Institut de recherche
Robert-Sauvé en santé
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Preventing Skin Exposure to Pesticides Among Apple Growers and Factors Influencing Use of Protective Clothing

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STUDIES AND
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Legal Deposit
Bibliothèque et Archives nationales du Québec
2019
ISBN : 978-2-89797-090-1
ISSN : 0820-8395

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This study was funded by the IRSST. The conclusions and recommendations are solely those of the authors.
This publication is a translation of the French original; only the original version (R-1021) is authoritative.

PEER REVIEW
In compliance with IRSST policy, the research results published in this document have been peer-reviewed.

ACKNOWLEDGMENTS

We would like to extend our special thanks to the following people and organizations:

- The apple growers who welcomed us to their orchards on four different occasions at the height of the spraying season to observe their operations and conduct interviews.

- The members of the monitoring committee: Mélanie Noël and François Blouin representing Quebec apple growers (Producteurs de pommes du Québec, PPQ); François Granger of the Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST); Diane Fortin of the Union des producteurs agricoles (UPA); Évelyne Cambron-Goulet of the Direction de la santé publique de la Montérégie; and Isabelle Gorse of the Quebec ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (MDDELCC).

- Various industry stakeholders, such as the Agropomme agricultural advisory club, the organizers of the Journée horticole Pommes [apple growers' day] in Saint-Rémi for their support for the project, and especially the PPQ for their assistance in recruiting participants.

- Colleagues at the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST): Martine Poulin and Maud Gonella of the OHS Problem Prevention and Rehabilitation Division, Marie-France D'Amours and Dominique Desjardins of the Communications and Knowledge Transfer Division, and Maryse Gagnon of the Research and Expertise Division, who supported the study and collaborated in a variety of ways.

ABSTRACT

International research has shown that the skin is the main route of exposure to the pesticides used in agriculture. The use of personal protective equipment (PPE) plays a key role in preventing exposure. However, failure to use recommended PPE systematically is well documented and has become a prime target of initiatives to reduce exposure to pesticides. This study expands on the findings of a first investigation of apple growers by looking specifically at skin exposure to pesticides and the use of protective clothing (PC). The purpose of the study was to describe exposure situations during the main activities involved in using pesticides and to link them to apple growers' perceptions of risk, use of PC and prevention practices. The findings advance our knowledge of the factors that facilitate or interfere with the use of PC.

The first step was a literature review that looks at different perspectives on PPE use in general and PC use in particular. PPE and PC use, definitions, characteristics and effectiveness and the way they are used are examined, and the results of studies with diverse perspectives on PPE use or prevention practices are presented. Knowledge and perception of risk have always been considered key variables in explaining PPE use. Thanks to the advancement of knowledge, the need to consider factors related to the social and economic context in order to understand and influence growers' PPE use practices is now also recognized.

The review also examines methodological features of the studies of PPE use, helping to situate the particular contribution of this study. For one thing, the heterogeneity of the studies of PPE users, in particular the populations studied, the data collection methods and the variety of aspects studied, make it difficult to compile results and draw conclusions. In addition, the methods used to measure exposure in epidemiology and toxicology do not provide information on how exposure occurs. Field studies, often from the standpoint of ergonomics or the sociology of work, use activity observation and interviews to describe work and exposure, including PPE use, in real circumstances.

For this study, a method based on the sociology of work and on ergonomics was used to examine how apple growers commonly protect their skin against exposure to pesticides under a variety of exposure conditions. Data were collected from a small number of volunteer growers during the pesticide mixing-loading and application (spraying) phases. Repeated observations and interviews under conditions differentiated according to predetermined variables made it possible to study a number of work and exposure situations during which PC is worn and contributed to the validity of the results. Through systematic analysis of videos of grower activities, various aspects of the work setting and activity phases were described, common exposure situations associated with contact with pesticides were studied and many facets of PC use were observed. Analysis of the interviews enriched and confirmed our understanding of exposure situations, prevention practices and PC use.

Qualitative analysis of the observations highlighted the significance of varied, repeated, routine "microexposure" situations, where exposure is of low intensity and short duration, not particularly visible and an integral part of activities. These situations are related to actions, movements and handlings that are likewise frequently repeated and associated with activity determinants. Incidents involving unexpected major exposure and disruption of the activity are actually infrequent. Repeated microexposures added a quantitative dimension to observation

analysis, and a hypothesis of cumulative skin exposure during the observed activities was formulated. In the absence of quantifiable biological exposure measurements, this information can help to make users more aware of pesticide-related risks and encourage implementation of effective skin protection measures.

The growers who participated in this study wore work clothes that included long sleeves and long pants, as well as PC, in most of the exposure situations analysed. However, there was considerable variety in the PC worn and it was not always used as recommended on the pesticide labels or in a way that fully ensured the desired level of protection. The growers expressed their concerns about their health and their doubts about the efficacy of the PC they were using. The literature review confirms that real protection does not always match anticipated protection. These findings are related to a number of shortcomings with respect to PC available in Quebec, particularly with regard to certification, clear labelling, recommendations for PC use depending on exposure situations and information on PC use and its distribution. The effectiveness, thermal comfort, suitability for work and cost of PC also influence its use.

The data show, however, that apple growers also rely on trade know-how in developing and implementing prevention practices that become an integral part of their activities and that they present as complementing their use of PC. These findings suggest that practices that do not comply with recommendations may be seen as adaptations to common microexposure situations, to a lack of information about PC or to rules unsuited to the realities of growers' work and needs. The prevention practices reveal the growers' concern about the risks associated with their work.

Thanks to a combined sociological and ergonomic approach, this project produced findings and recommendations firmly rooted in the realities faced by growers. Getting farm workers involved in developing, testing and validating safety rules through trade collectives could yield outcomes that result in better protection against pesticide exposure. If the agricultural community and public health stakeholders join forces, it should be possible to design measures grounded in the realities of growers' work and social dynamics.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

CNESST	Commission des normes, de l'équité, de la santé et de la sécurité du travail [Quebec labour standards and OHS board]
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec [Quebec ministry of agriculture, fisheries and food]
PC	Protective clothing (see subsection 3.1, Terminology, for further information)
PMRA	Pest Management Regulatory Agency, a branch of Health Canada
PPE	Personal protective equipment
PPQ	Les Producteurs de pommes du Québec [Quebec apple growers]

1. BACKGROUND

Accounting for approximately 29% of Canada's apple production, Quebec ranked second among apple-producing provinces in 2013. The total land area devoted to apple growing has been declining since the 1940s, but this has been offset by an increase in yield per hectare, which has helped maintain a significant production level that reached 24.8 t/ha in Quebec in 2014. There were 28,000 farms in Quebec in 2012, including 480 apple orchards, which accounted for a quarter of all fruit farms. The reported number of apple growers varies depending on the source of the data. The Quebec apple growers association (Producteurs de pommes du Québec, PPQ) said there were 522 active growers in 2013. The average orchard size in 2013 was 8.4 ha, and a large proportion of growers operate small orchards of 5 ha or less (ministère de l'Agriculture, des Pêcheries, et de l'Alimentation du Québec, 2015).

One of the characteristics of farming all around the world is the heavy use of pesticides to eliminate pests and diseases, protect crops and boost productivity. For many years now, international researchers have been studying the acute and chronic effects of exposure to the pesticides used intensively in agriculture. For instance, occupational exposure to some pesticides has been associated with an increased probability of developing Parkinson's disease (Moisan and Elbaz, 2011) and a type of non-Hodgkin's lymphoma (Dreiher and Kordysh, 2006; Fritschi *et al.*, 2005). For Quebec agricultural workers, however, the risks associated with using these pesticides are not well documented in the compensation statistics of the Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST) because many agricultural producers are considered to be self-employed and are therefore not required to contribute to the CNESST. In addition, under-reporting of cases of minor illness or injury seems to be an accepted fact in the agricultural sector (Bekal *et al.*, 2011). In spite of this problem, addressing the occupational hazards associated with chemical and biological contaminants in agriculture is a priority research area at the IRSST. Studies done in Quebec (Belleville, Boudreault, Carrier and Régie régionale de la santé et des services sociaux de la Montérégie, 1997; Bouchard, Carrier and Bruneau, 2008; Bouchard, Carrier, Brunet, Dumas and Noisel, 2006) and elsewhere in Canada (Band *et al.*, 2011; McDuffie *et al.*, 2001; Pahwa *et al.*, 2012) have documented exposure to various molecules, and have led to a better understanding of their effects on the health of pesticide users.

Eliminating hazards at source, which is the most effective prevention strategy, is central to the Quebec Act respecting occupational health and safety (AOHS) (CQLR c. S-2.1). The Pesticides Management Code (CQLR c. A-9.3, r. 1) and the health component of the Quebec phytosanitary strategy 2011–2021 (ministère de l'Agriculture, des Pêcheries, et de l'Alimentation du Québec, 2011) advocate applying this principle through the reasonable, reduced use of pesticides to protect both the environment and user health. The next step in the strategy is secondary prevention of exposure, which consists in reducing risks through technical and administrative collective means and protective measures. The problems involved in implementing these first two approaches to prevention in agriculture have been described in a Quebec study (Tuduri, Champoux, Jolly, Côté and Bouchard, 2016). In this context, to which must be added the specific characteristics of the organization of farm work (Fiske and Earle-Richardson, 2013; MacFarlane, Carey, Keegel, El-Zaemay and Fritschi, 2013), personal protection must necessarily play a significant role. The use of personal protective equipment (PPE) is one of the conditions of the safe use of products registered by the Pest Management

Regulatory Agency (PMRA) in Canada and is a regulatory requirement for pesticide users. Although the PMRA provides for the use of collective protection equipment (CPE) in the exposure assessment process, the recommendations given on labels rarely mention such equipment. There is a consensus in the scientific literature, however, about the low rate of use of PPE in situations where it is prescribed (Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; MacFarlane *et al.*, 2013; Mohammed-Brahim, 2009; Tuduri *et al.*, 2016).

International research has shown that the skin is the main route of exposure to the pesticides used in agriculture (Institut national de la santé et de la recherche médicale, 2013; Laughlin, 1996; Tsakirakis *et al.*, 2014) with the hands being the main site of contamination. Given the way farm work is organized and the way pesticides are used, however, the exposure of other body parts is estimated to be approximately 50%, and demands a targeted research and prevention approach. The exposure of the body excluding the hands is the subject of this study. Protection through the use of protective clothing (PC) is recommended in a wide range of situations. In addition to providing significant background information, one Quebec study has found that the use of protective clothing by apple growers is not systematic, which is consistent with the results of international research. Furthermore, skin exposure is perceived as being less of a risk than exposure through the respiratory tract (Tuduri *et al.*, 2016). Other evidence includes the fact that the protective clothing often worn in agriculture was developed for industrial use and has proven to be not particularly effective in testing of pesticide permeation (Agence française de sécurité sanitaire de l'environnement et du travail, 2010), as well as the lack of any certification for the protective clothing recommended in Quebec (Tuduri *et al.*, 2016). Findings from international studies, compiled for instance on the discontinued website International Center for Personal Protective Equipment for Pesticide Operators and Re-entry Workers (http://www.ic-ppe.org/), emphasize the need to develop new protective clothing adapted to the conditions of use in farming.

The first step in this study involved a literature review that looked at different perspectives on PPE use in general and protective clothing use in particular. The review helped with the groundwork for the data collection and is also used in the discussion of the study results. The survey of the methodological aspects of studies of PPE use also served to situate the contribution of this study in relation to the literature.

The second part of the study consisted in delving deeper into the results of an initial study of the use of pesticides and personal protective equipment in apple growing (Tuduri *et al.*, 2016). This part looked exclusively at skin exposure situations, on the one hand, and the pesticide mixing-loading, spraying and equipment-cleaning phases associated with the most regular and most significant exposure. Data collection therefore did not take into account either hand exposure or a wide range of secondary tasks that can also be associated with pesticide exposure.

For this study, a method based on the sociology of work and on ergonomics was used to examine common practices among apple growers for protection against skin exposure to pesticides under a variety of conditions, as well as the factors that facilitate or interfere with the wearing of protective clothing against skin exposure to pesticides.

The study draws, on the one hand, on action theory in sociology, according to which actors' strategies can be inferred from their practices, which are regular, repeated behaviours that can be documented empirically. Those practices are developed in a social context, and it is in that context that they must be analysed. They reveal the understanding and competency of the actors involved: they are adapted to the constraints and resources of the specific context in which they are developed, and the actors are able to explain them (Bourdieu, 1994; Crozier and Friedberg, 1977). The study also draws on the perspective of ergonomics, which considers the effects of a variety of economic, organizational, technical and personal determinants on work activity and actor practices (Garrigou, 2010). According to St-Vincent *et al.* (2011, pp. 43–44), a determinant is a "factor of the work situation that is at the root of the way a person can perform an activity"; moreover, a "determinant is itself often determined by a series of other factors." More specifically, in this report a determinant is a factor that explains the occurrence of exposure within that activity framework. The simultaneous effect of several determinants may, for instance, explain not only the use of pesticides, as well as the resulting exposure, but also growers' PPE use practices.

Qualitative data—that is, repeated observations over several work cycles under a variety of work and exposure conditions—were collected and then semistructured interviews were conducted in the field with a small sample of volunteer growers. An ergonomic work activity analysis was then applied to the observational data. Inductive analysis of the interview responses was used to supplement the activity analysis. The detailed analysis of skin exposure situations based on the documented observations was first done from a perspective that focused on the observed activity. That helped to identify the local determinants of exposure, which are often technical in nature. The analysis of the data from the observations and interviews took into account organizational factors that help explain the observed and described practices. The purpose of the analysis was to highlight the links between exposure situations, risk perception and the various prevention practices adopted by the apple growers. Thanks to a combined sociological and ergonomic approach, this project generated findings and recommendations firmly rooted in the realities faced by growers.

The findings presented here will be used to identify possible avenues for research and action designed to promote prevention awareness and training for farm workers. They will also facilitate the involvement of Quebec researchers in local and international projects to develop and test protective clothing for agricultural workers.

2. RESEARCH OBJECTIVES

Primary objective

This research project set out to examine common situations of skin exposure to pesticides in apple growing, as well as the factors that facilitate or interfere with the use of protective clothing.

To achieve this objective, there were two parts to the project:

1. A literature review

2. Data gathering in the field through observation of work activity and interviews

Secondary objectives

This study helped supplement the findings of a previous IRSST study on the use of PPE in apple growing in Quebec. The knowledge gained will serve to design further research projects focusing on the development of PPE and various initiatives to improve pesticide exposure prevention among apple growers.

3. METHOD

The study set out to examine skin exposure situations and link them with work practices, prevention practices and the wearing of protective clothing by apple growers. The study also looked at the factors that facilitate or interfere with the use of protective clothing.

To achieve this objective, the research project was divided into two parts: a literature review and data gathering in the field that involved observing work activity and conducting interviews. A brief section on terminology is provided below before the study methodology is presented.

3.1 Terminology

In this report, the meaning given to some terms may differ from the meaning attributed to them in other scientific fields. The following terms are used as defined below:

Exposure – Contact between a worker and a pesticide. Once exposed, the worker has been contaminated by pesticides, even though the effects of the contamination may not be noticeable.

Contamination – Physical presence of a contaminant in an environment, on an object, a person, or inside that person if the contaminant has been absorbed, regardless of whether personal protective equipment is worn.

Skin exposure situation – Situation where the likelihood of contact between the worker's skin and a pesticide seems high, regardless of the intensity of the exposure or whether personal protective equipment is worn. The study focuses on the exposure of the body excluding the hands.

Microexposure – Exposure limited in intensity (user only comes into contact with small amounts of pesticide) and duration (the transfer is brief), and in which the pesticide is visible to a certain degree (on PPE, equipment and tools, in the workplace). Microexposure situations are common, repeated and an integral part of the activity.

Identification of personal protective equipment

Two terms are used in this study to describe the clothing worn by growers: work clothing and protective clothing (PC). In the interests of clarity and consistency, the following definitions taken mainly from the Worker Protection Standard (WPS) (EPA Worker Protection Standard, 40 CFR, Part 170 (2017)), the occupational health and safety regulations specific to agricultural workers and pesticide handlers in the United States, are used.

Work clothing – Clothing worn by growers, whether or not they handle pesticides. In some cases, wearing long pants and a long-sleeve shirt may be the only guideline given to people who handle pesticides.

Protective clothing – Clothing or apparel intended to protect the body from contact with pesticides. Such clothing or apparel may cover or replace work clothing. This category includes:

- **Suits or coveralls** (one- or two-piece) – Made out of cotton or a polyester-cotton blend, they cover the entire body, except for the head, feet and hands. Dupont says that Tyvek® clothing meets the regulatory standards (Dupont, 2016b).

- **Chemical-resistant suits –** Suits made of a material that allows no measurable movement of the pesticide through the material during use. Dupont says that Tychem® clothing meets this regulatory standard.

- **Waterproof clothing –** Clothing made of a material that allows no measurable movement of water through the material during use. *Apple growers do not necessarily agree with this definition. They want waterproof clothing that does not allow spray solution, regardless of what formulation is used, to pass through it. They give the term "waterproof" a broader meaning that is closer to "chemical resistant."*

- **Clothing for protection against chemicals –** Clothing covering a large part of the body, worn to protect against chemicals, the criteria and performance requirements for which are clearly defined and standardized in, for instance, ISO 16602 (International Organization for Standardization, 2007). DuPont's Tyvek® and Tychem® clothing may be classified in this category, as well as its ProShield® line, or clothing in Kimberly Clark's KleenGuard line.

- **Clothing for protection against pesticides –** Protective clothing specifically designed to protect against liquid pesticides, the criteria and performance standards for which are clearly defined and standardized in, for instance, ISO 27065 (International Organization for Standardization, 2011).

3.2 Literature Review

The objective of the literature review was to establish the current state of knowledge on three main topics: skin exposure situations associated with the use of pesticides in commercial agriculture, the use of protective clothing against skin exposure, and the factors that facilitate or interfere with the use of this type of personal protective equipment. A section of the review looked into the methods used in studies that focused on PPE use. The characteristics and advantages of studies conducted in the field, in real farm work situations, are presented. The specialized literature on PPE against skin exposure was also reviewed. The review looked specifically at skin exposure situations associated with spray solution mixing, spray equipment loading and spraying operations conducted with towed spray equipment, with or without driver cabs, in all types of agricultural production. The populations targeted were all farm workers performing the targeted activities, whether owner-producers or paid employees. All kinds of protective clothing against skin exposure were considered.

An extensive survey of the literature published in French or English in developed countries (Canada, U.S.A., Australia, New Zealand, Europe) for the years 2000–2015 was carried out. A very small number of earlier publications were also included. Twelve databases were queried in May 2015 and June 2016: CCHST, Compendex, Embase, GEOBASE, Google Scholar, ICONDA, Inspec, ISST, OSH Update, Pascal, PubMed and TOXLINE. The sources were queried with the main keywords—commercial agriculture, pesticides, exposure and real situation, PPE—and terms used to specify them, such as field test, ergonomics, observation, task, activity, pesticides and agricultural production, pesticide mixing, spraying, towed spray equipment, protective clothing, suit, Tyvek®, comfort, thermal comfort, cost, availability, suitability for work, effectiveness, perception of risk, safety practices. Publications had to exclude studies conducted in the lab, greenhouse production, commercial applicators and animal production. Sources explored as part of an earlier project (Tuduri *et al.*, 2016) also served to identify other publications that were deemed relevant. Appropriate references for the work activity analysis and the specific situation of small businesses, taken from the fields of ergonomics and sociology, were also cited.

The aspects examined were grouped into major topics: extent of skin exposure, prevention practices, factors that explain PPE use (sociodemographic and socioeconomic factors, macrosocial perspective) and methodological characteristics of PPE studies.

The review helped us direct the data collection (develop appropriate interview forms), and analyse the observational data. It was also pursued parallel to the data collection, focusing on the factors that facilitate or interfere with the use of protective clothing against skin exposure to pesticides. The review was one of the specific objectives of the study and is presented as the report's first set of findings. The literature review also proved useful when it came to analysing the interviews and observations, as well as discussing the findings.

3.3 Original Data Collection: Observations and Interviews

For this study, a method based on both the sociology of work and ergonomics was used to examine apple growers' common practices for protection against skin exposure to pesticides under a variety of exposure conditions, as well as the factors that facilitate or interfere with the wearing of protective clothing against skin exposure to pesticides.

The study draws, on the one hand, on the theory of action in sociology, according to which actors' strategies can be inferred from their practices, which are regular, repeated behaviours that can be documented empirically. These practices are developed in a social context, and it is in that context that they must be analysed. They reveal the understanding and competency of the actors: they are adapted to the constraints and resources of the specific context in which they are developed, and the actors are able to explain them (Bourdieu, 1994; Crozier and Friedberg, 1977). The study also draws on the perspective of ergonomics, which considers the effects of a variety of economic, organizational, technical and personal determinants on work activity and actor practices (Garrigou, 2010). The simultaneous effect of several determinants may, for instance, explain not only the use of pesticides, as well as the resulting exposure, but also growers' PPE use practices.

Qualitative data collected through observations and in interviews with apple growers were used to analyse pesticide exposure situations and grower practices. Two different data collection methods were used in order increase the number of viewpoints and boost the validity of the results (St-Vincent, Denis, Imbeau and Ouellet, 2007). Repeated on-site observations, as well as post-observation interviews, were conducted. In this case, the observational data served to describe not only the constraints of the work and exposure situation in which the growers operate, but also the use of protective clothing and prevention practices in this context. The interviews supplemented the observations and helped to understand grower practices. With this approach, it was possible to observe real work situations, describe the constraints on growers and document how they describe their activity and the compromises they make. Through the combination of the two perspectives and the two types of data, the researchers were able to produce results that accurately reflected the growers' reality.

The research protocol is exploratory in the sense that the objective of the data collection was not to produce results representative of all possible skin exposure situations and all prevention practices among apple growers. The objective was rather to produce qualitative data that could be used to describe and explain the use of protective clothing and prevention practices, and to link them with typical exposure situations.

3.3.1 Recruitment of Volunteer Growers

The data collection was done at five apple-growing operations. The limited number was essentially due to the fact that it's hard to find growers who are available during the peak season. The five volunteer apple growers from the outskirts of Montreal were recruited through industry contacts.

The average age of the participants was about 56, only slightly higher than the average age of apple growers in 2013–2014, which was 53 (Tuduri *et al.*, 2016). Three of the five growers owned their operations, another worked on the farm that he had sold to his son and the fifth ran a family orchard that still belonged to his parents. Their situations with respect to ownership and the financial health of their businesses seemed reasonably positive. The average size of the participants' orchards was 12 ha on average at the time of the data collection, whereas the average size of Quebec orchards was 8.4 ha in 2013.

The original data collected came from the observation of apple growers at work and from semistructured interviews with them. The study was granted an ethics approval certificate by the IRSST's Research Ethics Committee. All the participating growers were given detailed oral and written explanations about the study objectives, the terms and conditions, and privacy guarantees. They all signed a consent form and kept a copy of it.

3.3.2 Organization of Data Collection

To organize the data collection, the researchers were in regular contact by phone with the growers who had agreed to take part in the study. The growers were also asked to give the research team sufficient advance notice of when they would be spraying to allow the researchers time to travel to the orchard so they could be on site for the operation. A commitment from the researchers about adapting to the growers' operating constraints and not delaying their work was a key condition of the growers' agreement to take part.

The orchard visits, observations and interviews took place in the Montérégie and Basses-Laurentides regions between early June and late July 2015. On a few occasions, several orchards were visited on the same day. The visits were organized so that the researchers could monitor the growers' activities through a complete treatment cycle—the entire chain of steps from start-up to mixing of the spray solution and loading of the spray equipment, the spraying itself and return to the loading site and clean-up.

The observations and interviews were repeated and planned so that the researchers could examine a variety of work and exposure situations, under four different exposure conditions (Table 1). The time of the season, associated with different ambient temperatures (cool or warm), as well as whether spraying operations were conducted with or without a vehicle cab, were deemed to be significant factors, considering the presumed effect of ambient temperature and duration of spraying on a worker's willingness to wear protective clothing. The collection also provided data for examining the use of two separate families of pesticides: fungicides and insecticides. As a result, the researchers were able to compare data collected from the same grower under different conditions. Repeating the observations and interviews also helped the researchers to familiarize themselves with the sites and work situations, as a relationship of trust with the growers makes it more likely that the researchers will be able to observe usual practices, rather than practices that their sole presence could have prompted, as well as more in-depth discussions concerning factors influencing decisions about the use of PPE. Observations were made at five orchards, over the course of 19 different situations; a fourth meeting with one of the five growers could not be arranged.

