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Dermal exposure of applicators to chlorpyrifos on rice farms in Ghana

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HIGHLIGHTS

- Dermal exposure to chlorpyrifos among applicators in Ghana was evaluated.
- Exposure was 24 mg for the median exposed group and 48 mg for the highly exposed group.
- Unit exposure were 0.03% (median exposed group) and 0.06% (highly exposed group).
- The hands and lower anatomical region of the applicators were the most contaminated.
- Exposure was influenced by the quantity of insecticide applied and crop height.

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ABSTRACT

Studies evaluating dermal exposure to pesticides among applicators in tropical countries have largely been conducted using the patch dosimetry and hand wiping/washing techniques. This study used the more accurate whole-body dosimetry technique to evaluate dermal exposure to chlorpyrifos among applicators on rice farms in Ghana. The exposure levels were plotted as Cumulative Probability Distribution (CPD). Total Dermal Exposure (TDE) of chlorpyrifos among the median exposed and the 5% highly exposed groups during a spray event were 24 mg and 48 mg, respectively. When these were converted as a percentage of the quantity of active ingredient applied (Unit Exposure, UE), UE values of 0.03% and 0.06% were found among the median exposed and the 5% highly exposed groups, respectively. Overall, the hands were the most contaminated anatomical regions of the applicators, both in terms of proportion of TDE (39%) and skin loading (13 μg/cm^2). Also, the lower anatomical region was more contaminated (82% of TDE) compared to the upper anatomical region (18% of TDE). The levels of chlorpyrifos TDE among the applicators were found to be influenced by the quantity of insecticide applied and the height of the crops sprayed ($p < 0.05$). The pesticide UE data of the present study can be used to estimate the levels of dermal exposure under similar pesticide use scenarios among applicators. The findings of the present study suggest that protecting the hands and the lower anatomical regions with appropriate PPE may significantly reduce exposure among applicators.

1. Introduction

The dermal route generally constitutes the major exposure pathway for agricultural pesticide applicators (Van Hemmen and Brouwer, 1995; Vitali et al., 2009; Fenske et al., 2012; Macfarlane et al., 2013). Studies on dermal pesticide exposure are needed to enhance understanding of the contribution of the dermal route to total exposure, the patterns of dermal exposure, as well as help to identify effective exposure prevention and control strategies (Leckie and James, 1998; Marquart et al., 2001).

Pesticide applicators in tropical countries do not usually use Personal Protective Equipment (PPE) during pesticide application activities, mainly due to the discomfort associated with the use of PPE under hot and humid climatic conditions (Clarke et al., 1997; Adjrah et al., 2013; Jepson et al., 2014). Also contributing to the limited use of PPE in most tropical countries are financial constraints and inaccessibility of PPE (Clarke et al., 1997; Issa et al., 2010; Stadlinger et al., 2011). Consequently, these applicators are

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more vulnerable to dermal exposure than their counterparts in temperate countries. In addition, under tropical conditions applicators easily sweat, which may enhance dermal absorption of pesticides (Williams et al., 2004; Blanco et al., 2005).

Studies have been conducted in some tropical countries to evaluate dermal exposure to chlorpyrifos, a commonly used insecticide, among applicators (Farahat et al., 2010; Pan and Siriwong, 2010; Syamimi et al., 2011; Fenske et al., 2012; Lappharat et al., 2014). Generally, these studies have employed the patch dosimetry (Farahat et al., 2010; Fenske et al., 2012; Lappharat et al., 2014) or hand wiping (Pan and Siriwong, 2010) techniques. The patch dosimetry technique involves extrapolation from the level measured on a patch to the whole body, thus exposure may be incorrectly estimated. Similarly, the hand wiping technique does not account for exposure on other parts of the body. Whole body dosimetry provides a more accurate means of evaluating dermal exposure to pesticides because it does not involve extrapolation.

Only Syamimi et al. (2011) has employed the whole body dosimetry technique to evaluate chlorpyrifos exposure in a tropical country, where spraying practices differ from more temperate climates. While Syamimi et al. (2011) focused on the patterns of dermal exposure, the present study applied the whole-body dosimetry to investigate a broad range of parameters regarding dermal exposure to chlorpyrifos. Also, the present study involved a relatively larger number of subjects and thus allowed a probabilistic evaluation of the levels of dermal exposure. The objectives of the present study were to evaluate the magnitude, patterns and determinants of dermal exposure to chlorpyrifos among applicators on rice farms in Ghana, a tropical country where use of chlorpyrifos is high and use of PPE is limited.

