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Pesticide Risk Perceptions, Knowledge and Attitudes of Operators, Workers, and Residents: A Review of the Literature

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ABSTRACT
The literature on the risk perceptions, knowledge levels, and attitudes of operators, workers, and residents in relation to non-dietary exposure to agricultural pesticides is reviewed. No literature was identified in relation to bystander exposure. Research has primarily been conducted on participants in developing countries and migrant workers in the U.S. For operators and workers, illiteracy, poverty, and a perception that exposure to pesticides is an inevitable part of their work results in limited adoption of safety precautions while using and storing pesticides. As a result, risk communication activities aimed at operator and workers need to take account of the wider socio-economic and cultural conditions in which workers and operators are working and living. There is less research focused on residents’ and bystanders’ perceptions, attitudes, and behaviours. The lack of European data in general, and residents’ and bystanders’ data in particular, represents a knowledge gap that is pertinent to emerging EU legislation requiring residents’ and bystanders’ inclusion in pesticide risk assessment. This review provides a comprehensive overview that can assist policy-makers, and risk communicators in the development of targeted training and awareness-raising material for operators, workers, bystanders, and residents. Areas for future research are suggested.

**Key Words:** agricultural pesticides; risk perceptions; operators; workers; residents.
INTRODUCTION

Pesticides are a significant source of mortality and morbidity worldwide, especially in developing countries where economies are heavily reliant on agriculture (WHO 2003; Pimentel 1996). The acute health problems associated with pesticide exposure include headaches, nausea, eye irritation, skin rashes, and flu-like symptoms. Long-term chronic health problems include neurological and reproductive disorders and various forms of cancer (Salazar 2004). Concerns about the potential adverse health effects of pesticides have driven the development and publication of the recently revised EU Directive on the sustainable use of pesticides (European Union Parliament and Council 2009). The Directive aims to reduce the risks to human health and the environment from the use of pesticides, and requires EU member states to implement training for all professional pesticide users, along with awareness-raising programmes targeting the wider public. These include, in particular, “residents”, who live in areas adjacent to those where pesticides are applied, and “bystanders”, who are inadvertently exposed to agricultural pesticides through non-agricultural activities. As a consequence of the sustainable use directive, member states are required to develop training materials to minimise occupational exposure to pesticides (operators and workers), as well as risk communication programs aimed at raising awareness amongst residents and bystanders about the risks of pesticide exposure, and provide advice on how exposure risks can be minimised (Pasiani et al. 2012; Sam et al. 2008).

Nearly 50% of the world’s labour force is employed in agriculture (Maroni et al. 2006). In developing countries, agricultural employment predominates across the workforce. Modern agriculture relies on the use of pesticides to increase crop yields and sustain food safety and
security for the global population (Cooper and Dobson 2007). Most pesticides, however, are
toxic to non-target species and can result in substantial health risks, especially if not used in
accordance with safety advice (Pimentel et al. 1992). Occupational exposure occurs either
through acute intoxication due to accidents while mixing, loading, or applying pesticides or
through contact with treated crops (Damalas and Eleftherohorinos 2011). Exposure risk increases
when operators and workers ignore safety instructions on how to properly use pesticides, and
guidelines on the use of personal protective equipment and adoption of sanitation practices
(Damalas and Eleftherohorinos 2011). It is argued that engagement in unsafe pesticide use and
disposal practices is the result of a lack of knowledge and misperceptions of the risks associated
with pesticides amongst operators and workers (Obopile et al. 2008; Koh and Jeyaratnam 1996).

Recent years have witnessed an increase in awareness from policy-makers on the adverse
effects of passive exposure to pesticides from residents and bystanders (Butler-Ellis 2012; The
Royal Commission on Environmental Pollution 2005). Epidemiological data have also become
available that provide evidence for a direct causality between morbidity and pesticides exposure
in these groups (Galea et al. 2011). As a consequence, many countries have enacted legislation to
protect residents and bystanders and minimize their exposure. In the UK, for example, the Royal
Commission on Environmental Pollution (2005) published a report on crop spraying that raised
concerns about the pesticides approval process and arguing that there is a need for clearer
communication and provision of information to the public about pesticide spraying. In response,
the government recognized the need to develop a better understanding of residents’ and
bystanders’ exposure to pesticides, along with the need to revise the current model for their
exposure.
Central to the development of effective training and risk communication materials is an understanding of how different stakeholders perceive the risks associated with pesticide exposure, and how these perceptions are shaped by socio-economic, cultural, environmental, and/or institutional factors. Seminal research originating in behavioural decision-making by Slovic and colleagues (see, inter alia, Fischoff et al. 1978; Slovic 2000) have demonstrated that how people perceive risks may differ from expert risk assessments. Moreover, these differences have explanatory value regarding why people react negatively to risks that are judged acceptable by technical risk assessors (see, inter alia, Frewer et al. 2012; Slovic 1987; Hinman et al. 1993; Whitfield et al. 2009; MacGregor and Fleming 1996; McCauley et al. 2002). Alternatively, individuals may discount risks to themselves by applying a cognitive mechanism such as optimistic biases, where people perceive that they are personally at less risk than an average member of their society, or relative to an individual who engages in riskier behaviours (Weinstein 1982; Helweg-Larsen and Shepperd 2001; Klein and Helweg-Larsen 2002). Potential cultural differences in risk perceptions and communication preferences also need to be considered (Renn and Rohrmann 2000). It is generally assumed that risk perceptions need to be taken into account when developing risk communication, as informational content needs to address people’s concerns and existing beliefs about potential hazards as well as technical risk estimates (Fischhoff 1995; Sandman et al. 2006). The need to take risk perceptions into account when developing intervention-based policies to reduce exposure to potentially hazardous events has been noted in the literature (e.g., see Slovic 2000; Frewer et al. accepted).

