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Knowledge, attitudes, and practices on pesticide application among farmworkers from communities in western Catamarca Province, Argentina

Conocimiento, actitudes y prácticas relacionadas con la aplicación de plaguicidas en trabajadores agrícolas de las comunidades del oeste de la provincia de Catamarca, Argentina

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Abstract

Unsafe management practices and overuse of pesticides have led to environmental contamination and farmworkers poisoning. For this reason, the problem of pesticide exposure must be framed in the socio-cultural and environmental context of the affected communities, analyzing the factors that contribute to the greater risk of exposure of farmworkers and their families, in order to propose educational strategies and develop effective public health strategies. This study evaluated the knowledge, attitudes, and practices regarding local pesticides handling of farmworkers from Singuil town, Catamarca province, northwestern Argentina, and the possible impact of these behavioral patterns on Singuil River. Farmworkers from Singuil town participated through a cross-sectional, face-to-face survey. Subsequently, samples from Singuil River were taken for determination of pesticides residues.

Approximately 83 % of those surveyed have worked with pesticides for more than 10 years. Although most workers prepare their pesticide formulations, 25 % of them never use any personal protective equipment, while the remaining 75 % usually use face masks and gloves to protect themselves. Post-spraying personal hygiene practices, such as changing clothes or showering, are often not applied. To reduce health risks, many respondents perform sprinkling at sunset (66.7 %) or early morning (50 %), and avoid it during windy and sunny weather. Besides, they usually burn (58.3 %) or stockpile (41.7 %) empty pesticide containers. In case of poisoning, 91.7 % of workers would go to hospital for medical attention. Glyphosate, mancozeb, and propamocarb are the most commonly used pesticides. Finally, no pesticide residues were detected in the water samples collected from Singuil River.

Keywords: occupational exposure; environmental risk; personal protective equipment; chemicals; agrochemicals; workers; risks; residues; glyphosate; mancozeb; propamocarb; Singuil river; environment; water samples; contamination

Resumen

Las prácticas inseguras de manipulación de plaguicidas y su uso excesivo han conducido a la contaminación ambiental y a la intoxicación de los trabajadores agrícolas. Por ello, la problemática de la exposición a plaguicidas debe enmarcarse en un contexto sociocultural y ambiental de las comunidades afectadas, analizando los factores que contribuyen al mayor riesgo de exposición de los trabajadores agrícolas y sus familias, con el fin de proponer estrategias educativas y desarrollar estrategias efectivas de salud pública. En este estudio se evaluaron los conocimientos, actitudes y prácticas sobre el manejo local de plaguicidas de trabajadores agrícolas de la localidad de Singuil, provincia de Catamarca, noroeste de Argentina, y el posible impacto de estos patrones de comportamiento en el río Singuil. Los trabajadores agrícolas de Singuil participaron a través de una encuesta desarrollada de manera personal. Posteriormente, se tomaron muestras del río Singuil para la determinación de residuos de plaguicidas.

Aproximadamente, el 83 % de los encuestados ha trabajado con plaguicidas durante más de 10 años. Aunque la mayoría de los trabajadores prepara sus formulaciones de plaguicidas, el 25 % de ellos no usa ningún equipo de protección personal, mientras que el 75 % restante generalmente usa mascarillas y guantes para protegerse. Las prácticas de higiene personal posteriores a la pulverización, como cambiarse de ropa o ducharse, a menudo no se aplican. Para reducir los riesgos que estas prácticas ocasionan a la salud, muchos encuestados aplican los plaguicidas al atardecer (66.7 %) o temprano en la mañana (50 %), evitando realizarlo durante los días ventosos y soleados. Además, suelen quemar (58.3 %) o almacenar (41.7 %) los envases vacíos de plaguicidas. En caso de intoxicación, el 91.7 % de los trabajadores acudiría al hospital para recibir atención médica. El glifosato, mancozeb y propamocarb son los plaguicidas más utilizados. Finalmente, no se detectaron residuos de plaguicidas en muestras de agua recolectadas del río Singuil.

Palabras clave: exposición ocupacional; riesgo ambiental; equipo de protección personal; productos químicos; agroquímicos; trabajadores; riesgos; desperdicio; glifosato; mancozeb; propamocarb; río Singuil; ambiente; muestras de agua; contaminación

1. Introduction

Agricultural production is one of the main world economic activities, so since the decade of 1950 the application of chemical compounds to control crop pests has been steadily increasing. Pesticides ensure high crop yields and improve product quality by reducing physical effort, controlling different pests, and being economical (Amoatey *et al.*, 2020). However, its overuse caused acute and chronic adverse effects on human, animal, and environmental health (Sapbamrera & Thammachaia, 2020). The health effects of chronic exposures to pesticides (in low and frequent doses) are continually studied and there is sufficient evidence that they are a serious threat to the health and well-being of exposed population groups, especially those most vulnerable such as the child population and pregnant women. The environment surrounding such residues is also affected, since pesticides can have long-term effects on the soil, fauna, and flora native to these areas (Silveira-Gramont *et al*., 2016).

Farmworkers are exposed to high levels of these compounds directly during all stages of handling and/or managing (mixing, loading, spraying, and cleaning of application equipment), or indirectly by re-entry tasks in pesticides treated crops or by taking home contaminated equipment or workwear. The main routes of entry of pesticides into organisms are skin (dermal absorption), respiratory system (inhalation), and mouth (ingestion) (Negatu *et al*., 2016). The consequences associated with pesticides exposure, such as dermal, ocular, gastrointestinal, cardiovascular, carcinogenic, and respiratory effects are generally more intense in occupationally exposed workers, depending on the kind of pesticide, the dose and duration of exposure (Ntzani *et al*., 2013; Negatu *et al*., 2016).

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) jointly developed the International Code of Conduct on Pesticide Management framework, aimed at reducing the effects of pesticide on applicators. However, public health problems have been increasing due to inappropriate handling of pesticides and disposal of its empty containers (FAO, 2015). For example, WHO reported about 370 000 deaths related to overexposure to pesticides (WHO, 2016). Also, the rural family can be constantly exposed to these toxic pollutants due to the unsafe practices of farmworkers (Benítez-Díaz & Miranda-Contreras, 2013).

Recent studies showed that unsafe attitudes and practices related to pesticides application and overspray, lack of personal protective equipment (PPE), incorrect pesticides storage and leftover disposal, weather conditions during pesticides spraying, incorrect containers disposal, reuse of washed pesticide containers for food and water storage, poor understanding of labels, among others, may be related to knowledge gaps and lack of training on the safe and effective use of pesticide (Gesesew *et al*., 2016; Ndayambaje *et al*., 2019; Joubert *et al*., 2020). Although many pesticides have been restricted or banned, farmworkers are often unaware that modern pesticides also retain a significant toxicological profile, with a consequent impact on global health (Fan *et al*., 2015). Even though, many farmworkers are aware of the risks associated with pesticides misuse, they disregard its correct application to avoid lower crop yields, while others find the use of PPE very uncomfortable due to the high temperatures and humidity in the fields (Gatto *et al*., 2015).

Argentina stands out as the second Latin American country in term of agricultural activity, being soybean and corn the crops with the greatest territorial expansion (Costa-Gutiérrez *et al*., 2021). This agricultural production requires applying several pesticides in different seasons, such as insecticides in summer, pre-emergent herbicides in winter-spring, post-emergent herbicides in summer and winter, and fungicides in spring. Consequently, Argentina invested approximately US $ 229 million in pesticides during 2018 (Pérez *et al*., 2017).

