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# Chemical exposure reduction: Factors impacting on South African herbicide sprayers' personal protective equipment compliance and high risk work practices

Federico Andrade-Rivas [a,b], Hanna-Andrea Rother [a,*]

[a] Environmental Health Division & Centre for Environmental and Occupational Health Research, School of Public Health and Family Medicine, University of Cape Town, Anzio Road, Observatory 7925, South Africa
[b] Universidad El Bosque, Research Vice-rectoray, Bogotá, Colombia

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ABSTRACT

The high exposure risks of workers to herbicides in low- and middle-income countries is an important public health concern because of the potential resulting negative impacts on workers' health. This study investigated workers' personal protective equipment (PPE) compliance as a risk mitigation measure; particularly workers who apply herbicides for Working for Water (WfW) – a South African invasive alien vegetation control programme. The study aim was to understand workers' low PPE compliance by analysing their risk perceptions of herbicide use, working conditions and socio-cultural context. Research methods included ethnographic observations, informal interviews, visual media, questionnaires and a focus group. Study results indicated that low PPE compliance persists despite workers' awareness of herbicide exposure risks and as a result of the influence from workers' socio-cultural context (i.e. gender dynamics and social status), herbicide risk perceptions and working conditions (i.e. environmental and logistical). Interestingly, teams comprised of mostly women had the highest compliance rate. These findings highlighted that given the complexity of PPE compliance, especially in countries with several economic and social constraints, exposure reduction interventions should not rely solely on PPE use promotion. Instead, other control strategies requiring less worker input for effectiveness should be implemented, such as elimination and substitution of highly hazardous pesticides, and altering application methods.



## 1. Introduction

Reducing pesticide exposures and health risks for workers in low- and middle-income countries (LMIC) is a low prioritized public health concern. As surveillance systems are poor in most LMIC, the assumption is that pesticide poisonings, chronic effects and fatalities are limited (London and Bailie, 2001). However, Balbus et al. (2013) highlight that nearly two-thirds of global deaths are attributed to non-communicable diseases (NCD), with pesticides playing a significant risk factor. Africa accounts for only 2–4% of the global pesticide market (Williamson et al., 2008), yet studies indicate that health risks from exposures and poisonings are higher in Africa due to weak pesticide risk management, such as low use of Personal Protective Equipment (PPE) (Matthews, 2008), unlabelled containers (Ngowi et al., 2007), lack of understanding of exposure risks, and poor risk communication strategies (Naidoo et al., 2010; Rother, 2008). Additionally, recent studies have highlighted that some underlying factors, such as poor nutrition, compromised immune systems, and exposure to other chemicals, might increase the risk of developing acute or chronic illnesses when exposed to pesticides (Holtan et al., 2008; Nweke and Sanders, 2009). This is problematic in countries like South Africa where these underlying social and health factors are common amongst workers using pesticides.

In this article we focus particularly on workers' exposures to herbicides since worldwide herbicide use is extensive as illustrated by herbicide sales accounting for the largest share of the global pesticide market sales (UNEP, 2013). Our particular focus was on the use of herbicides for invasive alien vegetation control (Buch and Dixon, 2009; Coulston, 2002; Holzmueller and Jose, 2009; Joshi, 2006; Norgaard, 2007; Simberloff, 2009). These control programmes aim to prevent major negative economic and ecological effects caused by invasive plants, such as damage to

* Correspondence to: Centre for Environmental and Occupational Health Research, School of Public Health and Family Medicine, University of Cape Town, Anzio Road, Observatory 7925, South Africa.
*E-mail address:* andrea.rother@uct.ac.za (H.-A. Rother).

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water resources. However, less attention is given to these programmes potential negative impacts on the health of the workers implementing the control strategies (Hansen and Donohoe, 2003; Little et al., 2006; McDaniel and Casanova, 2003; Norgaard, 2007; Thompson and Pitt, 2011; Wagner et al., 2004). Research has shown that long-term low dose exposures to some herbicides may accumulate in the body and may be a factor in the development of chronic health effects (Boers et al., 2005; Costello et al., 2009; Dich et al., 1997; Lim et al., 2009; Phillips and Tanphaichitr, 2008; Samanic et al., 2008). However, further research needs to be conducted as the effect of particular herbicides on different health outcomes is not yet well understood and study results vary (Corsini et al., 2013; Parrón et al., 2014). Of concern is that maternal exposures to herbicides, such as atrazine, have been associated with the prevalence of small-for-gestational-age infants (Ochoa-Acuña et al., 2009) and foetal gastroschisis (Waller et al., 2010). Moreover, many LMIC, like South Africa, are considered to be highly vulnerable to NCD (e.g. herbicide related health effects) given existing socio-economic (e.g. poverty, inequity), socio-cultural (e.g. the perception of ideal body shape), health (e.g. high prevalence of chronic infectious diseases) and demographic factors (e.g. population ageing and migration from rural to urban areas) (Boutayeb, 2010; Levitt et al., 2011; McCormack and Schüz, 2012). The potential for herbicide related health effects, the vulnerability of LMIC to NCD, and the increased risk of herbicide exposures from the ever increasing global use all point to the crucial role of and need for effective exposure reduction mechanisms.

Globally, a key strategy to prevent or reduce workers' pesticide exposures is through providing and promoting PPE use (Keifer et al., 2010; Rother et al., 2010). This is despite in the Hierarchy of Control model for the reduction of hazardous occupational exposures (Wirth and Sigurdsson, 2008), PPE use is advocated only after elimination, substitution, engineering, and administrative control measures have been implemented or ruled out (Lunt et al., 2011). What is noteworthy is that of all the control measures in the Hierarchy of Control model, PPE is the last recommendation for risk reduction as it requires the highest supervision inputs for compliance and is ultimately less effective in reducing worker exposures (Keifer et al., 2010). PPE, however, is extensively promoted by employers (e.g. government institutions, farmers) and industry as a feasible and inexpensive primary risk reduction method (Lunt et al., 2011). This is evident in industry driven training programmes where the safe use of pesticides is directly associated with PPE compliance. Many LMIC lack the financial and human resources to develop pesticide risk management training programmes and therefore industry designed training programmes are the main training provided to workers (Murray and Taylor, 2001). Given the significant emphasis placed on PPE as a control measure, the issue of worker PPE compliance is paramount for effectiveness.