Risk perception has been shown to influence pesticide exposure. For example, Koh and Jeyaratnam (1996) argued that occupational poisoning episodes in developing countries can
largely be attributed to the erroneous beliefs of workers that impair their capacity and motivation to protect themselves from the associated risks. It is argued that the number of cases of occupational poisoning can be significantly reduced if appropriate training is provided on pesticide use and associated potential health risks. To be successful, such training must build on existing perceptions, attitudes, and beliefs held by operators and workers about: 1) how to handle and use pesticides and 2) the risks to human health from pesticide exposure.

In recent years, a significant body of literature has emerged that has examined how risk perceptions held by different stakeholders are linked to exposure to pesticides. These studies have mainly focused on addressing occupational hazards associated with the mixing, loading, and application of pesticides (operators), or working in treated fields or with treated crops (workers). Less research has examined how residents and bystanders living in agricultural areas perceive the risks from inadvertent pesticide exposure. The aim of this study is to review existing research that has linked perceptions to self-protective behaviours associated with pesticide exposure in four key stakeholder groups potentially exposed to pesticides through agricultural application: operators, workers, residents, and bystanders.

METHODS

Studies are included if they consider risk perceptions, knowledge, and associated attitudes, associated with pesticide exposure, independent of geographical location or the type of crops being treated. Only studies published in peer-reviewed journals have been reviewed to ensure the quality of the research. Due to linguistic constraints, the articles included are restricted to English language publications.
The databases searched included Scopus, Google Scholar, and the bibliographic database PubMed. The search strings applied were: ‘pesticides’ AND ‘risk perceptions OR knowledge OR attitudes’ AND ‘residents OR bystanders OR neighbours OR operators OR workers OR farmers’. The review focuses on studies on risk perception and related attitudes associated with 1) occupational exposure for operators and workers (Part 1); and 2) residents’ and bystanders’ exposure (Part 2). Papers were excluded from the review if they did not assess perceptions and attitudes towards pesticide exposure (for example, if they dealt only with exposure).

RESULTS

Presented in Table 1 is a summary table outlining the key findings from the literature and maps these against the stakeholder groups investigated, the country/region in which research has taken place, the methods and sample size used, and the number of papers and key references. The geographical distribution of the studies is graphically depicted in Figure 1.

Occupational Hazards for Operators and Workers

Consumption of food and water contaminated with pesticide residues can represent a significant route for exposure, and have been extensively addressed in the existing risk perception literature. However, these data are excluded from this review unless exposure occurs as part of daily working practices, or through residents’ or bystanders’ exposure. The ecological impacts of pesticide use are also out of the scope. For the same reason, risk perceptions associated with the domestic use of pesticides are also excluded.

The studies reviewed in this paper are not following the official definition of workers as developed by the European Food Safety Authority (EFSA). Instead, the term workers often refers to people performing operator and re-entry tasks, whereas a ‘worker’ in the EFSA (2010) definition is defined as a person who, as part of his/her employment, enters an area that has previously been treated with pesticides or who handles a crop that has been treated with pesticides.
The literature on risk perceptions and attitudes of operators and workers draws primarily on studies in developing countries and studies examining migrant and seasonal farmworkers in the U.S. (see also Figure 1 on the case study areas). These groups are considered to be more vulnerable to pesticide exposure since they have limited access to societal institutions and resources necessary to promote awareness and self-protection (Parrott et al. 1999). Furthermore, high illiteracy rates, poverty and language barriers within these groups may represent significant barriers to the development of risk communication and training materials (Salameh et al. 2004).