Table 1. Breakdown of visits to five orchards, by contrasting exposure conditions

Observations / Exposure conditions — Grower / Tractor with or without cab	Date (2015) and start time of observations	Temperature (°C)	Product types	Activities observed	Total length of observations filmed, by grower (hh:mm:ss)	Total length of interviews, by grower (hh:mm:ss)
No. 1 (with cab)	June 4, 7 a.m.	14–24	Insecticide, fungicide and fertilizer	Mixing-loading	01:00:33	02:06:47
	June 26, 7:30 a.m.	18–20	Fungicide and fertilizer	Mixing-loading AND spraying		
	July 2, 5 p.m.	20	Insecticide	Mixing-loading		
	July 11, 7 a.m.	18	Insecticide	Mixing-loading AND spraying		
No. 2 (without cab)	June 4, 7 p.m.	24	Fungicide	Mixing-loading AND spraying	01:17:17	02:38:20
	June 11, 6 p.m.	23	Insecticide	Mixing-loading AND spraying		
	June 17, 10:30 a.m.	18	Insecticide	Mixing-loading		
	June 26, 6 p.m.	22	Fungicide	Mixing-loading AND spraying		
No. 3 (with cab)	June 4, 3:30 p.m.	24	Insecticide and fertilizer	Mixing-loading	00:07:35	02:18:02
	June 25, 4 p.m.	21–27	Insecticide and fertilizer	Mixing-loading AND spraying		
	July 25, 9 a.m.	21	Fungicide	Mixing-loading AND spraying		
No. 4 (without cab)	June 4, 10:30 a.m.	18	Fungicide and fertilizer	Spraying	00:44:05	02:36:35
	June 17, 7:30 p.m.	19	Insecticide and fungicide	Mixing-loading		

Observations / Exposure conditions — Grower / Tractor with or without cab	**Date (2015) and start time of observations**	**Temperature (°C)**	**Product types**	**Activities observed**	**Total length of observations filmed, by grower (hh:mm:ss)**	**Total length of interviews, by grower (hh:mm:ss)**
	July 2, 8:30 p.m.	18	Insecticide and fungicide	Mixing-loading		
	July 28, 7 p.m.	19	Insecticide and fertilizer	Mixing-loading AND spraying		
No. 5 (without cab)	June 1, 2 p.m.	11	Fungicide	Mixing-loading AND spraying AND clean-up	01:10:34	02:09:44
	June 4, 1 p.m.	23	Insecticide	Mixing-loading AND spraying		
	June 12, 8:30 a.m.	20	Fungicide	Mixing-loading AND spraying		
	July 9, 10 a.m.	20	Insecticide and fungicide	Mixing-loading AND spraying		

Some observations were made starting at seven in the morning, while others, begun late in the evening, were completed after midnight. The growers themselves organized their work so as to avoid the hottest times of the day as much as possible. The thermometer reading at the time of the observations ranged between 11°C and 24°C, and most growers were met at least once when the ambient temperature was below 18°C (see Table 1). A small number of observations were made in conditions where the growers thought the ambient temperature was cool.

All the growers were observed and interviewed when they were using only one of the two product types targeted: fungicide or insecticide. Observations were also made when several products were being used simultaneously. Observations were made for products in liquid, powder or granular form; the use of products in water-soluble packets was also observed. Last, three of the five growers did their spraying from a tractor without a cab, which is a higher than expected proportion: one recent study estimated that around 30% of apple growers sprayed without a cab in 2013–2014 (Tuduri *et al.*, 2016).

3.3.3 Direct and Filmed Observations

The data were collected in the field by a team of three researchers. As all the observations were systematically made by two of the researchers, the direct analysis of the exposure situations during the observations served to identify the main characteristics of the exposure situation and the clothing worn, as well as to prepare the subsequent validation interviews for the situations observed. A preparatory team meeting was held to review the information to be collected at the next visit.

Observations focused on skin exposure situations, prevention practices and the use of protective clothing during complete activity cycles. Observations were filmed using two video cameras, so that a finer analysis of the activity could be performed later. A stationary camera, set up so that it could provide continuous monitoring of the mixing and loading site, as well as of the grower in the sagittal plane during his/her interaction with the spray equipment, provided observational evidence of the grower's posture. A second camera, a mobile one, was used to observe exposure situations from different angles and to film additional characteristics of the work sites or unforeseen circumstances, as needed. One research team member used the mobile video camera, while the other took photographs and noted aspects of the activity that could be discussed in the interviews.

Observations of the start-up, spray solution mixing and loading, and clean-up phases were continuous. These phases of the activity were carried out in fixed locations, which facilitated the researchers' work. However, the phases are associated with big variations in activity, which explains why it is worth analysing them in detail. In contrast, it was not deemed necessary to film the whole of the spraying phase; in this case, the grower moved around on the tractor, and unless an incident occurred, there was very little variation in the activity despite the length of time it took. Observations were conducted at the start of the spraying, when switching from the end of one row to the beginning of the next, from observation posts at height in some cases, and also when tractors returned to the loading station. Incidents were observed in the two main phases. As a result, not all the possible exposure situations were examined exhaustively.

Observations began in the places where the growers put on their PPE, in the vicinity of their pesticide storage facility or loading site. On some occasions, growers had already donned their PPE when the meeting took place. All in all, observations were made for 24 mixing-loading operations, 12 spraying operations and one clean-up operation; during some visits to growers, an initial cycle, plus one or two mixing-loading phases, were observed. Detailed actions (e.g., removing the raw material from the packaging, measuring, weighing, pouring and mixing the pesticide), and the incidents (e.g., unintentional release from the nozzles, overflowing of the sprayer tank) associated with contact with pesticides were observed and filmed. The observations helped the researchers to understand the activity by examining a variety of situations. The average length of the mixing and loading operations was 12 minutes, while the spraying operations took about 60 minutes on average. The total length of the observations was estimated to be 23 hours.

3.3.4 Interviews

Growers' comments on their activities served as a point of departure for the interviews, which were systematically conducted by the two researchers at the end of the activity cycle. In a small number of cases (3 visits out of 19) the growers had to continue on with their activities immediately after the cycle in which the observations were made, and so the interview was done over the phone at the end of the day or the next morning. Some of the questions were asked during the observations. An interview checklist was developed on the basis of the review of the literature and data collected in an earlier study (Tuduri *et al.*, 2016). The semistructured interviews focused first of all on the exposure situations observed, the usual or unusual nature of each situation, the work methods and prevention practices, the problems and work strategies chosen to tackle them, and trade-off situations. The interviewers also asked about the protective clothing used, the PC chosen, the place of purchase, the cost, the perception of risk, the comfort of the PPE (suitability for work, thermal comfort) and the work clothing worn under the PC, as well as the factors associated with the decision about whether to wear the PC or not. The purpose of the interviews was to find links between exposure situations, perceptions, prevention practices and PC use, and to identify the organizational and technical factors associated with exposure situations.

The interviews supplemented the observational data in two ways. They helped to explain the practices and actions observed and to provide specific information about how operators regarded risk, in particular. The interviews also served to enhance the analysis of the observational data and to take into account organizational determinants of exposure situations, which cannot be observed. The growers also often referred to other similar or contrasting situations, which helped to enrich the information on the usual or unusual nature of the situations observed and on intraindividual variations in practices. This spontaneous development added depth to the information produced, and helped offset the effect of the small sample size on the validity of the results.

To facilitate discussion between the researchers and the growers, and with the growers' written consent, the interviews were recorded. At the end of each interview, the researchers orally provided the grower with a review of the key points of the observed situation and a summary of the main factors facilitating or interfering with the wearing of protective clothing. At the end of the fourth visit, a longer interview served to go back over all the observations and practices, confirm growers' explanations about their practices and specify the factors facilitating or interfering with the wearing of protective clothing.

Consequently, three interviews of an average length of 20 minutes and a final interview that lasted 25 minutes on average were conducted with each grower, for a total of 19 interviews. With one grower, only three interviews were done, instead of four.

3.4 Analyses

The objective of the data collection was to produce qualitative data for describing common exposure situations and to establish links with perceptions, prevention practices and the use of protective clothing. The objective was not to produce exhaustive results representative of all possible skin exposure situations. The data were discussed with the growers on several occasions in the regular interviews and the final interview, as well as within the research team. The data analysis was validated several times.

The activity analysis approach developed in ergonomics was used to analyse observational data recorded on video for the purpose of obtaining an overview of recurring exposure situations, the main points of contact and main determinants of exposure in the course of work activities. The observations also helped the researchers visualize PC use and usual prevention practices for the observed exposure situations.

The analysis of these observations, enhanced by the interviews, divided the pesticide use activity into four phases: start-up, mixing-loading, spraying and clean-up. This categorization was also congruent with the reviewed literature. Thanks to the observations, some phases could be further subdivided into various steps:

1. Start-up
    a. Planning treatment
    b. Donning clothing
    c. Attaching sprayer to tractor and towing it to loading station
2. Spray solution mixing and sprayer loading
    a. Filling with water
    b. Measuring
    c. Adding pesticides to sprayer tank
    d. Storage

3. Spraying
4. Clean-up

For analysis purposes, the videos from the two cameras, providing different viewpoints, were synchronized using the Kinovea® video player to allow simultaneous viewing. The videos were then viewed in their entirety by the ergonomist who had taken part in all the field visits. The following procedure was applied to each of the growers' videos for the 19 visits: (1) a detailed, systematic analysis was carried out for each phase of the work; (2) the videos shot at a given grower's when repeating a phase (e.g., second spraying) were viewed to check for the presence of new elements, for the purpose of confirming or refining the first analysis.

The detailed analysis is based on a description of the activity of each grower, describing each action (example for the action "measure the product": go into the shed, get the bucket, bring it outside, open the stopper, turn the measuring glass, etc.) and illustrating it with screenshots. For each action, the ergonomist recorded the presence of observable determinants of exposure, exposure indicators and the areas of the body exposed. More specifically, these observable characteristics are

- pesticides (e.g., packaging, form, family, viscosity),
- equipment (e.g., sprayer, tractor, tools, containers),
- set-up (e.g., location of water supply points, storeroom, set-up around sprayer),
- posture (e.g., supported, bent over, crouching),
- exposure sites (e.g., various parts of the body) and
- contact (e.g., visible indication of contact with product, such as cloud, splashing, direct contact).

Other aspects that could have an influence on exposure were also noted, such as

- all trips between pieces of equipment and components of set-up on premises,
- the PPE worn and its use (e.g., putting on, taking off), as well as
- aspects of work organization (e.g., work schedule, number of repeats of work phases or steps in the activity).

A summary was then produced to consolidate the information. First, the exposure situations observed over the course of the four visits to each grower were described, which helped to make connections to what was said in the interviews. Second, all the skin exposure situations for the 19 visits were grouped by activity phase, or even by step. The summary was also useful in studying intra- and intergrower variability, which was one of the study objectives.

The findings present all the skin exposure situations grouped according to the four phases of the activity: start-up, mixing-loading, spraying and clean-up. The findings are first presented in the form of a description of the activity and the associated exposure situations. The description tends to underscore the usualness of the exposure situations. Information from the interviews is then incorporated to supplement the descriptions. The exposure situations are then summarized in tables 2 to 8. Five variables represent different aspects of the exposure situation: the action (what the grower does, grower's actions), the contact observed (what the grower comes into contact with), the site of the contact (parts of the body affected), the form of the product involved (commercial formulation, spray solution, residue) and the determinants of exposure (set-up of premises, equipment, products).

The tables present the determinants of exposure that are the easiest to observe and facilitate the understanding of a significant part of the exposure situation. They highlight the need for a good design of the set-up of the mixing-loading facilities, tractors, spraying equipment and product containers, taking the work activity into account in order to reduce exposure (note: to pesticides, but design also affects work posture, force required, etc.). The more detailed descriptions and summaries combining the data from the observations and interviews acknowledge, however, that apple growers' activity is subject to a wide range of environmental, economic, organizational and technical determinants and constraints.

The presentation of the exposure situations also includes a description of any incidents observed and the PPE worn. With regard specifically to protective clothing against skin exposure, the fine analysis of the observations allowed the researchers to examine the characteristics of the clothing worn, the time it was put on and taken off, the place where it was stored, the methods of putting it on and taking it off, the movements made to adjust the clothing (opening/closing the zippers, removing a piece of clothing) or the presence of sweat, marks on the skin, etc. The analysis of the observations also helped to highlight the number and variety of prevention practices developed by growers and incorporated into their work activities.

4. FINDINGS

4.1 Literature Review

The use of personal protective equipment as a means of protection against exposure to pesticides comes third in terms of application and effectiveness among approaches to prevention, after the priority measures that are elimination of the hazard at source and implementation of administrative and engineering measures. In practice, however, given the limits on primary and secondary means of prevention and the characteristics of agricultural work, a very significant part of user protection against pesticides in agriculture relies on the use of PPE (Jouzel and Dedieu, 2013). The purpose of this review was to determine the state of knowledge on the use of PPE, and protective clothing (PC) in particular, as well as on the pesticide exposure prevention practices employed by apple growers.

Exposure to pesticides through the skin is covered first. The review then looks at PPE and PC, the way they are used, their effectiveness and their characteristics. Prevention practices and their links with PPE use in general are discussed. The survey then reviews the findings of studies that have examined the links between various types of factors and the use of PPE or prevention practices. These factors are grouped by the level of analysis to which they correspond, as different types of factors require different types of protective measures (Feola and Binder, 2010; Galt, 2013). One section covers the results of studies that took a microsocial analysis perspective to document the effects of stakeholders' "dispositions" (perceptions and ideas, values, conceptions and knowledge) and sociodemographic factors (age, education, language, ethnic origin). A second section looks at the results of studies that took a meso- and macrosocial analysis perspective, at the company or societal level, to document the effects of socioeconomic factors (income, employment status, migratory status, economic constraints, institutional framework) on prevention practices. To conclude, the methodological characteristics of studies on PPE are discussed.

4.1.1 Extent of Exposure through the Skin

Research in toxicology and epidemiology has established that exposure through the skin is the most common form of exposure in agriculture (Aggarwal *et al.*, 2014; Laughlin, 1996; Machera, Goumenou, Kapetanakis, Kalamarakis and Glass, 2003; Perry and Marbella, 2002; Protano, Guidotti and Vitali, 2009; Zhao, Yu, Zhu and Kim, 2015). Some studies report that the majority of accepted compensation claims involve exposure of the skin to pesticides (WorkSafeBC, 2010).

The hands account for at least half of total skin exposure (Baldi *et al.*, 2006; Hines, Deddens, Coble, Kamel and Alavanja, 2011; Moon, Park, Kim, Lee and Kim, 2013). Given how pesticides are used in agricultural production, overall exposure of the other parts of the body is, however, almost as significant, accounting for approximately 50% of exposure during the mixing-loading phase and just over 40% of exposure when spraying with towed spray equipment. These figures are from studies on vineyards (Baldi *et al.*, 2006) and on apple and peach production (Hines *et al.*, 2011; Moon *et al.*, 2013). Skin exposure is deemed to be more significant during mixing and loading because of the concentrated form of the products (commercial formulation used), and less significant during actual spraying of diluted products (Aggarwal *et al.*, 2014). Overall skin exposure is, however, significantly higher when spraying is done with a tractor without a cab or with an open cab, and skin exposure through the thighs, arms, back and chest can then exceed that through the hands (Baldi *et al.*, 2006; Zhao *et al.*, 2015). Exposure in the case of spraying using a tractor with a closed cab, including getting into and out of the cab and the resulting contamination of the interior, is chiefly associated with the respiratory tract. Nevertheless, skin exposure can still occur as a result of contact with residue found on the tractor or spray equipment (Aggarwal *et al.*, 2014).

Spraying from a tractor without a cab, although still done and associated with a high skin exposure rate, is increasingly rare among apple growers in North America. Still, skin exposure through parts of the body other than the hands has also been associated with a wide range of secondary, unavoidable tasks that must frequently be repeated. Contact with residue on trees when re-entering treated blocks to perform tasks such as screening, pruning and harvesting can also be associated with skin exposure, which will vary with the time since spraying was done and whether the residue is wet or dry (Aggarwal *et al.*, 2014). Exposure to residue can also occur when adjusting spray equipment during spraying, or when performing mechanical repairs on equipment (Hines *et al.*, 2011; Zhao *et al.*, 2015).

4.1.2 Personal Protective Equipment

Agricultural pesticide users are strongly urged to read packaging labels to find out the instructions specific to each product. For most pesticides, the instructions recommend at least the wearing of chemical-resistant gloves and safety goggles (Jouzel and Dedieu, 2013; Perry and Marbella, 2002). One recent study has shown that pesticide labelling in Quebec and elsewhere in Canada has a number of shortcomings with respect to skin protection. For instance, protective clothing is not described clearly and is not certified in any way, which makes it difficult to choose PC according to needs and required performance levels (Tuduri *et al.*, 2016). The Pest Control Products Act (S.C. 2002, c. 28) does not set out any specific definitions for the protective clothing requirements on labels.

Certification describes situations where regulatory requirements regarding PPE take the form of a standard that sets and specifies performance criteria and requirements. The certification for protective clothing is not systematic in North America (Tuduri *et al.*, 2016). Compliance describes a situation where a practice is in agreement with a requirement—such as wearing PPE as recommended on the label of the pesticide being used.

4.1.2.1 Use and Characteristics

The limited, non-systematic use of PPE in agriculture is well documented in the scientific literature (Carpenter, Lee, Gunderson and Stueland, 2002; Galt, 2013; Hines, Deddens, Coble and Alavanja, 2007; Lambert and Grimbuhler, 2015; Nicol and Kennedy, 2008; Perry and Marbella, 2002; Tuduri *et al.*, 2016) and acknowledged by Canada’s Pest Management Regulatory Agency (PMRA) and by Health Canada’s Regions and Programs Bureau for compliance and enforcement (Pest Management Regulatory Agency, 2016). According to two surveys done recently in Quebec, approximately 50% of apple growers report using protective clothing always or often (ministère de l’Agriculture, des Pêcheries, et de l’Alimentation du Québec, 2014; Tuduri *et al.*, 2016).

The proportion of pesticide users who report using PPE varies greatly by study, by country where the studies were done, by the way the data were collected and by type of personal protective equipment. For example, MacFarlane *et al.* (2013) and Salvatore *et al.* (2008) consider long-sleeve clothing to be part of PPE. In a study of PPE use among Greek tobacco growers that explicitly excluded this type of clothing, Damalas, Georgiou and Theodorou (2006) included coveralls, without specifying whether they were made of cotton, cotton and polyester, or were disposable Tyvek® suits, as did Hines *et al.* (2011). In contrast, other authors (Stone, Padgitt, Wintersteen, Shelley and Chisholm, 1994) describe long pants and long-sleeve shirts as being work clothing, and disposable suits as being PPE.

It is actually extremely difficult to assess the compliance of practices with legal requirements on the basis of public data, owing to shortcomings in terms of PPE definitions, clear and consistent designations, and the criteria used in the literature to define what constitutes “proper use” of PPE. In Canada, the PMRA considers long pants and a long-sleeve shirt to be clothing that protects against pesticides, and use of such clothing is recommended on the labels of crop protection products. In Europe, these same items of clothing are regarded as work clothes that do not meet the criteria of European Council Directive 89/686/EEC (Council of the European Union, 1989) or the underlying standards that specify performance criteria and requirements, and therefore cannot be considered to be PPE.

The wearing of PPE has also been studied in the literature by researchers seeking to assess an acceptable level of personal protection. Blanco-Munoz and Lacasana (2011) consider that the wearing of three or more items of waterproof skin-protective PPE (such as clothing, gloves, boots) during all activities constitutes proper use. Nicol and Kennedy (2008) define the best PPE use as the simultaneous wearing of chemical-resistant gloves, a respiratory protective device and a spray suit. Matthews (2008) mentions the recommended wearing of five key items: long pants and a long-sleeve shirt (or a suit), gloves, boots and a visor or face shield. Schenker, Orenstein and Samuels (2002) characterize better protection as being the wearing of three items of PPE among gloves, protective clothing, cartridge or other respiratory protective devices, visors or safety goggles, and rubber boots at least 50% of the time. Finally, only Avory and Coggon (1994) use the following of PPE recommendations on product labels as a safe behaviour criterion.

PPE effectiveness is assessed on the basis of its capacity to reduce pesticide exposure. The vast majority of published studies concern gloves and protective clothing of different types. Effectiveness can be demonstrated qualitatively and visibly by adding fluorescent tracers to the spray solution. Exposed or protected areas are revealed when subjected to UV rays (Fenske, 1988; Samuel and St-Laurent, 1996; Samuel, St-Laurent, Dumas, Langlois and Gingras, 2002). Skin exposure can also be measured by means of patches placed on either side of an item of protective clothing or glove to measure pesticide penetration. Using this approach, regulatory agencies can recommend different types of protective clothing and gloves and attribute protection factors to them. One recent exhaustive review of the literature would seem to confirm the appropriateness of the protection factors chosen by the PMRA, in particular, but the small number of clothing items and product formulations tested, the lack of studies listed and their methodological differences make it hard to reach a definitive conclusion on the subject (Tuduri *et al.*, 2016).

The body's pesticide contamination can also be measured biologically (pesticides or pesticide metabolites in urine or blood) to assess PPE effectiveness. However, interindividual variability in metabolization, the need for large numbers of samples and the small number of known metabolites currently limit the applicability of this type of measurement. Furthermore, with the current state of knowledge, it is not possible to associate biological contamination results with a specific route of exposure, at least not with certainty. Biological measurements must therefore be supplemented with external exposure measurements (respiratory and skin), observations or an investigation of safe practices in order to properly assess the effectiveness of the PPE used (Aprea *et al.*, 1994; Aprea *et al.*, 2004; Davies *et al.*, 1982; Lander and Hinke, 1992; Salvatore *et al.*, 2008).

Kiefer (2000) lists some studies that examine PPE effectiveness, without, however, specifying whether the reduction in exposure achieved was sufficient to reach an acceptable level of exposure. Compliance with PPE requirements under the U.S. Worker Protection Standard is clearly associated with reduced exposure to organophosphorus insecticides (Salvatore *et al.*, 2008).

On the other hand, some authors have documented that the reduction in exposure due to the use of PPE may be limited. Among users reporting appropriate knowledge and use (not verified) of required PPE, biological measurements still reveal pesticide contamination (Salvatore *et al.*, 2008). Recommended protective clothing may not have been tested for agricultural use, and wearing it may in fact result in increased exposure (Baldi *et al.*, 2006; Garrigou, Baldi and Dubuc, 2008). The effectiveness of the protection provided by PPE varies not only with the PPE used, but also with how it is used and with work methods (Garrigou *et al.*, 2008; Hines *et al.*, 2008; Vitali, Protano, Del Monte, Ensabella and Guidotti, 2009). Improper or non-systematic use of PPE also reduces the degree of protection (Baldi *et al.*, 2006; Brouwer, Marquart and Van Hemmen, 2001; Lambert and Grimbuhler, 2015). Poor maintenance or improper storage of PPE, reusing disposable suits, or using already saturated respiratory protection cartridges, for instance, can compromise the effectiveness of the protection (Navarro, Denis and Grimbuhler, 2011).

Some PPE characteristics may constitute factors that facilitate or interfere with its use. Ideally, skin protection should offer effectiveness, thermal comfort and good social acceptability (Branson, DeJonge and Munson, 1986). It is known that thermal comfort plays a key role in pesticide users' decisions about wearing PPE, especially protective clothing (PC). It is sometimes noted that protective clothing is seldom worn because it is uncomfortable (Garrigou *et al.*, 2008; Navarro *et al.*, 2011). Comfort is inversely proportional to the air permeability of the fabric and clothing, and high temperatures will exacerbate any discomfort (MacFarlane *et al.*, 2013).

The comfort and effectiveness of PC vary with the materials used: there seems to be broad recognition that PC made of cotton is the most comfortable (Branson *et al.*, 1986; Chester, Adam, Inkmann Koch, Litchfield and Tiunman, 1990; Davies *et al.*, 1982; DeJonge, Vredevoogd and Henry, 1983). KleenGuard® LP and Gore-Tex® clothing are better accepted than the various Tyvek® products (Branson *et al.*, 1986; Chester *et al.*, 1990; Krieger, Dinoff, Korpalski and Peterson, 1998). A possible compromise between the comfort and effectiveness of the protection has also been studied. PC made of a cotton and polyester blend provides better protection. Tyvek® PC is considered to be less comfortable than PC made of Gore-Tex®, which in turn is less comfortable than cotton PC (Branson *et al.*, 1986). Depending on the studies and target populations, contradictory results about preferences with regard to PC comfort and effectiveness have been reported. For some users, comfort is the main quality sought in PC (Perkins, Crown, Rigakis and Eggertson, 1992). One study has reported that comfort is a more important criterion than effectiveness among apple growers in Virginia (Keeble, Norton and Drake, 1987), while DeJonge *et al.* (1983) found that fruit growers in Michigan are more concerned about protection than comfort.

Suitability for work also has an influence on PPE and PC use. Some users feel that wearing PPE slows them down (Austin *et al.*, 2001; MacFarlane *et al.*, 2013; Perry and Bloom, 1998). Some types of PC are cumbersome and hamper work performance (Isin and Yildirim, 2007; MacFarlane *et al.*, 2013). The benefits of PC do not sufficiently outweigh the disadvantages of wearing it (DeJonge *et al.*, 1983; Nicol and Kennedy, 2008).

The possible effect of the cost of PPE on its use has also been studied. Where the cost is considered to be high, it raises an obstacle to its use (Damalas *et al.*, 2006; Navarro *et al.*, 2011; Perry and Bloom, 1998; Van Tassell, Ferrell, Yang, Legg and Lloyd, 1999). High perceived cost also explains the reuse of disposable suits, with or without cleaning (Garrigou *et al.*, 2008; Navarro *et al.*, 2011). PPE availability also has an impact on practices (MacFarlane *et al.*, 2013; Perry and Bloom, 1998). Some types of PPE commonly used in workplaces, especially long-sleeve shirts, gloves and boots, are not necessarily appropriate for real exposure situations (MacFarlane *et al.*, 2013).