PPE compliance is influenced by several key factors. Firstly, compliance is determined by access to the right equipment (i.e. the availability and quality of equipment, correct equipment-e.g. chemical resistant gloves, suitable PPE for local population characteristics) (Forst et al., 2006; MacFarlane et al., 2013; Matthews, 2008). Secondly, by external factors such as weather conditions (extreme heat) and the working environment (Barraza et al., 2011; MacFarlane et al., 2013; Matthews, 2008). Thirdly, an equally significant, are worker behavioural factors (i.e. influences on workers' willingness to use PPE) (Palis et al., 2006). Specifically, worker's compliance has been shown to be influenced by their and others pesticide risk perceptions (Feola and Binder, 2010; Norgaard, 2007; Peres et al., 2007; Rother, 2005), the social environment (Ríos-González et al., 2013), gendered roles (Atreya, 2007; Barraza et al., 2011; Norgaard, 2007; Peres, 2007; Reed et al., 2006; Rother, 2005) and workers' tendency to conform to perceived peers practices (Feola and Binder, 2010; Hunt et al., 1999; Peres, 2007). In this article we present findings from the South African herbicide use context highlighting key factors that impact on workers' PPE compliance behaviours.

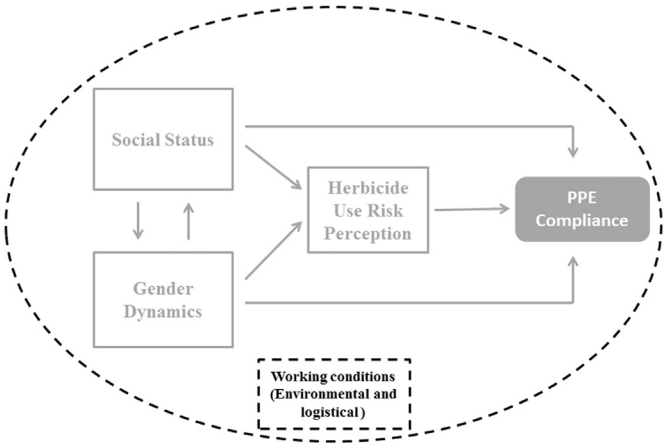


**Fig. 1.** Conceptual Framework of Worker-Related Factors Impacting on PPE Compliance.

The conceptual framework in Fig. 1 is based on the literature and informed this study (Atreya, 2007; Barraza et al., 2011; Feola and Binder, 2010; Forst et al., 2006; Hunt et al., 1999; Matthews, 2008; Naidoo et al., 2010; Norgaard, 2007; Palis et al., 2006; Peres, 2007; Rother, 2005; Rother et al., 2010). It illustrates how the interaction between workers' gender dynamics and social status influences PPE compliance and other safety-related behaviours through two different pathways: Firstly, through gender dynamics and social status influences on workers' perceived risks of herbicide use, and secondly through gender dynamics and social status direct impacts on PPE compliance. These interactions operate within and are impacted by different characteristics of workers' working conditions, such as environmental and logistical circumstances, which influence their PPE compliance. Most of the PPE compliance literature focuses on farm worker and farmers. Despite large invasive alien vegetation control programmes globally using herbicides extensively, the literature for these workers is limited. In this article, therefore, we present findings from a qualitative study aimed at understanding South African vegetation removal workers' perceived risks of herbicide use and their socio-cultural working context to highlight how these impacted on PPE use compliance.

## 2. Methods

This study was part of a larger research project assessing workers' herbicide exposures with the objective of developing and implementing effective and socio-cultural relevant interventions for exposure reduction (Rother et al., 2010). These workers work for South Africa's Department of Environmental Affairs (DEA) Working for Water (WfW) invasive alien vegetation removal programme. The findings presented here informed the development of exposure reduction interventions under the larger study. Ethics approval was granted by the University of Cape Town's Health Sciences Faculty Human Research Ethics Committee.

### 2.1. Setting

In 1995, one year after the first democratic elections, the WfW programme was launched by the South African government to control invasive alien vegetation while simultaneously

contributing to poverty alleviation through job creation and skills training (Buch and Dixon, 2009; Woodworth, 2006). WfW conducts over 300 control and management projects, providing around 45,000 jobs per annum for at least 50% women, in all of South Africa's nine provinces (personal communication A. Khan, [14-04-2014]; Hope, 2006). This study took place in the Western Cape Province, a region that faces several challenges due to the extension of the alien plant invasion (Turpie et al., 2008; Buch and Dixon, 2009), and therefore the importance of WfW control activities. The programme offers jobs to the unemployed and unskilled at wages below market averages (between US$ 9 and $25 per day, which is below the country's minimum daily wage requirements) in an effort to train as many workers as possible. The intention is that workers will gain enough skills and work experiences in the WfW programme to secure jobs elsewhere, apply for a higher paying WfW contractor position (Buch and Dixon, 2009) or, in some cases, form their own contract teams and continue working for WfW. Workers are hired by independent contractors who have a tender with DEA. Workers come from very difficult contexts were people must overcome several barriers to access to the benefits of South African economic growth (Buch and Dixon, 2009). Contractors are responsible for ensuring workers comply with WfW procedures for invasive alien vegetation removal, and herbicide application health and safety practices, as well as procuring the correct PPE (WfW, 2003).

WfW controls invasive alien vegetation with two herbicide application methods: (1) spot-spraying (when the herbicide is applied directly on the tree stump using a hand-held sprayer) and (2) foliar-spraying (when the herbicide is applied on plants leaves/foliage using a backpack sprayer). The programme uses many different herbicides to control numerous invasive species, examples of active ingredients include: glyphosate, 2-4D, picloram, clopyralid, tebuthiuron, triclopyr, fluroxpyr, metsulfuron methyl and diquat dibromide. A recommended list of herbicides to use in the WfW programme to kill specific invasive alien species was designed taking into account registered products available in South Africa, kill effectiveness and whether the product was affordable for large scale procurement. Prior to this study, herbicide toxicity in relation to worker exposure risks was not factored into the equation for choosing the appropriate herbicide.