**Developing countries**

**Illiteracy levels**

An important finding from the studies conducted in developing countries is that high illiteracy rates contribute to farmers’ (and farmworkers’) difficulties in understanding and following pesticide use instructions and safety advice. This is considered to be a significant impediment to risk communication efforts. Ibitayo (2006) reported a 55% illiteracy rate amongst the Egyptian farmers included in their research, and Kimani and Mwabthi (1995) reported that 24% of their Kenyan participants are illiterate. Similar findings were reported for farmworkers in Brazil (Recena et al. 2006; Pasiani et al. 2012), Tanzania (Stadlinger et al. 2011), Lebanon (Salameh et al. 2004), Ethiopia (Karunamoorthi et al. 2011), and for Mexican operators and workers (Blanco-Muñoz and Lacasaña 2011). In Ghana, the majority of farmers had received only basic education (Ntow 2006). Two exceptions were found in Gaza (Yasin et al. 2002) and Kerala, India (Devi 2009), where higher literacy rates amongst agricultural workers were identified. Gender differences in the level of education are also evident. Atreya (2007) examined
gender differences in pesticide use, knowledge, attitude, and practices for Nepalese farmworkers and reported that female workers had lower literacy rates than male workers. Consequently the female workers were less likely to be able to read and understand pesticides labels. Participants across the studies were found to have difficulty in understanding the toxicity level indicated on pesticide labels and few reported having attended any training on pesticide use and storage. In Bangladesh, only 4% of farmers reported receiving any training on how to use and handle pesticides (Dasgupta et al., 2007). Hashemi et al. (2012) found that almost none of the Iranian participants in their study had received any special training in pesticide safety.

Unsafe pesticides practices

The prevalence of unsafe pesticide practices among farmworkers and operators in developing countries is also identified as a potential risk factor. Ibitayo (2006) reported that, in Egypt, almost all participants admitted storing pesticides in their bedroom. Storage in bedrooms was also widespread in Kenya (Kimani and Mwabthi 1995). Farmworkers in Palestine admitted unsafe practices, including the preparation of pesticides in kitchens, inadequate disposal of empty pesticide containers, and eating and drinking during pesticide application (Zyoud et al. 2010). Use of pesticide containers for drinking and food storage was reported in Ethiopia (Karunamoorthi et al. 2011). Inadequate use of protective equipment is also a cause of concern. In studies by Dasgupta et al. (2007) and Salameh (2004), participants (87% - Bangladesh; 50%: Lebanon, respectively) stated that they did not take any protective measures when using pesticides. In Tanzania, more than 50% of the farmers did not use any protective equipment during mixing or application of pesticides. Poor adoption of protective equipment was also
identified amongst farmworkers in Gaza (Yasin et al. 2002), Ghana (Ntow 2006) and Brazil (Pasiani et al. 2012). The reasons commonly stated for misusing protective equipment were the cost and discomfort associated with their use (Ntow 2006; Devi 2009). In Ghana, the great majority of farmers further admitted disposal of sprayer wash water and empty pesticide containers by throwing them on the field or nearby waterways (Ntow 2006).

Knowledge levels, risk perceptions, and safety practices

Correlations between knowledge levels about pesticide-related health risks and adoption of safety practices have been reported in various studies. The findings are mixed. In the Gaza, for example, almost 60% of farmworkers are not in favour of the use of pesticides for pest control. Furthermore, they reported high levels of knowledge on the potential health impacts of pesticides and routes of exposure. However, use of protective measures was reported to be poor, since the majority believed that their body has developed resistance to pesticides (Yasin et al. 2002). Similarly, Ghanaian farmers have high risk perceptions regarding hazards from pesticides but fewer than 30% wear full protective covering (Ntow 2006). Perceived resistance to pesticides is also reported by Palis et al. (2006) in their research on Pilipino farmers’ knowledge and attitudes, where about a quarter of the participants take no special precautions to protect themselves from pesticide exposure. Knowledge was not found to influence practices in Brazil. Recena et al. (2006) note that almost all the participants included in the study considered pesticides to be poisonous, with the majority also expressing concerns regarding the adverse effects on the environment. However, the use of personal protective equipment during pesticide application was not found to be common practice.
In a more recent Brazilian study, the majority of participants admitted having received information about pesticides from the government and claimed to be reading the instructions and warnings on the products’ labels. However, many did not take adequate protective measures. This inconsistency was attributed to the low mean educational level of study participants. Ethiopian farmers were also aware of the adverse effects of pesticides on human health. However their reported safety practices and use of PPE were found to be inadequate (Karunamoorthi et al. 2011). Similarly, high risk perceptions did not significantly influence the extent to which Turkish farmers adopt safety practices (Isin and Yildirim 2007) nor did they increase the use of personal protective equipment in Mexico (Blanco-Muñoz and Lacasaña 2011) and Lesotho (Mokhele 2011). Salameh et al. (2004) noted that more experience of pesticide application did not translate into higher adoption of protective equipment in Lebanon. However, having experience of pesticide related education increased both the likelihood of participants adopting preventative measures and risk perceptions, despite the low educational level of study participants. Dasgupta et al. (2007) reported that approximately 47% of their sample of farmworkers in Bangladesh overused pesticides. Over usage was, in turn, positively correlated with low perceptions of pesticide risk by the farmers. Similarly, knowledge about pesticide related health risks positively correlates with the adoption of safety practices in Palestine (Zyoud et al. 2010).