4.1.3 Factors That Explain PPE Use

Aside from the actual characteristics of the PPE, there are many different factors involved in PPE use, and these factors work in complex ways (Salvatore *et al.*, 2008). The need to accurately characterize the populations before drawing any conclusions is a key point in a number of lines of research.

The concepts of “dispositions” (perception and representation of risk, values, attitudes, beliefs, knowledge, social norms and peer pressure) and capacities (resources of all kinds) have been used in relation to the social practices of stakeholders (Bourdieu, 1994; Crozier and Friedberg, 1977) and have been applied to OHS (Champoux and Brun, 2010; Walters, 2001).

Several studies have examined the dispositions of stakeholders in relation to PPE use. According to those studies, as many as three of every four users consider that pesticides carry risks for human health and the environment (Galt, 2013; Isin and Yildirim, 2007). Research has been taking a keen interest in the perception of risk, which would appear to play a determining role in decisions to comply with recommended prevention practices, such as the wearing of PPE, and regarding the choice of pesticides (Boissonnot and Grimbuhler, 2012; Union régionale des caisses d’assurance maladie de Bretagne et Direction régionale des affaires sanitaires et sociales de Bretagne, 2003). Factors that influence risk perception also have to be studied in order to gain a better understanding of health needs and to be able to plan OHS prevention programs (Wadud, Kreuter and Clarkson, 1998).

For some authors, PPE use is the most direct, most visible indicator of risk perception; high risk perception should translate into increased use of protective equipment (Boissonnot and Grimbuhler, 2012; Schenker *et al.*, 2002). In some cases, the perception of safety is more positive among operators who wear several items of PPE (Lambert and Grimbuhler, 2015). Overall, PPE use seems greater at the spray-solution-mixing phase and for insecticides, and lesser in the spraying and clean-up phases and for all the other tasks requiring re-entry into already sprayed areas, which is consistent with the documented perception of risk according to work phases (MacFarlane *et al.*, 2013; Nicol and Kennedy, 2008; Tuduri *et al.*, 2016).

Researchers have shown that there are a number of specific aspects to the representation of chemical risk. First, "whatever is toxic in the work environment is seen as a 'hidden constraint,' in that it is not readily recognizable. As a result, it does not—or at least does not appear to—constitute a significant determinant of the compromises the operator makes to fulfill the requirements of the task, from the standpoint of possibly hazardous contact with toxic substances" (Mohammed-Brahim, 2009).

Occupational toxicology also raises the question of the link between workers' representation of risk and their practices. "How do we explain, for instance, that winegrowers who choose phytosanitary products that are sufficiently toxic to kill weeds or harmful insects are not more aware of how they're risking their own health? How do we explain that the compromises they end up making at work are often harmful to their own health, when they know perfectly well that the products are hazardous?" (Mohammed-Brahim and Garrigou, 2009).

Other researchers have looked at the influence of values and culture on the perception of risk and on practices (Feola and Binder, 2010). Some studies have investigated the effect of attitudes and personality on the perception of risk and prevention practices; it has been noted that people who are judged to be of a risk-accepting personality type (Dellavalle, Hoppin, Hines, Andreotti and Alavanja, 2012) or a depressive personality type (Beseler and Stallones, 2010) were less likely to follow instructions about PPE and pesticide use. In some populations, the observed health effects of pesticides are attributed to individual allergic reactions or to a person's fragile health rather than to the pesticides themselves (Galt, 2013; Perry and Bloom, 1998; Snipes *et al.*, 2009).

The perception of the risk associated with pesticides is not uniform; it varies by product, and the most effective pesticides are often perceived as being the most toxic for human beings (Boissonnot and Grimbuhler, 2012; Union régionale des caisses d'assurance maladie de Bretagne et Direction régionale des affaires sanitaires et sociales de Bretagne, 2003). Parameters such as smell, form and class of a product—insecticides, for example—have a strong influence on the perception of risk. Skin is considered by science to be the main route of exposure to pesticides, but a high proportion of users perceive the respiratory tract to be the main route because of the smells, visible particles and suspended matter resulting from spraying (Boissonnot and Grimbuhler, 2012; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001).

Some researchers have noted that growers' personal experiences have a greater influence on their perception of risk than scientific information does (Boissonnot and Grimbuhler, 2012; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Isin and Yildirim, 2007; Judon, Hella, Pasquereau and Garrigou, 2015). The lack of clear information about risk may exacerbate this situation (Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001). Among the personal factors investigated, experience of harmful health effects and concerns about personal health are associated with a high perception of pesticide-related risk, better knowledge about risk and safer practices, including the wearing of PPE (Adjémian, Grillet and Delemotte, 2002; Ali, Clayden and Weir, 2006; Carpenter *et al.*, 2002; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Feola and Binder, 2010; Galt, 2013; Kearney, Xu, Balanay, Allen and Rafferty, 2015; Lichtenberg and Zimmerman, 1999; Nicol and Kennedy, 2008; Wadud *et al.*, 1998). It has also been noted that an incident involving significant exposure to pesticides does not necessarily convince someone to use PPE (Alavanja *et al.*, 1999).

Some studies have shown that a high perception or good awareness of risk and knowledge of the harmful effects of pesticides are not enough to change people's behaviour (Isin and Yildirim, 2007), whereas the reverse has also been observed (Ali *et al.*, 2006; Boissonnot and Grimbuhler, 2012; Union régionale des caisses d'assurance maladie de Bretagne et Direction régionale des affaires sanitaires et sociales de Bretagne, 2003). Some authors emphasize the need to take into account the effects of psychosocial variables on perceptions and representation of risk in specific population groups, such as young people or migrant workers. Risk perception is not reflected directly in behaviour and prevention practices, which are, it seems, also influenced by economic and social constraints, and by characteristics such as age, professional experience and level of education. Also, practices may not be consistent with perceptions of risk (Ali *et al.*, 2006; Galt, 2013; Isin and Yildirim, 2007; Nicol and Kennedy, 2008; Perry, Marbella and Layde, 1999).

The perception of being able to control risks may give different results. Having access to information on recommended prevention practices may result in a reduced perception of risk and not necessarily foster the adoption of safe practices such as the wearing of PPE (Ali *et al.*, 2006). The perception that exposure can be controlled has also been associated with a greater likelihood of adopting practices that protect health (Wadud *et al.*, 1998). The false impression of having adequate knowledge about exposure may in some cases be associated with unsafe practices (Olsen and Hasle, 2015).

Some studies have noted that people who think they have good control over the risk to which they are exposed have less safe practices and do not wear PPE, for instance. Other studies have documented that workers or small-scale growers who do not have any latitude to modify their working conditions may say they are helpless to protect their own health and become fatalistic and resigned about the possibility of protecting themselves against the effects of pesticide exposure (Perry and Bloom, 1998; Strong, Thompson, Koepsell and Meischke, 2008). Other authors report that the perception of being able to exercise some control over one's work is associated with intentions of safe practices (Colémont and Van den Broucke, 2008; Wadud *et al.*, 1998).

The effect of knowledge on OHS practices has been studied extensively. It is frequently reported that agricultural producers think that the information available on the health risks associated with pesticide use is inadequate (Perry and Bloom, 1998; Perry and Layde, 1998; Tuduri *et al.*, 2016). Increasing knowledge is the way most often recommended to improve OHS practices.

A number of studies report incorrect knowledge about the main route of exposure (Damalas *et al.*, 2006; Martinez, Gratton, Coggin, René and Waller, 2004; Quandt, Arcury, Austin and Saavedra, 1998). The respiratory tract rather than the skin is still often regarded, wrongly, as the main route of exposure (Martinez *et al.*, 2004). The fact that the effect of exposure may be (1) immediate or long-term, or (2) acute or chronic, makes the perception of risk more complex (Commission des normes de l'équité de la santé et de la sécurité du travail, 2016). Exposure that has immediate, even acute, effects, as in the case of exposure via the respiratory tract, is often perceived as being more dangerous than exposure that has long-term effects and may be chronic, as in the case of skin exposure (Martinez *et al.*, 2004).

The findings regarding the effects of OHS training on safe behaviour are contradictory (Hwang *et al.*, 2000). Some authors have concluded that it has a positive effect (Ali *et al.*, 2006; Damalas and Hashemi, 2010; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; MacFarlane *et al.*, 2013; MacFarlane *et al.*, 2008), whereas others have found that knowledge about safety or providing additional information does not necessarily translate into safer practices and increased use of PPE (Galt, 2013; Martinez *et al.*, 2004; Salvatore *et al.*, 2008; Vitali *et al.*, 2009). Access to information about safe approaches can sometimes lead to a reduced perception of risk (Ali *et al.*, 2006).

Training and coaching do not guarantee that agricultural workers will adopt safe practices (Salvatore *et al.*, 2008). Researchers have noted that PPE use is low even under the most favourable circumstances—that is, well-informed subjects, permit holders, financially secure owner-operators or subcontractors specializing in year-round pesticide treatments. They have concluded that limited PPE use is the norm and that describing the situation as abnormal or paradoxical does not reflect the evidence (Galt, 2013; Perry, Marbella and Layde, 2000). Some authors note that risk perception remains low in spite of training (Vitali *et al.*, 2009). In some cases, respondents say they have the knowledge required to ensure their own safety, with respect to PPE use in particular, but their responses and practices show that they are unsure about the level of risk to which they are exposed and the possible health effects. This type of result suggests that safe practices are being learned mechanically or superficially, and that these learned practices are not really tied to actual health concerns (Martinez *et al.*, 2004; Olsen and Hasle, 2015; Perro *et al.*, 2000).

Sociodemographic factors are another line of investigation. User age has been one particular aspect that studies on PPE have focused on. The findings regarding the influence of age on prevention practices are contradictory, too, however. The perception of the risk associated with pesticides varies with age especially. Studies have found a higher perception of risk among young people (Isin and Yildirim, 2007). Youth are more concerned about the harmful effects of pesticides than older people are, and tend less to think that the benefits of using them outweigh the risks (Damalas and Hashemi, 2010; Isin and Yildirim, 2007). Workers who consider pesticides to be hazardous substances are younger, more educated and less experienced (Isin and Yildirim, 2007).

PPE use is higher among young pesticide users according to some studies (Damalas and Hashemi, 2010; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; MacFarlane *et al.*, 2013), whereas in other cases, age was found to have no effect on this practice (Adjémian *et al.*, 2002). Other studies have instead noted that young farm workers may consider the harmful effects of pesticide use to be acceptable if the benefits are significant enough, but have trouble following the safety recommendations (Ali *et al.*, 2006).

Other studies reveal that age may be an obstacle to the adoption of safe practices and to the willingness to wear PPE, in particular (Damalas and Hashemi, 2010). Among older workers, low participation in training goes hand in hand with a reduced perception of risk and low PPE use (Damalas and Hashemi, 2010; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; MacFarlane *et al.*, 2008). Older or more experienced workers (two strongly correlated variables) get used to risk (Damalas and Hashemi, 2010), which appears to influence their perception of risk and feeling of safety. A plausible explanation for these results, it would seem, is users' growing familiarity with pesticides over time. This familiarity can lead people to follow less safe practices and know-how that make them believe that risks are under control. In this case, operators no longer see safety as a priority (Damalas and Hashemi, 2010; Lambert and Grimbuhler, 2015). It is also much more difficult to convince older workers to change their habits and practices (Damalas and Hashemi, 2010; Hwang *et al.*, 2000). Other authors have noted, in contrast, that older or more experienced workers tend to use trial and error to develop and adopt practices and methods to protect themselves against exposure, which can have a positive effect (Isin and Yildirim, 2007).

Some authors have shown that PPE use has a positive correlation with level of education (Feola and Binder, 2010; Perry *et al.*, 1999). Furthermore, language, culture and immigration status may constitute obstacles and influence perceptions and opinions (Ali *et al.*, 2006). Ethnic origin is often associated with differential use of PPE. Studies conducted in the United States, where a large proportion of the labour force consists of immigrant workers, have shown that white farm workers, as opposed to those of Hispanic origin, are found more often in work situations where PPE is supplied by the employer, where safety training is provided and where tasks are associated with less significant skin exposure (Strong *et al.*, 2008).

Socioeconomic factors must also be considered in connection with PPE use. Agricultural producers and their employees may have widely differing beliefs or perceptions about risk and safety; nor are they in the same position when it comes to controlling their exposure to pesticides (Ali *et al.*, 2006). Depending on the type of agricultural job, different stakeholders have different work conditions and rights. For instance, OHS training and access to PPE are mandatory only for workers who do the actual spraying or have to re-enter an area that has been sprayed; those who prune trees or harvest the fruit are not necessarily protected by these measures (Snipes *et al.*, 2009).

Labour relations between employer and employee, workplace communications (Strong *et al.*, 2008) and worker status have an impact on PPE use (Davillerd, 2002a, 2002b; Galt, 2013; Isin and Yildirim, 2007; Salvatore *et al.*, 2008). Agricultural workers with higher incomes report greater PPE use (Kearney *et al.*, 2015). In some cases, the employer provides the PPE because it is legally required to do so, but it can exert pressure so that employees don't use the equipment (Snipes *et al.*, 2009; Strong *et al.*, 2008). Even in cases where PPE is supplied by the employer, workers don't necessarily use it; wearing PPE can slow work down and reduce productivity, which penalizes in concrete terms those who are paid on the basis of the area pruned or quantity produced or harvested (Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Salvatore *et al.*, 2008; Snipes *et al.*, 2009; Strong *et al.*, 2008). Factors such as access to breaks and appropriate facilities, as well as a real commitment from employers and supervisors to ensure safe working conditions, facilitate the sustainable implementation of recommended prevention and hygiene practices (Salvatore *et al.*, 2008).

For many authors, a perspective that takes in a broad range of social factors is necessary for a clear understanding of stakeholders' practices. The explanatory power of variables related to the social setting is more significant than that of individual variables such as representation or knowledge of risk, which act simultaneously as determinants of behaviours and practices (Colémont and Van den Broucke, 2008; Galt, 2013; MacFarlane *et al.*, 2013; Nicol and Kennedy, 2008; Perry and Bloom, 1998). Knowledge about the harmful effects of pesticides is not sufficient to modify behaviour because farmers' main concerns are damage to harvests and potential economic losses (Isin and Yildirim, 2007).

Many researchers refer to a model that associates the providing of information and knowledge about pesticide risks with improved prevention practices, especially greater PPE use. This *Homo economicus* (Galt, 2013) model suggests that enlightened users who make rational decisions based on all the relevant information and who are responsible for their own safety will only use pesticides that are really necessary and means of protection that are prescribed and made available. The model underlies the principles and process of registering phytosanitary products: users are informed by labels about the recommended protective measures to ensure safe use. Responsibility for taking these measures is left, to a very great extent, to pesticide users themselves (Damalas and Hashemi, 2010; Galt, 2013; Garrigou, Baldi and Jackson, 2012; Jouzel and Dedieu, 2013; Perry and Marbella, 2002). The same model is implicit in the approaches of OHS institutional systems. Users must take training on the safe use of pesticides and hold a permit authorizing them to use them, in addition to taking responsibility and assuming the obligation of using the collective and individual protective measures recommended in the product registration. Aside from steps to convince and support stakeholders, and increase compliance with good practices, coercive measures may be applied if instructions are not followed (Chaumény, 1996). However, the fact that workplaces are so widely scattered and work activities and schedules so varied makes outside control almost impossible in agriculture (Béguin and Pueyo, 2011; Galt, 2013; MacFarlane *et al.*, 2013; Olsen and Hasle, 2015; Perry *et al.*, 2000).

Critics argue that the model is inadequate because there is already a broad consensus in the scientific literature about the lack of compliance with instructions for PPE use, even among users well informed about pesticide risks. In their view, the model proposes a narrow conception of human behaviour in which the sole determining factor of behaviour is information. For that reason, initiatives that seek only to raise pesticide users' awareness and provide information are implicitly denying the influence of other factors on users' practices and indirectly favouring the status quo and the persistence of problems related to pesticide exposure (Galt, 2013; Garrigou *et al.*, 2012; Vitali *et al.*, 2009).

For many authors, if the other factors that have an influence on behaviour and practices were taken into account, it would help to develop more comprehensive, more effective approaches and controls over exposure. For instance, the most harmful pesticides could be banned or their use could be restricted or better regulated, integrated production models could be promoted and supported, work organization, including time limits on pesticide use and exposure, could be better regulated, and required PPE availability could be defined through standards and certification (Béguin and Pueyo, 2011; Feola and Binder, 2010; Galt, 2013; MacFarlane *et al.*, 2013; Salvatore *et al.*, 2008).

Intensive, industrialized agricultural production (rationalization, work organization, process and product standardization) is associated not only with declining numbers of farms and farmers, but also with increasing ecological and health crises (Béguin and Pueyo, 2011; Deléage, 2005; Forney, 2011). In a context where there is simultaneously a need to increase agricultural production and develop sustainable, more environmentally friendly agriculture, the work of farmers, in all its complexity, often goes unnoticed (Béguin and Pueyo, 2011; Salaris, 2014; Spoljar, 2015). Quantitative studies have shown, however, that farm working conditions tend to deteriorate under the combined effects of organizational and financial constraints, hot weather, physical and postural constraints, and exposure to biological agents and chemicals; the sector has an exclusionary effect on those who work in it. Farm working conditions are characterized in particular by high exposure, in terms of frequency and duration, to the various constraints, along with the seasonal and flexible nature of the work, as well as the small size of the businesses. The transformation of work caused by the industrialization of agriculture has led to the dispersal of communities (Béguin and Pueyo, 2011; Spoljar, 2015). Current systems of production are characterized by "disproportionality between the care given to the specification of […] tools, devices, materials […] or technical protocols, on the one hand, and the attention given to those who, through their work, keep them going day to day, on the other" (Béguin and Pueyo, 2011; Spoljar, 2015).

The growing interest in sustainable agricultural production rooted in communities and that combines performance, fairness and ecology holds out promise for the survival of small-scale production. The survival of small farms depends on the difficult task of finding a balance between significant economic and environmental constraints, the management and marketing of quality products, and objectives of independence and passing on to the next generation (Béguin and Pueyo, 2011; Forney, 2011; Galt, 2013; Hervieu, 2013). The precarious situation of small farms in a highly competitive context is associated with the growing use of pesticides despite the doubts expressed by some growers (Galt, 2013; Tuduri *et al.*, 2016). This precariousness threatens the survival of some farms, as well as the lifestyle and way of working of the families that operate them (Carpenter *et al.*, 2002; Hwang *et al.*, 2000; Lambert and Grimbuhler, 2015; Perry and Bloom, 1998). Specific cultural dispositions and conditions, such as the lack of separation between work and family life, the fact that the family home is located on the farm site, the fact that working hours tend to extend throughout the whole day for owner producers, and the participation of family members in production and maintenance activities (Baker *et al.*, 2005; Curwin, Sanderson, Reynolds, Hein and Alavanja, 2002; Kearney *et al.*, 2015; Perry *et* *al.*, 1999) are other characteristics associated with small farms that can have an impact on exposure. Decisions about prevention practices are made individually, by growers themselves, and are strongly determined by the constraints on their operations and by their knowledge (Carpenter *et al.*, 2002; Olsen and Hasle, 2015). In many cases, the size of the investments in safety required to reduce exposure would add to production costs, making growers' products less competitive on the market (Beseler and Stallones, 2010), and so growers may choose to adopt less safe practices (Galt, 2013; Hwang *et al.*, 2000). The economic and environmental challenges mean that the protection of growers' health has to take a back seat; and they are at the root of the contradictions seen between perceptions, knowledge and practices (Boissonnot and Grimbuhler, 2012; Isin and Yildirim, 2007; Perkins *et al.*, 1992; Perry and Bloom, 1998).

The issue of prevention practices, and of PPE use in particular, can also be addressed from the standpoint of regulation and compliance with rules within work collectives. Work culture and rules emerge from the activity within collectives or relational systems in the workplace, from common objectives and shared and discussed experiences. Trade know-how can be shared and discussed within a collective with a view to establishing rules leading to preventive action (Caroly, 2010). In all organizations or institutions, formal (explicit, posted) and informal (parallel, clandestine) rules coexist, and the actual rules are the result of compromises between the two. Formal rules are often developed by institutions or management without worker input, and prescribed without taking into account the full range of requirements and working conditions. The two types of rules have common goals, but informal rules rely on knowledge of work realities and on aspects that formal rules do not take into consideration. Informal rules developed in the field are rooted in the social logic of the stakeholders. They involve a high degree of external rationality, denote a concern for production efficiency and are closely linked with the real work (Béguin and Pueyo, 2011; Galey, 2013; Simard and Marchand, 1997). Through discussion within collectives, trade rules and safety practices can be developed, validated, adopted and adapted, and then put into practice individually (Caroly, 2010; Cuvelier and Caroly, 2011; Tomas, Simonet, Clot and Fernandez, 2009). The perceived legitimacy and effectiveness of formal rules play a role in maintaining them (Galey, 2013; Simard and Marchand, 1997). Sources of legitimacy and criteria for effectiveness vary by type of rule, the issue in question and the project to which they refer. Whatever the work or the organization, and despite the force determining the constraints or rules, stakeholders retain a degree of freedom and latitude within which they exercise their competency and make choices. Stakeholders' strategies are rational, but their rationality is not necessarily the same as that of the organization or institution (Béguin and Pueyo, 2011; Raynaud, 1989, 1991).

Other lines of research focus on the social norms that are expressed through peer pressure, which is actually another way to refer to collectives. It is through social norms that collectives or institutions can influence growers' decisions regarding their personal protection and the use of PPE (Galt, 2013). According to this view, growers will conform and adopt a practice, either because a positive value has been taken on by the collective, or to avoid the collective's symbolic disapproval (Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001). Peer pressure can be favourable to the use of PPE (Nicol and Kennedy, 2008) and can also have an influence even if the recommended practice is not consistent with label instructions (Perry *et al.*, 2000). In many situations where the wearing of PPE is recommended, complying with directions can be an assertion of one's identity or, on the contrary, its negation (Mohammed-Brahim, 2009). Given the demonstrated effect of collectives and norms adopted by peers, rather than individual approaches conceived by experts, collective approaches developed and rooted in the agricultural community can be explored, in order to both promote and support safe practices and PPE use and foster the development of innovations conducive to risk reduction in farm work (Black, Shaw and Harned, 2015; Feola and Binder, 2010; Isin and Yildirim, 2007; Perry and Bloom, 1998; Perry *et al.*, 1999; Vitali *et al.*, 2009). The natural networks and sources of information identified by stakeholders themselves must also be taken into consideration and should be tapped to facilitate the sharing of information about prevention (Nicol and Kennedy, 2008; Wadud *et al.*, 1998).

Prevention Practices

According to the theory of action, all behaviour is active and has an intrinsic, strategic meaning. Actors' strategies can be inferred from their practices, which are regular, repeated, empirically documented behaviours. These practices are developed in a social context in which they must also be analysed. They reveal the understanding and competency of the stakeholders: they are rational, adapted to the constraints and resources of the specific context in which they are developed, and the stakeholders are able to explain them (Bourdieu, 1994; Crozier and Friedberg, 1977).

Aside from PPE use, other prevention practices can also reduce exposure (Galey, 2013; Nicol and Kennedy, 2008; Salvatore *et al.*, 2008; Vitali *et al.*, 2009). These practices are planned, repeated actions, with the main, explicit objective being to prevent exposure, and they can be made an integral part of the performance of production tasks and contribute to work efficiency. They can also be referred to as "behaviours" and include work methods and hygiene practices (Lambert and Grimbuhler, 2015). They do not necessarily lend themselves to quantitative measurement; they may, however, be otherwise documented, described or observed. Qualitative studies have shown that the real conditions under which work is performed differ quite frequently from the expected or planned conditions. Occupational safety is often better served when workers participate in risk control by taking their own initiatives and developing their own safety practices (Béguin and Pueyo, 2011; Galt, 2013; Simard and Marchand, 1997). For many authors, following safety instructions and wearing PPE are a specific category of prevention practices. Observations help to objectivize the relative role of PPE use in stakeholders' prevention practices (Judon *et al.*, 2015; Lambert and Grimbuhler, 2015; Salvatore *et al.*, 2008).

The practices that have been studied the most are hygiene practices, which consist in handwashing with water and/or soap before eating and after working with pesticides, taking a shower, removing work clothing immediately when work is over, washing work clothes separately, putting on clean clothes every day, etc. It has been shown that these measures effectively reduce skin exposure (Salvatore *et al.*, 2008). Conversely, practices such as eating or smoking during a shift, not immediately removing work clothing or rewearing it without washing it, and not taking a shower are frequently observed or described, and can be associated with exposure. A certain consistency has been observed: people who wash their hands are more likely to wear clean, recommended clothing or to wear gloves (Salvatore *et al.*, 2008).