2. Methods

2.1. Study area and participants

The study was conducted among applicators (n = 24) growing rice with irrigation from a typical farming community in the southern part of Ghana, where small scale farming is the main source of livelihood. The use of pesticides to control farm insect pests was predominant, with chlorpyrifos being one of the commonly used insecticides. Participants for the study were selected among 214 farmers who had previously taken part in a pesticide-use survey in the study area and had expressed interest in the present study. The pesticide spraying schedules of the potential participants were obtained and those with schedules coinciding with the sampling period of the present study were included in the study. The protocol for the study was reviewed and approved by the Ghana Health Service Ethical Review Committee (GHS-ERC: 10/07/15) and Griffith University Human Ethics Committee (GU Ref. No: ENV/24/15/HREC). The approved protocol, detailing the study objectives, activities, and rights of the participants was explained to the participants in both the local and English languages prior to recruitment. Written informed consents were obtained from those that volunteered to take part in the study.

2.2. Field observations and pesticide application method

Data for the study were collected between December 2015 and January 2016. It involved a single pesticide spraying event for each applicator on each separate occasion. During each spray event, field factors were observed and documented. The information collected included PPE usage, type of clothing worn, duration of spraying, quantity of insecticide applied, crop height, farm size, as well as incidences of spills, and leakages. The applicators were asked to carry out their pesticide spraying activities the normal manner. Chlorpyrifos (Dursban - 480 g/L Emulsifiable Concentrate) was the insecticide applied, using hand-pressurized knapsack spraying devices that were carried on the back. The sprayings were done with the lance positioned in front of the applicators while they walked forward through the area being sprayed. The spraying activities were all carried out in the morning between the hours of 6–8 a.m. The applicators preferred to spray in the morning, when the temperature was cooler. By observation, there was no significant variation in the weather conditions that could impact the exposure levels that was investigated.

2.3. Dermal sampling procedure

Dermal sampling was based on the protocols of the World Health Organisation (WHO, 1982) and Organisation for Economic Co-operation and Development (OECD, 1997). On the day of spraying, each applicator was given a new set of Tyvek under-wear garment made of flash-spun, high-density polyethylene (DuPont™ Tyvek®), white cotton hand gloves, and socks. These sampling media were worn by the applicators with their usual farm clothes worn over the sampling media before beginning any pesticide spraying activity. The purpose of this sampling procedure was to capture pesticide residues that penetrated applicators' clothing during spraying activities and potentially reaching their skin, as well as residues adhering to body areas of the applicators not covered by their farm clothing. These exposed areas included the face, neck, hands and feet. Tyvek under-wear garments and cotton sampling media have been found to satisfactorily trap and retain chlorpyrifos-methyl (Castro Cano et al., 2000) and other organophosphate insecticides (Castro Cano et al., 2001; Machera, 2003).

Immediately after spraying, the Tyvek underwear garment and the rest of the sampling media were carefully removed from the applicators and dissected into nine anatomical regions (Fig. 1). The head, front abdomen, back abdomen, upper arms, lower arms, hands, upper legs, lower legs, and the feet were labelled as 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively. The face and neck of each applicator were wiped with 2 pieces of 8-ply dry sterile surgical cotton gauze (10 cm by 10 cm) and added to the sampling media of the head section (anatomical region 1). Each section was folded, wrapped with aluminium foil, placed in a pre-labelled zip-lock plastic bag and then kept in an ice chest packed with ice, away from direct sunlight. The label on the bag consisted of the code of the applicator, anatomical region, and the date of sampling. The samples were transported to the laboratory within 1 h and stored at −25 °C until analysed.

2.4. Extraction of Tyvek Under-wear garments, cotton hand gloves, socks and gauze

The extraction and analysis of the samples for chlorpyrifos were carried out at the Pesticide Residues Laboratory of Ghana Standards Authority, using a modified version of the analytical methods for agricultural chemicals of Japan's Department of Food Safety (Department of Food Safety, 2006). The pesticide sampling media (Tyvek garments, cotton hand gloves, socks and gauze) were placed in pre-washed glass bottles of various volumes depending on the size of the sampling media. Pesticide grade ethyl acetate (Fisher Scientific, UK) (150 mL–1,150 mL) was then added to each sample until fully submerged. The bottles were placed in ultrasonic water bath (Decon FS400B) and sonicated for 45 min at room temperature (25 °C). The extracts were then filtered with anhydrous sodium sulfate (5 g) (Glass World, South Africa). Aliquots of the extract (70–200 mL, depending on the quantity of the initial volume) were taken and concentrated with a rotary evaporator (Büchi Rotavapor