**Determinants of risk perceptions**

Socio-economic and cultural determinants of risk perceptions and practices have also been examined. Isin and Yildirim (2007) report that, in Turkey, younger and better-educated
individuals, as well as those having less farming experience, have higher perceptions of the health risks associated with pesticide exposure. Similarly, younger and less-experienced farmers report higher risk perceptions in Iran (Hashemi et al. 2012). Blanco-Muñoz and Lacasaña (2011) find that, in Mexico, the perceived risk of pesticides is positively correlated with educational level but is not influenced by age or gender. Atreya (2007) did not report significant differences in perceived risks for an individual’s own health or to the environment among male and female farmworkers in Nepal. However, the characteristics of the risk “target” may influence risk perceptions. For example, Barraza et al. (2011) report higher risk perceptions among mothers in Costa-Rica, compared to fathers and other stakeholders, when it comes to pesticide-related health risks for children.

Heong et al. (2002) note that influence from reference groups is highly correlated with behaviour. Farmers in Laos were asked what they thought was expected of them with respect to the frequency of insecticide spraying by different reference groups, including neighbours, village heads, spouses, and extension technicians. Farmers rated technicians as the most influential reference group. Palis et al. (2006) also stressed the role of associated beliefs in shaping risk perceptions. For example, Pilipino farmers tended to view pesticides as a “medicine” for the plants rather than a “poison” for pests, and therefore saw no point in investing in protective equipment.

Almost all of the studies in the developing world highlighted the need for targeted training and awareness raising programs. Palis et al. (2006) emphasised the need to assess belief systems and perceptions before training and awareness-raising material are developed. Atreya (2007) also stressed the need for such programmes to be gender-sensitive, given potential
gender-related differences in attitude and perceptions, although research is needed *a priori* to establish what these are.

**Immigrant workers in the U.S.**

**Safety practices**

Some of the earlier evidence from the U.S. comes from research that aimed to reduce farmworker pesticide exposure by developing an education program targeting specific cultural groups (Arcury *et al.* 2002; Austin *et al.* 2001). These studies examined the knowledge levels, attitudes, and risk perceptions of North Carolina Latino and Hispanic farmworkers. Participants were reported as not being able to understand English, the language in which training materials were provided. The majority reported that they perceived having no control over reduction of personal pesticide exposure. Salazar *et al.* (2004) reported that the majority of immigrant workers in Oregon tended to perceive adverse health effects as an inevitable by-product of their work, or believed that only weaker individuals were vulnerable to the effects of pesticide exposure. Both lines of reasoning were found to lead to participants’ adopting limited precautions. Acury *et al.* (2002) and Austin *et al.* (2001) further reported very limited use of protective equipment by immigrant workers, and attributed this to the absence of protective equipment in the workplace and work pressure. These findings are reinforced by recent studies with immigrant workers in the U.S. These demonstrated that stress at work and an inability to access equipment limited workers’ use of protective equipment (Salazar *et al.* 2004; Parrot *et al.* 1999; Flocks *et al.* 2012). McCauly *et al.* (2002), noted that 40% of their sample (from Oregon, USA) considered themselves as never having been exposed to pesticides, or having limited
control in being able to protect themselves if they were exposed. As a result, only half the sample reported using protective equipment regularly while working with pesticides.

### Illiteracy rates

Another common finding among studies of immigrant workers in the U.S. (and similar to the situation in developing countries) was the high illiteracy rates associated with those who were the recipients of pesticide application training. McCauly et al. (2002) noted that only a third of the farmworkers in Oregon received pesticide safety training. Similarly, in California, Cabrera and Leckie (2009) reported that the majority of the participants could not speak or read in English, and only half received any type of training in pesticide use.

### Determinants of risk perceptions

Some demographic differences in risk perceptions amongst the U.S. farmworker population have been identified. For example, Cabrera and Leckie (2009) noted that risk perception scores are higher for women in California’s Salinas Valley, and they are able to identify a wider range of long- and short-term health effects associated with pesticide exposure. Higher risk perceptions have also been reported among female farmworkers in Florida (Flocks et al. 2012). Focus group discussion reveals that female farmworkers were aware of the health hazards associated with pesticide exposure, in particular during pregnancy, and could recall incidents of illness affecting them and their children. Strong et al. (2009) further examined attitudes and knowledge of immigrant female farmworkers (or mothers in farm-working households). Using in-depth interviews, they reported that female workers could describe how
pesticides could enter their homes (take-home pathway) but were less able to connect it to exposure of children. The study argues that existing health beliefs play a role in determining safety practices. Strong et al. (2009) found that the majority of farmworkers reported delaying showering after work in order to cool down. Family dynamics, as well as community and worksite characteristics, were also found to influence the adoption of behaviours aimed at reducing the “take-home” pathway of pesticide exposure.