In Catamarca province (northwest Argentina), a high percentage of the population lives in rural areas, thus agriculture plays an important role as a source of employment for its inhabitants. The most prominent crops are walnut, olive, jojoba, citrus, paprika, tobacco, and cotton (Alderete-Salas, 2011). Provincial Law N° 4395 of Catamarca regulates the use of chemical and biological products in agricultural practices, protecting human health, domestic animals, and renewable resources through the correct use of agrochemical products, avoiding contamination of food and the environment, but allowing the profitability of the agricultural sector (saij.gob.ar).

This study researched the knowledge, attitudes, and practices related to pesticide handling of workers in Singuil town (Ambato department, Catamarca province), and evaluated the potential impact of pesticide handling on the water quality of the Singuil River. This information is crucial for developing effective public health strategies to protect farmworkers and their families, animals, and the environment from risks related to pesticides exposure.

2. Methods, techniques, and instruments

Subjects and settings

The study was carried out in Singuil, a rural town located in the Ambato department (4468 inhabitants at the 2010 census), Catamarca province (28° 10′ 14″ S; 65° 47′ 29″ W), at 1230 m above sea level (figure 1A). The Singuil River, with an approximate length of 50 km, crosses the town and empties into the Escaba dam, in neighboring Tucumán province (Alaniz, 2011). Agricultural-livestock activity significantly sustains the regional economic development, based mainly on the production of different commercial crops. Most of the productive farms in Singuil town are located a few meters from the river, and workers use this water source for irrigation of crops and for consumption in homes and schools.

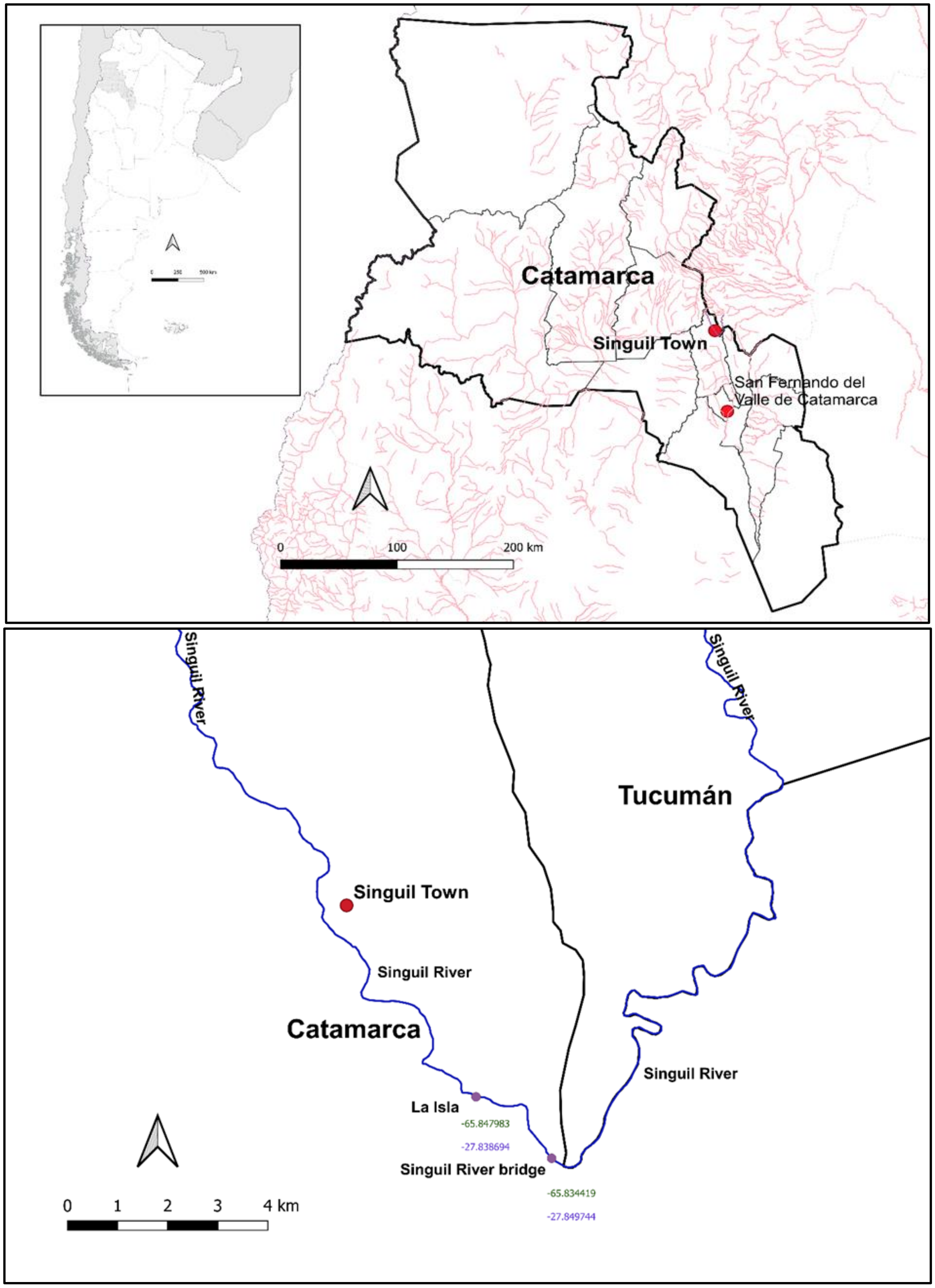

Figure 1. *A. Geographic location of the Catamarca province and Singuil town. B. Geographic location of the sampling points at La Isla and Singuil River bridge.*
Source: Own realization with QGIS V 3.20.3-Odense software.
Figura 1. *A. Ubicación geográfica de la provincia de Catamarca y de la localidad de Singuil. B. Ubicación geográfica de los puntos de muestreo en La Isla y El Puente sobre el Río Singuil.*
Fuente: Realización propia con QGIS V 3.20.3-Odense software.

Participants

Twelve farmworkers from Singuil town, aged between 30 and 60 years old, were included in this study. These participants were selected because they are owners or managers of the farms and they gave their consent to participate in the study. Their agricultural activities take place every year, between November and February, until April and May in some cases. The surveys were performed in February 2019.

Analysis instruments

Survey

The survey questionnaire was developed by researchers from the National University of Catamarca and PROIMI-CONICET based on standardized questionnaires surveys (Negatu *et al*., 2016; Ndayambaje *et al*., 2019; Riccò *et al*., 2018), and was divided into four sections to collect basic information on:

1) Socio-demographic features of farmworkers.

2) Farm establishments.

3) Pesticides handling and farming practices.

4) Knowledge related to pesticides exposure and toxicity.

The participation of interviewed farmworkers in the survey was individual, anonymous, and voluntary. Prior consent was obtained from the participants after explaining to them the study aims, the confidentiality of the provided information, and their rights to ask any question and to interrupt the participation at any time during the interview.

Sampling of Singuil River water

After conducting the surveys and determining the most widely used pesticides in the area, water samples were collected at two different points of the Singuil River in December 2019. The coordinates were -27.849744, -65.834419 (Singuil River bridge) and -27.838694, -65.847983 (La Isla) for the first and second points, respectively (figure 1B). For sample collection, appropriately labeled 1-L caramel-colored glass bottles were washed with sterile distilled water, dried at 70 °C, and rinsed with acetone. Subsequently, the bottles were rinsed with water from the river, placed at a midpoint in the mainstream, and kept them submerged for approximately 30 s with the mouth opposite to the water stream. Then, the samples were analyzed in an accredited laboratory (Faisan Respuesta Integral, Buenos Aires, Argentina) to detect the presence of pesticides residues.