#### 2.1.1. Study population

The research participants included 34 WfW workers (19 females and 15 males) and 13 contractors (two females and 11 males) working on clearing vegetation. Written consent was provided by each participant. Workers who participated were sourced and employed by WfW contractors as part of their working teams and therefore full teams were part of the study sample. Contractors were selected and identified by the WfW programme management based on their proximity to the university through purposive sampling. Three teams were recruited in close proximity to the Cape Town metropole area and were located in the Table Mountain National Park which is part of the South African National Parks (SANParks) system. Each team consisted of approximately ten workers holding positions according to the training they received and activities they were certified to perform. That is, teams were generally comprised of one driver, one health and safety representative, one first aider, one or two peer educators and the rest were general workers. Despite holding a particularly job title, all workers in a team applied herbicides.

### 2.2. Data collection

Data collection was conducted by the authors and ten trained fieldworkers (eight females and two males) fluent in two or more of workers' languages (predominately English, Afrikaans and isiXhosa). Fieldworkers were first trained to have a general knowledge of herbicide use, health effects, and data collection strategies. An in-depth understanding of workers' socio-cultural context and herbicide risk perceptions was sought through a combination of ethnographic observations, informal interviews, visual media collection (video and photographs), questionnaires and a focus group. By combining these different methods it was possible to assess differences and similarities between expressed perceptions and observed practices. Data collection was conducted from February to September 2012. Fieldwork was structured so as to limit impact on working activities by conducting data collection during planned spraying activities and without interrupting workers' tasks.

#### 2.2.1. Ethnographic observation

Ten site visits were made during the study period. Three different groups were observed controlling invasive species with the two herbicide application methods – that is, (1) spot-spraying and (2) foliar-spraying activities. The main author and fieldworkers spent an average of 5.5 hours per visit observing workers. An observation guide was developed for capturing the key exposure behaviours and herbicide use practices in different stages of spraying activities (Table 1). These observations were documented in field research journals and included interactions with peers (e.g. assisting with putting on PPE, resting behaviours), as well as the working environment/conditions (e.g. sunshine and cloudy conditions).

#### 2.2.2. Informal interviews

Contractors and workers had several logistical constraints, including transportation and lack of free time that impeded on conducting formal interviews. Therefore, the Periodically Divided Interviews (PDI) strategy was used on the three teams selected (Cabrera-Orozco, 2009). This entailed formulating casual questions, based on the observation guideline (Table 1), for workers and contractors while working onsite and recording these as soon as possible in field journals. These PDI provided more detail of observed practices, as well as allowed to better understand how perceptions and attitudes were constructed. Researchers used the existing social spaces (for example lunch and resting time) to gather deeper information on risk perceptions and socio-cultural relevant issues through observations and informal interviews. PDI were conducted on the three teams selected.

#### 2.2.3. Visual media collection

Photographs and video clips were used to capture herbicide mixing and application practices and particularly in relation to PPE compliance. These were taken during the ethnographic observations site visits. As recommended by Bean (2008) and Didkowsky et al. (2010), visual research tools were used as a strategy to overcome potential barriers between study participants and researchers, such as language differences and differences in the way

**Table 1**
Key Areas in the observation guide.

| Stage of spraying activities | Activities documented during observations |
|---|---|
| Pre-spraying preparation | • Transport of herbicides<br>• Mixing of herbicides |
| During spraying | • Use practices<br>• Handling spills and emergencies<br>• Eating and breaks |
| Post spraying | • Cleaning up of self and equipment<br>• Procedures after spraying |

that emotions are socialised (for example fear or fatigue). Only study participants who provided prior consent were filmed or photographed.

#### 2.2.4. Focus group

A focus group of 13 contractors (of which two were women) was conducted to solicit contractors' perception of workers' safety-related behaviours, as well as to identify WfW training issues which may have impacted on PPE compliance. Twelve contractors already had a working team and one (male) was in the final stage of its training as a contractor. The discussion, held in English, was tape-recorded (with consent) and transcribed. The focus group was held at a SAN Parks office and training facility.

#### 2.2.5. Questionnaires

Face-to-face questionnaires were administered to two contractors (both males) and 20 workers (12 females and eight males) during an herbicide health and safety training session administered by the larger research project at the University. Prior to this training session, fieldworkers and the authors administered the piloted and revised questionnaires to each worker and contractor individually in their language of choice. Questions were structured to gather information on general risk perceptions associated with the job, perceptions of health effects, perceptions of herbicide use, training received, PPE practices and other herbicide-related safety practices.

### 2.3. Data analysis

The ethnographic observation and informal interviews data documented in the field journals were transcribed within five days after visiting the site by the lead author and fieldworker. Visual media material was double-checked by a fieldworker in order to exclude material which accidentally captured workers or contractors who did not agree to be filmed or photographed. The recordings of the focus groups were transcribed the day after the session. All the transcriptions and visual material were coded using the qualitative data software management programme QSR Nvivo 10.

All transcribed data and visual material were analysed through content and thematic analysis (Ray and Smith, 2012). Themes were based on studies of PPE compliance (Feola and Binder, 2010; Forst et al., 2006; Hunt et al., 1999; Peres, 2007; Reed et al., 2006), pesticide use risk perception (Arcury et al., 2002; Barraza et al., 2011; Horlick-Jones and Prades, 2009; Naidoo et al., 2010; Norgaard, 2007; Palis et al., 2006; Rother, 2005), and the findings from the fieldwork and questionnaires (e.g. the emerging social and cultural categories associated with workers' perceptions of herbicide risks). Each questionnaire was recorded and transcribed removing any identifying information from the verbatim transcripts. Questionnaire results were analysed using the software for statistical analysis SPSS 21. The self-reported information gathered through the questionnaires and the focus group was contrasted with observations findings (ethnographic observation and data collected through visual media). This was done by comparing observed safety-related practices in the field and those self-reported by workers.