Other practices, like taking into account the wind direction when handling products and spraying, or differing use of equipment, such as tractors, are more integrated into the work process. Measurements of respiratory tract and skin exposure are significantly higher among operators of tractors without cabs or of tractors with enclosed cabs but with windows left open during spraying, than among operators using tractors with air-conditioned, airtight cabs with appropriate filter systems (Baldi *et al.*, 2006; Vitali *et al.*, 2009).

The social context of the workplace has an effect on employees' ability to adopt and maintain practices developed through experience or recommended by institutions. This effect has been studied, for instance, with respect to access to a source of water in the workplace for washing hands, showering and washing work clothes and to breaks long enough to allow employees to take appropriate hygiene measures (Mayer, Flocks and Monaghan, 2010; Salvatore *et al.*, 2008; Snipes *et al.*, 2009). Paying employees by the hour rather than on a performance basis promotes prevention practices (Salvatore *et al.*, 2008; Snipes *et al.*, 2009). It has been noted that time constraints and fatigue may encourage stakeholders to make compromises between safety and speed or efficiency, and to adopt operating methods that are associated with greater exposure through contact (Lambert, Richardson and Grimbulher, 2011). Socioeconomic conditions also have an effect on the adoption of integrated production practices associated with lower exposure (Hwang *et al.*, 2000; Nicol and Kennedy, 2008). Older, more experienced workers have in some cases been described as being more likely to comply with the recommended doses, rather than use stronger doses, and to avoid smoking while using pesticides (Isin and Yildirim, 2007). Other studies have, in contrast, found that young people are more concerned about pesticide use and more interested in alternative approaches, such as integrated production, than older workers are (Damalas *et al.*, 2006; Hwang *et al.*, 2000).

4.1.4 Methodological Characteristics of Studies on PPE

A number of authors are of the view that the factors involved in pesticide users' decisions to adopt safe practices are not well enough documented and known (Perry *et al.*, 2000). A number of aspects of the surveyed studies, such as sources of information, data collection methods and the topics examined, are associated with biases, making it difficult to compile and compare knowledge.

The wide diversity of the sources of information, such as the subjects or people studied, and the often limited sample sizes, have been noted, in particular. This diverse range includes professional users of pesticides in agriculture, small owner-operators using pesticides themselves, or permanent or casual wage-earning farm workers who agree voluntarily to respond to a survey questionnaire on their knowledge during refresher training (Salvatore *et al.*, 2008). In other cases, it may include immigrant or temporary immigrant workers, some of whom hold permits to apply pesticides. Some studies were conducted in North America or Europe, others in countries where the level of economic development and the climate are quite different. It is therefore very hard to generalize the results to broader populations. Some authors also note that the lack of any significant association between specific demographic characteristics and prevention practices could be associated with a "healthy farmer effect," where operators or agricultural workers who have had serious health problems have left the industry (Salvatore *et al.*, 2008; Schenker *et al.* , 2002).

A broad range of aspects have been studied. These include perceptions, ideas, opinions, described or reported practices, intended practices, common or occasional practices, as the case may be; observed activities related to pesticide use; one-time or repeated situations. The desire to make a good an impression on people associated with institutions may introduce a bias in the answers to questions about practices. The study design may be cross-sectional or longitudinal, and the measurement single or repeated (Damalas *et al.*, 2006).

The different methods followed exacerbate the problem of compiling results. They include the use of subjective measurements to describe exposure and hazards; the use of questionnaires that are (most often) self-administered or administered by a researcher in a structured interview or conducted with the help of an interpreter; self-reported data; face-to-face interviews with or without an interpreter; telephone interviews; and focus groups. User observation and participatory observation are less frequently used. Some studies combine two collection methods and two types of data—for instance, data taken from answers to a survey questionnaire, combined with data from observations or obtained through physiological measurements.

Some researchers underscore the need to study exposure situations and stakeholder prevention practices in the field. The conventional approach in epidemiology and toxicology, and the type of methods and measurements these disciplines use, are not sufficient to provide a clear understanding of exposure. The question of PPE use cannot be investigated solely from the quantitative or technical standpoint. Field studies that employ activity observation and interview techniques provide more in-depth knowledge of growers' work. Ergonomics relies on field studies to distinguish prescribed work from actual work, and to take into account "the difference between what is planned by the designers of the work and what is really done by the workers" (St-Vincent *et al.*, 2011). The actual situation and all the relevant working conditions must be taken into account to properly evaluate exposure among agricultural workers (Garrigou, Baldi, Le Frious, Anselm and Vallier, 2011).

Information that has intrinsic value can be derived from observational data, especially data that describe what stakeholders really do, the way they use their equipment, including PPE, over the course of the day and according to weather conditions: open the windows of the tractor cab, take off their gloves, put them back on, open up their coveralls to cool off, etc. These exposure situations can only be perceived through observation, and would not be reported in answers to a survey questionnaire about the type of PPE used (Lambert and Grimbuhler, 2015; Vitali *et al.*, 2009). The interviews provide information about stakeholders' perception of their work and the risks to which they are exposed, as well as about the vocabulary they use (Lambert and Grimbuhler, 2015; Mohammed-Brahim, 2009; Snipes *et al.*, 2009). When they are repeated, observations and interviews provide information on intra- and intersubject variations (Lopez, Blanco, Aragon and Partanen, 2009; Vela-Acosta, Bigelow and Buchanan, 2002).

On-site observations provide a lot of objective quantifiable data on actual PPE use. They serve to establish the percentage of stakeholders who wear PPE and how frequently the PPE is used in a given exposure situation on the basis of repeated observations. Examining real work situations is a way of studying the constraints under which growers operate, the compromises they must make, the information available, their perception of risk and the most important characteristics of PPE (Hines *et al.*, 2007; Hubbell and Carlson, 1998; Nicol and Kennedy, 2008). Repeated observations of pesticide application operations using a tractor and sprayer show that more than one of every two operators never wears coveralls (Garrigou *et al.*, 2008). It is useful to observe whether the type of PPE worn is appropriate, whether it is being worn properly and whether it is being worn when required (Baldi *et al.*, 2006; Garrigou *et al.*, 2008; Garrigou *et al.*, 2011; Lambert and Grimbuhler, 2015). Studies that rely on observations have shown that PPE use is generally inadequate and unsuited to the pesticides being used (Lambert and Grimbuhler, 2015). In 90% of the situations observed, operators were not wearing all the adapted or necessary PPE (Garrigou *et al.*, 2011; Lambert and Grimbuhler, 2015). In their answers to survey questions, agricultural workers tend to overestimate the protection associated with wearing PPE (Salvatore *et al.*, 2008) or to respond differently depending on the circumstances. Observations need to be repeated under varied conditions to ensure the validity of the observational data (Vela-Acosta *et al.*, 2002).

Observational data on the objective wearing of PPE and on prevention practices can be cross-checked with subjective social data on peer pressure, public image or perception of risk (Garrigou *et al.*, 2008; Judon *et al.*, 2015). They can also be cross-checked with data from survey questionnaires, helping to qualify the results (Salvatore *et al.*, 2008; Vela-Acosta *et al.*, 2002). The data may cast a new light on toxicological measurements, as in occupational toxicology studies combining activity observations and analysis with toxicological data to produce a new assessment of exposure and risks (Garrigou *et al.*, 2011; Mohammed-Brahim and Garrigou, 2009; Vitali *et al.*, 2009). Last, field data may also provide explanatory variables for epidemiological studies (Baldi *et al.*, 2006; Garrigou *et al.*, 2011; Salvatore *et al.*, 2008; Vela-Acosta *et al.*, 2002).

To conclude, the review of the scientific literature provides an overview of a broad range of factors whose effects on PPE use have been studied. With regard to PPE itself, shortcomings in definition, clear designation and certification constitute real obstacles to its use. PPE designers should additionally focus their efforts on wearer comfort and suitability for work.

The characteristics of PPE users have long interested researchers. Knowledge of risks and perception of risk have always been regarded as key variables in explaining PPE use, but their effect is limited. With advances in knowledge, there is an increasing need to consider social and economic factors when seeking to understand and influence PPE use.

The review also examines methodological features of the studies of PPE use, making it possible to situate the specific contribution of this study. For one thing, the heterogeneity of the studies of PPE users, in particular the populations studied, the data collection methods and the variety of aspects studied, makes it difficult to compile results and draw conclusions. In addition, the methods used to measure exposure in epidemiology and toxicology do not provide information on how exposure occurs. Field studies, associated with ergonomics or the sociology of work, use activity observation and interviews to describe the work and exposure, including PPE use, in real circumstances.

4.2 Data Collection among Apple Growers

This part of the study focused primarily on describing three things: situations in which skin exposure to pesticides occurs, prevention practices and the wearing of protective clothing (PC). The objective was to set out and make connections between skin exposure situations and the prevention practices of apple growers. It was hoped that the data would show which factors promote or interfere with PC use, with a view to improving skin protection when pesticides are used.

4.2.1 Skin Exposure Situations: Outcome of Observations and Interviews

Skin exposure situations are presented as they occur during the workday when pesticides are used. This description of the workday is not exhaustive and is based on field observations.

As Figure 1 shows, the work associated with using pesticides involves four main phases, some of which are subdivided into further steps. Figure 1 also shows that the treatment of orchards may require several consecutive mixing-loading and spraying cycles before the workday ends. Depending on the surface area to be treated, the grower may, according to our data, perform the mixing-loading and spraying cycle from one to four times in a single day.

For each of the four work phases, the skin exposure situations described by combining information from the observations and interviews, and the protective clothing (PC) worn by the growers, are presented. The most common exposure situations are described first, using the expression: “The grower …” Variations are also described, however, to account for the diversity of the work and exposure situations. Instances of contact with the product or with residue were observed in several cases, or were considered likely, given the observed characteristics of the activity and exposure situation. The exposure situations are also presented in summary form in the tables based on five variables obtained through a fine analysis of the activity: the action (what the grower does), the description of the contact (what the grower comes into contact with), the contact site (the body part affected), the form of the product (commercial formulation, spray solution or residue), the directly observable determinants of exposure (set-up, equipment, products) (see Method, section 3.3).

A comprehensive summary of exposure by work phase is presented in section 4.2.2.

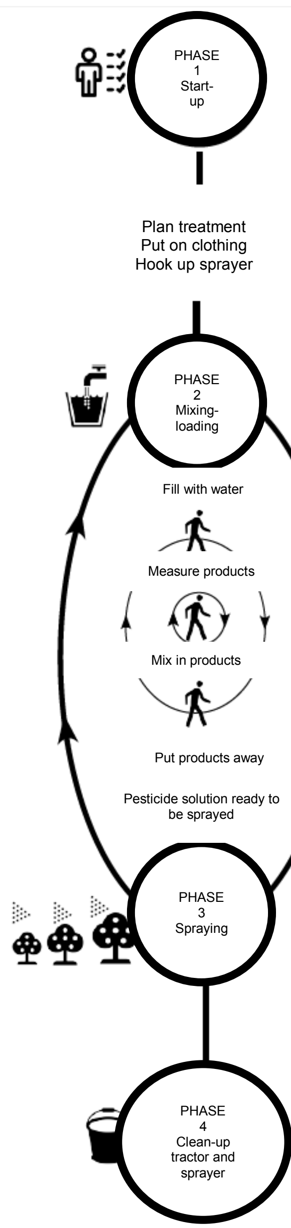


Figure 1. Work phases when pesticides used

4.2.1.1 Description of Technical Determinants of Exposure

The purpose of this introductory section is to define the three categories of technical determinants identified on the basis of the activity analysis and used to describe the exposure situations.

The category “set-up” refers to the physical organization of the premises, that is, the characteristics of the pesticide storage facility and the loading site.

The storage facility is usually divided into two parts: a product storage area and a work area. The organization of the storage part depends on the product quantities and how they are stored (Figure 2, photos 1 and 4). The work area consists of a table or the top of a drum or container on which the weighing scale sits (Figure 2, photos 2 and 3).

Figure 2. Examples of pesticide storage facilities at two growers

The loading site includes the place where the sprayer is parked, the tank that provides the water and the place where the grower stands to measure the products. The sprayer can be parked on the grass, on a gravel bed or on a concrete slab. A variety of set-ups around the sprayer were seen: one example was a raised loading platform (Figure 3, photo 1). Volume measurements are usually made on a work surface on the ground (Figure 3, photos 4 and 5), which can be raised, for instance, by using a bucket or pallet. The distance between the water tank and the sprayer may vary. The water supply hose may or may not be supported (Figure 3, photos 1, 2 and 3). The valve for opening and closing the tank may be on the hose or on the tank itself (Figure 3, photos 1 and 2). Various types of valves, such as guillotine and faucet valves, were seen.

Figure 3. Examples of work set-up around sprayer

The “work equipment” category refers to the characteristics of the sprayer and tractor.

The analysis identified five chief characteristics of the sprayer that relate to exposure. There isn’t always a running board. If there is one, it’s on one side of the sprayer only and isn’t always aligned with the fill opening (Figure 4, photos 1, 2 and 3). The opening is at the centre of the tank or off centre, to one side (Figure 4, photo 4). The cover has two parts, so that either it can be opened completely or else just the small stopper can be removed (Figure 4, photo 5). There is a basket in the fill opening; the water intake is through either the top or the bottom of the basket, depending on the model (Figure 4, photo 6). The gauge may be located on the side (Figure 4, photo 2) or on the front part of the sprayer, far from the fill opening (Figure 4, photo 7). On some models, the nozzles are fastened to a tower at the back of the sprayer (Figure 4, photo 1). Some sprayers have a vacuum attachment (Figure 4, photo 8) for sucking up products instead of pouring them into the tank.

Whether or not there’s a cab and, if so, its technical specifications, are essential determinants associated with the tractor. Even when a tractor has a cab, the actual protection for the operator depends on the airtightness of the cab and the type of filters used (dust filter, activated charcoal filter, etc.) (see Figure 5).

The “work equipment” category also includes tools, such as measuring containers, that are used. The graduated or non-graduated containers come in various sizes, like a bucket that has been graduated beforehand using a felt pen, according to the most commonly used products and quantities.

Figure 4. Examples of sprayer features

Figure 5. Tractor cab with openings

The “products” category covers all the pesticides used and some of their characteristics. The products used come in granular, powder or liquid form. They are packaged in different types of containers: bag, drum, bucket; some are sold in a bag that contains water-soluble pouches.

Depending on the stage of the work activity, the products are found in various forms. The initial form is the commercial formulation of the product before it is diluted. The spray solution is the product after dilution with water or a mixture of several products. Residue refers to deposits of the commercial formulation or spray solution on surfaces; it may be dry or wet. Aerosol is defined as the “suspension of microsized solid or liquid particles in a gaseous medium” (Office québécois de la langue française, 1992); the commercial formulation and the spray solution can both be found in aerosol form.

4.2.1.2 Start-up Phase

Treatment planning

Work planning was not observed. The interviews, however, provided information about work planning and practices that reveal exposure prevention objectives among growers.

The time management and work organization strategies reported in the interviews were aimed at choosing the best possible conditions for spraying (even with a tractor cab), with respect to both treatment effectiveness and grower comfort. Growers can choose to dilute products less in order to reduce spraying time. They can also choose to spray early in the morning or late in the day rather than at the hottest times. Winds are also usually lighter in the morning and evening, which has the advantage of causing less spray drift.

One grower described what he considered to be ideal conditions for everyone: “a temperature of around 20°C, and wind at 10 or 15 km/h.” One day when he began a spraying cycle at seven in the morning and the temperature was around 10°C, which is a little colder and a little windier than the ideal, the grower explained: “Well, it’s not excellent conditions, but not far off, just a little below, to avoid having to spray when it’s hotter.”

Clothing

Protective clothing worn

The growers we met were wearing either work clothes or a variety of protective clothing: reusable watertight PC (coat and pants), disposable Tychem®, ProShield® or Tyvek® brand suits. One of the growers was wearing a short-sleeve T-shirt and long pants.

Protective clothing, when used, is put on before filling the tank with water, in most cases, or before the spray solution is mixed. PC is sometimes put on in the place where it is stored, sometimes outside, near the place where the spray solution is mixed. The growers observed all kept on their work shoes or boots when putting on their PC or when taking it off at the end of the day, which could contaminate the inside of the clothing.

The times when PC is taken off and put back on depend to a large degree on the type of tractor used. Growers who use a tractor with a cab remove their PC before getting in to do the spraying, and then put it back on as soon as they leave the cab to start a new cycle. They do, however, keep their PC on when they enter the cab during loading to work the controls that let water circulate in the sprayer. They leave their PC next to the mixing-loading station during the spraying.

Growers who spray using a tractor without a cab wear the PC during all phases of the work. They put it on before the mixing-loading and keep it on after spraying when they come back to start a new cycle. Most growers we met kept their PC on when they themselves took care of cleaning the tractor and sprayer.

Observations showed that between uses, PC was hung up to dry in a storage area where residue was present and could contaminate it. PC was, for instance, hung up in a closed locker in a storage facility, on a hook in a storage facility or in a hallway leading to a pesticide storage room. Several items of PC were sometimes hung on the same hook. Disposable PC was thrown out if damaged.

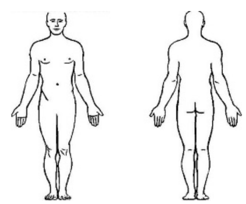
Hooking up sprayer to tractor and towing it to loading site

Growers began their workday by getting their spraying equipment ready **(Table 2)**.

The grower hooks up the sprayer to the tractor (situation 1). As the tractor can be used for other jobs in the orchard, it is not left hooked up to the sprayer permanently. Connecting the sprayer's drive shaft to the tractor's power take-off is a delicate, demanding operation in which growers have to hold the shaft close to their body to reduce the physical strain. Grease and pesticide residue can be present on the mechanical parts and leave visible traces on the legs and crotch of the PC.

The grower climbs into the operator's seat and drives the tractor and sprayer to the mixing and loading site (situation 2). The driver's station can be soiled with varying amounts of spray solution residue, depending on whether the tractor has a cab or not.

Table 2. Exposure situations when hooking up and driving tractor

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
1	Hook sprayer up to tractor	Contact with drive shaft		Residue	**Equipment – sprayer** • Weight and type of system for attaching sprayer's drive shaft
2	Climb into operator's station	Contact with operator's station		Residue	**Equipment – tractor** o Operator's station without cab o Operator's station with cab ▪ Type of filter ▪ Airtightness

4.2.1.3 Mixing-Loading Phase

The mixing and loading phase involves several steps (filling with water, measuring products, adding products, putting products back in storage). Observations revealed wide variability in constraints and exposure situations.

Protective clothing worn

The growers we met were wearing either work clothes or a variety of protective clothing: reusable watertight PC (coat and pants), disposable Tychem®, ProShield® or Tyvek® brand suits. One of the growers was wearing a short-sleeve T-shirt and long pants.

Filling with water

The length of the mixing-loading phase depends on how long the water filling takes, which was 12 minutes on average according to our observations, and varies with the amount of water needed and hose throughput **(Table 3)**.

Once the equipment has been set up at the loading site, the grower opens the cover of the sprayer (situation 3) and leans over the tank to perform a visual inspection of the inside. The dimensions of the sprayer and the access to the fill opening can increase the likelihood of growers being exposed when they lean against the tank to reach the cover and unscrew it (see Figure 4, photos 1, 2 and 3). The filling of the sprayer with water can continue while the products are being added.

A variety of loading station set-ups were observed. In set-ups where the hose is not secured, the grower has to pull it toward the sprayer, insert it in the opening of the tank and make sure it stays in place during loading (situation 4; see Figure 3, photos 2 and 3). To keep their balance during this operation, growers often have to lean against the sprayer, thus coming into contact with residue. The hose itself may have residue on it. In most cases, the loading site set-up includes a stationary hose, the end of which is positioned close to the opening of the tank. The end of the hose may be equipped with a plastic elbow for securing it to the edge of the opening, or a wood stand can be installed near the sprayer to hold the hose in position (see Figure 3, photo 2). One grower had a raised loading dock (see Figure 3, photo 1) on which a water supply tank was installed. The sprayer was parked against the dock, under the stationary hose for loading.

A high-volume hose is often used for the water filling. The location of the valve and the type of valve (faucet, guillotine; see Figure 3, photos 1 and 3) for regulating the flow are major factors in the grower’s ability to reduce the flow quickly in the event of splashing or to cut it off in the event of overflow.

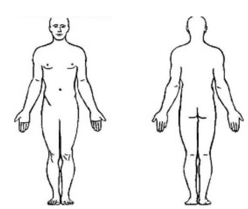
Some growers fill the sprayer completely with water before adding the products. Various explanations of this technique were provided in the interviews. At one orchard, the water supply tank is located at a different spot from the loading site, which means the grower has to fill the tank before adding the products. Another grower completely filled the sprayer with water before using a product vacuum system. These techniques help to prevent the spray solution from overflowing and contaminating the sprayer.

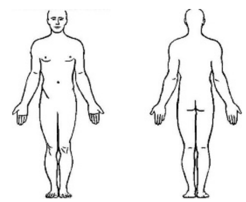
Once the loading has started, the grower climbs into the cab and turns on the sprayer's water circulation system (situation 5), which helps to dissolve and mix the products during loading. As in situation 2, the operator's station in the tractor (with or without a cab) may be soiled by spray solution residue. A grower exposed in any of the five preceding situations (1 to 5) could in turn be a residue carrier and end up contaminating the tractor operator's station.

On some sprayer models, the tank's water circulation system and the fan are turned on at the same time, which means that residue may get projected into the mixing-loading area and onto the grower (situation 6).

Incident 1. Unintentional operation of the nozzles was observed several times at this stage. At the end of spraying, the grower stops the fan and water circulation, and then closes the sprayer nozzles. If the grower forgets to close them, the product that is still in the piping will shoot out of the nozzles and splash all over the loading site or the grower as soon as the water circulation system is turned back on. The indicator lights on the tractor controls can be hard to see in the daylight or because of a build-up of residue, and so it is not always easy to determine whether the nozzles have been closed properly.

Table 3. Exposure situations when filling with water

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
3	Open cover	Leaning against sprayer tank		Residue	**Equipment – sprayer** • Height • Tank diameter • Position of opening • Design or lack of running board
4	Bring hose over and insert it in sprayer	Contact with hose and from leaning against sprayer tank		Residue	**Set-up – loading site** • Hose – Not supported – Rigidity
5	Operate control at tractor operator's station to turn on water circulation in sprayer	Contact with operator's station		Residue	**Equipment – tractor** • Operator's station without cab • Operator's station with cab

Situation	**Action**	**Description of contact**	**Site of contact**	**Form of product**	**Determinant of skin exposure**
6	Move around sprayer	Contact with aerosolized residue		Wet residue	**Equipment – sprayer** Simultaneous operation of fan and water circulation system

Pesticide measurement

To mix the pesticide spray solution, the grower fetches the necessary products from the storage facility. This requires entering and leaving the facility several times, depending on the variety and quantity of products to be used. Repeated trips—up to 14 to-and-fros for a single mixing phase—over a variable distance between the storage facility and the measurement site were observed **(Table 4)**.

Some storerooms are small and cluttered and have little or no ventilation or lighting (see Figure 2, photos 1 and 2). The clutter was both observed and described by some of the growers. Containers of various shapes and sizes, unopened or opened, were stored and piled up. A table, shelf or plastic barrel was sometimes being used as a work surface for weighing products with a scale (see Figure 2, photos 3 and 4). Dust and product traces could be seen on the floor, on the containers or on work surfaces, in some cases. The layout of the storeroom had an effect on access and moving around, on the amount of package and other handling that had to be done, and therefore on exposure (situation 7).

In the interviews, growers put the disorder down to lack of time and information: “Theoretically, all my fungicides are supposed to go in their own section, but … sometimes, things happen and …” One grower said that when he finished work at 5:30 p.m. the day before, there was still some Gramoxone out and he put the liquid in a bucket, but there was no cover. Regarding facility storage and cleaning, another said: “Yes, except that I don’t know what to do … The real answer is: when I vacuum, what do I do with what I’ve vacuumed up?”

The weight of the containers ranges from 1 kg to 20 kg. When moving and handling the containers, which can be heavy, growers sometimes hold them against their chest or hip for a time, depending on the distance they’re going, to make it easier to carry them (situation 8).

Some of the product containers are hard to open, which can also lead to exposure. Paper bags are kept upright on the ground by means of hands and legs, and opened using a utility knife (like an X-Acto) (type 1 – situation 9).

Liquid product containers sometimes have a seal under the stopper (type 2 – situation 10): “The worst is when they put two covers, when there’s aluminum foil … That’s a real pain because you have to cut through it, so you have to have a knife or something sharp you can use to open it … So I open it, I make an X like that … Then after that you have to rinse it … but you’ve still got the pieces of aluminum in the way. If you take it off, there’s product all over it, so where do you put it? And if you want to put it in the recycling, you can’t have any product on it, so I’m stuck with it.”

Growers who use products sold in water-soluble packets prefer to open the packet and pour the contents in to avoid blocking the sprayer filtration system, or else to use only the amount required (type 3 – situation 11). The powder is very fine, like talc, and highly volatile.

Products are measured by volume or by weight. Measurement is done several times, depending on the amount of product needed and the size of the measuring containers used.