Data analysis

A researcher performed the questions to farmworkers and recorded the answers, while another researcher reviewed and ensured the data entry accuracy. A lead researcher analyzed unclear answers generating heterogeneous interpretation to determine the «appropriate» answer. The population was characterized by a descriptive statistics analysis. Means ± standard deviations were calculated for continuous variables and frequency and percentile values for categorical variables. Frequency data were normalized to percentage values regarding the total number of participants to facilitate the responses understanding (minimum: 0 %; maximum: 100 %).

3. Results and discussion

3.1. Socio-demographic characteristics of the surveyed farmworkers

The socio-demographic features of the surveyed farmworkers are presented in table 1.

Table 1. *Socio-demographic features of the surveyed farmworkers.*
Tabla 1. *Características sociodemográficas de los trabajadores agrícolas encuestados.*

Category	Variables	N (Frequency)	%
Gender	Male	12	100
	Female	0	0
Age (years)	≤ 30	0	0
	31-40	4	33.3
	41-50	6	50.0
	51-60	2	16.7
	≥ 61	0	0
Educational level	Complete primary school	3	25.0
	Complete secondary school	1	8.3
	Complete tertiary school	1	8.3
	Complete university	1	8.3
	Incomplete primary school	0	0
	Incomplete secondary school	4	33.3
	Incomplete tertiary school	1	8.3
	Incomplete university	1	8.3
Occupational status	Owner	11	91.7
	Employee	1	8.3

The total studied population was male (100 %) and most of them was aged between 31 and 50 years old (83.3 %). The mean age of the interviewees was 44.6 ± 9.0 years. All participants had completed at least primary education, and 33.3 % of them had not completed secondary education. A high percentage of the respondents (41.7 %) had secondary education or higher education. Although all the workers can read and write, the survey was performed face to face, as an interview, reading and explaining each question to the interviewees to avoid problems in understanding. Most of the surveyed workers were small agricultural producers. In Argentina, small producers are the heterogeneous group of producers and their families who present the following requirements: they intervene directly in production -contributing to physical labor and productive management-, they do not hire permanent labor, but rather temporary and on an ad hoc basis, as they have limited land, capital, and technology (Carballo *et al*., 2004). These small producers are owners of the agricultural enterprises that lease the farmlands each year between November and February and perform all kind of tasks on the farms.

3.2. Description of agricultural establishments

Most farms (33.3 %) range between 11 and 20 hectares, with an average size of 16.0 ± 2.9 hectares (table 2). Only two farms are larger (150 and 300 hectares) than the others. Most of them are located a few meters from the Singuil River.

The main crops grown in this area are potato (50 %), squash (33.3 %), and corn (25 %). Thus, agricultural activities are performed during the summer season, requiring large amounts of water taken directly from the river through a pumps system. Other vegetables also grown are walnut (16.7 %), grape (8.3 %), tomato (8.3 %), and tobacco (8.3 %) (table 2).

Table 2. *Features of the agricultural establishments.*
Tabla 2. *Características de los establecimientos agrícolas.*

Category	Variables	N (Frequency)	%
Farm size (hectares)	0-10	3	25.0
	11-20	4	33.3
	21-30	2	16.7
	31-40	1	8.3
	> 100	2	16.7
Type of crop*	Potato	6	50.0
	Squash	4	33.3
	Corn	3	25.0
	Tomato	1	8.3
	Tobacco	1	8.3
	Walnut	2	16.7
	Grape	1	8.3

Note: * as multiple answers were allowed, total sum may exceed 100 %.
Nota: * dado que se permitieron múltiples respuestas, la suma total puede exceder el 100 %.

3.3. Attitudes, practices, and behaviors of the surveyed farmworkers for handling pesticides and containers in agricultural establishments

Table 3 shows how workers handle pesticides and containers. Most of the participants (83.3 %) have been working with pesticides for more than 10 years, while the remaining 16.7 % have been working with pesticides for less than 10 years. Besides, 75 % of the workers prepare the pesticides formulations themselves, making the best use of them for economic reasons, while only 16.7 % of the respondents highlighted that trained personnel, as agricultural engineers, are hired to perform this function. Rarely, e.g., when the farmworker is allergic to the pesticides, formulations are prepared by anyone on the farm (8.3 %).

Table 3. *Practices, attitudes, and personal behaviors related to the pesticides use of the surveyed farmworkers, and their knowledge about risks associated with pesticide exposure.*
Tabla 3. *Prácticas, actitudes y comportamientos personales relacionados con el uso de plaguicidas de los trabajadores agrícolas encuestados y su conocimiento sobre los riesgos asociados con la exposición a plaguicidas.*

Category	Variables	N (Frequency)	%
Years of pesticide use	< 1	0	0
	1-10	2	16.7
	> 10	10	83.3
Person who prepares pesticides	Interviewed farmworkers	9	75.0
	Hired professional	2	16.7
	Others	1	8.3
Type of personal protective equipment*	Gloves	6	50.0
	Safety shoes	1	8.3
	Goggles	2	16.7
	Specific pants	2	16.7
	Specific shirt	3	25.0
	Face mask	8	66.7
	None	3	25.0
	Others	0	0
Storage of clothing and PPE after pesticide working	Home	10	83.3
	Farm	1	8.3
	Others	1	8.3
Weather conditions taken into account during the pesticides application*	Wind	11	91.7
	Rain	4	33.3
	Temperature	7	58.3
	Humidity	3	25.0
	None	0	0
	Others	1	8.3
Frequency of pesticides application	Every day	3	25.0
	Every two day	1	8.3
	Every 7 days	2	16.7
	Every 20 days	3	25.0
	Others	3	25.0

Time of day for pesticide application*	Early morning	6	50.0
	Midmorning	1	8.3
	Midday	0	0
	Nap	1	8.3
	Sunset	8	66.7
	Others	0	0
Main information sources about pesticides use	State agency	1	8.3
	Private agency	0	0
	Supplier	2	16.7
	Another producer	0	0
	None	5	41.7
	Others	4	33.3
Frequency of application equipment maintenance	Weekly	1	8.3
	Monthly	0	0
	Every six months	0	0
	Before use	0	0
	After use	4	33.3
	After pesticide change	5	41.7
	Never	2	16.7
Places for pesticides acquisition	Forages	2	16.7
	Agrochemical sales stores	9	75.0
	Nurseries	0	0
	Private suppliers	0	0
	Others	1	8.3
Application form	Individual	5	41.7
	Mixtures	7	58.3
Instruments for application	Backpack sprayer	7	58.3
	Agricultural sprayer machinery	5	41.7
Pesticides storage	Outdoor	1	8.3
	Simple warehouse	8	66.7
	Home	2	16.7
	Others	1	8.3
Disposal of surplus pesticides	Throwing on garbage sites or specific disposal	0	0
	Total application	11	91.7
	Others	1	8.3
Reading pesticides labels	Yes	9	75.0
	No	3	25.0
Label section more difficult to understand	Preparation mode	0	0
	Dosage	0	0
	Application	0	0
	Toxicity	2	16.7
	Use form	0	0
	Compatibility	1	8.3
	Total understanding	6	50.0
	Not labels	2	16.7
	Not reading	1	8.3
	Others	0	0