Europe

Risk perceptions and behaviours

Less research was identified that dealt with the risk perceptions associated with pesticide application of European operators and workers, when compared to developing countries and immigrant worker populations in North America. It is also possible that the relatively lower exposure risks due to more effective legislation and training in Europe has resulted in less research being done on risk perceptions for different stakeholder groups. The available data do not indicate a different pattern of perceptions and behaviours to those identified elsewhere. Damalas and Hashemi (2010) examined pesticide risk perceptions and the use of personal protective equipment among cotton growers in Northern Greece. They compared the attitudes and perceptions of younger and older farmers. The results suggest that younger farmers perceived higher levels of risk associated with pesticide use, and that they were less likely to agree that the benefits from pesticides outweighed the risks. Furthermore, younger farmers were more positive towards the adoption of integrated pest management (IPM) practices, although adoption scores were generally low. The frequency of use of protective equipment was also
found to be considerably lower for older farmers. Damalas et al. (2006) reported high levels of awareness regarding the potential health risks associated with handling pesticides amongst Greek tobacco farmers. However, these did not translate into high levels of adoption of safety precautions, with almost half of the sample reporting not using any personal protective equipment (PPE) when spraying pesticides.

Emerging evidence on European farmers’ perceptions comes from a small but growing literature that applies non-market valuation techniques to investigate the welfare costs associated with pesticide use. These costs mainly refer to risk to the farmers’ health from acute and chronic exposure to pesticides and more recently the effects on the environment and biodiversity, which are out of the scope of the current review.

Residents’ and Bystanders’ Exposure

Risk perceptions and behaviours

Little research on the perceptions of, and attitudes towards, non-dietary exposure as a result of pesticide drifts from treated areas has been published in peer-reviewed journals to date. In part, this may be a problem of definition, in particular in relation to who is represented by the term “bystanders”, and collecting perceptual data from these individuals. There is a literature on people’s valuation of negative environmental effects associated with pesticide use (see Cuyno et al. 2001 and Foster and Mourato 2000 among others), although this does not equate directly with assessment of the perceptions and attitudes of residents and bystanders, and associated behaviours in relation to agricultural pesticide use.
Ahmed et al. (2011) studied the risk perceptions of residents living close to agricultural fields in Sweden, and compared residents’ perceptions of risk and attitudes towards pesticides with those of local farmers. The residents were found to perceive pesticides to be more harmful to the environment, and in general expressed more negative attitudes towards pesticide use than the farmers. Women and older residents expressed higher concerns regarding the potential risks of pesticides.

DISCUSSION

Pesticide use may be associated with health risks as a result of occupational (operator/worker) and passive (resident/bystander) exposure. Understanding how different “at risk” group, perceive the risks associated with pesticides, and how these vary between different socio-demographic and stakeholder groups is necessary to assist policy-makers and other interested actors in designing effective risk reduction measures and risk communication materials and activities (e.g., Slovic 2000). This review aimed to summarize the limited though growing body of literature that considers the perceptions, attitudes, and levels of knowledge of pesticide risk and exposure across different “at risk groups”.

The research reported in this review was collected primarily in developing countries, or in the U.S. (particularly in regard to immigrant populations). The body of evidence suggests that, for populations where data are available, operators and workers rarely wear protective equipment, thereby exposing themselves to direct contact with pesticides. A significant finding is that higher risk perceptions and better levels of knowledge about the associated risk do not always translate into better use of, and adherence to, protective advice, guidelines, and protective
equipment use, suggesting that the relationship between risk perception and behaviour is not direct. Other factors, such as economic and employment pressures, and those related to peer group influences, may also influence risk-related behaviours. As a consequence, many workers and operators do not adopt protective practices nor use protective equipment.

There is some evidence to suggest that potential gender differences can be identified. For example, female workers tend to perceive higher levels of health risks associated with pesticides, and engage in more self-protective behaviours, although they also tend to receive less training (Cabrera and Leckie 2009). However, this finding needs to be corroborated in other geographical regions and cultures, in particular in Europe. This is in line with research in other areas (for example, see Gustafson 1998), who reported that higher risk perceptions associated with a particular issue are experienced by women, possibly because they perceive that they are excluded from the risk management decisions that have imposed the same risks upon them in the first place. In addition, the low rates of literacy among farmers are a particular concern in developing countries and amongst U.S. migrant workers, in particular amongst female workers. Again, further research is needed to confirm that this is the case in other regions, in particular in Europe, as this has direct implications for the design and implementation of training and communication materials.