When products in powdered form are measured by volume (situation 12), the grower transfers the product into a measuring container. The task of measuring by volume is chiefly done outside, with the grower's back to the wind. The set-up of the site has an effect on posture (standing, bent over, crouching). The grower places the measuring container on a work surface: directly on the ground, on an upside-down bucket or on the corner of a pallet, for instance. The weight, as much as 20 kg, and shape of the bags do not make them easy to handle; this means growers often have to hold the package against their chest or hip so as not to drop it. When the powder is transferred from the package to the container, some of it can be seen suspended in aerosol form above the package and measuring container and can settle on the grower.

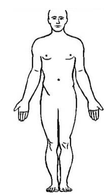
For the measurement by volume of certain liquid products, some drums of insecticide have graduated markings (situation 13); some drums are too opaque, however, making it impossible to use the markings. If growers transfer the product to another container for measuring purposes, they expose themselves to the risk of being splashed. To measure product quantities precisely, growers sometimes have to raise the containers up to eye level, near their face.

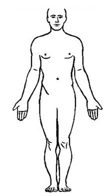
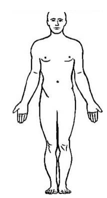
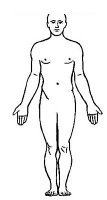
Measurement of products by weight is usually done inside, occasionally outside, on the ground, a table, a shelf or a plastic container turned upside-down to serve as a work surface. Using a container, the grower takes a certain amount of the product from the package and weighs it (situation 14). Products are weighed particularly when small quantities are required and the amounts must be measured precisely.

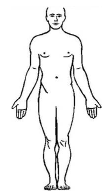
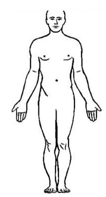
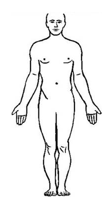
Growers explained in the interviews that they realize that the weighing of products in powdered form is a source of exposure: "I've got my little shelf in the corner, but you take the spoon, you drop a bit on the shelf" (see Figure 2, photos 3 and 4). Using the measuring containers that manufacturers frequently provide with their products helps to reduce that exposure: "It's a lot easier to use that. You measure using the little cylinder. You don't have to handle anything with a spoon … I can get the product directly. So I weigh the little container as well, but at least by pouring it that way (pushing the graduated container up against the opening of the container), you avoid handling it, you don't end up contaminating the pesticide storeroom."

Another method that was observed was a way of avoiding the handling associated with transferring using a measuring container. One grower uses a scale, like a bathroom scale, at the same time as the sprayer's product vacuum system is used to remove the amount required from the bag of pesticide. Growers still have to use their legs, however, to keep the bag upright and prevent spillage during the vacuum operation (situation 15).

Table 4. Exposure situations when measuring products

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
7	Move around in storeroom	Contact with open containers, products or residue on surfaces		Commercial formulation Residue	**Set-up – storage facility** • Cramped • Quantity of products stored • Storage **Product – packaging** • Open
8	Handle containers	Contact with containers		Commercial formulation Residue	**Product – packaging** • Weight • Form • Open

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
9	Open container: Type 1 – bag	Contact with bag and product		Commercial formulation	**Product – packaging** • Instability **Product – form** • Powder
10	Open container: Type 2 – drum	Contact with drum and product		Commercial formulation Residue	**Product – packaging** • Safety seal under lid
11	Open container: Type 3 – water-soluble packet	Contact with packet and product		Commercial formulation	**Product – packaging** • Packet hard to dissolve **Product – form** • Very fine powder

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
12	Measure volume of product in powdered form	Contact with aerosol		Commercial formulation	**Set-up – loading site** • On ground **Product – form** • Powder **Product – packaging** • Weight • Form
13	Measure volume of product in liquid form	Contact through splashing		Commercial formulation	**Set-up – loading site** • Working on ground **Product – packaging** • Opaque drum
14	Measure weight of product in powdered form. Method 1: with tools	Contact with aerosol		Commercial formulation	**Set-up – loading site** • On work table **Product – form** • Powder

Situation	**Action**	**Description of contact**	**Site of contact**	**Form of product**	**Determinant of skin exposure**
					Product – packaging • Weight • Form
15	Measure weight of products in powdered form. Method 2: vacuum	Contact with bag		Commercial formulation	**Product – packaging** • Instability **Equipment – sprayer** • Vacuum system

Adding pesticides to sprayer

After measuring the products, the grower adds them to the sprayer (Table 5). The measurement and addition steps can be repeated several times in a mixing-loading cycle, depending on the variety and quantity of the products to be used. Numerous trips to the storeroom and back to the sprayer, along with repeated handling, were observed.

The grower walks over to the sprayer carrying the measuring container and pours it into the tank (situation 16). Some growers only have to take one or two steps, while others have to walk several metres in each direction. The quantity of product in relation to the size of the measuring container, as well as the characteristics of the container (rigidity of the plastic, handle, volume, shape, etc.) may also lead to the product being splashed during transport.

The products are then poured into the sprayer. The characteristics of the sprayer, such as access, positioning of the lid and the presence of a running board (see Figure 4, photos 1, 2, 3 and 4), have an effect on contacts with the sprayer and exposure of the grower to residue.

In some cases, adding the products to the tank takes longer. Powdered or viscous products sometimes get stuck to the bottom of the measuring container; when this happens, the grower has to hit the measuring container against the inner walls of the sprayer, but this can cause aerosol particles of the product to form (situation 17). When a liquid is sticky, the grower has to lean against the sprayer tank for however long it takes for the product to flow into the sprayer.

One grower uses the sprayer's vacuum system (see situation 15, Table 4) to transfer powdered products into the tank (see Figure 4, photo 8). When the desired amount has been vacuumed, the grower holds the vacuum pipe up vertically and shakes it to make sure all the powder has been vacuumed. During this process, the grower is exposed to contact with the product on the outside of the pipe, resulting from the end of the pipe being pushed into the bag (situation 18).

Water circulating in the sprayer helps to dissolve products in the basket. The growers say that they try to facilitate the dissolving, so as to reduce the wait time, prevent blockage of the sprayer and ensure thorough mixing of the spray solution. Four dissolving methods that could lead to exposure were observed.

When growers use a hose that isn't stationary, they move it around in a circular motion to make sure they wet all the product (method 1 – situation 19). Growers lean against the sprayer to keep their balance while handling the hose.

Method 2 is used when the water circulating in the sprayer comes through the bottom of the basket rather than the top (see Figure 4, photo 6). Growers who do not have access to a filling hose for the water lean against the sprayer while they lift up and handle the basket to ensure the water circulates properly (method 2 – situation 20).

Where the set-up includes a stationary hose for the water supply and a raised loading dock, growers stand on top of the sprayer and use a tool to direct the flow of water and make sure it reaches the whole of the basket. This situation exposes growers to the risk of being splashed on the legs (method 3 – situation 21).

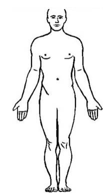
For some products, when the area to be sprayed is small or when the product must be applied in high concentrations, the water level needed in the sprayer does not reach the basket, and the product then has to be dissolved beforehand in a bucket. For growers, this extra handling means an additional risk of being splashed (method 4 – situation 22). Products are poured into containers, sometimes mixed with other products or diluted with water, before being poured into the tank. Growers also sometimes use a tool or a stick to mix and dissolve the products.

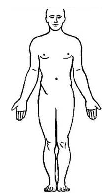
Incident 2. The grower, using the sprayer's vacuum to do the loading, leaves the sprayer's lid closed while working. A few minutes after vacuuming in the products, the grower opens the lid to check that the products have dissolved properly, but forgets to turn off the water circulation and gets splashed by the spray solution.

The loading of the sprayer, which usually takes place at the same time as the products are being added, continues until the desired level has been reached. The grower monitors the water level in the tank through an opening in the sprayer to prevent the spray solution from overflowing (situation 23), which could lead to exposure. The sprayer gauge is rarely used. On most sprayers, the gauge is located far from the opening, at the front of the sprayer, near the tractor's power take-off (see Figure 4, photo 7). Depending on the type of valve (guillotine or faucet) and its location (on the hose, at the supply tank, etc.), the grower can control the flow rate to a certain degree and also cut off the flow of water entirely. Furthermore, some products have a tendency to foam when they are being dissolved in the tank. Foaming can interfere with visual monitoring of the water level, cause the spray solution to overflow onto the sprayer and result in pesticide exposure for the grower. Growers sometimes sweep away the foam with their arm to clear the opening of the sprayer so they get a good view of the water level. This action exposes them to contact with the spray solution and the residue on the sprayer.

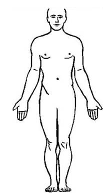
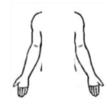
Incident 3. A product that does not dissolve easily can block up the filter of the sprayer. In this case, the grower has to unscrew the filter and clean it. Depending on the characteristics of the sprayer, removing the filter may cause significant splashing: "When you undo the filter, as soon as it starts to come loose, all the product runs out on the ground. Because it's this part here that gets full, so as soon as you unscrew it, it splashes on you!"

Table 5. Exposure situations when adding products

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
16	Carry liquid products	Contact with product		Commercial formulation	**Set-up – loading site** • Distance (storeroom to sprayer) • Uneven ground or clutter **Equipment – measuring container** • Characteristics of measuring container • Amount of product
17	Pour products	Contact with product and leaning against sprayer		Commercial formulation Spray solution Residue	**Equipment – sprayer** • Height • Tank diameter • Position of opening • Lack of running board **Product – form** • Powder or viscous liquid

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
18	Add products by vacuum	Contact with product escaping from vacuum hose		Commercial formulation	**Equipment – sprayer** • Vacuum hose
19	Help with dissolving – method 1: hose handling	Leaning against sprayer		Commercial formulation Spray solution Residue	**Set-up – loading site** • Hose – Flow rate too low **Equipment – sprayer** • Height • Tank diameter • Position of opening • Lack of running board
20	Help with dissolving – method 2: handling of basket	Leaning against sprayer		Commercial formulation Spray solution	**Equipment – sprayer** • Height • Tank diameter

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
				Residue	• Position of opening (centered) • Lack of running board • Water circulation
21	Help with dissolving – method 3: using tools	Standing on sprayer, contact through splashing		Commercial formulation Spray solution	**Equipment – sprayer** • Height • Tank diameter • Position of opening (centered) • Lack of running board **Set-up – loading site** • Hose – Flow rate too low – Stationary hose • Loading dock

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
22	Help with dissolving – method 4: pre-dissolving	Contact through splashing of spray solution		Commercial formulation Spray solution	**Set-up – loading site** • Container on ground **Equipment – sprayer** • Basket not immersed
23	Complete loading and control water level	Contact with hose and spray solution		Spray solution	**Set-up – loading site** • Hose ○ Valve or no valve ○ Distance (valve to sprayer) ○ Type of valve **Equipment – sprayer** • Gauge location **Product** • Foam

Storage

At the end of the mixing and loading phase, the grower triple-rinses the empty containers before putting them in the recycling (Table 6).

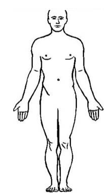
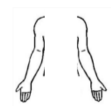
The rinsing is sometimes done directly above the sprayer opening, which means the grower has to lean against the sprayer. In set-ups where the water supply hose is not stationary, the grower has to hold the hose in one hand and the container to be rinsed in the other (method 1 – situation 24; see Figure 3, photos 2 and 3). In set-ups where the water supply hose is stationary and the sprayer is parked alongside a loading dock (see Figure 3, photo 1), the grower stands on the tank and bends over the sprayer opening, holding the container to be rinsed in one hand and using the other hand to direct the stream of water (method 2 – situation 25). One grower preferred to do the triple-rinsing by plunging the container directly into the sprayer tank, but that exposed him to contact with the spray solution (method 3 – situation 26).

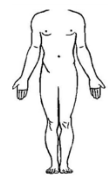
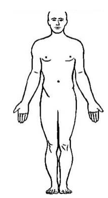
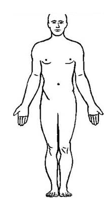
In other cases, the rinsing is done on the ground, using a watering hose or by plunging the container into a bucket full of water. The grower goes over to the sprayer opening three times to pour out the contents of the rinsed container (method 4 – situation 27). These various rinsing methods expose growers to being splashed with spray solution.

Packaging that still contains product is put back in storage. The lids or stoppers on some rigid containers can be reclosed easily. It was observed that when growers tried to fold or roll up the tops of bags containing powdered products, air was forced out of the bag and aerosolization of particles could occur (situation 28). Bags that have been opened tend to unfold and stay open. During handling (situation 8, Table 4), growers carry the bags by holding them against their chest or hip. Growers also reported having to remove products from the storeroom that had not been used during the season, in order to store them in a place insulated against freezing. This operation involves handling a variety of containers, some unopened, others open and possibly contaminated.

Growers then close the lid of their sprayer (see situation 3, Table 3). They lock up their storeroom and head over to the orchard to do the spraying.

Table 6. Exposure situations when storing products

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
24	Triple-rinse, method 1: above tank with unsupporte d hose	Contact with hose and leaning against sprayer Contact through splashing		Commercial formulation Spray solution Residue	**Equipment – sprayer** • Height • Tank diameter • Position of opening (centered) • Lack of running board **Set-up – loading site** • Hose not supported • Valve or no valve to control water flow
25	Triple-rinse, method 2: above tank with supported hose	Contact with product remaining in packaging		Commercial formulation Spray solution	**Set-up – loading site** • Hose supported • Loading dock

Situation	Action	Description of contact	Site of contact	Form of product	Determinant of skin exposure
26	Triple-rinse, method 3: in tank	Leaning against sprayer and contact with spray solution		Commercial formulation Spray solution Residue	**Equipment – sprayer** • Height • Tank diameter • Position of opening (centered at the end of the mixing • Lack of running board
27	Triple-rinse, method 4: on ground in bucket or with hose	Contact through splashing		Commercial formulation Spray solution	**Set-up – loading site** • Hose ○ Flow rate
28	Close bags	Contact with bags and aerosol particles		Commercial formulation	**Product – packaging** • Does not stay closed

4.2.1.4 Spraying Phase

As soon as the mixing-loading phase has been completed, the growers begin spraying the blocks of the orchard to be treated, which takes 90 minutes on average. The number of repeats of the spraying depends on the surface area to be treated, product compatibility and dilution of the spray solution. The various exposure situations for growers who use a tractor with or without a cab are described (Table 7).

Protective clothing worn

Significant differences were noted among growers with respect to use of protective clothing, depending on whether they sprayed with a tractor that had a cab or with one without a cab. Growers who spray from a tractor without a cab need far more protection. One of these growers wore two-piece waterproof protective clothing throughout the entire cycle and all season long. Another also wore PC throughout the entire cycle: two-piece waterproof protective clothing at the start of the season, when temperatures were cool, and a Tyvek® disposable suit when the weather got hotter. A third grower wore a Tychem® disposable suit for the full cycle.

The two growers who sprayed using a tractor with a cab did not wear PC during the spraying.

Before heading off to spray, growers adjust the nozzles according to the size of the trees to be treated. During spraying, when moving from one block of the orchard to another, they sometimes had to adjust the nozzles again. In some cases, growers who use a tower sprayer have to hold onto it or lean against it to adjust the upper nozzles (see Figure 4, photo 1). In doing so, they likely come into contact with residue on the tower or nozzles. Residue present prior to spraying is dry, while residue deposited during spraying is wet (situation 29).

The direction of the fan blades must be adjusted before leaving the loading site, or else during a stop in the orchard, depending on the spraying to be done (situation 30). Growers have reported finding residue or products in aerosol form when making fan adjustments: "To change the speed, yes, I have to stop the tractor, because I don't want to change it while it's spinning. I get off … I come around here where there's definitely going to be more product, then I move the speed shift lever."

The spray solution is sprayed from a tractor with or without a cab. The grower gets into the driver's seat to start the spraying. Having been exposed in the situations described above (situations 1 to 30, tables 1 to 7), growers themselves can carry residue and end up contaminating the operator's station in the tractor.

Growers who spray from a tractor with a cab (situation 31) may be exposed during this operation. The operator's station may expose growers to residue brought inside whenever they get out and climb back in. A cab that isn't airtight or that has inadequate or inefficient filters may also be contaminated during spraying (see Figure 5).

When getting behind the wheel of a tractor without a cab, growers come into contact with a number of tractor parts on which residue from previous sprayings has been deposited (see situation 2, Table 2). Growers who spray using a tractor without a cab are also heavily exposed during spraying (situation 32). The tractor moves through the orchard for hours, followed closely by a cloud of suspended particles. When growers spray with the wind behind them, or when they turn back at the end of a row, they are directly exposed to the pesticides. The state of the tractor at the end of the spraying is a good indicator of operator exposure. If the tractor hood is covered with residue, it is likely that the operator (positioned between the sprayer and the hood) has been contaminated, too.

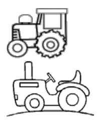
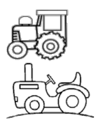
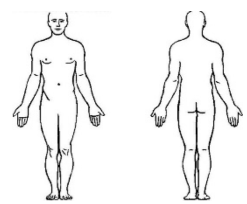
In the interviews, growers who spray from a tractor without a cab described their experiences: “When it comes to the actual spraying, it’s not *at all* the same thing, because whether you like it or not, it comes flying back at you to varying degrees. To take an example, let’s say there’s a 5 km/h wind. You turn at the end of the row and start two rows further down. Well, even if the wind is only 5 km/h, the whole cloud, all the stuff is still there, and you end up going through it.” They say that wind direction affects exposure. Growers who wear full face masks say that the visor soon gets filthy, making it hard for them to see. Others say that their hood and the mask get dirty. Growers talk about the increased risk of exposure associated with essential spraying to control severe infestations, but done when the wind speed exceeds recommended levels.

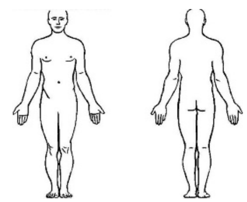
During spraying, growers check nozzle operation visually. They operate a control to open and close the nozzles, following the layout of the rows (dwarf trees, semi-dwarf, standard). Besides checking the ground ahead when driving the tractor, growers also have to observe the trees. They have to turn their head and upper body frequently to look ahead, to the sides and behind, thus exposing their back, face and chest to the suspended products if they are on a tractor without a cab.

At the end of the orchard block to be sprayed or when the tank is empty, growers have to stop the fan and close the nozzles (see incident 1). They then go back to the loading site to refill the sprayer tank, if necessary.

Incident 4. Sometimes an incident can force the grower to leave the driver’s seat during the spraying, such as to repair something on the sprayer or fix a flat tire. In this case, growers who spray from a tractor without a cab are already wearing their PPE. Growers who spray from a tractor with a cab don’t wear PC or masks; in some cases, they have protective gloves they can put on to avoid hand contact with dry or wet residue.

Table 7. Exposure situations when spraying

Situation	Action	Type of tractor	Description of contact	Site of contact	Form of product	Determinant of skin exposure
29	Adjust nozzles		Contact with sprayer tower		Dry residue (before spraying) Wet residue (during spraying)	**Equipment – sprayer** • Height of tower • Simultaneous operation of fan and water circulation system
30	Adjust fan		Contact with sprayer fan		Residue	**Equipment – sprayer** • Design of controls
31	Drive tractor		Contact with operator's station		Spray solution Residue	**Equipment – tractor** • Cab not airtight • Filtration other than activated charcoal **Products** • Suspended spray solution

Situation	Action	Type of tractor	Description of contact	Site of contact	Form of product	Determinant of skin exposure
32	Drive tractor		Contact with cloud of spray solution		Spray solution	**Equipment – tractor** • Without cab **Products** • Suspended spray solution

4.2.1.5 Clean-Up Phase

After finishing spraying for the day, growers sometimes wash off their tractor and sprayer. Cleaning frequency varies with the type of pesticides used and the other jobs the tractor has been used for (Table 8).

Protective clothing worn

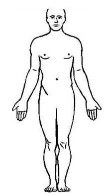
For the clean-up phase, growers who sprayed from a tractor with a cab put back on the PC that they used for mixing and loading. Growers who sprayed from a tractor without a cab kept on the PC they used for spraying. The PC worn when observations were made consisted either of reusable waterproof protective clothing (jacket and pants) or of Tychem®, ProShield® or Tyvek® disposable suits. One of the growers wore a short-sleeve T-shirt and long pants, regardless of the activity phase.

The tractor and sprayer need cleaning because of the product residue that accumulates on them during spraying and when products are added to the sprayer tank. Residue on the windows of a tractor with a cab reduces the driver's visibility, while residue on many surfaces of a tractor without a cab is associated with possible exposure and discomfort for subsequent users. The presence of residue on the sprayer is also associated with possible exposure for those who do subsequent loadings. Cleaning is also required when a tractor is used for purposes other than spraying and exposure to residue must be avoided, or to prevent the build-up of grass in the moving parts of the sprayer. The inside of the tank is also rinsed occasionally, to wash out residue from one product before adding a different one to the tank.

Growers do the cleaning with a filling hose, watering hose or pressurized water jet. Cleaning using hand tools, such as a mop, brush or sponge and dish soap, before rinsing with a hose, was also seen. The act of cleaning is associated with varying degrees of splatter of spray solution residue, depending on the flow rate and force of the water jet (situation 33).

Growers said in the interviews that they didn't clean their equipment very often because they didn't have the time: "Whenever I think I have the time to do it." One grower said that cleaning was especially necessary after spraying fungicides, which leave a sticky residue, or antibiotics like streptomycin, whereas the spraying of insecticides didn't leave visible traces, he said. "Polyram is a product that works because it's sticky. It sticks to the apples and makes them look yellow. When we've finished spraying, the sprayer and sometimes even the tractor are yellow, so then I wash everything from top to bottom."

Table 8. Exposure situations when cleaning

Situation	Action	Description of contact	Site of contact	Type of contact	Determinant of skin exposure
33	Clean tractor and sprayer	Contact with projected residue		Residue	**Set-up** • Hose – Water flow **Equipment** • Pressurized water jet

4.2.1.6 Risk Perception

Growers' perception of pesticide-related risk is explored here in connection with exposure situations, and because of the likely link with prevention practices and the wearing of protective clothing. This information was collected in the interviews.

The perception that pesticide-associated risk is less significant than it used to be seems to be fairly widespread. However, the risk associated with prolonged, repeated exposure does concern growers: "Pesticides have a warning label marked poison … A build-up occurs … over time. There's an accumulation of the product. You can't know for sure. Just because you're exposed to pesticides doesn't mean you're going to die from it, but I'd say you're not putting the balance of probabilities on your side."

Uncertainty about pesticide-related risk was mentioned in particular in connection with mixing-loading and spraying. But it was also raised in connection with exposure associated with other tasks, which required going back into already sprayed areas, for instance: "What about our workers who don't do the spraying, but who work in the orchard? How are they exposed?"

The interviews reveal that several factors are involved in the perception of risk. The perception rests in part on personal experiences and how people feel. One grower explained that, since there was no visible splattering when he was handling the products, he didn't come into contact with them and didn't think that he'd been exposed: "When you don't get splashed, you think you're safe."

Growers also link risk perception with the information people get and their awareness of the risk: "These are all things that make you more aware, too ... There was a training session on sprayers. That's one thing, then there was another on occupational health and safety. That's four or five years ago, and then I started to realize what's what."

One grower talked about the need for a campaign to raise awareness about the pesticide risk, which could be included in training courses on pesticides, for instance, to make people more aware of the risk and of practices: "I can't remember when I took the pesticide course, but it was a long time ago." Some growers said that the regulatory requirements helped make people more informed and more aware: "The sheds started to become available when the government began requiring you to have a licence to use pesticides. People griped and grumbled, saying that … that the government just wanted to make money. Then in the years after that, people started buying closed sheds."

The interviews revealed that the perception of risk tended to vary with the risk factors involved. Risk perception varies in particular with the exposure route. Exposure through the respiratory tract is the route associated with the highest risks by the greatest number of growers. Here, too, personal experience was mentioned, and the perception of smells plays a role in that representation. Smell is a sign of danger: "But there are some insecticides that really smell bad, so that has an effect without my even realizing it … I'm going to keep it farther away, and I'm going to hurry to put it in the sprayer, because I feel it's more dangerous, that's what I think anyway." Growers also rely on what they see to assess the risk and conclude that the respiratory tract is the most significant route: "You could see the dust rising, and that's the dust you see; the dust you don't see, that's something else again."

Exposure through the skin is not well known or well understood. For instance, one grower wondered out loud whether a product in powdered form could only give rise to exposure through the skin if it was dissolved in water, in other words in liquid form, or whether the dry form could penetrate the skin, too. Growers assume that exposure through the skin can be hazardous, too, but to a lesser degree than exposure through the respiratory tract. Most growers do, however, seem to recognize the significance of exposure via the hands.

The perception of risk by exposure route is connected to the form of the product: powder, granular or liquid (concentrated or diluted). The powdered form, which is widely used, is strongly associated with respiratory tract exposure during handling that causes aerosolization. Granules have less of a tendency to aerosolize, say growers. “I don’t feel like I’m being exposed to anything. I’m not in contact with it. It’s granules. I don’t have any dust.” The liquid form is associated by growers more with the risk of splashing, although the liquids are described as being easier to handle and less hazardous than the powders. Splashes can consist of the commercial formulation in liquid form, or of diluted product, or even a mixture of various diluted products. Others thought that the only link to respiratory tract exposure was aerosolization of the spray solution during spraying: “The way I see it, it’s the vapour, the droplets or the vapour. When it’s in a liquid state like that, I don’t feel there’s a risk.”