Empty containers disposal*	Drill	1	8.3
	Bury	1	8.3
	Burn	7	58.3
	Stockpiling	5	41.7
	Washing and reusing	1	8.3
	Throw on the garbage sites	0	0
	Others	0	0
Do you apply the Triple-Rinsing?	Yes	7	58.3
	No	5	41.7
Dump place of washing liquids*▲	Water courses	1	8.3
	Fumigating machine	4	33.3
	Soils	3	25.0
	Others	4	33.3
Thinking pesticides are dangerous	Yes	9	75.0
	No	3	25.0
Main pesticide exposure routes*	Oral	5	41.7
	Eye	5	41.7
	Dermal	8	66.7
	Inhalation	9	75.0
	I do not know	2	16.7
	Others	0	0
Behaviour after potential intoxication*	Go to hospital	11	91.7
	Wash the face	0	0
	Take milk	0	0
	Cause vomiting	0	0
	Change clothes	1	8.3
	Others	1	8.3

Note: * as multiple answers were allowed, total sum may exceed 100%. ▲ Exclusive question for those who apply the triple-rinsing technique.
Nota: * dado que se permitieron múltiples respuestas, la suma total puede exceder el 100%. ▲ Pregunta exclusiva para quienes aplican la técnica del triple-lavado.

The use of PPE is summarized in table 3. It shows that 75 % of the surveyed farmworkers use some type of PPE, being face masks, gloves, and specific shirts the most commonly employed PPE, while goggles, specific pants, and safety shoes stand out as the least used PPE. Only one of the respondents uses full PPE. The remaining 25 % of the surveyed farmworkers do not protect themselves with any of the elements during pesticide preparation and application.

Leaving clothing and PPE away from the home contributes to the health care of workers and their families. However, 83.3 % of farmworkers return home wearing the PPE without changing their clothes previously, while 16.6 % of them change clothing and PPE after pesticide exposure: 8.3 % leave these elements on the farm while the remaining 8.3 % leave them in appropriate places (table 3).

During pesticides application, certain weather conditions should be considered to ensure the efficacy of the applied products and a lower impact on human and environmental health. All interviewees take into account weather conditions during their work, being wind and temperature the most relevant factors (table 3). Moreover, farmworkers apply fungicides and herbicides in different ways: by wetting plants with the product or adding it to irrigation water, and by spraying as a fog, respectively. Therefore, their application requires different climatic conditions.

The frequency of pesticide application varies greatly among workers because they generally do not take this factor into account during their activities, as they give priority to the urgency of harvesting on time or to weather conditions. However, most of them apply pesticides every day (25 %) or every 20 days (25 %), while a quarter of the interviewees apply pesticides with a frequency different from the options provided in the survey, e.g., three times a month or depending on weather conditions and the urgency to harvest. The frequency of application depends on the pest (population size and dynamics), the stage of the crop (development, harvest), the type of pesticide (degree of toxicity, persistence, maximum residual limit), and environmental conditions (in nightshades, such as potatoes and tomatoes, humidity favors fungal growth); however, this information was not reported by the interviews. Regardless of the application frequency, the most suitable times of the day to apply pesticides are sunset (66.7 %) and early morning (50 %), as this avoids immediate evaporation (table 3).

According to national regulations in force in Argentina, the advice of specialists such as technicians or agricultural engineers is necessary for the acquisition and application of phytosanitary products. A high percentage of respondents (58.3 %) receive advice on the uses of pesticides before applying these chemical compounds. Specifically, 16.7 % of them receive information on pesticides handling from the professionals present in the agrochemical sales premises during the product acquisition (suppliers), while 33.3 % of them ask for information on pesticides handling from hired professionals. Only one farmworker receives information from state agencies. Besides, 41.7 % of farmworkers do not consider this practice necessary before preparing and applying pesticides (table 3).

For a proper application of pesticides, the equipment used requires periodic maintenance, with a correct control and cleanliness: 41.7 % of the participants check and wash the pesticides application equipment when changing the used chemical compound, in some cases at the end of the summer season, whereas 33.3 % of the total respondents check and wash the equipment immediately after work, regardless of whether they have changed the pesticide or not. Some workers (16.7 %) do not consider this practice necessary since they always work with the same chemical compound (table 3).

Most of the surveyed farmworkers (91.7 %) acquire chemical compounds in small private shops: 75 % of them acquire pesticides in agrochemical stores in Tucumán province, while 16.7 % of them acquire pesticides in forage shops. Only one of the respondents acquires pesticides from other farmworkers. Some products are acquired in fractional form without adequate packaging, and therefore lack appropriate labeling (table 3).

Pesticides are applied individually or as mixtures, according to the compatibility among them indicated on the labels. Most producers (58.3 %) apply mixtures of several pesticides to control crop pests and use the backpack sprayer as the preferred equipment (table 3). Besides, 66.7 % of individuals have simple warehouses for pesticide storage, located a few meters from their houses and without safety measures such as fire extinguishers or signage; 16.7 % of farmworkers store these compounds indoors, and 8.3 % of workers store them outdoors (table 3).

When pesticide formulations are over-prepared for application, small or large amounts of the solution may remain. Thus, farmworkers were questioned about the measures they take with leftover pesticides: 91.7 % of them perform repeated applications of the pesticide formulations in different areas of the field until finishing the prepared product, while the remaining 8.3 % store them until reuse (table 3). No one declared to throw or pour the leftover pesticides on garbage sites, specific disposal, or nearby aquifers.

Regarding the labeling of phytosanitary products, 75 % of farmworkers regularly read the labels and instructions on pesticides packaging, whereas the remaining 25 % do not read this information because it is too complicated (8.3 %) or because they acquire loose agrochemicals without labels (16.7 %). Notably, the majority of farmworkers who read the labels understand all written information (50 %), while a minority of them has difficulties understanding the section referring to pesticide toxicity (16.7 %) and their compatibility with other compounds (8.3 %) (table 3).

On the other hand, 58.3 % of the respondents burn the empty containers, while 41.7 % collect and store them in simple depots until they are exchanged at agrochemical stores, located in Tucumán province (table 3). In some situations, farmworkers who store empty containers bury them in the farming field (8.3 %), drill them (8.3 %), or reuse them for fuel storage (8.3 %). None reported to throw containers on garbage sites.

The triple-rinsing technique, included in the Argentine National Law N° 27279, is a 3-stage rinsing process considered the best method for cleaning empty agrochemical containers in developing economies. This strategy mitigates the impact of pesticides containers on the environment and human health; hence, its implementation is very important. In this study, 58.3 % of the surveyed individuals know and apply this technique, and the washing liquids are generally poured into spraying machines, soils, backpacks, water courses, and/or crops (table 3).

Table 4 (next subsection) presents the 16 pesticides employed by the farmworkers, according to WHO classification and chemical class. The most commonly used pesticides are glyphosate (41.7 %), propamocarb (33.3 %), and mancozeb (25 %). Besides, 2,4-D, infinite®, talone®, decis forte®, cypermethrin, sulfur, and copper sulphate stand out for being applied by 16.7 % of the surveyed population. Taking into account its biological action, most of the used pesticides are fungicides (47.1 %), insecticides (41.2 %), and herbicides (17.7 %). Regarding its chemical structure, most of them are organic compounds. These pesticides belong to toxicological classes Ib to U, according to the classification of the World Health Organization (WHO, 2019), being 43.8 % and 12.5 % of them moderately and slightly hazardous (classes II and III), respectively. One pesticide was registered as highly hazardous (WHO Class Ib), while none was registered as extremely hazardous (WHO Class Ia). The other pesticides are unlikely to present an acute hazard in normal use (WHO Class U).

