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Dermal exposure assessment of pesticide use: The case of sprayers in potato farms in the Colombian highlands

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ABSTRACT

Quantifying dermal exposure to pesticides in farming systems in developing countries is of special interest for the estimation of potential health risks, especially when there is a lack of occupational hygiene regulations. In this paper we present the results of a dermal exposure assessment for the potato farming system in the highlands of Colombia, where farmers apply pesticides with hand pressure sprayers without any personal protective equipment. The fractioning of the pesticide, in terms of potential and actual dermal exposure, was determined via the whole-body dosimetry methodology, using the tracer uranine as pesticide surrogate, and luminescence spectrometry as analytical method. We assessed the three activities involved in pesticide management: preparation, application, and cleaning; analyzed three types of nozzles: one with a standard discharge and two modified by farmers to increase the discharge; and derived the protection factor given by work clothing. Our results suggest that to reduce the health risk, three aspects have to be considered: (i) avoiding the modification of nozzles, which affects the droplet size spectrum and increases the level of dermal exposure; (ii) using adequate work clothing made of thick fabrics, especially on the upper body parts; and (iii) cleaning properly the tank sprayer before the application activity.

1. Introduction

Pesticides are a key element of pest management programs in modern agriculture to increase the levels of production. Their use is stimulated by the commercialization and intensification of agriculture, the difficulty in expanding cropped acreage, the increased demand for agricultural products as population rises, and the shift to cash crops for domestic and export sales (Repetto and Baliga, 1996). It is estimated that annually 2.5 million tons of pesticide are used worldwide and 220,000 people die because of poisoning from these substances (Pimentel et al., 1996). Most of these poisonings occur in developing countries because of weak safety standards, minimal use of protective equipment, absence of washing facilities, poor labeling, and lack of information programs (Feola and Binder, 2010a, 2010b; Hughes et al., 2006; Pimentel et al., 1996; Ramos et al., 2010).

The agricultural sector in Colombia uses 3.8 million hectares of land for permanent and transitory crops. During the period of 1999 to 2009 an average of 82,000 tons of pesticides were applied per year (17% insecticides, 47% herbicides and 35% fungicides and bactericides) (FAO, 2009). This suggests that part of the population and the environment in Colombia are likely to be exposed to the negative effects derived from pesticide use. The potato farming system occupies 128,700 ha with 230,000 production units which in 2009 produced in total 2.3 million tons and used 32.5 kg/ha of pesticide active ingredients (M.A.D.R., 2009). For this reason the quantification of dermal exposure to pesticide use in the potato farming system in the highlands in Colombia is crucial to provide information about the level of risk faced by farmers and to support the development of proper policy measures.

Therefore the goals of this paper are:

(1) To quantify the current level of potential and actual dermal exposure to pesticides under the current working conditions (i.e., no use of personal protective equipment, and work clothing consisted of trousers and short-sleeve shirts) in the potato farming system in the highlands of Colombia, using the tracer fluorescein as pesticide surrogate.
(2) To identify the dermal exposure to pesticides on different body parts during the pesticide management activities (i.e., pesticide preparation, pesticide application and cleaning of the equipment).

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(3) To determine the level of health risk due to dermal exposure faced by farmers under the current working conditions, finding out the critical activities that affect it.

2. Methodology

2.1. Study area

The study area is located in Vereda La Hoya near Tunja, the capital city of the province of Boyacá, Colombia (Fig. 1). This is a rural region devoted mainly to the cultivation of potato in production units of around 3 ha. The crop depends on rainfall; therefore, the production is generally organized into two periods, one from March to September and another from October to February, corresponding to the two rainy seasons. Average annual productivity is 18.3 ton/ha (M.A.D.R., 2009). Potato crops in this region are vulnerable to three major pests: the soil-dwelling larvae of the Andean weevil (*Premnotrypes vorax*), the late blight fungus (*Phytophthora infestans*) and the Guatemalan potato moth (*Tecia solanivora*) (M.A.D.R., 2009). These pests, together with the weeds present in the early phases of the crop, are controlled by the application of chlorothalonil, chlorpyrifos, cymoxanil, glyphosate, mancozeb, metamidophos and paraquat (Feola and Binder, 2010a; Juraske et al., 2010). A survey made in the location showed that a high percentage of farmers experience various symptoms related to the use of pesticides (i.e., headaches, 24%; eye irritation, 20%; bronchial irritation, 9%; skin irritation, 5%; dizziness, 42%; nausea, 7%) (Feola and Binder, 2010a).

