta* (S2) followed by the backpack sprayers (S1). Subsequently, the system turbo atomizer (S3) and, lastly and lower risk, the paint roller (S4). The areas of the body that were most affected by the *Capeta* method were those of the head, torso, and upper-body limbs.

The simulations involving pressurized equipment registered the best- and worst-case ED results. The simulation with the turbo-atomizer (S3) registered a ED of only 59.3 ml/day, while the *capeta* method (S2) registered an exposure rate of 1913.67 ml/day.

The areas of the body of the tractor driver that were most affected were the gloves and back. For the worker with *capeta* system, the most affected body areas were upper-body limbs, chest, back, and right hand.

By variance analysis (ANOVA) can be concluded that the 4 treatments caused significantly different exposures (F = 14.176 > Fcrit = 2.839).

A toxic product from each toxicological class was used during evaluation, spanning all varieties of targets (pests, diseases, growth controllers) (**Table 3**).

The backpack sprayers simulations performed at agricultural firm, resulted in significantly level of exposure (EDS = 389.03 ml/day) creating working conditions determined to be insecure (MS < 1) for applications with Equation GDA and Folicur 200CE and secure for use of, Amistar 500 WG, Dipel insecticide and Pro-Gibb hormone (**Table 4**).

The *Capeta* method was deemed unsafe (MS < 1) for working with Amistar 500 WG, Equation GDA, Folicur 200 CE and required a level of exposure control (ECN) above 90%. The only product used with the *Capeta* that was within safety parameters was the Dipel insecticide.

In **Table 5**, the turbo-atomizer system is considered safer than the *Capeta* sprayer with an EDS of 107.27 ml/day (5.6% of S3—**Table 2**).

The simulation using Dormex and the paint roller method (S4) could only be evaluated in terms of probability of acute intoxication since the Noel of the product could not be determined (**Table 6**). The area of the body that suffered the greatest exposure was the right hand (the worker was right-handed).

The conditions of storage of pesticides, preparation of operations and care of application equipment and protective observed in medium-sized agricultural company were higher than those of settler's farm.

Table 2. Potential dermal exposure of the five employees on different Suit Parts.

Suit Parts		Backpack Sprayers (S1)	Capeta (S2)	Turbo-Atomizer (S3)	Paint Roll (S4)
C1	Hood	7.92	120.86	5.55	4.96
C2	Right Arm	46.85	273.13	4.55	13.34
C3	Left Arm	8.79	229.20	5.39	4.1
C4	Chest	8.79	470.80	5.15	13.26
C5	Back	24.32	228.48	8.83	13.86
C6	Front Thigh	3.27	93.40	6.48	7.75
C7	Back Thigh	22.20	50.53	2.76	4.24
C8	Right Leg	15.21	68.92	1.37	3.02
C9	Left Leg	15.98	50.22	2.21	0.47
C10	Right Glove	42.17	240.24	8.50	33.61
C11	Left Glove	193.53	87.90	7.95	8.50
ED (ml/day)		**389.03**	**1913.67**	**107.27**	**59.30**

Concentration of the "artificial coloring": 1.28 g/l.

Table 3. Toxicological information of pesticides.

Trade Name	Concentration (g/l)	Dosage (g/l)	Class Toxicological	DL50 Dermal (mg/kg)	NOEL (mg/kg/day)
AMISTAR 500 WG	500	0.24	IV	5000	18.2
DIPEL	33.6	1	IV	5000	4000
EQUATION GDA	300	50	III	2000	10
FOLICUR 200 CE	200	0.6	III	5000	30
DORMEX	520	1	II	848	*
PRÓ-GIBB	1.00	0.015	III	5000	1000

*Unknown Value. Source: EPA [13] [14].

Table 4. Simulation involving manual spray (S1).