3.4. Knowledge of farmworkers about risks associated with pesticide exposure

Table 3 shows the farmworkers knowledge towards pesticides: 75 % of them affirmed that pesticides are hazardous to human and environmental health. However, they are unclear about some concepts and underestimate the toxicity of herbicides, considering them less dangerous than other types of pesticide.

Most of the surveyed farmworkers understand that dermal uptake (66.7 %) and inhalation (75 %) are the main routes of pesticides exposure. Also, a significant proportion of the participants (41.7 %) identified the eyes and oral ingestion as important routes of pesticides exposure. Only 16.7 % of the farmworkers are unaware of the penetration of pesticides into the human body. In case of pesticide poisoning, the farmworkers would immediately go to the hospital for medical attention (91.7 %), while others would take measures such as changing their clothes (8.3 %) or informing their manager (8.3 %).

Tabla 4. Principales características de los plaguicidas utilizados por los trabajadores agrícolas encuestados.
Table 4. Main characteristics of the pesticides used by the surveyed farmworkers.

Trade name*	Active product	Chemical group	Biological action	Toxicological class by WHO**	N (Frequency)	%
Round up®	Glyphosate	Phosphonomethyl aminoacid	H	III	5	41.7
Proplant®	Propamocarb	Carbamate	F	U	4	33.3
Mancozeb	Mancozeb	Dithiocarbamate	F	U	3	25.0
2,4-D	2,4-dichlorophenoxyacetic acid	Phenoxyacid	H	II	2	16.7
Infinite®	Fluopicolide + propamocarb	Benzamide and pyridine + carbamate	F+I	U	2	16.7
Talone®	Chlorothalonil	Derived from benzene	F	U	2	16.7
Decis Forte®	Deltamethrin	Pyrethroid	I	II	2	16.7
Cypermethrin	Cypermethrin	Pyrethroid	I	II	2	16.7
Sulfur	Sulfur	Inorganic	F	III	2	16.7
Copper sulphate	Copper sulphate	Inorganic	A, F, Mo	II	2	16.7
Ametrine	Ametrine	Triazine	H	II	1	8.3
Furadan	Carbofuran	Carbofuran	I, N	Ib	1	8.3
Potassium phosphite	Potassium phosphite	Inorganic	FF, F	U	1	8.3
Confidor®	Imidacloprid	Neoninicotinic, chlorinated	I	II	1	8.3
Dimethoate	Dimethoate	Organophosphate	I, Mi	II	1	8.3
Intrepid®	Methoxyphe-nozide	Diacylhydrazide	I	U	1	8.3

Note: * as multiple answers were allowed, total sum may exceed 100 %. ** Class Ia: extremely hazardous; Class Ib: highly hazardous; Class II: moderately hazardous; Class III: slightly hazardous, and Class U: unlikely to present acute hazard in normal use, according to WHO (WHO, 2020). H: Herbicide; F: Fungicide; I: Insecticide; A: Algaecide; Mo: molluscicide; Mi: miticide; N: Nematicide, and FF: Foliar fertilizer.
Nota: * dado que se permitieron múltiples respuestas, la suma total puede exceder el 100 %. **Clase Ia: extremadamente peligroso; Clase Ib: muy peligroso; Clase II: moderadamente peligroso; Clase III: poco peligroso, y Clase U: es poco probable que presente un riesgo agudo en uso normal, según la OMS (OMS, 2020). H: Herbicida; F: Fungicida; I: Insecticida; A: Alguicida; Mo: Molusquicida; Mi: Acaricida; N: Aematicida, y FF: Fertilizante Foliar.

3.5. Determination of pesticides in samples from Singuil River

After conducting the surveys, water samples were collected at the two different points of Singuil River to evaluate the presence of pesticides belonging to different chemical families, such as organophosphates, phosphonomethyl aminoacids, and pyrethroids, covering a broad spectrum of compounds used by farmworkers.

Despite some unsafe practices of the workers, the evaluated pesticides were not detected in the water samples, since the concentration value of each compound was below the limits of quantification of the analytical methods used (table 5).

Table 5. Analysis of pesticides presence in samples 1 (taken in Singuil River bridge) and 2 (taken in La Isla) from Singuil River.
Tabla 5. Análisis de presencia de plaguicidas en las muestras 1 (tomada en el Puente sobre el Río Singuil) y 2 (tomada en La Isla) del río Singuil.

Pesticide	Concentration sample 1 (μg L^{-1})	Concentration sample 2 (μg L^{-1})	Limit of quantification (μg L^{-1})	Used method or standard
Chlorpyrifos	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Dichlorvos	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Dimethoate	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Ethyl parathion	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Malathion	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Methyl parathion	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Bromophos	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Diazinon	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Ethyl Bromophos	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Etion	< LOQ	< LOQ	0.02	EPA 8270-GCMS
Glyphosate	< LOQ	< LOQ	0.05	EPA 547
Cypermethrin	< LOQ	< LOQ	0.01	HPLC UV
Deltamethrin	< LOQ	< LOQ	0.01	EPA 1660

Note: LOQ: Limit of quantification.
Nota: LOQ: Límite de cuantificación.

3.6 Discussion

Due to the lack of reports about to the application of pesticides in Catamarca province, practices, attitudes, and personal behaviors as well as the level of knowledge about risks associated with pesticide exposure were investigated among farmworkers in Singuil town. The studied area is located in the west of Catamarca province and the evaluated farms were selected based on their proximity to the town, the school, and the Singuil River. It is important to note that the number of farmworkers and farms in Singuil town is scarce, since it is a geographically small town. Once the farmworkers understood that the work was for scientific purposes, they agreed to respond the questionnaire survey.

Socio-demographic features of farmworkers

The study revealed that all farmworkers are male with different levels of education and have been working with pesticides for more than 10 years. These results have advantages over those reported by researchers in other countries (Negatu *et al*., 2016; Ndayambaje *et al*., 2019): women do not handle pesticides, which implies a low rate of exposure of pregnant or lactating women and unborn babies to pesticides, and reduces the toxicological risks of this population. Besides, the level of education and experience of workers would facilitate the development of training programs, aimed at reducing toxicological risks to human, animals, and the environment (Negatu *et al*., 2016). All farmworkers in Singuil town completed primary education, so they are literate, unlike that reported by Bernardino-Hernández *et al*. (2017) who found high percentages of respondents responsible for agricultural activities in rural and indigenous communities in Mexico could neither read nor write. Being literate increases 1.9 times the perception of the subjects of a high susceptibility to threats to their own health. High susceptibility is related to the acceptance that pesticides are dangerous, and that the farmworker and his family can get sick from the use of these inputs (Bernardino-Hernández *et al*., 2017).

The median age of the interviewees in Singuil town was 45 years old, similar to that observed by Bernardino-Hernández *et al*. (2017). The age of rural workers has a variable influence on their perception of the risk posed by the use of pesticides. For example, Damalas and Hashemi (2010) found that young producers in Greece showed higher levels of perception of risk to adverse effects of pesticides on their health and higher levels of adoption of Integrated Pest Management practices than the oldest producers. On the contrary, Bernardino-Hernández *et al*. (2017) revealed that the age of the workers in Mexico is one of the factors influencing the perception of technological and economic benefits, with younger farmworkers prioritising technological and economic benefits over health care.