Risk perception also varied by type of product, but this was also a reflection of lack of information and uncertainty. Insecticides, especially organophosphates, are regarded as being the most hazardous products: “Insecticides, first because they smell bad, and second because they’re toxic and maybe more insidious … Its type of toxicity, in other words, what’s its role and what’s it going to do in the human body in the short, medium and long term? I’d rather just try to make sure I touch it as little as possible.” Nevertheless, some growers don’t rule out the fact that fungicides can be hazardous, too, simply because they’re used often and in larger amounts.

Risk perception also tends to vary with the activity phase. Many growers consider the mixing-loading phase to be the most hazardous because it involves handling concentrated commercial formulations and because of the aerosolization that occurs when handling a number of products in powdered form: “In my view, the main risk is during the loading stages. That’s the way I see it, anyway. Because that’s when you’re holding the containers in your hands, when you’re handling them, so the concentrations are inevitably higher, because you haven’t diluted them yet.” Not all growers feel the same way, however: “When I leave the orchard, I feel like I’ve left the risk behind me, so when I’m here (mixing-loading), I feel like I’m in a protected area.”

Other growers are more concerned about the exposure associated with the actual spraying, especially when it is done from a tractor without a cab: “I feel the danger in the spraying, but I don’t feel it in the mixing, or I feel it’s very minimal.” The length of the activity, even with a tractor cab, adds to that perception: “For me, that’s the main thing, because you spend hours in there”; as well as exposure to residue: “Even if I’ve washed the machine, it’s been a while since I last used it. Do the products still on it break down? I don’t know … but I do know that I’m fairly exposed.”

Growers who spray from a tractor with a cab generally feel that the mixing-loading phase is the most hazardous, but they don’t all see it that way. The possibility of the inside of the cab getting contaminated is considered by some growers who voice reservations about their safety. Other growers who spray from tractors without a cab, but are happy with their PPE, feel they are better protected than if they sprayed from a tractor with a cab: “I was wondering whether I wouldn’t be running more of a risk with a cab … because when you’re in the cab, you don’t have anything. So you have to get dressed for loading, then you take your suit off to get into the cab. I’m going to have to think about it. I’d definitely put on the little blue gloves. That’s for sure, but afterwards, so as not to contaminate everything … the floor, the steering wheel and everywhere else … That’s really something, when you contaminate the inside of the cab. Then the other problem is how to do the handling, how to put the products in the sprayer while protecting myself. And how to make sure you don’t take all that with you inside the cab.”

4.2.1.7 Prevention Practices

The observations and interviews were also a way of examining practices, which to a certain degree reflect the perception of risk expressed in the interviews or noted in the observations. These practices, which are distinct from PPE use, are planned, repeated actions, and though their aim is not directly related to the performance of production tasks, they can contribute to activity efficiency. The explicit objective of these practices is to prevent exposure: “Often it’s in the details that you can make a difference. When you’re emptying or loading, if you turn your back to the wind, you can avoid getting splashed ... It’s in the details, but now, how do you go about selling attention to detail? That’s a completely different problem.”

For some growers, these practices have the potential to reduce exposure, and their protective effect is in addition to the use of PPE: “I’ve always thought that … for PPE, like for anything else … it’s better to use something properly that’s not (perfect?) than to use something improperly that’s very good. Having said that, I’m not claiming that I do everything properly. I’m sure I don’t.” Others feel that the know-how and prevention practices of experienced growers can be effective enough to reduce the need to wear PPE: “There are people who wear what you people wear (researchers wearing PC) to fill the tank. Maybe they’re growers who haven’t been doing it for long.”

Some experienced growers say that they are more aware and careful than when they first started. Others, in contrast, note that repetition, habits and long workdays may lead them to become more lax about safe work practices: “At the start, we were really scared. We definitely protected ourselves more”; “The long days, the accumulation … It inevitably pushes up the risk of making mistakes when you increase *…”* Growers note the inconsistency between knowledge, opinions and practices: “In the whirlwind of day-to-day life, there are things you do that at some point you realize maybe you shouldn’t be doing it like that, but you do it anyway … Why? I don’t know.”

Growers say they develop their work methods to reduce their exposure by trial and error. Some say that work methods and prevention practices aren’t a topic of discussion in their community: “There’s no real place where growers can discuss things … We talk about it a bit, but not that much. Maybe it’s a topic they could develop for technical workshop days.” Some growers would like to receive practical training: “Definitely, it’s all trial and error, because people either learn it from their parents or … It would be good if, in the training on pesticides, for instance, … where they show us how to prune in the orchard, but never how to do the loading, how to use the pesticides. Well, yes, we learn, but we don’t see how it’s done physically.”

The purpose of some of the observed or described practices is to reduce exposure during mixing and loading. Regarding the effect of the set-up of the workplace for loading, for instance: position the tractor and the sprayer, taking into account the direction of the wind and the slope of the ground. One grower explained in an interview that he would never again work at an orchard where the loading station isn't set up. He associated a good set-up with making the work easier and more efficient, with less need to hold a tiring posture and with reduced exposure.

Some of the practices described depend on the choice of products: choosing a granular rather than a powdered form, spraying the most toxic product last so as to reduce exposure time to the most hazardous products that settle on clothes and equipment: "Yes, because my clothing would inevitably be contaminated by the insecticide."

The aim of the practices is to avoid contact with the products: paying special attention to not getting wet; standing outside the shed with your back to the wind when handling powder or liquid, and "trying to make sure the stuff doesn't fly around all over the place"; keeping the pesticide storage facility as clean as possible, cleaning it up (rare). Another practice was to use a product that helps to reduce foaming and prevent the sprayer from overflowing.

The aim of other observed or described practices is to reduce the amount of handling required for measurement or weighing: measuring the amount using a graduated container rather than weighing it; estimating the amount or the weight when a precise measurement is not absolutely necessary; adding a little more or a little less to avoid having to weigh or to avoid opening a new container; using the sprayer's vacuum hose and putting the product bag on a scale to estimate the quantity aspirated; use the sprayer's vacuum hose only for powdered products to prevent humidity inside the hose from causing subsequent blockages.

Growers generally do not follow different methods for fungicides and insecticides when mixing the spray solution. All of them said, however, that they take extra precautions when using the insecticide Imidan®, a fine, highly volatile powder sold in water-soluble packets, which gives off a strong smell that is perceived to be particularly toxic. All growers reported methods to help dissolve water-soluble packets, prevent blockages in the sprayer and facilitate clean-up operations that could expose them to risks. Some growers place the packets in the basket at the sprayer opening, close the lid and use the filling with water and the agitation in the tank to ensure the packets dissolve properly. Others reported adding the packets of Imidan® through the small cover of the sprayer to avoid being exposed to aerosolization of the product placed in the basket. Some handling operations, such as dissolving the packets in a bucket ahead of time and then pouring the mixture into the sprayer, or tearing the packets open and pouring the powder directly into the sprayer, help prevent incidents, but they can nevertheless lead to exposure.

Prevention practices followed during spraying were also observed or described. For example, organizing the spraying so that it is done in the same direction as the wind; closing the nozzles when doing a U-turn at the end of each row and then opening them again on starting the next row; spraying every second row so as to avoid being exposed to the cloud of suspended pesticide particles blown by the wind. A number of prevention practices reveal concerns about getting "wet" from the suspended products: "I pay special attention to make sure I never let any droplets land on me."

If an incident occurs that requires the operator to get out of the cab to adjust or repair something during spraying, one practice that was observed was to go to the end of the row and stop the tractor in a clear area, well away from any suspended droplets. “When you spray, there’s always a mist, humidity, a cloud of pesticide droplets in the air, so the idea is to make sure I’m out of that area … to try to stop in a place that, if possible, is downwind.” One grower explained that he takes the time to check his tire pressure before starting to spray so as to reduce the risk of a flat tire and the exposure that would result from having to fix it.

4.2.1.8 Inter - and Intraindividual Variations in Exposure

Field studies have shown the need to consider variations in exposure situations in order to arrive at an accurate assessment of risk. The repetition of the observations and interviews helped to gauge inter- and intrasubject variations (Garrigou *et al.*, 2011; Hines *et al.*, 2011; Lopez *et al.*, 2009; Vela-Acosta *et al.*, 2002). On-site observations help with the understanding of variations in exposure in connection with environmental, organizational and technical determinants, in particular. Taking these variations into account is an essential contribution to the validation of data for assessing risk, understanding exposure mechanisms and stakeholder practices, and developing recommendations or prevention guidelines for pesticide users, for example.

Analysing observations is a way to study inter- and intraindividual variations in grower exposure on the basis of three categories of determinants and ambient temperature. The technical determinants of the activity have an effect on exposure and on contacts between the grower and pesticides, as well as on the prevention practices observed. The three categories of determinants studied were the physical set-up of the workplace (storage facility, measurement station, loading station, access), the products (form, packaging, weight, format, type of opening) and the equipment and tools (design, size, access, use, maintenance). These determinants were targeted because observations make it possible to study them and because of their effect on work methods, actions, handling and movements. Furthermore, many of the prevention practices observed or described by growers also focused on these determinants.

The work equipment, especially the tractor, with or without a cab, is associated with the greatest interindividual variation observed in exposure and prevention practices. From the perspective of study objectives, this foreseeable result is relevant for a number of reasons. The exposure situation connected with spraying from a tractor without a cab is associated with specific individual protection needs and also with a demonstrated effect on stakeholders’ prevention practices at all phases of pesticide use. In apple growing, spraying from a tractor without a cab is still done by about one in every three producers in Quebec, but it is probably declining (Tuduri *et al.*, 2016).

Other characteristics of the tractor, including model, type of filter and airtightness of the cab, conditions and maintenance, are also associated with variations in exposure between individuals. Sprayer characteristics, such as size, access, positioning of the opening and nozzles (airblast or airblast tower), and presence of a vacuum system, also have an effect on interindividual variations in exposure.

The observations revealed that the physical set-up of the workplace has a number of effects on interindividual variations in exposure. In particular, a raised or ground-level loading station, the access to and supply of water, the use of a stationary or unsupported filling hose and the control over the water supply flow rate have a noticeable influence on work methods, posture, movements and handling and are associated with variations in exposure. A number of storage facility characteristics—layout, clutter, work surfaces, etc.—also have an effect on work activity and exposure.

The effect of products on interindividual variations in exposure appeared to be slightly less significant. Variations in exposure seem to be associated with the choice of form of product (powder, liquid, granules), the quantities stored and the methods of measuring, dissolving and transferring products, for instance.

It is likely that ambient temperature is also associated with interindividual variations in exposure. Some growers revealed in the interviews that they sometimes sprayed when temperatures were higher than recommended, especially when they had to deal with environmental constraints or exceptional weather conditions. These situations may be associated with specific physiological and toxicological effects and with unsafe PC use practices stemming from efforts to reduce discomfort due to heat. The effect of ambient temperature is particularly important for growers who spray without the protection of an airtight, air-conditioned cab.

Intraindividual variations in exposure also caught the attention of the researchers. Exposure situations and grower practices seemed to vary slightly with certain product characteristics and with ambient temperature. The perception that insecticides are more toxic than fungicides and are associated with greater health risks was stated by some growers. Special methods for handling, dissolving and adding the insecticide Imidan® to the sprayer were observed and described by some growers. Different practices in PC use were also observed and reported by some growers, depending on whether they were using insecticides or fungicides.

Ambient temperature was also associated with intraindividual variations in exposure and practices. All growers reported trying to organize their work to follow a spraying schedule that allowed them to avoid the hottest times of the day. PC use may also vary with ambient temperature or the perception of product risk. Some growers reported that they resisted the temptation to open their PC to cool off in hot weather more when they were spraying insecticide.

4.2.2 Summary of Skin Exposure Situations

1. Observations revealed a wide range of common, familiar situations of microscopic exposure through the skin; exposure is limited in intensity (the amounts of product the user comes into contact with are small) and duration (the transfer is brief), visible to varying degrees (on PPE, equipment and tools, workplace).

2. Microscopic exposure situations are the most frequent and occur often; they are an integral part of work activity components that are themselves repeated: activity cycle, phases, movements, handling, interactions with equipment and tools.

3. The frequency of microexposure situations could be a factor in the limited perception of the significance of exposure through the skin.

4. Incidents are actually quite infrequent. Situations associated with sudden, significant, unexpected, drastic exposure are very rare. Incidents can occur at various stages, for

instance, if filters get blocked, if the tank overflows, if the nozzles start spraying accidentally, during repairs to the sprayer.

5. Exposure varies strongly with the phases of the work.

During the **start-up phase** (Table 2, situations 1 and 2), the planning of the work to ensure both the effectiveness of the treatment and the grower's comfort has an impact on exposure at all the other stages. Exposure situations are characterized by contact with product residue deposited on equipment that has been used or inside and outside protective clothing that has been put on and worn. Exposure varies with the maintenance and cleaning of equipment and PPE.

During the **mixing-loading phase**, there are a large number of situations (tables 3 to 6, situations 3 to 28) that expose growers to pure, diluted and residual products. This phase is associated with a wide range of microexposure situations, as well as with incidents in which exposure may be significant. The repetition of some steps according to the number and quantity of products to be used, as well as the area to be treated, increases exposure opportunities. Exposure also varies by stage.

- Water-filling stage: Decisions and work methods for the total or partial filling with water can cause variations in exposure at this and subsequent stages. Variations in exposure are often related to the sprayer, its design and its operation (simultaneous operation of fan and water circulation system, information on opening of nozzles). The set-up of the loading station, especially access to water and control over flow rate, can also cause variations in exposure. Equipment and set-ups have a significant effect on posture and contact sites.

- Pesticide measurement stage: The various work methods used to measure pesticides (by weight and volume) have an effect on variations in exposure. A number of determinants of microexposure situations explain the variations, in particular the set-up of the storeroom (cramped space, quantity of products stored and how they are stored) and mixing site (ground or table used as work surface) and the characteristics of the product packaging (weight, form or instability) and the products themselves (form, viscosity). The equipment used to do the spraying can also be a factor in variations in exposure. For instance, the method involving the use of a vacuum system, despite less handling being required for measurement, can be associated with exposure of a grower's legs to the products. Variations in exposure may also be related to organizational determinants, such as time constraints and lack of information.

- Stage of adding pesticides to sprayer: The actions and methods growers adopt to ensure that products dissolve quickly and properly also lead to variations in exposure. At this stage, a number of actions (mixing, opening of water-soluble packets, predissolving of products, visual control, etc.) to prevent blockages could require additional actions and further expose growers. The characteristics of the sprayer (access, water circulation, basket, gauge, etc.), products (form and propensity to foam), water supply (flow rate, stationary hose, valve, etc.) and loading site set-up (distance from storeroom to sprayer, uneven or cluttered ground) are all determinants that can cause variations in exposure.

- Storage stage: The four work methods observed for the triple rinsing were associated with specific exposure situations. The exposure situations varied with choice of method (rinsing in the tank or in a bucket), characteristics of product packaging (closing and stability of containers) and site set-up (distance between loading station and storeroom, space in storeroom).

During the **spraying phase**, the variety of exposure situations is less (Table 7, situations 29 to 32), but exposure is significant in intensity and duration (1.5 hours on average). Equipment characteristics lead to variations in exposure. Spraying from a tractor without a cab is a special, critical situation. A grower spraying from an enclosed-cab tractor can also end up being exposed (precontamination and non-airtight cab, ineffective filters). The characteristics of the sprayer, the height of the tower and the design of the control systems, for instance, can also cause variations in a grower's activity and exposure, especially when adjustments must be made between blocks. Work planning has a particularly significant effect because the spraying phase generally has to be repeated two to three times, depending on the size of the area to be sprayed.

During the **clean-up phase** (Table 8, situation 33), the exposure that is a hazard throughout the activity is associated with the projection of residue from earlier sprayings. The characteristics of the equipment (hose or pressurized jet, mop) and positioning in relation to the sprayer are key factors that cause variations in exposure. Owing to a lack of time, this phase is rarely completed, thus increasing the risk of exposure to residue at all the other phases.

6. All parts of the body are subject to exposure to pesticides, from head to toe and from front to back. The repetition of skin exposure situations could be associated with a significant build-up.

7. Products are associated with variations in exposure. With the exception of special methods for the insecticide Imidan®, observations revealed very few variations in the use of insecticides and fungicides. Observations did, however, reveal the effects of the form of the product and packaging characteristics on work activity and on the occurrence of microexposure situations.

8. The findings highlight the need for a good design of the set-up of the mixing-loading site, tractors, spraying equipment and product containers, which takes the work activity into account and helps reduce exposure.

9. Apple growers' activity depends on a wide range of determinants and environmental, economic, organizational and technical constraints.

10. Analysis of the activity reveals the use of varied, integrated prevention practices that are adapted to exposure situations. Prevention practices reflect growers' risk perceptions and know-how.

4.2.3 Use of Protective Clothing (PC)

Two types of findings are presented. Table 9 lists the types of pesticides being used when orchards were visited, the instructions on product labels, and the work clothing and protective clothing actually worn by growers. Five aspects of PC use examined in the interviews with growers are discussed.

4.2.3.1 Packaging Instructions and PC Used

For each product used during the observations, Table 9 indicates the work clothing and PC recommended on the package labelling and the clothes worn by the grower. Two types of clothing are mentioned in the recommendations given on the labels of the products used at the time of the observations: long-sleeve shirt and long pants, and chemical-resistant suit. According to the WPS, the first type of clothing is regarded as being equivalent to work clothing, whereas the second is a type of protective clothing. In the presentation of the findings, the terms “work clothing” and “protective clothing” are used.

The findings presented in Table 9 indicate the variety of work clothing (short- or long-sleeve T-shirt, shorts, pants) and PC (suit, waterproof protective clothing, chemical-resistant suit) worn by growers. It should also be noted that the work clothing and PC actually worn do not always follow the recommendations. With regard to work clothing, although most growers say they wear long-sleeve shirts and long pants, variations were observed or reported: in hot weather, three out of five growers wear short-sleeve shirts. Four of them also wear PC when using fungicides and insecticides for which this protection is not required according to the labels. Last, two growers used fungicides and insecticides for which the labels specifically recommended the use of a chemical-resistant suit. One grower did wear a suit that met this requirement, but the other one wore only waterproof PC. Except in the case of the grower who never wears PC, two of the growers who do not follow the recommendation to wear a “long-sleeve shirt and long pants” do, however, wear PC over top of their work clothes.

Table 9. Label recommendations by pesticides used, work clothing and protective clothing worn by growers spraying from a tractor with or without a cab

	Insecticide		Fungicide			Insecticide	Fungicide
Products	Rimon® (Chemtura Canada Co./Cie) Intrepid® (Dow AgroSciences) Calypso® (Bayer CropScience Inc.)		Supra®Captan (Loveland Products Canada Inc.) Maestro® (Arysta LifeScience North America LLC) Altacor® (E. I. DuPont Canada) Polyram® (BASF Canada Inc.)			Imidan® 70 WP (Gowan Company) Assail® (Nippon Soda Co., Ltd.)	Manzate® (E. I. DuPont Canada)
Clothing recommended on label	Long-sleeve shirt AND long pants					Long-sleeve shirt AND long pants AND chemical-resistant suit	
Growers	**No. 1**	**No. 2**	**No. 3**	**No. 4**	**No. 5**	**No. 2**	**No. 4**
Work clothing worn	Short-sleeve OR long-sleeve shirt AND shorts or pants	Long-sleeve T-shirt AND long pants	Short-sleeve OR long-sleeve T-shirt AND long pants	Long-sleeve shirt AND long pants	Underclothing OR short- or long-sleeve T-shirt AND/OR shorts or pants	Long-sleeve T-shirt AND long pants	(Short-sleeve T-shirt AND) long-sleeve shirt AND long pants
Protective clothing worn	Suit (ProShield®)	Waterproof clothing	None	Chemical-resistant suit (Tychem®)	Suit (Tyvek®) OR waterproof clothing	Waterproof clothing	Chemical-resistant suit (Tychem®)
Tractor	Cab	Without cab	Cab	Without cab	Without cab	Without cab	Without cab

4.2.3.2 Information on Protective Clothing

The lack of information about PC, especially chemical protective clothing, was clear from the interviews. The five growers said they didn't really know what they should be wearing, and were not sure at all about the effectiveness and safety of the protection afforded by their PC.

Almost all of them said they had serious reservations about the effectiveness of the PC they were using: "What I'd like to be sure of is that the suits I wear really are effective, really provide a barrier against the different pesticides. I don't think that's the case"; "If it was written, I don't know, *approved* under standard ATSM XYZ for growers ... Except that ..."

Growers say they all need to be proactive and get more information. Those who do their spraying from a tractor without a cab seem more concerned and more proactive: "But I'm worried enough, or careful enough, to do something to appease my conscience, and I think that's going to continue ... Look what I can do, in any case at least for my own health, and … ways of doing things."

The sources of information available on PC are not thought to be very useful, and no suitable, credible source was named. The information given on packaging (pictograms) or on labelling helps some growers to estimate product risk, but is generally not a reliable source of information for choosing clothing to protect the skin: "For personal protective equipment, no ... The truth is that I don't think there's any useful information in all that." Some growers don't read the labels: "It's a hazardous material. We handle them all the same way."

In contrast, one grower who sprays from a tractor without a cab and who bought a Tyvek® suit from his pesticide supplier didn't bother seeking out further information: "It's written on the bag when you buy the Tyvek® that it's good for chemicals."

Given the lack of useful information on the labels, growers described a variety of information search strategies. The Internet is one source considered by all the growers interviewed, but it is not easy to find information on PPE. One grower found a solution and some satisfactory PC on a specialized site of Company X, which he thought seemed reliable: "I told them what business I'm in and what I do. And this is what they suggested I use ... It's just Tychem® ... After that, I went on the Web to see what Tychem® is … I'd never heard of it before, and I saw that it was more waterproof than Tyvek®, so I said fine … That seems better."

SAgE pesticides (http://www.sagepesticides.qc.ca/, a reference site for agriculture, doesn't provide sufficient information about PPE, say the growers: "There's not much about protective equipment on SAgE pesticides … The information may be available, but you can't find it … They show a photograph of what you're supposed to wear in the way of protective equipment, but nothing comes with it to tell you how to use it, or what sort, or where to get it."

The question of the availability of PC and of the credibility of the sources of supply of PC was raised by several growers. Some pesticide sellers also sell PC. Generally speaking, PC sellers are deemed by growers to be poorly informed and lacking in credibility when it comes to PPE: "Yeah, well, the lady who was there didn't seem to know much about the products."

Given the lack of credible information on the effectiveness of PC, growers rely on their experience: "No, it's not reference material, but when I was spraying with no cab and the wind was blowing like that … damn gusts … and when the moisture … seeps through …. No, it's not waterproof, because I can feel it."

4.2.3.3 Choice of Protective Clothing

The problem with choosing PC was articulated concretely in the interviews. Given the lack of precise information, personal perceptions and criteria, based on experience, play a major role. The growers described their criteria for choosing PC. The effectiveness of the protection is the primary criterion when choosing PC, say the growers. There was clearly some confusion among participants between the concepts of waterproof (clothing that doesn't let water through) and resistant to chemicals (PC that prevents pesticides from getting through). Neither type of clothing breathes much. Growers also noted a lack of information about protection needs, depending on whether the products are in powdered or liquid form, or whether the product formulation is concentrated or diluted: "I think, though I may be wrong, that as long as you're not wet, the suit is effective, but that when you're wet, the protection is less effective."

The two aspects are especially important for growers who spray from a tractor without a cab, given the duration of the exposure, which can be several hours in a row in some cases. They can also end up spraying in very windy conditions, when they are heavily exposed: "I've got to admit that we do spray when it's windy, sometimes … 20 km/h, but you don't have a choice because either you spray or else you're forced to apply an eradication product that's more expensive and worse for the environment. So, I admit that I've already had some liquid fungicides on me."

Growers who own a tractor with a cab are also concerned about the effectiveness of the protection afforded by PC because of likely repeated exposure, albeit of short duration, to (undiluted) commercial formulations during the mixing of the spray solution.

As regards concrete experience, the growers expressed a need to be dry and comfortable inside their PC and to feel safe, even if the PC is dirty on the outside. "I feel better in the Tychem® than the Tyvek® … because it's waterproof … Because if I sprayed when it was raining, the Tyvek® used to get soaked through. And, sometimes, if I sprayed when there was a wind … a slight breeze, but it blew the product back on me, if you like, then I had the feeling that I was getting soaked, too, so I just found that it was really unpleasant."

Another characteristic that growers look for is waterproof stitching and zippers: "Two layers that cover the zipper, to make sure that nothing gets in through the zipper. That's something I think is important, too, that nothing can get in."

Thermal comfort is the second criterion growers use when choosing PC. Clothing that is waterproof or chemical-resistant is going to breathe less, which can be a major factor in hot weather: "Well, if you're willing to pay for a hi-tech one that breathes a little or something … But then again, you have to know exactly whether it's good or not. If you have waterproof clothing … made of fabric, say, and you wear that when it's hot, it doesn't take long before you're completely soaked with sweat, so it's not … If you wear that for an hour or two, … you feel like you're in a sauna."