Trade Name	EDS (mg/dia)	Risk (%DT/dia)	MS	ECN (%)	SWT (h)
AMISTAR 500 WG	72.7	0.02	1.59	0.0	t > 7
DIPEL	302.7	0.10	84.08	0.0	t > 7
EQUATION GDA	181.6	0.14	0.35	65.0	2.45
FOLICUR 200 CE	302.7	0.10	0.63	36.9	4.41
DORMEX	15.13	28.05	-	-	-
PRÓ-GIBB	4.5	0.001	1401.3	0.0	t > 7

Table 5. Simulation with *Capeta* (S2) and turbo-atomizer (S3).

Trade Name	EDS (mg/day)		Risk (%DT/day)		MS (SF: 100)		ECN (%)		SWT (h)	
	S3	S4	S3	S4	S3	S4	S3	S4	S3	S4
AMISTAR 500 WG	357.4	11.1	0.11	0.003	0.32	10.46	67.6	0.0	2.27	t > 7
DIPEL	1489.2	46.1	0.47	0.01	17.09	551.59	0.0	0.0	t > 7	t > 7
EQUATION GDA	893.5	27.7	0.70	0.02	0.07	2.30	92.9	0.0	0.50	t > 7
FOLICUR 200 CE	1489.2	46.1	0.47	0.01	0.13	4.14	87.2	0.0	0.90	t > 7

Table 6. Simulation with roller method (S4).

Trade Name	ED (ml/day)	DT/day%
DORMEX	4173.9	7.73

The company, which was about to be audited for the GlobalGAP certificate was defined protocols for all procedures in the storage and handling of pesticides and had the place to bath applicators and place of washing equipment, with collection and treatment of contaminated water. Moreover, the observed reality of settler unit indicated different risk situations, such as: storage of pesticides within easy reach along with clothing and personal equipment, food and seeds, workers without personal protective equipment and without proper place for bathing, creation sheep in the vineyard contaminated.

5. Conclusions

The use of pesticides by workers in the San Francisco Valley, proved acceptable in some application systems, where appropriate, especially the application by tractor with spray atomizer JET turbo-400 L. A little operator exposure is probably, for the safety of application equipment that allows the operator to keep up at a safe distance from the spray. The other application system that proved to be risky was acceptable to use the foam roller to apply Hydrogen Cyanamide (Dormex), however, what is observed in daily practice is that the employee, in seeking greater labor income neglects his protection and ends up crashing the runoff product on the skin, causing serious burns, which did not occur in the simulation.

The application system that provided greater exposure to workers was the system called *Capeta*, where the ECN reached 96.7% for the fungicide equation GDA control hardly attainable by all PPE found in the market today. The system with manual backpack sprayer is a system demanding in terms of protection and training.

These analyses have limitations on the number of repetitions applied to the systems and the number of applicators observed, as well as the execution time of simulations. It is worth noting the importance of the qualitative aspects which confirmed the observed discrepancies between the situations analyzed.

Beyond these considerations, it should be noted, finally, that it is always rash to extrapolate laboratory data obtained from small animals to humans, and even among humans, because we have a lot of variability.

Regarding the disposal of empty pesticide containers, it would be beneficial to promote environmental education campaigns for farmers and rural workers seeking greater awareness for the proper disposal of empty containers, as well as greater oversight of government agencies on the subject.

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Notes

List of Abbreviations

%DT—Percentage for the Total Dose
CODEVASF—San Francisco and Parnaiba Valley Development Corporation
Dormex—Trade Name of Hydrogen Cyanamide
ECN—Exposure Control Need
EDS—Simulated Dermal Exposure
GlobalGAP—Non-Governmental Organization that Sets Voluntary Standards for the Certification of Agricultural Products around the Globe
IDA—Ingestion Daily Allowance
LIV—Limit Index Value
NOEL—Non-Observable Effect Level
OECD—Organisation for Economic Co-Operation and Development
SF—Safety Factor
SM—Safety Margin
SWT—Safe Work Time