Demographic factors (education level, disease experience, and economic incomes), farm structure and size, behavioral and psychosocial factors (pesticide contact, perception, attitude, awareness, norms, and beliefs), and environmental factors (information and knowledge about pesticides, access to extension services, training programs, and farm organization) are determinant factors influencing on safety practices related to handling pesticides (Sapbamrera and Thammachaia, 2020).

Farm establishments

The excellent geographic conditions of the Catamarca province, such as the soil heterogeneity and the presence of rivers, allow the development of different species and varieties of crops (Alderete-Salas, 2011). In Singuil town, farms size mostly ranges from 10 to 20 hectares and are located near the rural houses, on both sides of the main access road to the town or on the surrounding hills. The farms were alike in many aspects but they differed only in size. The main economic activities are the cultivation of potatoes and squash. Corn is also widespread grown in this region. The agricultural activities are carried out during the summer season. This season is optimal for the main crops in the Ambato Valley due to the warm temperatures and the rainfall regime (350-800 mm mainly concentered between January and February) favor the plant growth and the crop rotation (Palmieri *et al*., 2005).

Because potato is part of the daily diet of all humans, as an abundant and relatively inexpensive source of high-quality nutrients, ensuring sustainability of its production is currently an important challenge facing agricultural professionals worldwide. Nematodes, *fusarium*, *rhizotonia*, *verticillium*, early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*), and insect pests are major biotic factors affecting potato yield and tuber quality (Kroschel *et al*., 2020). For this reason, the application of highly toxic agrochemical on potato crops is increasing, as farmers intensify production and expand cultivation into areas and planting seasons beyond the crop's traditional range. The results are alarming levels of pesticide poisoning in farming communities (FAO, 2008). In the case of corn crops, the incidence of pest infestations from germination to harvest, can compromise grain yield and quality, causing crop damage, with significant economic loss. The use of insecticides seed treatment is an alternative for minimizing the action of pests and preventing productivity losses, which is translated into an economic return (Grande & Rando, 2018).

Pesticides handling and farming practices

The application of safe practices and the use of appropriate PPE during pesticides handling reduce significantly the risks associated with exposure to toxic chemical compounds (Yarpuz-Bozdogan, 2018). In 2015, both FAO and WHO announced the International Code of Conduct on Pesticide Management, which establishes guidelines for pest control (FAO, 2015). Additionally, the United States Environmental Protection Agency (US EPA) announced revised Worker Protection Standards regarding pesticides application, detailing guidelines that owners and employees should be aware of during their activities, e.g., the mandatory use of PPE by pesticide applicators that must be provided by its employers (US EPA, 2015). PPE required during pest control operations include face shields or full-face respirators, clean long-sleeved coveralls, washable hats, eye and face protection, chemical resistant boots, aprons, and gloves. Generally, the required PPE are described on the label of each product, according to pesticide toxicity to guarantee their safe use. Although the surveyed workers have wide experience in crop management, ranging from 10 to 15 years, their protection is practically non-existent at the beginning of their job, either due to misinformation or to reduce costs. Only one interviewee employs the complete equipment, while 25 % of them do not protect themselves with any element during the preparation and application of pesticides, exposing their hands, palms, fingers, and face. Reasons cited by agricultural workers for not wearing PPE include climatic conditions, lack of knowledge, lack of PPE provision, high PPE cost, and discomfort caused by wearing PEE. Similarly, Gesesew *et al*. (2016) found that nearly 42 % of farmers in southwest Ethiopia, have never used PPE to protect themselves during pesticide application. Meanwhile, Oesterlund *et al*. (2014) reported that 73 % of farmers in two districts in Uganda wear ordinary clothing, such as boots and long-sleeved T-shirts, when spraying pesticides. It was reported that the most common employed PPE by farmworkers in different regions of the world are long-sleeved shirts, long trousers, and hats, while the lowest employed PPE are aprons, goggles, gloves, boots, and masks (Sapbamrera & Thammachaia, 2020). The educational level, the performed agricultural activity, the PPE availability, and the economic level of agricultural workers explain the main differences related to the use of PPE in the evaluated regions (Sapbamrera and Thammachaia, 2020). Farmworkers in rural communities in Mexico claimed that it would be very difficult for them to get used to using PPE and that being mocked by their social environment would inhibit them to use PPE (Bernardino-Hernández *et al*., 2017).

Other unsafe practices reported in this study include preparation and application of pesticides formulations by non-specialized personnel, carrying work clothes and PPE to the home, inadequate personal hygiene, ineffective laundry procedures, lack of professional advice on pesticides handling, and inadequate pesticides storage. Only 16.7 % of surveyed farmworkers hire trained professionals to prepare pesticide formulations. Although some pesticide applicators are advised by professionals from agrochemical sales stores or by state agencies, they perform practices involving the total application of the prepared pesticides in order not to affect the harvest and generate monetary losses. This situation represents a risk to individual and family health, as well as to the final consumer. Health and environmental risks cannot be isolated from economic concerns because inappropriate pesticide application causes yield loss, health problems and possible air, soil, and water pollution. The problem of farmers' health should be an important concern for policymakers when looking at the economic and efficiency of pesticides in horticultural production (Ngowi *et al*., 2007). For this reason, the combination of a higher awareness of the cost-effectiveness of pesticide application and of the negative effects of this activity among workers from Singuil town, accompanied by more effective state regulations, is important for reducing the use of pesticides with unknown active ingredients.

Notably, 75 % of workers read and understand pesticide labels; however, sections referred to toxicity and compatibility of these compounds might be difficult to understand. This is not surprising because some labels and application instructions are written in non-native languages, such as Chinese and English, reducing the ability of farmworkers to interpret this information. Even the reduced levels of formal education of farmworkers or the lack of specific training on pesticide safety hinder their ability to understand labels in local languages (Ndayambaje *et al*., 2019). Likewise, a study developed in central-eastern Ethiopia demonstrated that only a quarter of workers from small-scale irrigated farms usually read the labels of pesticides containers (Negatu *et al*., 2016).

Improper storage of pesticides and disposal of empty containers is also a major source of exposure to toxicity of these chemicals to humans, animals, and the environment (Ndayambaje *et al*., 2019). The storage place for pesticides, including the proper signposting of the installations, ordered shelves with adequate separation of products, and fire extinguishers must guarantee the effectiveness of the products and the health of workers. In this work, most surveyed farmworkers store pesticides in simple depots until these compounds are fully used in agricultural activities.

These sites lack safety measures, such as fire extinguishers or proper signage, and are located near the houses where they live to avoid theft of equipment and pesticides. The minority of farmworkers store pesticides in a room in the house or leave them outdoor, implying the potential exposure of them and their families to these substances (Gesesew *et al*., 2016).

In general, farmworkers do not have an organized management of empty pesticide containers, since the containers are burned in open-air, with the consequent emission of gases, and there is no control by any environmental authority. Unfortunately, the Argentine National Law N° 27279, related to the treatment and destination of phytosanitary product containers, has not yet been approved in Catamarca province, thus the agricultural producers are unaware of this regulation and of the actions related to the destination of empty containers. However, no farmworker uses empty containers to store food or other household products. Unlike this, Ndayambaje *et al*. (2019) reported that all small-scale farmers surveyed in Nyagatare district, Rwanda, store pesticide cans in different areas of their homes, mainly in the kitchen, and used empty containers to fetch water for domestic purposes, such as washing clothes, cooking, and drinking.

