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Occupational exposure to plant protection products and health effects in Switzerland: what do we know and what do we need to do?

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Summary

AIMS: There is currently no centralised database on workers' exposures to plant protection products (PPPs) in Switzerland, nor a national register for negative health effects linking them to occupational PPP exposure. This lack of basic data makes it difficult to implement either epidemiological research or prevention campaigns for the agricultural sector. The first objective was to understand the level of information and flow of data on occupational PPP exposures and health effects in the Canton of Vaud, Switzerland. Then, to apply this information to develop recommendations for improving a vigilance system for occupational health effects related to PPP exposure.

METHODS: A mapping study and semistructured stakeholder interviews were conducted to better understand the flow of data on occupational PPP exposures and health effects. A clinical records investigation of workers occupationally exposed to PPPs was undertaken to understand the magnitude of this potential problem. Finally, a workshop brought together relevant stakeholders to discuss recommendations for the way forwards.

RESULTS: A lack of data on PPP exposures and associated health effects was revealed. This highlighted important knowledge gaps at different levels of the current institutional information flow system. We found that although there were numerous stakeholders that worked efficiently in their own mandate, there was a clear need for increased collaboration and coordination in order to make use of existing data to promote safer PPP use among agricultural workers in Switzerland.

CONCLUSIONS: Due to increasing evidence of an association between PPP exposure and health effects, increased collaboration between stakeholders is necessary to develop links between the data sources that already exist. Our study was the first to investigate the health effects linked to PPP exposure among the Swiss agricultural population. The recommendations presented in this paper would help promote a safer and healthier agricultural workforce in Switzerland, as well as the population at large.

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Introduction

Plant protection products (PPPs) are extensively used in agriculture worldwide to control harmful pests and prevent crop damage. PPP is a generic term that includes thousands of different products used to prevent, destroy or control harmful organisms or diseases, and to protect plants or plant products during production, storage and transport [1]. The term PPP is a regulatory term often used interchangeably with "pesticide"; however, pesticide is a broader term that also covers non-plant/crop uses, such as biocides and veterinary drugs [1]. PPPs are only applied on plants or crops and do not include biostimulants, which are regulated as fertilisers. Despite beneficial actions of PPPs for agricultural production, their widespread use and inherent toxicity has posed long-recognised threats to human health [2]. Of potential PPP exposures, those that occur in the workplace are of particular epidemiological importance because of the likelihood of chronic exposures [3]. Agriculture in every industrialised country is one of the most hazardous occupations, on the basis of fatality and injury rates, as well as illness rates [4]. From an occupational health perspective, chronic health effects, such as cancers and neurodegenerative diseases, are more important than acute effects because of their severity, impact on the quality of life of workers and their families, and their incurred costs to the public health system. The association between occupational PPP exposures and chronic health effects has been well documented, providing evidence of a positive association between occupational exposure to PPPs and neurological pathologies (including Parkinson's disease), prostate cancer and haematopoietic cancers (non-Hodgkin's lymphoma and multiple myeloma) [2, 5–7].