High levels of knowledge and perception of risk are not enough to influence workers’ and operators’ self-protective behaviour. This must be considered when designing training programs to increase safety. Other economic and socio-cultural pressures may also need to be addressed. These might include economic and employment pressures. The influence of potentially influential peer groups may also need to be addressed in risk communication initiatives directed
at both employers and workers, or as part of other interventions targeting the implementation of self-protective behaviour associated with pesticide use.

Gaps in knowledge have also been identified that need to be addressed in future research. In particular, research is needed to better understand the risk perceptions and related attitudes and knowledge levels about pesticide exposure associated with agricultural application for members of the public considered to be at significant risk of exposure. These include, in particular, residents living and/or working in close proximity to agricultural fields, and bystanders who visit rural areas for leisure/work and who find themselves in close proximity to agricultural fields. Such research is necessary if, as now required by EU legislation, effective targeted risk communication and awareness-raising material for residents and bystanders is to be developed.

As research into the risk perceptions and attitudes of operators and workers has primarily been centred on those of developing countries, equivalent research in Europe is needed to inform the development of effective training and awareness material targeting these groups in line with the EU directive on the sustainable use of pesticides. The evidence suggests that it may be necessary to take gender differences into account, as women are widely involved in agricultural activities in many parts of the world and can be extremely vulnerable to adverse health effects of pesticide exposure (Murphy et al. 1999), and also potentially have different levels of risk perception, training, and education compared to men. In developing countries, in particular, accumulated epidemiological evidence shows that women are more sensitive to adverse effects from exposure whilst at the same time have limited opportunities to control their exposure given
that production is organized in a gender-specific way (London et al. 2002). At the same time, the evidence for a causal relationship between risk perceptions and related attitude is equivocal.

Some limitations of this review can be identified. The authors acknowledge that the inclusion of only English languages publications may have excluded articles of interest published in non-English language journals. The authors suspect that such a literature may be available in languages published in Europe and beyond, for example in Chinese or Spanish. However, it is clearly not possible to include all languages of potential relevant publications in a review due to first of all the impossibility of systematically identifying all such articles, (even if abstracts are published in English translation of the article is required), and because of the linguistic limitations of the databases accessed. A further limitation to identification of studies for inclusion may relate to the databases utilised, as not all journals are included in all data-bases. In this study, we have included those most normally used for research in the area of study (Scopus and Biomed central) and Google Scholar (which has broader inclusion of publications). We are reasonably certain, therefore, that the review has included the range of scholarly English language publications available, although there may be some omissions related to the data-bases selected.

Several studies have reported increased risk of toxicity when an individual spends more time involved in pesticide application, unless greater attention is simultaneously paid to implementation of protective measures (Bell et al. 2006; Jensen et al. 2011; Jors et al. 2006). Research within the EU Framework 7 funded BROWSE project is currently assessing the relationship between exposure and frequency of application for different crops and European climatic conditions, as both crop type and climate may influence this relationship. Of course,
research is also needed outside Europe, as socio-cultural, climatic, and crop-related variation will potentially influence pesticide exposure. An alternative strategy may be to reduce the frequency of application through adoption of alternative agricultural practices, such as integrated pest management and precision agriculture approaches, which might usefully represent a topic for future research.

Consumer perceptions of risks associated with consumption of pesticide residues on food has been reviewed elsewhere (e.g., see Aertsens et al. 2009; Yiridoe et al. 2005). This issue has been excluded from the current review, which has focused only on collating information relevant to developing effective interventions aimed at promoting the protection of operators, workers, bystanders, and residents exposed to pesticide through their agricultural applications, but not through consumption of foods obtained within (for example) retail environments. Raymond et al. (2005) present a meta-analysis of the economic literature eliciting Willingness to Pay (WTP) values to hedge against negative effects of pesticides use on individual health and the environment. Other researchers have considered consumers’ perceptions of risk associated with domestic pesticide use, such as in the garden (e.g, see Schutz and Wiederman 1998; Templeton et al. 1998; Nieuwenhuijsen et al. 2005), and it is possible that perceptions of risk associated with different types of pesticide use are related to, or determine, each other. This may be particularly relevant in relation to resident and bystander perceptions and behaviours, and this may represent useful topic for future research.

The use of meta-analysis on risk perception data has previously allowed the “mapping” of changes with time, and between geographical regions (Frewer et al. 2013). This type of analysis would require identification of appropriate dependent variables in a range of studies that
could be aggregated in the process of meta-analysis. This, \textit{a priori}, would require the implementation of “standard operating procedures” or comparable dependent variables across studies, which would limit the geographical range of the review as the numbers of studies would be much reduced. The adoption of comparable dependent variables in future research would facilitate formal meta-analysis and allow significance testing of differences in time and between different geographical regions (Ronteltap \textit{et al.} 2011).