### 2.4. Study definition of PPE compliance

Practices categorised during the research as PPE "compliant" or "non-compliant" were based on WfW's PPE policy criteria (WfW, 2014, 2003). That is, a worker using herbicides is compliant when wearing, irrespective of the active ingredient or formulation, the following for both foliar and spot application: (1) protective pants and long-sleeved shirt, (2) a hard hat, (3) steal-tipped boots, (4) chemical resistant rubber gloves (wrist length for spraying, elbow length for mixing), (5) goggles and (6) filter mask. In

**Table 2**
High herbicide exposure risk work-related practices identified.

| Herbicide activity stage | Activities documented | Spraying method | Common exposure risk practices | Data source[a] |
|---|---|---|---|---|
| **Pre-spraying preparation (mixing and equipment loading)** | Transport of herbicides | Both | Working clothes with residues worn during transportation. | EO |
| | Mixing of herbicides | Both | Mixing without prior training | II, VM, EO |
| | | Both | Non-compliant PPE practice (e.g. wearing fake leather absorbent gloves not designed for herbicides handling) | Q, FG, VM, EO |
| | | Both | Limited PPE Compliance (e.g. workers did not use the protective blue cotton jacket and only wore the WfW yellow cotton long or short sleeved) | VM, EO |
| **During spraying** | Use practices | Both | Spraying without prior training | II, VM, EO |
| | | Foliar-spraying | Spraying in a line, one worker next to the other | VM, EO |
| | | Foliar-spraying | Spraying close to each other (Walking into each other plumes) | VM, EO |
| | | Foliar-spraying | Walking through newly sprayed plants | VM, EO |
| | | Foliar-spraying | No wearing goggles and filter mask | FG, VM, EO |
| | | Both | Non-compliant PPE (e.g. workers only wearing WfW cotton shirts which are prone to absorb herbicides) | Q, VM, EO |
| | | Both | Putting contaminated gloves inside pockets with personal belongings | VM, EO |
| | | Foliar-spraying | Using higher concentration than recommended | II |
| | | Foliar-spraying | Spraying on days with inappropriate weather | VM, EO |
| | | Both | Working fast, reduced focus on PPE compliance (e.g. not using glove to handle spray equipment faster) | VM, EO |
| | | Spot-spraying | Hand-held sprayer misuse (e.g. walking stick, hooked to workers' belts) | VM, EO |
| | Handling spills and emergencies | Spot-spraying | Fixing sprayers in the field without using gloves | VM, EO |
| | Eating and breaks | Both | No demarcated area for spray equipment and PPE | VM, EO |
| | | Both | Resting and eating next to spray equipment and PPE | FG, VM, EO |
| **Post spraying** | Cleaning up of self and equipment | Both | No washing hands after spraying | FG, VM, EO |
| | | Foliar-spraying | Washing equipment in the field | EO |
| | Procedures after spraying | Both | Wearing work clothes with residues home | II, VM, EO |

[a] Ethnographic observation (EO), Visual media (VM), Informal interviews (II), Focus group (FG), Questionnaires (Q).

addition, a knapjacket (Fig. 3; special protective apron for spraying) and respirator must be worn when foliar-spraying.

## 3. Results

This section presents the results from the questionnaires, focus group, informal interviews, visual media collection and ethnographic observations. The findings are presented in relation to identified workers' potential high herbicide exposure risk practices and the factors impacting on workers' PPE non-compliance. WfW policies and standard operating procedures were reviewed under the larger study and some of these findings are referred to in this paper for explanation purposes.

### 3.1. High exposure risk practices

Table 2 summarises the findings of documented working practices potentially leading to high exposure risks supported by the interviews, focus group, visual media, ethnographic observations and questionnaire data. Foliar spraying herbicide applications by far provided the highest exposure risks (Table 2) and where PPE compliance was the most crucial for risk reduction. However, workers' PPE compliance when foliar-spraying with backpack sprayers was observed to be limited and not consistent. The highest worker PPE compliance documented during the ten field visits was the use of protective cotton blue pants, hard hats, leather boots with steel tips and gloves. The gloves, however, commonly provided to workers by contractors were a fake leather absorbent glove that is cheap but did not comply with the WfW standards. On the other hand, potential exposure risks from spot-spraying with hand-held sprayers were documented in the field observation journals as lower than in foliar-spraying but not non-existent.

#### 3.1.1. Pre-spraying exposure risk practices

During foliar-spraying activities workers were always observed working in close proximity to each other, often walking in each other's plume or in wet vegetation. During four of the 10 visits foliar-spraying activities were conducted and only one worker was observed wearing the required rubber gloves. Fig. 2 is a visual illustration of inconsistent use of required PPE during mixing to prevent skin (long-sleeved shirts and eyes goggles) and inhalation (filter mask) exposures.

**Fig. 2.** Workers, including a new worker without prior training, mixing with low PPE compliance.

**Fig. 3.** Workers foliar spraying in close proximity to one another with partial PPE use (for example short sleeved shirts and incorrect gloves. Spraying occurs in thick vegetation despite the WfW policy of spraying in waist high or lower plants).

Importantly, contractors were found to have the lowest PPE compliance and were often observed mixing and handling herbicides without using any PPE other than the protective blue pants. This contrasts with the questionnaire findings where contractors' were able to indicate potential herbicide health effects and list what PPE needs to be used to prevent exposures. Interestingly, contractors were able to cite in the questionnaires and focus group the required occupational health and safety practices outlined in the WfW protocols.

#### 3.1.2. During spraying exposure risk practices

Fig. 3 illustrates workers' partial PPE compliance during foliar-spraying activities. In addition, no workers, however, during the 55 h of observations, were observed using the required filter mask or had any on site. The focus group and informal interviews data revealed that workers either did not have access to a filter mask or did not want to wear it in the hot weather conditions indicating use was unbearable.

In this study, several non-application practices (i.e. behaviours) were observed that potentially increased workers' exposures to herbicide residues. Of particular concern were workers high exposure risk practices during eating and breaks (Table 2). For example, Fig. 4 illustrates a worker resting using herbicide tainted gloves (evident from the blue dye added to the herbicides so workers are aware of where it has been sprayed) to block the sun and create a black environment. Similar practices were documented many times and workers used other PPE such as knapjackets, protective blue cotton jacket, and helmets to block the sun while resting with direct skin contact.

Other observed behaviours and practices potentially increasing workers' herbicide are summarized in Table 2. Using contaminated PPE to lie on and wearing PPE home, were the most common practices observed regarding herbicide residue exposures. In only one of the 10 field visits were workers observed placing the contaminated PPE in a demarcated area while resting as per WfW. Resting and eating close to PPE and spray equipment was documented both in terrain with convenient and safe spaces for resting and in terrain with limited space for resting.