2.2. Pesticide management in the study area

In the study area the pesticide management is performed along three main activities: the preparation of the pesticide, the application itself, and the cleaning of the spraying equipment. During the whole pesticide management, farmers use work clothing consisting of trousers, short-sleeve shirts and plastic boots. The three activities are explained in detail as follows:

Fig. 1. Study area in Vereda La Hoya, Province of Boyaca, Colombia (Oehler, 2008).

a) *Preparation:* This activity includes opening the bottle containing the pure pesticide substance, mixing the solution of (different) pesticides and water, and loading the tank of the knapsack sprayer. Farmers in Vereda La Hoya prepare the pesticides in a container of 100-L capacity. The pesticide and the water (normally 80 L to obtain four applications of 20 L each) are mixed in this container with the aid of a wooden stick. During the mixing and the filling of the tank there are usually spills out of the container reaching different parts of the body including hands, arms, chest and legs.
b) *Application:* Once the knapsack sprayer is carried on the back, the pesticide application starts with the spraying process on the field. During this activity the farmers' body is exposed to the droplets emitted by the nozzles. In the study area the spraying is performed with hand pressure sprayers which are, on average, 9 years old (Feola and Binder, 2010b; García-Santos et al., 2011). They consist of a tank with a 20-L capacity, an injection and pressure system with an external piston pump and a pressure chamber with a capacity of 21 bar, a spraying pressure of 3 ± 0.3 bar and a pressure range between 1 and 14 bar. Farmers use two types of nozzles for pesticide application which differ in the amount of pesticide discharged: a high-discharge (HD) nozzle used during the first crop phases (sowing and emergence) and a low-discharge (LD) nozzle used during the rest of the crop phases (growth, flowering and pre-harvest). The discharges of the HD and LD nozzles measured in the study area were 1.88 ± 0.12 L/min ($n = 24$) measurements, and 26 ± 0.08 L/min ($n = 24$) respectively. Farmers purchase standard discharge nozzles and then modify the plastic and metal structures of the nozzles in order to obtain these discharges. To find out the droplet size distribution emitted by these two nozzles, the methodology developed by Nuyttens et al. (2007a, 2007b, 2009) was followed, including as a reference in the measurement an unmodified nozzle with a standard discharge (SD) of 1.05 ± 0.02 L/min ($n = 8$).
c) *Cleaning:* Once the application is finished, farmers clean the sprayer and the container by pouring clean water on all the accessories in a procedure repeated three times. This procedure is included in the booklet "Good Agricultural Practices" (Fernandez et al., 2009) which farmers use as a reference for the pesticide management. During this activity, there are numerous spills from the equipment and the accessories reaching the farmer's body.

2.3. Sampling procedure

The pesticide fractioning on the body was measured during the three activities of the pesticide management with the whole body dosimetry method (WHO, 1982; Chester, 1993) using the tracer uranine (Fluorescein Sodium Salt; $C_{20}H_{10}Na_2O_5$; CAS Registry Number: 518-47-8; PubChem Compound ID: 10608) as surrogate for the pesticides. The selection of this tracer was based on its low detection level, rapid quantification, solubility in spray mixtures, minimum physical effect on droplet evaporation, distinctive property differentiating it from background or naturally occurring substances, stability, moderate cost, nontoxicity and acceptability under Food and Drug regulations (Akesson and Yates, 1964). Also a previous study made in Vereda La Hoya was used as a reference in which a similar procedure was carried out using patches as sampling media and the tracer uranine to study the human exposure to pesticides (García-Santos et al., 2011). The degradation rate of uranine due to solar radiation measured in the study area was: -8.9 ± 1.2%/h, $n = 14$. Tyvek garments (DuPont™ Tyvek®) and cotton gloves were used as sampling media. Before the test, tyvek garments were labeled according to each body part: arms, thighs, legs (left, right, frontal and dorsal leg parts), chest, abdomen and back (upper and lower back part) (Fig. 2). When the evaluated activities