**CONCLUSIONS**

Research regarding the perceptions and attitudes of vulnerable populations is required to inform the development and implementation of effective risk communication strategies. In Europe, where there are few available data, this information is required by the EU Sustainable Use Directive. An international gap in knowledge relates to the perceptions and attitudes of residents and bystanders. The development of risk communication and training presents additional challenges given low educational attainment, low literacy rates, ethnic and cultural diversity, and language barriers for many agricultural workers in the developing world. Low rates of literacy among farmers are a particular concern in developing countries and amongst U.S. migrant workers, an issue potentially of greater concern for female workers. The association between risk perceptions and behaviours in not direct, as other factors (work, economic and peer group pressures, and cultural factors) may also influence the extent to which operators and workers and potentially residents and bystanders adopt self-protective behaviours.

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Table 1: Summary of the studies included in the review

<table>
<thead>
<tr>
<th>Reference</th>
<th>Countries /Regions</th>
<th>Sample Size</th>
<th>Stakeholder group</th>
<th>Methods used</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed et al. (2011)</td>
<td>Sweden</td>
<td>617</td>
<td>Residents and Farmers</td>
<td>Face to face interviews</td>
<td>Residents perceived pesticides more harmful for the environment and expressed more negative attitudes towards pesticide use compared to farmers. Women and older residents showed higher concerns about pesticides harmfulness. Education was not found to significantly influence risk perceptions.</td>
</tr>
<tr>
<td>Arcury et al. (2002)</td>
<td>North Carolina</td>
<td>293</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>Most participants did not understand the language of risk communication materials. The majority reported having no personal control over reducing pesticide exposure. No relationship between farm-worker background characteristics and perceived risk/control. Increased access to pesticide safety information associated with higher perceived control scores and lower risk scores.</td>
</tr>
<tr>
<td>Austin et al. (2001)</td>
<td>North Carolina</td>
<td>270</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>Participants reported lack of control over pesticide exposure in the workplace. Perceived lack of control is not attenuated with training.</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Participants</td>
<td>Data Collection Methods</td>
<td>Summary</td>
<td></td>
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<tr>
<td>Barraza et al. (2011)</td>
<td>Costa Rica</td>
<td>Farmers, NGOs, NGOs, farmers unions</td>
<td>Focus groups and Face to Face interviews</td>
<td>Inability to speak the same language was a barrier to training farm-workers. Very limited use of protective equipment. Absence of protective equipment and pressure at work resulted in low levels of self-protection.</td>
<td></td>
</tr>
<tr>
<td>Blanco-Munoz and Lacasana (2011)</td>
<td>Mexico</td>
<td>Operators and workers</td>
<td>Face to Face interviews</td>
<td>Participants expressed little and diverse knowledge on pesticides exposure routes and chronic effects. Mothers perceived higher risks in particular for their children. Aerial spraying considered by most participants as the main source of exposure for residents.</td>
<td></td>
</tr>
<tr>
<td>Cabrera and Leckie (2009)</td>
<td>California</td>
<td>Farmworkers</td>
<td>Face to Face interviews</td>
<td>Most participants could not understand the language in which training materials were provided. 50% of participants had received no pesticide training. Participants reported high risk perception scores which were more elevated among women. Participants identified a range of long and short term health effects linked pesticides exposure. Most participants did not engage in self-protective behaviours.</td>
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</tr>
<tr>
<td>Damalas and Hashemi (2010)</td>
<td>Greece</td>
<td>Farmers</td>
<td>Face to Face interviews</td>
<td>Educational levels were higher among younger, compared to older, farmers. Older farmers perceived lower risks and higher benefits from pesticide use, and tended to be less risk averse than to young farmers.</td>
<td></td>
</tr>
</tbody>
</table>
Young farmers showed more favourable attitudes towards IPM practices. Older farmers used personal protective equipment less frequently. 

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Size</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damalas et al. (2006)</td>
<td>Greece</td>
<td>223</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Dasgupta et al. (2007)</td>
<td>Bangladesh</td>
<td>820</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Devi (2009)</td>
<td>India</td>
<td>280</td>
<td>Pesticide applicators</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Flocks et al. (2012)</td>
<td>Florida</td>
<td>35</td>
<td>Female Farm-workers</td>
<td>Focus groups</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Group</td>
<td>Method</td>
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<tr>
<td>Hashemi et al. (2012)</td>
<td>Iran</td>
<td>155</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Heong et al. (2002)</td>
<td>Laos</td>
<td>600</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Ibitayo (2006)</td>
<td>Egypt</td>
<td>188</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Isin and Yildirim (2007)</td>
<td>Turkey</td>
<td>61</td>
<td>Fruit growers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Karunamoorthi et al. (2011)</td>
<td>Ethiopia</td>
<td>291</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Sample Size</td>
<td>Respondents</td>
<td>Method</td>
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<tr>
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<tr>
<td>Kimani and Mwabthi (1995)</td>
<td>Kenya</td>
<td>1797</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>McCauly et al. (2002)</td>
<td>Oregon</td>
<td>102</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
</tr>
<tr>
<td>Ntow et al. 2006</td>
<td>Ghana</td>
<td>137</td>
<td>Farmers</td>
<td>Face to face interviews, Field observations and game</td>
</tr>
<tr>
<td>Palis et al. (2006)</td>
<td>Philippines</td>
<td>162</td>
<td>Farmers</td>
<td>Face to face interviews</td>
</tr>
</tbody>
</table>
a medicine for plants not a poison for pests. Inhalation and not dermal absorption was regarded as hazardous by most participants. Most participants saw no point in spending on protective equipment.