#### 3.1.3. Post spraying exposure risk practices

During the ten site visits, only one worker was observed changing their contaminated boots for street shoes at the end of the working day. Workers were observed wearing the clothes they foliar sprayed in and covered with residue either in the vehicles

**Fig. 4.** Worker resting and blocking sun with dye stained gloves. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

transporting them home or while walking home. This as per protocol requiring WfW workers to wear work-related identifiable clothing.

### 3.2. Factors impacting on worker non-compliance

Five key factors were identified, during all data collection methods, as playing an inter-related role in impacting on workers' lack of or limited PPE compliance (Table 3).

#### 3.2.1. Training

An important finding was that those workers who reported during informal interviews not having received any training were also observed having low PPE compliance. Fig. 3, is a good visual example illustrating non-compliance. Moreover, contrary to WfW standards requiring mandatory training prior to working with herbicides, several workers during most field site visits were observed mixing herbicides on their first day of work without having received formal training (Fig. 2). Ironically, PPE compliance was also low amongst those who received more training than general workers (including contractors and health and safety representatives). In the focus group and questionnaires, workers and contractors identified several problems with the current training regime highlighted in Table 3 (e.g., literacy, language of instruction, instruction format). For example, of the 22 questionnaire responses, 62% did not complete high school which could be problematic for workers having to learn the scientific aspects of herbicide use to reduce exposures.

#### 3.2.2. Herbicide use risk perception

How workers' perceived their health risks associated with herbicides impacts on their PPE compliance. Table 3 highlights key low and high risk perceptions, as well as misperceptions related to herbicide exposures, health risks and the role of PPE. Based on workers' and contractors' observed practices, it was found that the use of herbicides is not perceived as a major health concern. This finding contrasts the questionnaire findings where most study participants reported concern and awareness about herbicide exposures and their potential health effects. For example, most study participants indicated in the questionnaire that wearing gloves was a protection method, yet the observation findings revealed low glove compliance, particularly during mixing activities and the use of non-compliant gloves. One male contractor aptly captured this contradiction:

> *And the thing is that nobody knows herbicide is not a friendly substance. Yes people say they understand but they don't respect the long term causes. I doubt people know what they can get. If they know you can get it they aren't going to spill herbicide. I've worked in places where there is so little respect you spray each other for fun. But if they really know you can get cancer it won't be fun anymore. People wouldn't cut each other with a chain saw, you see.*

**Table 3**
Key factors identified impacting on non-compliance of workers' use of PPE.

| Factors | Key reasons for low compliance | Data source[a] |
|---|---|---|
| **Training** | Language of instruction is not always the language of workers (e.g. Xhosa) | II, Q |
| | Complicated scientific concepts associated with chemicals | II, Q |
| | Low literacy levels | II, Q |
| | Low formal education | Q |
| | Training format formal classroom style not conducive to sustained learning (less participatory; more top-down approach) | EO, II, FG |
| | Missing induction training at the beginning of the year | II, FG |
| | Knowledge and self-reported awareness about herbicides hazards does not translate into herbicides-related safety practices | EO, VM, Q |
| | Training does not emphasize potential health effects in relation to PPE use (Rother et al., 2010) | |
| **Risk perceptions** | PPE perceived for prevention of non-herbicide hazards-*misperception* | Q, EO |
| | Believe that mixing herbicides requires limited skills and has low risk-*low risk perception* | II, FG, Q |
| | Herbicide exposures is not a prioritized health risk particularly in relation with other occupational risks (e.g. snake bites and falling)-*low risk perception* | Q, EO, VM |
| | Workers not aware of herbicides residues-*no perceived risk* | EO, VM |
| | Cultural beliefs and awareness raising of snake bites-*high risk perception* | EO, VM, Q, II |
| | Workers interpret risk with a different rationale than experts-*misperception* | EO, VM, II |
| | Lack of comprehensive understanding of short- and long-term herbicide health risks-*low risk perception* | Q, II, FG |
| | Health & safety risk perceived as something that happens to others-*low risk perception* | II, FG, Q, EO |
| **Gender dynamics** | Male workers risky practices conformed to social norms (e.g. masculinity) | EO, VM, II |
| | Dangerous practices as a strategy to improve worker's status as males in the group | EO, VM, II |
| **Social status** | Perceived lack of control over health-related choices | FG, II |
| | Peer influence on PPE practices | EO, VM, II |
| | Mimic safety practices of those in perceived positions of power (e.g. contractors' non-PPE compliance) | EO, VM, II, FG, Q |
| **Working conditions** | Steep terrain and thick vegetation | EO, VM, II, FG, Q |
| | Extreme heat and humidity | EO, VM, II, FG, Q |
| | Low wages leading to high worker turn over | EO, II, FG, Q |
| | Worker and contractor pressured to wok fast in order to get paid for completed cleared site (compromised health & safety) | EO, VM, II, FG |

[a] Ethnographic observation (EO), Visual media (VM), Informal interviews (II), Focus group (FG), Questionnaires (Q)

The three contractors interviewed believed that mixing herbicides requires limited skills and thus exposure risks are low during this task; findings that were confirmed in the focus group. During the informal interviews discussions on mixing herbicides, contractors and workers never mentioned exposure to herbicides and potential health effects as an important issue but rather focused on topics related to the quality of the mixture (e.g. the active ingredients or concentration). One male contractor had his own interpretation for non-compliance during mixing saying that: "…. [Workers] have a different mind-set. It takes them longer to work with it [PPE] properly."

Participants were asked as an open-ended question to rank three occupational hazards of concern. The results showed agreement between self-reported and observed concerns regarding snake bites, falling, and being hit by a rock. In the field, workers and contractors implemented preventive strategies and discussed safety behaviours regarding falling and avoiding snake bites. None of these behaviours, however, were observed with regard to herbicide use safety. It is interesting to highlight that between January 2007 and July 2012 only two of the 188 work-related incidents/accidents reported to WfW were for snake bites and both were reported as non-fatal. The results from the questionnaires and the informal interviews also highlight workers' perception that protective pants and boots are a strategy to prevent snake bites rather than preventing herbicide exposure.

### 3.2.3. Gender dynamics and PPE compliance

Gendered differences in herbicide exposures and PPE compliance were evident through all the research methods. Indeed, the team with the highest observed PPE compliance was comprised of 90% female workers. This contrasts with the survey data where male workers expressed a higher understanding of herbicide hazards and risks as per those outlined in the WfW standards. Furthermore, most male workers responded *"yes"* to the question *"do you worry about possible dangers when working with or near herbicides?"* Where, in contrast, only half of the female workers worried about the potential dangers.