Only 58.3 % of farmworkers in Singuil town apply the triple-rinsing technique. Most of them have modern spraying machines, which thoroughly wash the pesticide containers, pouring the remaining liquids into the spraying machines or backpacks, making use of the content, and saving money. However, the minority of farmworkers discharge washing liquids into the soil and watercourses, which is a worrying situation.

Keeping clothing and PPE away from the home is key to the health care of workers and their families (Ndayambaje *et al*., 2019). However, 83.3 % of Singuil town workers return home without changing their clothes previously. Even PPE are also stored in their homes. These inadequate practices suggest an urgent need for training on safe pesticide storage and management.

Although the frequency of pesticides application varies among workers, pesticide spraying is usually done during the first hours of the day or the sunset, avoiding immediate evaporation. Thus, pesticide spraying does not require all-day exposure of workers. This situation is often similar on farms in other countries, where pesticides applicators work only half-day shifts, which implies less exposure to pesticides (Mekonnen & Agonafir, 2002). Moreover, the surveyed workers avoid windy and sunny days during pesticides application to promote safe pesticide use. Windy weather is not suitable for spraying pesticides because the wind can distribute them to places where they have never been used before, while sunny weather is undesirable because high temperatures can lead to rapid evaporation of applied pesticides (Mekonnen & Agonafir, 2002). Besides, agricultural workers from Singuil town avoid windy days because drift of pesticides presents risks for human, animal, and plant health and for environment when sprays and dusts are carried by the wind and deposited on other areas where have never been used such as nearby homes, schools, agricultural fields, plants, streams, and other water bodies.

Generally, during periods of high temperature and low rainfall, the presence of insects increases, while in periods of lower temperature and high rainfall, damage caused by fungal diseases increases (Bernardino-Hernández *et al*., 2017). Therefore, each interviewed farmworker, according to his experience, makes an application schedule to ensure a systematic and continuous application of pesticides in order to prevent and/or control losses due to damage, caused by different pests and diseases based on the type of crop. The compounds most used by Singuil farmworkers are glyphosate, mancozeb, and propamocarb. Glyphosate is a systemic herbicide belonging to phosphonomethyl aminoacids family and widely used in agriculture to eliminate perennial and annual weeds. Despite the countless adverse effects of glyphosate, agriculture today relies considerably on this herbicide, and viable and eco-friendly commercial alternatives are currently limited. Indiscriminate and repeated use of glyphosate potentially leads to contamination of bodies or water, soil fertility decline, adverse impact on microbial diversity and function, and changes in biodiversity. In addition, glyphosate residues can enter the food chain and be toxic to non-target organisms of different trophic levels (arthropods, worms, fish, amphibians, reptiles, mammals, plants, microorganisms). Besides, glyphosate can exert cytotoxic, genotoxic, teratogenic, and endocrine disruptive effects in some vertebrates (Singh *et al*., 2020). Despite numerous studies on the hazards of extensive use of glyphosate, it is not possible to establish the potentially harmful effects clearly and unequivocally on humans (Torreta *et al*., 2018). In fact, the use of glyphosate is controversial: while many regulatory agencies have determined that the use of this herbicide has little risk of adverse health effects to the general public or farmworkers if proper handling techniques are used, the International Agency for Research on Cancer (IARC) identified this compound as a category 2A carcinogen (likely to cause cancer in humans). From 2016, the response to this classification has been divided between both opinions (Richmond, 2018). Mancozeb and propamocarb are systemic fungicides belonging to the dithiocarbamate and carbamate families, respectively. Mancozeb is used on a wide variety of food/feed crops, including fruit trees, vegetables, grapes, ornamental plants, and grasses. Since these compounds are classified by the WHO as classes III (slightly hazardous) and U (unlikely to present an acute hazard in normal use) (WHO, 2019), their use is not restricted. However, it was reported that there is a long-term risk for cancer development and endocrine disruption resulting from farmer's exposure to fungicides containing mancozeb (Novikova *et al.*, 2003). It is important to note that one of the farmers reported the use of furadan. Furadan, the commercial name of carbofuran, is widely used to control agricultural pests such as insects, mites, and nematodes. This pesticide is classified as highly hazardous (class Ib) (WHO, 2019) and it is very toxic to non-target species. Carbofuran can be fatal if inhaled, ingested, or absorbed through the skin. Although its exposure effects even of a short duration may be delayed due to its formulation, there is a possibility of cumulative effects (Ngowi *et al.*, 2007). Besides, due to its high mobility in the soil, it can contaminate adjacent water bodies after rainfall events. For this reason, its use has been restricted or banned in many countries (Ramesh *et al.*, 2015).

Different types of insecticides and fungicides are used for the farmworkers, probably because insect and fungal attacks are a serious problem in vegetable production in Singuil town. Although glyphosate is highly used in this region, the variety of herbicides used is less than the variety of insecticides and fungicides applied. Probably, this situation is due to a perception by farmers that weeding can easily be done manually. Besides, the selection pesticides by workers from Singuil town depends on the farmers' technical knowledge, the pest population, their perception of the damage to the crops associated with pest and disease attacks, their perception about pesticide toxicity, farm size, price, weather conditions, and the information sources accessed by the workers. Generally, the applied amounts and types of pesticides notably vary among countries and, even, among regions within one country, depending on the type of agricultural production and level of economic development (Ngowi *et al.*, 2007). For example, in Ghana, herbicides are the pesticides types most used in vegetable farming, with a perception by agricultural workers that herbicides are more effective to eliminate weeds for a longer period and a higher area than manual weeding (Ntow *et al.*, 2006). For their part, smallholder farmers in Tanzania employs routinely insecticides and fungicides to control pests and diseases that attack vegetables including tomatoes, cabbages, and onions (Ngowi *et al.*, 2007). Besides, the influence of pesticides vendors and quick results obtained in the short term after pesticide applications are factors that probably encouraging surveyed workers to rely more on agrochemicals use than on other pest control methods (Ngowi *et al*., 2007).

Many farmworkers in Singuil town use mixtures of different products and these products are applied with backpacks or spraying machines. These modern machines allow to place the product in its container without the need to open it beforehand, avoiding contact between the worker and the pesticide. The use of pesticides mixtures on food crops in Singuil town is concerning as it may lead to their accumulation in different matrices negatively affecting non-target organisms and the environment. Although pesticides mixtures are formulated according to the compatibility among them indicated on the labels, there is a high perception in surveyed workers that mixing pesticides is appropriate to obtain a greater anti-pest effect and produce better yields. Besides, they stated that the use of pesticides mixtures reduces time, labor and cost due to more than one pesticide is applied in a single spray.

Risks to worker health do not only depend on unsafe practices and excessive use, but are mainly determined by the physico-chemical qualities (toxicity, persistence, re-entry time) of the substances applied in pest, disease, and weed control. All pesticides have the potential to harm human, animals, or other living organisms and the environment if used incorrectly. Worldwide, many farmers are annually deceased from the consequences of pesticide exposure. Short-term and long term health effects, including acute pesticide poisoning and carcinogenic and endocrine disrupting properties, respectively, have been informed as main consequences in the farming community, especially on vulnerable groups (Gesesew *et al*., 2016). For example, a study performed in Tanzania showed that 68 % of farmers presented different health problems including feeling sick, skin problems, and neurological symptoms, after exposure to pesticides (Ngowi *et al*., 2007).