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Size</th>
<th>Study Design</th>
<th>Frequency</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parrott et al. (1999)</td>
<td>South Georgia</td>
<td>279</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>Workers generally unaware of the risks associated with pesticides. Lack of protective equipment to purchase was the main reason for not taking precautions. Risk information was only available in the language of vulnerable workers.</td>
</tr>
<tr>
<td>Pasiani et al. (2012)</td>
<td>Brazil</td>
<td>112</td>
<td>Farmers</td>
<td>Face to face interviews</td>
<td>Low mean educational level. Most worker participants were aware of the risks associated with the use of pesticides and declared having received information about pesticides from government. The majority read the product labels with instructions and warnings. But, many did not take adequate protective measures.</td>
</tr>
<tr>
<td>Recena et al. (2006)</td>
<td>Brazil</td>
<td>250</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>Low literacy level. Almost all the interviewees considered pesticides to be poisonous. The use of personal protective equipment during pesticide application was infrequent.</td>
</tr>
<tr>
<td>Salameh et al. (2004)</td>
<td>Lebanon</td>
<td>89</td>
<td>Farmworkers, Pesticides distributors</td>
<td>Face to face interviews</td>
<td>Low levels of training regarding pesticides use among workers. Pesticide risk knowledge was substantially higher among pesticides distributors. Workers and distributors had better knowledge about pesticides than the general population. Long experience with pesticide application resulted in adoption of fewer prevention measures. Pesticide related education increased risk perceptions and the likelihood of adopting risk mitigation measures.</td>
</tr>
<tr>
<td>Salazar et al. (2004)</td>
<td>Oregon</td>
<td>33</td>
<td>Farmworkers</td>
<td>Focus groups</td>
<td>Participants were aware of the risks associated with pesticide exposure. Workers perceived adverse health effects as an inevitable by-product of their work or thought that only the</td>
</tr>
</tbody>
</table>
weaker workers were vulnerable to risks. Limited precautions were taken. Participants referred to stress during work and inability to access protective equipment as the main reason for engaging in unsafe work practices.

<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Country</th>
<th>Sample Size</th>
<th>Occupation</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stadlinger et al. (2011)</td>
<td>Tanzania</td>
<td>106</td>
<td>Farmers</td>
<td>Face to face interviews</td>
<td>Low knowledge about the chemicals they used. More than 50% of farmers did not use any protective equipment during mixing or application. Pesticides were often being mixed with bare hands. Safety instructions were often in English and could not be understood by the (illiterate) farmers.</td>
</tr>
<tr>
<td>Strong et al. (2009)</td>
<td>Washington</td>
<td>37</td>
<td>Female Farm-workers or mothers in farm-worker households</td>
<td>In-depth Interviews</td>
<td>Women could describe the pesticide “take-home” pathway but were less able to connect it with their family’s susceptibility to pesticide exposure. Women experienced difficulty integrating the prevention behaviors into their everyday lives because of competing responsibilities, conflicts with their husbands’ intentions and with cultural health beliefs, perceived lack of control, and community barriers.</td>
</tr>
<tr>
<td>Yasin et al. (2002)</td>
<td>Gaza</td>
<td>189</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>High levels of knowledge on the health impact of pesticides and routes of exposure. High mean educational level. Almost 60% of participants were negative about pesticides use. The majority believed that their body had developed resistance to pesticides. The use of protective measures was poor.</td>
</tr>
<tr>
<td>Zyoud et al. (2010)</td>
<td>Palestine</td>
<td>388</td>
<td>Farmworkers</td>
<td>Face to face interviews</td>
<td>Prevalence of unsafe behaviours. Knowledge about health risks positively correlated with the adoption of safety practices.</td>
</tr>
</tbody>
</table>

*not identified in the original search but recommended for inclusion by the reviewer.
FIGURE CAPTION

FIGURE LEGEND

Figure 1: Map of countries covered by the studies included in the review.

Note: Each red dot corresponds to a different study.