In addition, those workers who were leaders or "popular" amongst peers were more likely to engage in risky behaviours. This "careless" behaviour was mainly observed in strong, young males who, for example, did not wear a safety helmet and did not wear the required long sleeved shirt while spraying. Some male workers openly admitted in the informal interviews to not following the safety rules while making it clear how dangerous and important it was for women to comply with safety practices. For example, a male WfW worker, who was not wearing any PPE, was observed operating a chain saw while dancing and joking. Fellow workers, both male and female, reacted by laughing and celebrating this behaviour.

### 3.2.4. Social status and PPE compliance

WfW workers are stratified by their position within the team, such as general worker, first aider, health and safety representative, and peer educator. Non- general worker positions were paid a higher wage and received specialized training. It is noteworthy that both workers and contractors perceived health and safety representatives to have a higher status than other workers. This was evident during several site visits as health representatives were in charge of coordinating spraying activities in the event that contractors had to leave the site for administrative duties. Health and safety representative, however, played a limited role in training and overseeing herbicide risk mitigation, and mostly focused on assisting contractors with administrative duties such as filling in WfW required forms. This was despite workers' questionnaire responses indicated these representatives should distribute herbicide health and safety information. Moreover, it was observed and documented through the informal interviews that contractor and health and safety representatives had more control than general workers over certain decisions associated with herbicide use safety. For example, PPE availability and the type of PPE sourced is the responsibility of contractors, and health and safety representatives were observed coordinating herbicides mixing and making suggestions to the contractor regarding herbicide spraying.

### 3.2.5. Working conditions and PPE compliance

Access to the sites designated for invasive species clearing usually required workers and contractors to walk long distances carrying vegetation-removal gear (chain saw, cutting tools, full herbicide sprayers), personal supplies (food, water, clothing) and PPE. The programme requires teams to comply with tight invasive vegetation removal deadlines and payment is linked to fulfilling these. Work schedules were often disrupted or impacted, however, by frequently changing weather conditions unsuitable for spraying (e.g. rain, wind). Furthermore, teams were required to apply herbicides in terrains which present severe physical challenges (e.g. steep mountains with dense vegetation, unshaded; Fig. 3) and injury risks (e.g. falling and rock slides).

Workers were observed prioritizing preventing short-term risks, such as falling, even if these preventive strategies increased their exposure to herbicides. Several practices of hand-held sprayer misuse were documented (Table 2), and were influenced by workers intend to facilitate the walking and handling of the cutting tools. For male workers, this practices often positioned the hand-held sprayer near the scrotum area, which has the highest rate of absorption compared to other areas of the body (Karan et al., 2009; Ngo et al., 2010).

Weather conditions were observed as playing a significant role in lack of PPE compliance. Workers' foliar spraying were observed rolling up their shirt sleeves or using short sleeved shirts when it was hot, exposing their forearm skin to herbicides. This was also confirmed by the visible dye observed on most of the participating workers' and contractors' forearms. Contractors indicated during the focus group that workers complained about having to wear goggles and respirators as they sweat heavily and struggle to breathe.

When workers were asked in the questionnaires, "What would you say is currently your biggest worry in your life and with your current job?", the most frequent response was the current payment process. That is the current practice of paying contractors once a site has been fully cleared of invasive alien vegetation. Many contractors reported in the focus group and informal interviews having difficulty meeting deadlines under the current programme structure particularly because of unpredictable weather conditions. Although WfW workers receive a daily wage on paper, they only get paid once the site is fully cleared and the contractor is paid. They reported various strategies used in order to clear the invasive alien vegetation before the deadline stipulated by WfW. This included using higher concentrations of herbicides than recommended and spraying on days with inappropriate weather conditions (e.g. rain and wind).

Contractors reported in the focus group that workers' low wages present an enormous challenge. Particularly in relation to keeping workers motivated to work fast and hard, as well as to retain them long enough to complete clearing a site. As indicated by a male worker: "I have a cheap phone. I do not have money. I work for WfW that is like charity." The following male contractor's comment illustrates how preventing occupational hazards requires high worker participation and that their motivation is crucial for PPE compliance:

*For the contractor it is a good, regular job. He has a registered business of his own. It's a career for the contractor. But it is not like this for the workers. If my workers got benefits and enough money to live and to build their careers, they would pay more attention.*

As voiced by a male contractor: "A lot of training goes into getting one person sorted for the job and then you lose them to a job that pays R20 more a day."

## 4. Discussion

### 4.1. High risk practices

Several high exposure risk practices were identified illustrating low PPE compliance amongst workers and contractors. Although the acute toxicity of some herbicides used by WfW may vary, recommending which PPE to use depending on each herbicide would be confusing for workers and might have a negative impact on PPE compliance. Our research focused on observed practices and perceptions, however, it is important to note that workers same level of exposure is associated with different risks related to the herbicides active ingredients and co-formulants (i.e. inerts, adjuvants, solvents), as well as the worker's health status. In addition, it was found that partial compliance could increase exposure through other pathways (e.g. workers only wearing WfW cotton shirts which are prone to absorb herbicides and to increase dermal exposures and absorption). The results of this study are consistent with the literature were dermal exposures pose the highest occupational exposure risks (Protano et al., 2009). Although, it must be highlighted that not enough research exists on inhalation exposure risks from wearing filter masks versus respirators, and breathing in evaporating herbicides in high temperatures and repeated breathing in of spray vapours from multiple sprayers.

In some instances, measures to promote thorough vegetation removal compromised workers' health by extensive exposures. Particularly, workers were observed many times at risk of exposure to herbicides from peers and their own spray plumes as illustrated in Fig. 3. Higher exposure risk was found for foliar-spraying than for spot-spraying. This is because in spot-spraying workers come into less contact with the actual herbicide as it is sprayed directly to the stump and does not create a spray plume. In addition, spot-spraying does not produces high quantity of droplets as it does foliar-spraying. Despite this, dermal exposure was still a risk factor during spot-spraying since hand-held sprayer misuse (Table 2).