Thermal comfort is especially important for growers who spray from a tractor without a cab and who have to wear PC that breathes less, throughout the entire cycle of activity, so over a longer period of time, in addition to other PPE items (boots, gloves, mask, hard hat): "I was really knocked out by the heat. I was wearing a Tyvek®. It was really frightening. At 25°C, it's still bearable, but it's definitely not comfortable when it gets hot, in the sun." The Tyvek® suit, which breathes more than the Tychem®, is still uncomfortable for growers who spray from a tractor without a cab in hot weather.

The heat given off by the tractor increases the ambient temperature and can add considerably to their discomfort, especially for operators who spray from a tractor without a cab: "At the height of summer, when you're sitting on the tractor, and it's been running for two hours, and the engine's hot … not only are you not comfortable … but it gets to a point where you don't feel well … You're soaked in sweat and you start to feel ill."

Some growers are willing to compromise on how they feel temperature-wise: "Maybe I'd rather be a little too hot than have the feeling … that liquid is getting through my clothing." Discomfort is easier to put up with if you know the activity won't take long: "Getting through one tank, that's bearable." One grower recalled having sprayed one time when he was about to faint from heatstroke. "If it's really, really hot, we shouldn't be spraying (risk of phytotoxicity), but at the same time, we don't have a choice."

Discomfort from high temperatures may prompt growers to follow less safe practices. For instance, spraying with the tractor cab windows open, or not wearing PC the recommended way, opening it up to cool off or wearing a short-sleeve shirt and shorts underneath: "When you put on a waterproof suit and you get all soaked inside, at some point you open it up, you don't feel well." Because of the discomfort from the heat, some growers may decide not to wear PPE: "It definitely puts you off wearing it. When you're wearing something and you don't feel well, it's not complicated." In cases of thermal discomfort, growers reported taking fewer precautions with fungicides than with insecticides: "It bothers me less. I have less of a bad conscience about leaving it [the suit] open a little more."

Work suitability and the comfort of the movements required for working are also criteria growers use to choose PC: "To walk, to move around .... Of course it has to be comfortable when you're sitting down, especially it has to be loose enough in the crotch, but not too loose, so that you can still walk easily." The clothing also has to be suitable for working in a standing position and for walking around while carrying loads; growers sometimes also have to stay seated for long periods, and the operation of the tractor during the spraying requires them to be able to turn around and look back frequently. A wide choice of sizes to ensure comfortable movement is another selection criterion.

The strength of the fabric and the clothing, as well as the durability of the effectiveness of the protection afforded by the PC are also criteria, especially for growers who spray from a tractor with no cab. It's important to have a strong fabric that doesn't tear easily when you catch it on a branch, for instance: "You see splits at the elbows, the knees and the buttocks, of course, places where the clothing gets caught or where it rubs the most. Those are just things I've noticed. That's why the type of fabric, the material—yellow protective clothing, if I find something equivalent, I won't be far from something that I think will be reliable to ensure nothing gets in."

4.2.3.4 Disposable or Reusable PC

The growers interviewed use two different strategies. Among the growers who spray from a tractor without a cab, two have opted for reusable waterproof PC. One grower showers a few times outside during the season while wearing his PC, and then throws it out at the end of the season. Another grower has been wearing the same old PC for years, never rinses off, and leaves it to dry after using it; during hot weather, this grower uses a disposable Tyvek® protective suit. A third grower has opted for a disposable Tychem® protective suit. Two growers spray from a tractor with a cab; one of them wears disposable ProShield® PC for the mixing-loading work; the other doesn't wear any.

Overall, the growers associated the most benefits with disposable clothing, as it provides the desired protection, but also eliminates the problem of the exposure associated with contaminated reusable PC: "The best equipment, in my view, is the disposable clothing … Having something that's waterproof, disposable, inexpensive, but disposable—you know, you buy yourself 25 for the season, and then each time you spray, you can pull on a new one that isn't contaminated."

Among growers who spray without a cab, effective protection, related to the chemical resistance of the material, and reliable for the full duration of the application (several hours a day in some cases), is the main quality wanted in disposable PC: "Then you know that the material is fairly resistant, that it can withstand products for four to five hours, and that you can throw it out afterwards. And in the end it cost you, I don't know, a couple of bucks per or … In my view, that would be the best at the end of the day. With the right hood, it would be even better."

For reusable PC, the main questions raised by the growers concern the protection it provides, the length of time it can be used, the risk of contamination, maintenance and cost. Questions raised about the use of reusable PC concern how to use it without being contaminated yourself: "A waterproof suit, of course, each time I wear it … The first thing I put on are my gloves, a new pair of gloves. After that, I take the suit, put it on and all that, but after that, in all the handling, in four to five hours, of course … Say I have to go to the toilet between the two. I take my black gloves off. I often throw those away. I put on some new ones, but if I take them off, I'm already contaminated." The maintenance of reusable PC and the length of time it lasts are also issues that were raised in the interviews: "There's also the question of the clothing itself … You have to wash it, but how do you do that, and where?"

The observations and interviews revealed that, in practice, all PC, including disposable PC, gets reused. Disposable PC is used for varying lengths of time, depending on the case. Some growers who spray without a cab set the length of time they use disposable PC based on the number of sprayings or the products used. One grower reuses his Tychem® for several sprayings, but throws it out immediately after an application of insecticide, deemed more hazardous than fungicide: "Captan is essentially corrosive, whereas insecticide is much more of a poison, and maybe more toxic … I've got it dirty, really dirty. I don't feel like putting it back on, no way." A third grower reuses his Tyvek® for a whole season or until the fabric rips: "Sometimes when you put your foot in, it rips, so you have to get a new one." Another grower, who sprays from a tractor with a cab, wears a ProShield® suit for the mixing-loading and reuses it as long as possible "until it deteriorates to level X."

The growers said that it didn't make sense to throw away PC that didn't "look dirty," that didn't have any visible traces of residue or signs of deterioration: "Why would it no longer be waterproof after just one application?"

The cost of PC, especially disposable PC, was mentioned by all the growers. To judge from what was said in the interviews, however, they give more importance to the protection provided by PC than to the cost. Within certain limits, cost is less important than effectiveness and comfort. With regard to Tychem® PC being more expensive than Tyvek®, for instance: "Maybe a little [more expensive], but that hasn't been an issue." Given the lack of information about the actual protection provided, the cost of disposable PC is what gets the most attention. "If you've got a suit and each time you spray, you buy another one, I don't know if it's a ludicrously low price, but if it costs $25 to $30, that's not going to work"; "It doesn't make sense … For a single use, it's $7 a time. Over a whole season, it's going to cost me a fortune, just in clothing."

4.2.3.5 Other Factors Related to Protective Clothing (PC) Use

Wear and tear on PC varies with use. Growers who spray from a tractor without a cab note that their whole body can be contaminated, depending on the direction of the wind and when they make a turn at the end of a row. They said, however, that the back and shoulders, chest, top of the thighs and knees, and head (hood) are the parts of the clothing most affected during spraying; they get dirty and show signs of wear the fastest. Growers also note that, during the mixing and loading, several parts of the front of the PC get dirty because they have to lean against the sprayer a lot. Direct contact occurs in particular with the thighs, legs, forearms, elbows, hands and feet, depending on the situation. In all cases, observations were consistent with what was said in the interviews.

Growers say that they also wear PC to perform certain mechanical maintenance tasks on their tractors and sprayers, which probably have pesticide residue on them. These tasks are performed during the treatment cycle or at other times. The use of PC for mechanical maintenance tasks is associated with exposure and fast wear, or even tears, on the top of the legs and between the thighs.

Combining skin protection from clothing with that provided by gloves and boots seems to cause some practical problems. Growers put on their PC without taking off their work shoes. In the interviews, they acknowledged that if their shoes have been in contact with products, then they're going to contaminate the inside of the PC when they put it on.

The tight wrists of the PC can make it hard to put on: "What's a real hassle with the Tychem® is that to put it on and take it off, there are elastics that go around your hands and so on. So once you have it on, it's on and it's fine, but afterwards, to take it off, put it back on, take it off, to get into or out of the cab, I don't know."

Generally speaking, those who wear suits for the mixing-loading work also wear gloves. One grower interviewed never wore PPE, at any time. One reported instruction recommended wearing gloves inside PC. Chemical-resistant gloves that are often stiff and go well up above the wrist are reused. One basic problem concerns the order in which clothes are put on to ensure maximum skin protection of the hands without contaminating the inside of the PC. Gloves can be put on before or after the PC, provided that the sleeve of the PC goes over them. Whatever strategy is chosen, the tight wrists of the PC make it hard to pull on the sleeves with gloved hands or to slide the sleeves over the gloves, and it all takes time: "I always have trouble getting it over top." A number of growers wear chemical-resistant gloves over the sleeve of the PC, while others always wear small disposable gloves they put on at the same time as the PC, which they keep on underneath when they put on the big chemical-resistant gloves.

The hood is another important part of the protection provided by PC, both for the neck and the face. It is especially appreciated by growers who spray from a tractor without a cab.

4.2.3.6 Work Clothing and Hygiene

A variety of work clothing was observed: T-shirt (short or long sleeves), cotton shirt (short or long sleeves), cotton fleece hoodie, cotton work pants, jeans. PC is put on on top of the day's work clothing.

Most growers say they wear long-sleeve shirts and long pants whenever they are working with pesticides, that is, both during the activities examined here and for secondary tasks during which they don't wear PC. However, only two growers stated that they always follow this rule, while three colleagues said they occasionally opt for short sleeves when it's very hot out.

Some growers noted that it's sometimes hard to wear long sleeves and long pants under PC because of the heat. The choice of work clothing worn under PC can, however, allow growers to exercise some control over their thermal comfort, for example by choosing thinner or less tightly woven fabrics: "Whoa! I'm going to be hot, that's for sure. I'll put on some thin pants like that and a thin cotton long-sleeve shirt ... but I'll definitely wear the Tychem®."

Most growers wear work clothing under their PC for comfort reasons, because skin contact with the inside of the PC suits is unpleasant. A small number of growers consider work clothes to be an added layer of protection that helps avoid or limit pesticide exposure through the skin, even when there’s no certainty about the hazard.

A number of growers wear a cap to protect themselves from the sun. Some of them also wear it under the hood of the suit to protect themselves from droplets during spraying from a tractor without a cab and to prevent the hood from sliding down and interfering with their vision. These caps, which can get wet from the spraying, are not systematically washed after being worn, and are sometimes simply set aside to dry and then worn again.

About half of the growers interviewed remove their work clothes and take a shower as soon as they have finished the spraying. Others wait until the end of the workday to remove their clothes and take a shower. Last, it seems that some growers wash only their hands and face at the end of the workday and keep wearing their work clothes for the rest of the day’s activities. Other growers wear their work clothes for more than one day.

Half of the growers say they wash the clothes they have worn while working with pesticides separately from their family’s clothes, either in a washing machine strictly reserved for that purpose, or in the family washing machine, but in a separate load followed by running the machine through a full rinse cycle while empty. The other growers wash their work clothes with their family’s clothes.

4.2.4 Summary of PC Use

The main findings regarding PC use can be summed up as follows:

1. Most growers usually follow the recommendation to wear work clothing consisting of a long-sleeve shirt and long pants.

2. Four of the five growers taking part in the study wore PC; only one did not wear any PPE. The observations revealed the wide variety of PC used. A qualitative rather than quantitative assessment of PC use pointed to the limits of and gaps in its use. On the basis of the data, it cannot be established that the PC used is effective enough to protect growers in the exposure situations examined. It could be concluded, however, that the way work clothing and PC are used is not necessarily consistent with what is recommended. In some cases, PC is worn although it is not recommended on the product label; in other cases, the PC does not provide the recommended level of protection.

3. Growers express serious doubts about the effectiveness of the PC they use. Protection effectiveness is the PC characteristic to which growers attach the most importance. The uncertainty voiced in this regard seems to have an influence on decisions about PC use.

4. Comfort, suitability for work and cost are also criteria growers use for choosing PC.

5. The lack of information about the required PPE seems to be a major obstacle to the appropriate use of PC.

The analysis highlights the repeated reuse of disposable PC, ways of putting the clothing on and taking it off that contribute to PC contamination, and storage in a place that is not protected from exposure. Other aspects of the practical use of PC may also limit its effectiveness, especially its use combined with other PPE (gloves, respiratory protection) or accessories (cap). Last, after-work hygiene practices, such as hand washing, showering, and washing work clothes, are not necessarily appropriate and can end up prolonging exposure to pesticides even when the PC has been removed.

The findings show, however, that for growers, PC use and prevention practices go hand in hand. This viewpoint indicates both an effort to find effective protective gear and a concern for protecting their health, both now and in the future.

6. PC use also reflects, to a certain extent, the reduced perception of the significance of exposure to pesticides through the skin.

7. PC use can also vary with the technical determinants of exposure, such as work equipment and products.

Growers who spray without the protection of a tractor cab want PC that not only offers effective protection, but also lets them feel dry while working. When spraying from a tractor with a cab, growers remove their PC to get behind the wheel; as a result, if they have to get out of the cab during spraying, they won’t be wearing their PC. Some growers use PC differently depending on the product: for example, after applying an insecticide, some growers will throw their PC out.

Observations also revealed the effect of temperature on the use of work clothing. In hot weather, some growers do not wear the recommended long clothing. The types of work clothing worn underneath PC vary in thickness and warmth with the ambient temperature. The effect of temperature on the choice and use of protective clothing was also observed. For instance, one grower wears thick waterproof clothing in cool weather and a Tyvek® in hot weather; growers open up their PC to cool off in hot weather.

On the basis of the collected data, the factors that facilitate or interfere with PC use can be identified. The factors that interfere with PC use largely correspond to the absence of the factors that facilitate their use.

Factors that facilitate PC use	Factors that interfere with PC use
• Information on exposure risk and product toxicity • Effectiveness of the protection—the primary criterion for choosing PC • Thermal comfort is the second criterion for choosing PC • Work suitability and comfort during movement • Cost of PC • Resistance to wear and tear, and durability of effectiveness of protection • Ease of putting on and using it in combination with other PPE	• Lack of information about pesticide risks • Lack of information about PC and its effectiveness • Work routine, microexposure situations, familiarity with work and exposure situations • View that prevention practices other than wearing PPE have a protective effect • Thermal discomfort chiefly, general discomfort and poor suitability for work • Cost of PC, especially disposable PC • Availability of PC and difficulty finding reliable suppliers

5. DISCUSSION

In international research, skin is considered to be the most significant route of exposure to the pesticides used in agriculture. This study focuses on dermal pesticide exposure and the use of protective clothing (PC). It further explores the findings of an earlier study on apple growers (Tuduri *et al.*, 2016).

5.1 A Look Back at the Literature Review

A large part of the prevention of exposure to pesticides in agriculture relies on the use of PPE. Limited, unsystematic use of PPE is well documented, however, and is the starting point of the review, which presents several perspectives on ways to improve prevention of pesticide exposure through PPE use. The terms used in the study are defined at the start. The characteristics of the PPE itself and the rules governing its use, the difficulty of establishing its effectiveness and the gaps in the information available are all significant obstacles for PPE users.

The characteristics of users have often been targeted as an explanation for the limited use of PPE. The findings of studies on the perception of risk, knowledge of risk and ways for people to protect themselves, in particular, are inconsistent. These variables seem to play a role in PPE use, but it is frequently noted that knowledge about safety or providing additional information does not necessarily lead to safer practices and increased use of PPE. Sociodemographic factors are another line of investigation. Findings regarding age, level of education, language and migratory status are also often contradictory. According to many authors, the explanatory power of social context variables is greater than that of individual variables such as perception, level of knowledge of risk or age, although the latter do act simultaneously as determinants of behaviour and practices. The economic context, economic precarity and competition, status and job security must also be considered. Other lines of research suggest taking into consideration the role of work collectives and peers. Prevention rules or instructions regarding the use of PPE, for instance, developed by institutions without the involvement of the users in question and without taking into account all of the requirements and working conditions, tend to be perceived as less effective and less legitimate than if they were rooted in real work and trade know-how and were confirmed by users.

The review also looks at the methodological characteristics of studies on PPE use, which helps to situate the specific contribution of this study. First, the heterogeneity of the studies of PPE use, in particular the populations studied, the data collection methods and the variety of aspects studied, make it difficult to compile results and draw conclusions. Second, the methods used to measure exposure in epidemiology and toxicology do not provide a clear understanding of how exposure occurs. Field studies, associated with ergonomics or the sociology of work, use activity observation and interviews to describe the work and exposure, including PPE use, in real circumstances.

5.2 Linkage between Exposure Situations, PC Use and Grower Prevention Practices

This second study differs in its use of qualitative data, taken from observations of the activity of a small group of growers and from interviews, to describe exposure situations that occur when pesticides are being used and connect them with PC use and prevention practices. The factors that facilitate or interfere with the use of protective clothing have also been described.

The linkage between exposure situations, PC use and grower prevention practices hinges on bringing together perspectives associated with ergonomics and sociology. This study uses qualitative data derived from systematic observation of the activity during pesticide use and from interviews with apple growers. The on-site interviews conducted immediately after the observations gave growers an opportunity to voice their views on a number of aspects of the situations observed. This type of approach, which takes the standpoint of the subjects in order to understand what they actually do and to take into account the contexts in which they operate, can facilitate initiatives aimed at changing practices, such as adopting a specific means of protection (Mohammed-Brahim, 2009). Repetition of the observations and interviews helped with studying the variability of the situations examined (Vela-Acosta *et al.*, 2002). The findings presented allow hypotheses to be put forward about the linkage between certain variables focused on in the scientific literature, especially knowledge of risk, familiarity with exposure situations, perception of risk, prevention practices and PPE use.

The activity analysis performed in an effort to understand and describe the exposure revealed several key aspects. Exposure often takes the form of various common and familiar microexposure situations. The expression “microexposure” reflects the observation that exposure is limited in intensity and duration and that it is only visible to a certain extent. Microexposure situations, which are numerous and repeated, are clearly an integral part of the activity; they are not a disruptive factor in the activity or in the achievement of the ongoing work objectives. They occur in the course of various actions, movements and handling operations which, likewise, are frequently repeated.

Incidents such as technical problems or overflows during loading have been associated in the literature with increased exposure (Lebailly *et al.*, 2009). Our analysis of skin exposure situations shows, however, that incidents associated with significant, unexpected exposure and disruption of regular work procedures are rare. Last, the study revealed that all parts of the body targeted in the observations, from head to toe, and from back to front, are exposed, which has also been reported in other studies (Baldi *et al.*, 2006; Hines, 2011; Moon *et al.*, 2013).

The low frequency of incidents, exposure that is limited and only visible to a certain degree, and the absence of harmful effects on the health of the growers interviewed, although reported by 40% of growers in an earlier study (Tuduri *et al.*, 2016), seem to contribute to a reduced perception of exposure (Boissonnot and Grimbuhler, 2012; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Isin and Yildirim, 2007; Mohammed-Brahim, 2009) and skin exposure in particular (Damalas *et al.*, 2006; Martinez *et al.*, 2004; Quandt *et al.*, 1998; Tuduri *et al.*, 2016). The fact that the microexposure situations are an integral part of the activity also appears to contribute to a certain desensitization to risk. Some growers themselves admit that the repetition and familiarity with the exposure situations (Damalas and Hashemi, 2010; Lambert and

Grimbuhler, 2015), as well as fatigue (Lambert *et al.*, 2011), may lead them to be less vigilant and to adopt less safe practices.

Repeated exposure to low doses and the resulting health effects do not seem to have been studied much, nor taken into account in the pesticide registration process (Jouzel and Dedieu, 2013). These repeated microexposures added a quantitative dimension to observation analysis, and a hypothesis of cumulative skin exposure during the observed activities was formulated. Even without any measurements of skin exposure, this finding supports concerns in the research community and among occupational health and safety professionals about the need to study exposure situations in the field, on the one hand, (Garrigou *et al.*, 2011), and to raise the awareness of pesticide users, on the other (Damalas and Hashemi, 2010; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; MacFarlane *et al.*, 2013; MacFarlane *et al.*, 2008). Some growers suggest that periodic, compulsory refresher courses to obtain a certificate of authorization to use pesticides could offset the effects of habits and reawaken awareness. Training prior to taking the examination is not compulsory in Quebec. Renewal of the certificate is automatic every five years, provided the required payment is made, except if the minister considers that pesticide knowledge has changed and that the examination must be retaken (ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques, 2017).

The analysis of exposure situations when pesticides were being used, based on activity observations and interviews, highlights the significant effect of technical and organizational determinants of exposure. Examples of technical determinants are the layout of the premises and stations (e.g., storage facility, measuring station, loading station, access); the products themselves (e.g., form, packaging, weight, format, type of opening); the equipment: tractor with or without a cab, sprayer (e.g., design, size, access, use, maintenance); and tools (e.g., measuring containers). These technical determinants have an effect on work methods, actions and work posture (Lebailly *et al.*, 2009; St-Vincent *et al.*, 2011) and result in contacts with products in various forms (Garrigou *et al.*, 2011; Lebailly *et al.*, 2009). Their effect on exposure varies with the phase of the activity. Product mixing and loading are associated with a large number of exposure situations. Some prevention practices observed or described are related to these determinants. This information could be taken into consideration in initiatives to reduce exposure through the design of set-ups, equipment and tools, and in applied training on the safe organization of work.

Our analyses considered the effects of the variability of the activity on exposure. The findings show the effect of technical determinants on interindividual variations in exposure. The equipment, especially whether the spraying is done from a tractor with or without a cab, is a major factor. The layout of the premises and a number of product characteristics also have an influence on variations in exposure. Temperature is associated with inter- and intraindividual variations in PC use. All these factors must be taken into consideration for prevention initiatives.

The effects of equipment on variations in exposure and the implications for research and development are especially significant in the case of spraying from a tractor without a cab. This situation represents only a part of the tasks performed by growers that are associated with exposure. Nearly a third of Quebec apple growers do not have a tractor with a cab. While the exposure resulting from this situation is familiar and predictable, it can hardly be classified as microexposure; the intensity and duration are the two key characteristics of this exposure (Baldi *et al.*, 2006; Lebailly *et al.*, 2009; Vitali *et al.*, 2009; Zhao *et al.*, 2015). Growers who spray without a cab are especially concerned about PC effectiveness. With the information provided by the field study, it was possible to take into account the effects of environmental and organizational constraints on occasional practices that increase the likelihood of exposure, such as spraying when it is windy or very hot.

The analysis based on observations and the interviews shows that other determinants have a less direct, but nonetheless real effect on exposure situations. In particular, the effect of organizational determinants, such as the adoption of targeted practices associated with integrated fruit production which lead to the repetition of activity cycles, can be deduced from the exposure situations observed; time constraints; and the limited resources of small orchards, which mean that the growers themselves have to perform many of the tasks that are associated with exposure (Béguin and Pueyo, 2011; Spoljar, 2015; Tuduri *et al.*, 2016). The repetition of mixing-loading and spraying tasks over the course of a workday has been associated with increased skin exposure (Lebailly *et al.*, 2009). Environmental constraints, the weather and the temperature, in particular, also have an effect on activity and exposure (Béguin and Pueyo, 2011; Eizner, 1972). The effect of these determinants can also be seen in some prevention practices, such as organizing working hours so as to spray early in the morning or late in the evening, or spreading the spraying out over two days to give a tired grower some relief, although this means repeating part of the activity that creates exposure situations. The effect of organizational determinants on exposure and the means to address them could be subjects of further research.

The use of various types of protective clothing was observed at the orchards of four of the five subjects of the study; one of the growers said that he never used any PC. The observation that all parts of the body are exposed during the examined activities emphasizes the importance of wearing clothing that protects the whole body. The proportion of subjects wearing PC is higher than what has been reported in recent Quebec studies (ministère de l'Agriculture, des Pêcheries, et de l'Alimentation du Québec, 2014; Tuduri *et al.*, 2016) and higher than what is generally described in the literature. Considerations to do with small sample size, sample representativity and the effect of the data collection system are discussed below in relation to the scope and limitations of the findings. The variety of choices made by the growers with respect to PC (ProShield®, Tyvek® or Tychem®, waterproof clothing) may be associated with the lack of information and the difficulty of choosing that they have described. The growers said they always used the same PC for their work with pesticides; the PC was worn systematically when observations were made and always in the same way. The constancy of PC use stands out also because unsystematic use of PPE, along with different practices in similar exposure situations, has often been described (Garrigou *et al.*, 2008; Judon *et al.*, 2015; Lambert and Grimbuhler, 2015; ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, 2014; Tuduri *et al.*, 2016).

These findings on PC use can first be analysed in terms of compliance with the recommendations given on the labels of the pesticides used (see Table 9). According to the observations described, the use of work clothing and PC is insufficient in some cases, while it exceeds labelling recommendations in other cases. Pesticide mixing and loading without following the instructions to wear long-sleeve clothing and long pants, or the wearing of waterproof clothing rather than a chemical-resistant suit, are examples of noncompliance. With the exception of the one grower who never wears PC, some of the growers who do not follow the instructions regarding long sleeves and long pants do, however, wear PC when it is not indicated, which can be regarded as replacement protection. Wearing PC of any kind when it is not recommended on the label is also a situation of noncompliance. That could be the case in some of the situations observed; for instance, four of the growers wear PC when they use products for which PC is not recommended. The observations and interviews revealed that the growers who spray from a tractor without a cab and who voiced their need for effective protection most strongly wear their PC for the entire pesticide use cycle.