Notably, 75 % of the respondents recognize that pesticides are hazardous to human, animal, and environmental health, and most of them are aware of the main routes of pesticides exposure, including dermal, oral, and respiratory. The scientific literature also reports that skin contamination is the main route of pesticides absorption, so the use of gloves is a hygienic and safe protective measure (Mekonnen & Agonafir, 2002). Moreover, this finding indicates that farmworkers in Singuil town have a higher level of knowledge than workers in less developed countries in Africa, where farmworkers are unaware that the skin is one of the main routes of pesticides into the human body (Gesesew *et al*., 2016). Likewise, studies performed in countries where workers have a higher level of education, such as Brazil and Palestine, showed similar results to those observed in the present work (Recena *et al*., 2006; Sa'ed *et al*., 2010). Despite the recognition of the hazardous nature of pesticides and the knowledge of the damage to workers' health and the environment, pesticides are part of the production environment of the agricultural production system from Singuil town, as well as in less developed countries, inhabited by peasants in marginal socio-economic and environmental conditions (Espinosa *et al*., 2003). For this reason, several strategies which include having knowledge on protection against pesticides, using effectively full PPE, avoiding eating, chewing, or drinking in the sprayed agricultural field, proper disposal of empty containers, and understanding of labels, among others, are continually recommended for preventing pesticide exposure to agricultural workers. In countries like Mexico, farmworkers from rural communities stated that the illness or death of a friend or family member from pesticide use would make them reconsider using these toxic compounds (Bernardino-Hernández *et al*., 2017).

Agricultural workers must be aware of the different mechanisms of exposure to toxic compounds to protect themselves adequately. It is worth noting that some farmworkers in Singuil town buy pesticides fractionally, thus they do not have access to the original containers. Consequently, they do not know some terminologies and confuse some concepts, e.g., several respondents do not recognize herbicides as pesticides, considering that herbicides are less dangerous and toxic compounds than other pesticides. Therefore, they do not use PPE correctly.

In case of a pesticide poisoning, respondents would immediately go to the hospital, which is approximately 20 km away, while in very few cases they would change their clothes or inform their manager. Negatu *et al*. (2016) reported that 84 % and 32 % of farmers and farmworkers in east-central Ethiopia, respectively, wash their hands and take a bath or shower after work as hygienic protective measures against pesticides intoxication. Unfortunately, these practices are not performed by farmworkers in Singuil town, which implies risks to both themselves and their families.

Environment

Although the correct use of pesticides minimizes their impact on the contamination of natural resources, the movement of pesticides is very complex, involving their continuous transfer among the different environmental matrices. In this sense, their residues can be dragged by the wind, by continental and marine water courses, or through trophic chains, moving and reaching areas far away from the application site. Even, pesticides applied on crops may be absorbed by soil particles or reach surface waters by run-off or percolation (Raimondo *et al*., 2019; 2020). As the farms are very close to the Singuil River, the presence of different pesticides was determined in water samples from this river. No quantifiable levels of glyphosate, organophosphate, and pyrethroid pesticides were detected at both sampling points. Moreover, the Secretary of Water Resources Planning of the Catamarca province periodically carries out physicochemical analysis of the water from the Singuil River, and its quality meets the standards required by the Argentine Food Code (data not shown). These results indicate that the water of the Singuil River would be suitable for irrigation in agriculture, livestock, domestic purposes (drinking, cooking, washing clothes, watering home gardens), supplying water treatment stations, and consumption by local domestic and wild animal according to current regulations.

This result is advantageous because many researchers have shown the presence of pesticide residues in different aquatic systems in Argentina. The contamination of these systems is mainly due to the agricultural and sanitary use of pesticides in the surrounding agricultural establishments, and to the fact that these aquatic systems receive discharges of different industrial effluents. For instance, Chaile *et al*. (1999; 2011) revealed the presence of high concentrations of various organochlorine pesticides in the Salí River, the main hydrographical system of Tucumán province, with lindane, chlordane, and methoxychlor being the most abundant compounds. Likewise, Ballesteros *et al*. (2014) found residues of endosulfan, lindane, and dichlorodiphenyltrichloroethane (DDT), among other pesticides, in water, sediments, and suspended particulate material from Mar Chiquita (Buenos Aires province), at levels that exceed the allowed values. Another study registered the presence of pesticides in the water of the Pergamino stream basin, Buenos Aires province, mainly caused by runoff in the upper stream basin (Darder *et al*., 2016). Besides, extensive literature warns of the presence of residues and metabolites in adipose tissues of aquatic animals such as fishes, and mollusks, exceeding the maximum levels for consumption, representing a potential risk to humans who consume these organisms (Ondarza *et al*., 2014; Commendatore *et al*., 2015; Silva-Barni *et al*., 2016).

However, the situation of the Singuil River in the future may not be the same as reported today, due to the agricultural activity in and around Singuil town, so continuous environmental monitoring of pesticides in samples from this river should be established. In addition, other studies, such as the determination of total coliform microorganisms, need to be carried out throughout the year to guarantee the quality and safety of the water of the Singuil River.

4. Conclusions

This report is the first local research based on farmworkers from Catamarca province, addressing attitudes, practices, and behaviors for handling pesticides and containers, and knowledge related to pesticide toxicity in rural settings, particularly among pesticide handlers from Singuil town.

Although many farmworkers showed some positive attitudes towards the handling and management of these chemical compounds and were aware of the ways in which they are exposure to pesticides, some of their practices are unsafe. Despite the education level of the workers, many of them do not have appropriate knowledge about pesticides, do not use the correct PPE, wear the same clothing at work and at home, and do not respect the period of pesticide withdrawal from the crops before harvesting. Moreover, a quarter of the surveyed participants do not use personal PPE during pesticides application, a third of the surveyed participants do not read the labels on the containers, and most of them do not respect any management plan for empty containers. The main reason for these unsafe practices could be the absence of a responsible institution capable of providing formal training on occupational and environmental risks and safe pesticides handling strategies.

The farms are located on riverbanks close to homes of rural families and lack the corresponding signage and simple depots used for pesticides storage are also the resting places of farmworkers. This systematic survey demonstrated the use of several pesticides in farming establishments in the evaluated region. Notably, the absence of pesticides in the samples of the Singuil River indicates that its water would be suitable for domestic and agricultural-livestock activities, which is advantageous for the inhabitants of the studied town. However, additional studies must be carried out to guarantee the quality and safety of the Singuil River water.

This preliminary local study represents the first step for the subsequent evaluation of the sustainability of agricultural systems in Catamarca province. Further research should be done on the evaluation of useful indicators to compare different socio-productive models, environmental monitoring of pesticides in soils and surface and groundwater, and the simulation and application of pollutant transport models in this province.

Finally, it would be desirable to implement priority education and continuously updated training programs for farmworkers from Singuil town to develop safe practices related to the handling of pesticides and minimize their exposure to these compounds. Ongoing training is key for creating awareness and changing worker's behavior permanently. In this way, it would be desirable that the emergence of new bioproducts on the market would allow a gradual reduction in the use of pesticides, directing the productive activity towards environmentally and public health friendly alternatives.

5. Supplementary Information

No.

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Contribution of the authors in the development of the work

The authors declare that they contributed equally.

Interest conflict

The authors declare that there is no conflict of interest.

Ethical approval statement

This study did not involve the participation of animals or sick or disabled people, the study of biological fluids, nor conducting invasive experiments on people and clinical assays. Therefore, no Ethics Committee approval was required.

Consent to participate

Informed consent was obtained from all study participants.

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