Understanding workers' risks perceptions in regards to different occupational hazards is crucial as workers appeared to be willing to engage in prevention practices if their perceived risk was high. One concerning perception is that mixing herbicides requires limited skills and exposure risks are low. This is despite the literature indicating the contrary (Damalas and Eleftherohorinos, 2011; Remoundou et al., 2014): suggesting a low risk perception in relation to herbicide mixing, which also has been reported for farm workers in South Africa mixing pesticides prior to training (Rother, 2005). What is clear is that contractors know PPE use is required but seem to have a lack of understanding in the short and long term health effects. Training issues discussed in Table 2 impacts on their low risk perception which also results in contractors providing the wrong PPE.

### 4.2. Complexity of Factors impacting PPE compliance

Despite WfW's stringent protocols and mandatory chemical safety training, limited PPE compliance was observed, highlighting that a comprehensive herbicide use and risk reduction policy is not enough to promote PPE compliance. The issue is also whether the policy can be realistically implemented given the five key factors identified in this study that impact on PPE compliance (Table 3). One key working condition factor is the high turnover of workers resulting in many missing the induction training and consequently applying herbicides without training. For WfW workers, training may not be an important determinant of PPE compliance for several reasons (Table 3). As has been shown in other studies, pesticide safety knowledge training may not be a strong factor in promoting PPE compliance and exposure risk reduction (Arcury et al., 2002; Halfacre-Hitchcock et al., 2006; Perry et al., 2002). Evidence regarding the effectiveness of safety training on improving PPE compliance is contradictory and several factors (e.g. training quality and audience receptivity) may mediate the effects of training (MacFarlane et al., 2013) as it is the case for WfW.

It was also found that the use of herbicides is not perceived as a major health concern particularly in relation to other occupational health risks. Workers use or non-use of PPE directly related to the ability to work fast and comfort, while protecting them from more obvious dangers such as thorns and dry branches. The study findings not only depict the impact of the working environment on PPE use, but the risk prioritization of immediate hazards (cuts, thorns) over the less understood health risks from herbicide exposures and residues. Halfacre-Hitchcock et al. (2006) reported a similar practice amongst Latino migrant farmworkers in USA who used gloves to protect themselves from minor discomforts rather than from pesticide exposures. Moreover, while snake bites are a real danger and occupational risk for WfW workers and contractors, actual reported snake bites during the study period was much lower than workers' perception of the risk. Workers great fear of snakes may well result more from cultural beliefs yet impact worker's perceptions and risk prioritization. In addition, worker's risk prioritization might be influenced by their lack of knowledge of acute and chronic health effects associated with herbicides as these are not emphasized in the WfW training programme nor did workers report any herbicide poisoning incidences. Further research should be conducted to explore what other local beliefs and perceptions impact on workers PPE compliance and what factors shape these.

Low PPE compliance due to low risk perception (Table 3) and high exposure risk practices during resting and eating (Table 2) highlights the importance of assessing workers' interaction with PPE. This is important for developing strategies to protect workers from exposures to residues. As reported in other studies (Horlick-Jones and Prades, 2009; Ríos-González et al., 2013; Vaughan and Dunton, 2007), workers do not always interpret risks with the same rationale as experts. Workers' reasoning and interpretation of risk information is shaped by their particular socio-cultural context which may lead to practices different from those expected by the providers of risk information (Horlick-Jones and Prades, 2009). Therefore, even if a practice is considered favourable to protect workers (for example wearing gloves while spraying), the rationale behind why the worker is actually engaging in the practice should be analysed. This would assist with identifying and addressing perceptions that could lead to risky behaviours.

The use of multiple research methods highlighted that there was a difference between workers' statements and their actual practices in the field. Moreover, workers' knowledge of herbicide exposure risks did not always translate into or influence their safety practices. This contradiction is concerning as an important part of WfW herbicide exposure reduction strategy is based on training activities to increase workers knowledge. The difference between observed and self-reported practices could perhaps be explained as a perceived lack of control over health-related

choices predominant in individuals coming from deprived socio-economic contexts (Vaughan and Dunton, 2007). WfW workers deprived economic context might impact WfW workers perceived control over occupational choices, as well as their motivation and skills to engage with risk information. The resulting high turnover of workers is a major challenge for maintaining health and safety standards, team morale, and training effectiveness (Rother et al., 2010). Further research should be conducted to better understand WfW workers socio-economic context and how to address this in order to improve health and safety generally, and PPE compliance specifically. Access and provision of training is a key first issue, but the quality and nature of the content provided is equally significant. What is important is to understand the discrepancy between workers' knowledge of risks and lack of or improper use of PPE and the impact that the content of the training may have. What information workers receive during training also impacts on their perceptions and ultimately their safety behaviours.

The difference between observed and self-reported practices can result from workers' low perception of health risks from exposures to herbicides. Our results are similar to the risk perception and risk communication literature demonstrating that there is not a simple link between access to risk information and changes in risk perception and health-related behaviour (Arcury et al., 2002; Halfacre-Hitchcock et al., 2006; Recena et al., 2006; Remoundou et al., 2014; Ríos-González et al., 2013; Vaughan and Dunton, 2007).

The influence of gender dynamics on herbicide risk perception and PPE compliance needs to be understood and incorporated into exposure reduction measures. Gendered risk perceptions have been reported in previous research conducted in South Africa (Rother, 2005) and internationally (Barraza et al., 2011; Cabrera and Leckie, 2009; Norgaard, 2007; Peres, 2007; Reed et al., 2006), as well as for PPE compliance (Cabrera and Leckie, 2009; Reed et al., 2006). These studies predominately found that social constructions of gender were associated with potential exposures differences between males and females, and that males were more likely to engage in behaviours perceived as risky. Our findings supported these literature results. Additionally, the influence of social constructions of masculinity on men and women's health has been reported for various public health issues, including occupational exposure to pesticides (Courtenay, 2000; Naidoo et al., 2010; Reed et al., 2006). It is possible that low PPE compliance amongst male workers is partially explained by their tendency to conform to social norms such as masculinity (Table 3). This analysis is consistent with Cabrera and Leckie's study amongst Latino farmworkers (2009), in which the authors suggested that local constructions of masculinity may partially explain why women participate in more self-protective behaviours and have a higher risk perception of pesticide use than men.