These findings can also be considered in terms of the level of protection associated with each PC choice made by the growers, regardless of compliance or noncompliance. According to the Dupont classification (Dupont, 2016a), the level of protection associated with the PC worn is uneven. The three brands ProShield®, Tyvek® and Tychem® offer different PC. Wearing ProShield® PC could be suitable for a low-level risk, whereas a moderate-to-high risk would require Tychem® PC; between these two levels, Tyvek® PC could be suitable. One grower in the study used a ProShield® suit for mixing-loading and for clean-up; the growers who wore a Tyvek® or Tychem® chemical-resistant suit as PC, or waterproof protective clothing, also wore it for spraying from a tractor without a cab. It is extremely difficult to judge the real effectiveness of the protection afforded by the PC worn by these growers.

The effectiveness of the protection afforded by PC is the top PC selection criterion for growers, which in itself is revealing of their perception of risk and their concern with the effects of pesticides on their health. A number of them expressed doubts about the effectiveness of the PC they were using; they also noted how hard it is to obtain information about PC and how to use it, and about the risks to which they are exposed. Other studies have reported the same problems (Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Perry and Bloom, 1998; Tuduri *et al.*, 2016). These factors have an influence on PC use (Boissonnot and Grimbuhler, 2012; Schenker *et al.* , 2002). The review of the literature on the characteristics of PPE showed that growers' reservations and concerns are founded. An initial exhaustive survey done in Quebec had already identified numerous obstacles to the use of individual protection in the form of PC (Tuduri *et al.*, 2016). The effectiveness of PPE and PC in particular in reducing exposure in real exposure and work situations has not been fully established. The PC available in Quebec and elsewhere in Canada is not certified in any way, which is already a major problem (Tuduri *et al.*, 2016). It should be noted that the chemical resistance of this PC, even when it is certified in accordance with standard ISO 16602, for instance, is not measured using crop protection products. So, in addition to the fact that the level of protection is uneven, there is also the question of whether the level of protection is sufficient or appropriate for the "assessed" risk (Béguin and Pueyo, 2011; Feola and Binder, 2010; Galt, 2013; Garrigou *et al.*, 2011; Jouzel and Dedieu, 2013; MacFarlane *et al.*, 2013; Salvatore *et al.*, 2008; Tuduri *et al.*, 2016). The definition of the kinds of PPE and clear, consistent designation of the PPE required in specific exposure situations are also a problem (Damalas *et al.*, 2006; Hines *et al.*, 2011; MacFarlane *et al.*, 2013; Salvatore *et al.*, 2008). The information available about what constitutes an acceptable level of personal protection for any given exposure situation is not sufficient to guide users (Avory and Coggon, 1994; Blanco-Munoz and Lacasana, 2011; Matthews, 2008; Nicol and Kennedy, 2008; Schenker *et al.*, 2002). Last, information about how to use PPE is also inadequate (Lambert and Grimbuhler, 2015). Repeated use of disposable PC is a good example of this point (Navarro *et al.*, 2011).

Our findings underscore the fact that, in contrast with the WPS in force in the United States (EPA Worker Protection Standard, 40 CFR, Part 170 [2017]), the recommendations on the Canadian labels examined do not systematically take into account the task to be performed, such as product mixing-loading or spraying. A discussion with growers about the usefulness of product labelling also revealed that the labels sometimes recommend the use of different PC depending on the job title—e.g., “mixer/loader/applicators” or “custom mixer/loaders” (Gowan Canada, 2016)—and that it is not easy to understand the difference between the two. Recommendations may differ depending on what sources are consulted, for example, labels or the SAgE pesticide information tool of the Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ). This type of knowledge gap is particularly emphasized by authors who insist on the need to go into the field and conduct systematic, repeated observations of the work in order to understand what farmers really do and to examine the variety of exposure situations that recommendations about PC use must take into account (Garrigou *et al.*, 2011; Mohammed-Brahim and Garrigou, 2009; Nicol and Kennedy, 2008).

The findings particularly underscore the fact that the effectiveness of protection must meet different needs depending on whether growers are spraying from a tractor with a cab or without. The PC used in exposure situations associated with spraying without a cab must have special characteristics in terms of resistance to chemicals (effectiveness, duration of protection) and thermal comfort, considering the effects of wind and displacement speed on the intensity of the exposure and the duration, as well as the repetition of the exposure situation over the course of the same day (Baldi *et al.*, 2006; Vitali *et al.*, 2009; Zhao *et al.*, 2015). Paradoxically, the growers who wore waterproof PC or chemical-resistant suits for all their spraying from a tractor without a cab, regardless of what pesticide they were using, frequently failed to comply with the labelling recommendations. Even if just under a third of Quebec apple growers spray from a tractor without a cab, this special requirement should be explicitly stated on all labels, and be considered in research and development work on PC for agriculture. PC required in other exposure situations—mixing-loading and clean-up, but also for tasks that require going back into sprayed blocks—must meet different needs with respect to protection effectiveness (Branson *et al.*, 1986; MacFarlane *et al.*, 2013).

The observations and interviews revealed shortcomings in the way PC is used, especially as a result of wear and tear, repeated use of disposable clothing, ways PC is put on and taken off, and how it is stored. Other aspects of grower use of PC may also limit the effectiveness of the protection it offers, especially when it is worn in combination with other PPE (gloves, respiratory protection) or accessories (cap). Last, the use of work clothing and hygiene practices following pesticide use, such as hand washing, showering, and laundering work clothing, were not necessarily appropriate and could result in prolonging the duration of the exposure to pesticides, even after growers have removed their PC (Navarro *et al.*, 2011).

Aside from protection effectiveness, which was the first selection criterion of all the growers, the interviews revealed the growers’ other needs and selection criteria for PC: thermal comfort, suitability for work, cost, and resistance to wear and tear. Thermal comfort and work suitability have an influence on PC use (Branson *et al.*, 1986; Garrigou *et al.*, 2008; Isin and Yildirim, 2007; MacFarlane *et al.*, 2013; Navarro *et al.*, 2011; Snipes *et al.*, 2009). It turns out that PC protection effectiveness is inversely proportional to the user’s thermal comfort, with the best protection being given by PC that doesn’t breathe. The findings presented provide a basis for the hypothesis that the use of PC that doesn’t offer maximum effectiveness, but that is combined with a thermal comfort level that promotes its continuous use, could be considered in moderate exposure situations that also allow the use of additional prevention practices. This requires better characterization of the levels of protection offered intrinsically by the PC, inversely correlated to the user's level of comfort (Branson *et al.*, 1986; MacFarlane *et al.*, 2013; Navarro *et al.*, 2011).

These factors highlight the key importance of the work activity and the need to make prevention an integral part of it so that recommended OHS measures are adopted and followed systematically and effectively (Mohammed-Brahim and Garrigou, 2009; Simard and Marchand, 1997). The cost of PC, though less important than effectiveness and comfort, also seems to play a role in growers' PC choices (Damalas *et al.*, 2006; Garrigou *et al.*, 2008; Navarro *et al.*, 2011). Where effectiveness is equal, our findings suggest that disposable PC may be deemed too expensive, which would encourage repeated use of PC designed specifically for that purpose.

The activity analysis also revealed that growers devise and use a range of prevention practices developed by trial and error, and adapted and incorporated into common microexposure situations. The importance that growers attach to such practices was unexpected. These are planned, repeated actions whose purpose is not necessarily related to the performance of production tasks, even if they can contribute to the effectiveness of the activity, and the explicit objective of which is to prevent exposure. The growers themselves describe the connection between exposure situations and prevention practices, the integration of these practices into their usual activities, and the role of experience and trade know-how in devising these practices (Galey, 2013; Garrigou *et al.*, 2008; Salvatore *et al.*, 2008; Simard and Marchand, 1997; Vitali *et al.*, 2009). The possibility of feeling well protected by PC may conversely be associated with a relaxation of prevention through other practices integrated into the work activity and with greater exposure when the PC is not appropriate (Garrigou *et al.*, 2012). Examples of practices for reducing exposure include having workers take up positions with their backs into the wind, adopt work methods that help products to dissolve or reduce the amount of handling required, and set up the work premises appropriately. The interviews confirmed that growers underestimate the significance of exposure through the skin (Boissonnot and Grimbuhler, 2012; Damalas *et al.*, 2006; Davillerd and Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, 2001; Martinez *et al.*, 2004; Tuduri *et al.*, 2016). The prevention practices studied do not target any particular route of exposure, however; they are the expression of an integrated approach to prevention (Simard and Marchand, 1997).

A number of growers do not hesitate to voice their doubts about the effectiveness of the PC they are using (Galt, 2013). Depending on the case, the growers present prevention practices as being complementary or as an alternative to the use of PC (Ali *et al.*, 2006). When no clear information is available about risk and the PC being used, the development and integration of various prevention practices into the work activity are indications of a pragmatic approach to prevention, adapted to suit the most common exposure situations, based on know-how, experience and the pursuit of effectiveness (Colémont and Van den Broucke, 2008; Wadud *et al.*, 1998). The strategy that consists in combining two types of prevention practices (Simard and Marchand, 1997) to achieve greater effectiveness is therefore a thoughtful response to a difficult situation and one that is consistent with the concerns expressed about the effects of pesticides (Ali *et al.*, 2006; Boissonnot and Grimbuhler, 2012; Isin and Yildirim, 2007; Perry *et* *al.*, 1999; Raynaud, 1989). This aspect of prevention practices must be taken into account in approaches aimed at improving exposure prevention, especially through PPE use.

International research has studied the major role played by work collectives that bring workers together around common objectives (Caroly, 2010) and social norms shared by peers (Black *et al.*, 2015; Vitali *et al.*, 2009). Work collectives participate in developing occupational identity and trade know-how. The individual and collective development, testing, adaptation and implementation of safety rules and practices, such as PC use (Tomas *et al.*, 2009), can also be associated with collectives and peers, on condition that discussion forums exist for confirming and maintaining trade rules (Black *et al.*, 2015; Caroly, 2010; Cuvelier and Caroly, 2011; Perry and Bloom, 1998; Vitali *et al.*, 2009). An absence of discussion and debate can cause a delay in the adoption of trade rules in relation to the development of means of production, which can give rise to risks for both the health of operators and for the overall performance of the system (Béguin and Pueyo, 2011; Simard and Marchand, 1997; Spoljar, 2015). The effectiveness of intervention strategies based on collectivities rather than on the individual has been demonstrated (Feola and Binder, 2010; Perry and Bloom, 1998).

Grower isolation and the relative lack of discussion about health and safety issues described by growers in this and an earlier study (Tuduri *et al.*, 2016) are another significant finding in connection with the objective of supporting the adoption of prevention practices in agriculture. The industry association Les Producteurs de pommes du Québec, which represents virtually all growers, focuses on concerns and advocacy in favour of collective agreements with respect to quality, prices and product marketing. The growers confirmed, however, that they tend not to discuss work-related issues with their peers. Some expressed their disappointment that the agricultural industry does not organize more meetings to allow them to discuss risks, prevention practices and PPE use. Even though work collectives have been studied within large corporations, the needs expressed by small growers suggest that it might be worthwhile exploring natural networks and industry associations as a means of promoting discussions about their trade, the work and OHS issues (Black *et al.*, 2015; Caroly, 2010; Champoux, Baril, Beauvais and Brun, 2013; Cuvelier and Caroly, 2011; Perry and Bloom, 1998; Vitali *et al.*, 2009; Wadud *et al.*, 1998). The growers interviewed emphasized that their discussions with the researchers encouraged them to think about their work and prevention practices and be explicit in explaining them. The isolation, heavy workload and narrow operating margins of small growers were associated with an underestimation of risk, knowledge that is not up to date, and less-than-perfect adherence with prevention rules and recommendations (Beseler and Stallones, 2010; Boissonnot and Grimbuhler, 2012; Carpenter *et al.*, 2002; Champoux and Brun, 2010; Hwang *et al.*, 2000; Isin and Yildirim, 2007).

The comments received about the lack of discussions among agricultural producers highlight the fact that in the wake of the changes related to the adoption of new products and targeted treatment practices, technical protocols have received a lot of attention, whereas less effort has gone into studying the conditions under which farmers and farm labourers perform their work. This observation underscores the advisability of conducting field studies to gain a better understanding of farm work and the needs that arise due to the many constraints under which farmers must operate (Béguin and Pueyo, 2011; Galt, 2013; Perry and Bloom, 1998).

The findings on PC use also draw attention to the nature of the formal rules issued by institutions and organizations, and to the context that favours their implementation (Black *et al.*, 2015; Galt, 2013; Jas, 2007; MacFarlane *et al.*, 2013; Perry and Bloom, 1998; Salvatore *et al.*, 2008; Vitali *et al.*, 2009). The regulations respecting PPE use are derived from the pesticide registration process administered by Health Canada's Pest Management Regulatory Agency (PMRA) and from the essential linkage between compulsory PPE use and safe pesticide use. The findings presented here corroborate those of a recent study (Tuduri *et al.*, 2016). The incomplete linkage among a number of system components contributes to a reduced perception of risk, limited adoption of integrated prevention approaches and unsystematic or inappropriate use of PPE and PC in particular (Béguin and Pueyo, 2011; Galt, 2013; Jouzel and Dedieu, 2013). Hence the lack of information about pesticide-related risks; recommendations for PPE use that have neither been confirmed by the community nor adapted to suit specific work situations; limited coordination between an institution like the PMRA, local OHS authorities and farmers; the absence of standards or certification for PC, imprecise naming of PC, and distribution of PC by actors who do not have the required knowledge or credibility. All these factors are involved in exposure prevention efforts that are not totally effective.

The discussion of all the findings related to the review of the literature is summarized below by a model (Figure 6) that describes the links between key components of our analysis of the factors involved in PC use by apple growers. The model helps to appreciate the complexity of the interactions among various kinds of factors: knowledge and information about risk; personal experience with the use of pesticides, risk perception, trade know-how; multiple constraints; and pursuit of activity effectiveness that can give growers an incentive to combine PC use with prevention practices.

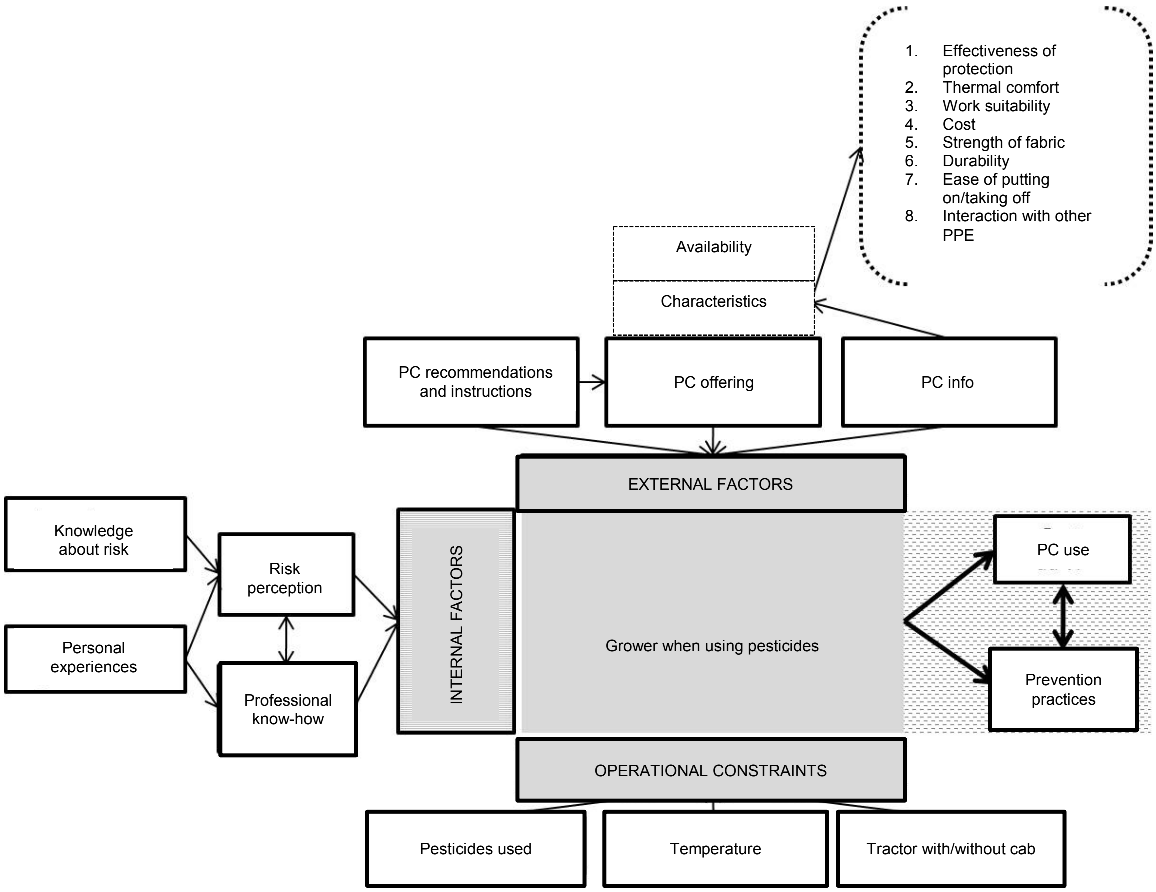


Figure 6. Model illustrating factors and constraints that influence decisions about wearing protective clothing (PC)

5.3 Scope and Limitations

This study expands on the findings of an initial study of Quebec apple growers by focusing specifically on skin exposure and the use of protective clothing. A distinguishing feature of this new study is the use of qualitative data—systematic and repeated observation of the work activity, followed by interviews—collected from a small group of apple growers. A goal of this study was to determine what factors facilitate or interfere with the wearing of PC.

A number of aspects define the specific contribution of this study. A review of various lines of research on PPE use, a primary objective of the study, provided a brief survey of several research trends on the impact of social factors on stakeholder practices. The methodological characteristics of the studies on PPE use were also discussed.

The qualitative research design adopted gives preference to the collection of data in the field and an inductive approach to the analysis of growers' practices. The use of the two data collection methods, and the systematic review of observations during the interviews, added precision to the information gathered. Repeated visits to five growers to examine predetermined exposure situations increased the number of observations. The repetition of the observations and interviews under different conditions depending on the variables described added an element of contrast and provided opportunities to examine several work and exposure situations during which protective clothing was worn.

The analysis of the work activity served to describe a variety of skin exposure situations characterized by microexposure that are an integral part of the usual, regular workday. The chosen research method also focused on the repetition of the exposure situations, and the likely build-up of the resulting skin exposure. With regard to these qualitative aspects, the findings provide an overview of exposure scenarios that are very likely representative of reality. Given the lack of quantifiable biological measurements of exposure, it can be assumed that this information about the repetition and build-up of exposure may help raise users' awareness of pesticide risks and encourage them to take effective steps to protect themselves.

On the basis of the data, exposure situations can be related to growers' practices involving PC. Observations revealed shortcomings in growers' wearing of work clothing, the length of time PC was used, the way it was put on and the way it was stored. This type of finding, which is not available with survey data, illustrates the added value of field studies. In addition, the interviews revealed the problems growers encounter in obtaining information on appropriate PC, as well as their reservations about the effectiveness of the protection afforded by their PC. They also served to identify factors that facilitate or interfere with the use of PC.

The methodology made it possible to examine a variety of prevention practices that were an integral part of the work activity and were based on experience and trade know-how. Growers resort to them in addition to their use of PC. The qualitative data on prevention practices confirm the many shortcomings in PC use, but also put them into context. Findings of this kind should be taken into consideration in OHS initiatives aimed at improving prevention of exposure to contaminants.

The number of visits and the repetition of the observations and interviews helped the researchers further their understanding of grower practices. The repetition also enhanced the quality of the discussions between growers and researchers. The establishment of a relationship of trust could be seen, in particular, in the fact that growers were quite willing to demonstrate or describe practices that do not necessarily follow recommendations, which contributed to the validity and usefulness of the findings. In addition, the growers revealed that the repeated discussions with the researchers had made them think about their work and raised their awareness about certain inconsistencies between principles, knowledge or opinions, and practices, and had prompted them to voice their concerns and expectations. For instance, during a discussion about why one grower didn't take his boots off when putting on his suit, he said it was because it was faster that way, then he thought out loud about how he was contaminating the inside of his suit. In another situation, when a researcher asked a grower why he didn't slip his gloves underneath the sleeve of his suit, as recommended, he said: "Ah! I was wondering when you were going to ask me that!"

As the data were gathered from a small sample of five growers, the study of exposure situations and prevention practices cannot be regarded as exhaustive. The effect of the small sample size on the quality and representativity of the information about risk perception and PC use cannot be ignored; it is one of the study's limitations.

6. CONCLUSION

In agriculture, the use of PPE plays a pivotal role, de facto, in the prevention of pesticide exposure risks. However, failure to use prescribed PPE systematically is well documented and has become a prime target of initiatives to reduce pesticide exposure. An in-depth on-site investigation based on observation of work activity and on interviews helped to identify the relationships between exposure situations, the use of protective clothing (PC) and prevention practices. An analysis based on the complementary nature of ergonomics and sociology produced information essential to the understanding of apple growers' practices. The findings presented here describe the combined effect of a number of different factors on the use of protective clothing against pesticide exposure.

The knowledge available and growers' personal experience with pesticides, especially the repetition of microexposure situations, seem to contribute to a reduced perception of the risks connected with skin exposure to pesticides among apple growers. Intervention initiatives focusing on these factors can be developed. In particular, information on repeated and cumulative skin exposure, and especially on the effect of technical determinants and work methods, may play a role in the adoption of protective measures. Even though growers express concerns about the effects of pesticides on their health, they do not always adopt practices consistent with the labelling recommendations regarding PC use.

It must be acknowledged, nevertheless, that it is hard to judge the real effectiveness of the protection offered by the PC items worn. The findings presented here reveal that the major shortcomings in PC availability definitely have an effect on the doubts expressed by growers regarding the protection effectiveness of their PC and on their use of it. These shortcomings concern the certification and clear naming of PC, the protection required in different exposure situations, information on how PC is to be used, and the distribution of PC by accredited suppliers. A better design of PC to make it more suitable for agricultural work must also consider the effectiveness of its protection according to exposure situations, thermal comfort and cost. For instance, spraying from a tractor without a cab is associated with specific protection needs. Joint efforts by institutional, research and OHS stakeholders are required in order to improve protection against exposure through the use of PC.

The data collected in the field show, however, that apple growers rely on their trade know-how in developing and implementing prevention practices that they integrate into the normal course of their activities and that they present as complementing the use of PC. These findings suggest that practices that do not comply with recommendations may be seen as an adaptation in the face of formal rules unsuited to the realities of the growers' work and needs.

Prevention practices developed in the field reveal growers' capacity to think about and respond to the risks associated with their work. The participation of farm workers in developing, testing and validating safety rules through trade collectives could be a good way to proceed. Getting various trade and industry groups to work with OHS stakeholders, for instance, could promote the development of safe practices that are well integrated into work activities and more systematic use of adapted, effective PC. Joint action between agricultural and OHS stakeholders would help with devising initiatives that are firmly rooted in real work and social dynamics.

Finally, the findings as a whole suggest that the various initiatives taken to improve the prevention of pesticide exposure must be consistent and complement one another. A number of aspects must be combined to persuade and support agricultural producers in their prevention efforts: information on the risks associated with pesticides, enhancing appreciation for prevention at source, updating training and having the workers themselves validate safety rules must all be part of a prevention strategy that relies, as a last resort, on personal prevention practices and the use of PPE.

6.1 Impacts of Study

The study findings provide grounds for a variety of possible OHS initiatives in agriculture.

RECOMMENDATIONS FOR INITIATIVES THAT PROMOTE USE OF PC

1) **Provide clear, comprehensive information on the risks associated with pesticide use:**
    - Raise grower awareness of “microexposures.”
    - Instigate a discussion on the design of equipment, products, set-ups and work organization, adapted to the work activity and with a view to minimizing exposure.
    - Provide information on skin exposure.
    - Provide information on the health hazards of fungicides and insecticides.
2) **Develop joint initiatives to review what is available in the way of PC for farmers in Quebec:**
    - Design and test effective protective clothing that is adapted to real work conditions (variety of exposure situations, thermal comfort, work suitability).
    - Study the possibility of establishing some form of PC certification.
3) **Develop joint initiatives to provide clear, reliable information on PC:**
    - Develop clear, standardized information on:
        - Choice of PC depending on exposure situations
        - PC use practices
            - Putting clothing on, taking it off
            - Maintenance, storage, replacement
            - Personal hygiene
    - Ensure distribution and sale of PC by informed, accredited suppliers.

RECOMMENDATIONS FOR JOINT INITIATIVES AIMED AT REDUCING EXPOSURE THROUGH A BROAD APPROACH TO PREVENTION

1) **Raise awareness of the importance of integrating prevention practices into work activities and ensuring they complement the use of PPE.**
2) **Support the establishment and operation of work collectives and discussion forums focused on improving prevention.**

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