Power relations played an important role in workers' health and safety and must be addressed when attempting to improve on PPE compliance. The observed low PPE compliance amongst health and safety representatives and contractors which workers mimicked raises several concerns. Feola and Binder's (2010) found that a strong predictor of PPE compliance and appropriate pesticide-related safety behaviours amongst farmers was their intention to conform to a group's social norms. Peer influence as a predictor of PPE use and compliance has also been documented amongst workers of fruit growing farms in the USA (Nicol and Kennedy, 2008). Thus, WfW's health and safety representatives and contractors limited PPE compliance could be indicating that they were somehow immune to herbicide health effects. Indeed, Palis et al. (2006) found in their study that those farmers who did not take any precaution when using pesticides considered themselves to be immune health effects. Power relations and the dynamics of social status amongst WfW workers needs to be addressed when promoting PPE compliance.

In this study, other contextual factors impacting compliance, such as working conditions (both logistical and working environment) were associated with low PPE compliance (Fig. 1; Table 3). The WfW working conditions in the Western Cape (i.e. the terrain, weather and programme structure) were major factors influencing workers and contractors lack of PPE compliance and consequently high exposure to herbicides. Since workers and contractors are only paid after a full site it cleared, this creates an incentive to work faster at the cost of high exposure risk and low PPE compliance practices. Low PPE compliance as a strategy to avoid slowing down the pace of work has also been cited by Forst et al., 2006 and Naidoo et al., 2010. Weather conditions (i.e. severe heat), for example, impacted the lack of PPE use amongst WfW workers. Heat discomfort from PPE has been confirmed by others as resulting in low PPE compliance (Clarke et al., 1997; Forst et al., 2006; MacFarlane et al., 2013; Mekonnen and Agonafir, 2002). Interventions addressing the characteristics of the PPE sourced by contractors could improve on comfort and appropriateness to the local weather conditions. However, cost plays a big factor in the type of PPE contractors procure and, as illustrated in the hierarchy of control, looking at substituting herbicides with less toxic herbicides or biological controls may be better.

The complexity of PPE use promotion and compliance raises questions of PPE viability as a key risk reduction strategy (Naidoo et al., 2010; Palis et al., 2006; Peres, 2007; Varona et al., 2007). The challenge is to remove invasive alien vegetation effectively, while not compromising the health of workers, taking the impact of economics on this into account. After the outcomes of this research, WfW management engaged with the findings and implemented some of the study recommendations such as ensuring the use of long-sleeved tops and requiring the use of carbon filter masks which are more comfortable in their policy documents (although these have yet to be purchased). However, exposure reduction challenges and the need for PPE still exist as herbicide use continues.

## 5. Recommendations

A suggestion is for WfW to focus on other mitigation strategies, including less reliance on herbicides and more use of bio-control measures including bio-pesticides. If PPE use is continued to be recommend for risk mitigation, then several different strategies will need to be implemented simultaneously to address the various factors reducing PPE compliance (e.g. training on health effects, training throughout the year, and increased knowledge of herbicide residue exposures). Particularly what is needed is guidance to programmes like WfW, farmers and others relying on PPE as the main means to protect workers. This guidance needs to address the particular socio-economic and climatic conditions impacting on workers' inability to wear and use the required PPE. For example, if workers are unable to wear the correct mask, what measures should management take? The Food and Agricultural Organization of the United Nations (FAO) and World Health Organization's (WHO) International Code of Conduct on Pesticide Management is a good framework to support this specific guidance recommended (Rother 2015), particularly the Code's recommendation that:

> *Pesticides whose handling and application require equipment that is uncomfortable, expensive or not readily available should be avoided….* (FAO/WHO, 2014).

The difficulties in ensuring PPE compliance in countries with several economic and social constraints highlights the importance

of not relying solely on PPE use as an exposure reduction strategy, but considering it as only one part of an exposure control programme. In LMIC with limited working options and vulnerable populations, the occupational exposure of workers to herbicides could offset the benefits of poverty relief programmes such as WfW. Interventions aiming to improve PPE must take into account particular characteristics of the socio-cultural context, local risk perceptions, and other broad contextual factors. In addition, PPE promotion strategies should not only target workers' knowledge of occupational risks, but also address administrative factors to increase workers PPE use; for example, producing PPE suitable for different weather conditions, increasing workers' wages, and improving on herbicide application methods. Promoting PPE compliance, as this study illustrated, is not an effective strategy that can easily be improved upon, given the external and individual factors involved. Therefore, it is also recommended that pesticide risk-reduction policies focus less on PPE compliance, and more on the elimination and substitution of highly hazardous herbicides as is a current endeavour by WfW. It is important to highlight that substituting herbicides for less hazardous ones does not guarantee lower exposures for workers, but rather a lower exposure to less hazardous herbicides. As there is uncertainty in the health effects associated with long term low dose and low hazard exposures, this raises concern about unprotected exposures. Furthermore, workers are exposed to multiple herbicides and the synergistic effects or multiple chemical exposure effect is not well understood. In addition, in order to design effective interventions or policies, risk perception studies should conduct in-depth analysis of study's population context in order to understand how risk information is interpreted and the particular social, cultural, and economic factors that shape risk perception.

Although this study highlighted key factors in understanding the lack of PPE compliance amongst workers, further research is needed. It is recommended that in-depth interviews are conducted to better understand the link between the social construction of masculinity and femininity, and safety practices, and how to address these to improve on health and safety practices. In addition, if funding is available, research with a larger sample size should be conducted including all nine provinces where WfW has programmes. Further research on invasive alien vegetation removal strategies would promote WfW's endeavours to reduce reliance on herbicides

## 6. Conclusions

This study described how risk perceptions, socio-cultural factors (gender, social status), and working context (terrain, weather, programme organization) impact on PPE compliance. We found that all these factors would need to be addressed for promoting PPE compliance. In addition to a low risk perception of herbicide use, this study showed that workers were willing to engage in prevention practices when their perceived risk of a particular danger was high (for example snakes bites). When PPE use is the key risk reduction strategy, the challenge is how to promote a higher perceived herbicide exposure risk to aid in PPE compliance and appropriate risk reduction behaviours. This study underscores the need for an integrated risk mitigation approach to reducing vulnerable and marginalized workers' chemical-exposures. Particularly, risk mitigation must not hinge on workers' PPE compliance and contractors responsibility of enforcing compliance as a key strategy.

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