Occupational PPP exposure in Switzerland

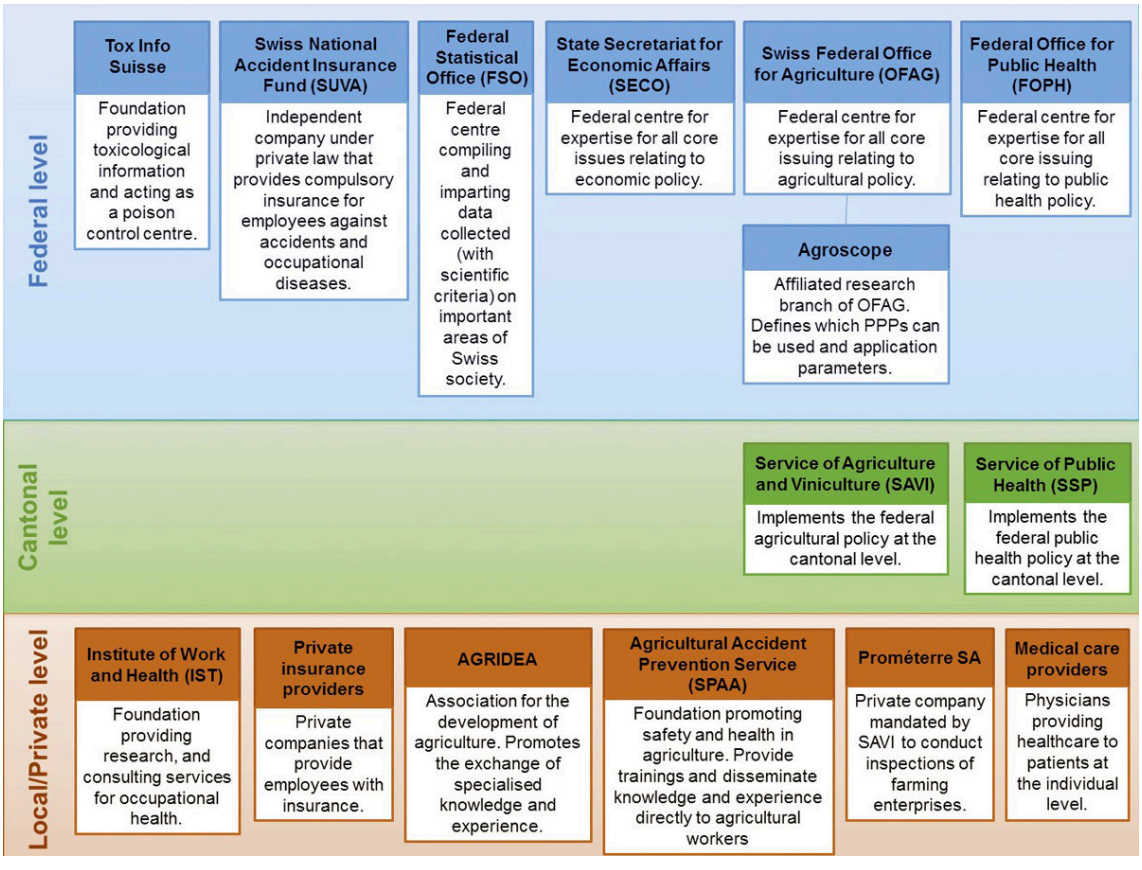
As in other countries, PPPs are widely used in Swiss agriculture to promote crop yield and quality, particularly on vulnerable, but high profit, crops such as grapes used for wine making and stone fruits (e.g., apricots in Wallis). Almost 400 active substances are currently registered in

Switzerland and are present in more than 1200 different types of marketed PPPs [8]. Almost 2200 tons of active substances are sold every year [9]. Despite knowledge of the amounts of active substances sold, precise information on the utilisation of active substances is limited. What is known is that approximately 1.1 million workers are affected by work-related health problems in Switzerland [10]. In terms of the financial repercussions of occupational exposures, this situation is not negligible. It is estimated that occupational disease costs amount to at least 3% of the gross domestic product (equivalent to CHF 20 billion per year [10]). In 2003 there were 1000 deaths due to occupational exposure to chemical products in Switzerland [11]. However, a critical link between PPP use and subsequent exposures, as well as potential incurred health effects among Swiss workers, is currently lacking. What are the incidence rates for PPP-related disease among Swiss agricultural workers? How can we know if an occupational health risk exists among this population?

This lacuna of information may be a symptom of a lack of attention to workplace health indicators, but it is also possible that it results from a more generalised problem of transparency and health information management. According to an Organization for Economic Co-operation and Development (OECD) study, Switzerland is one of the countries with the most limited health information systems [12]. Of an analysis of health information systems across 22 OECD countries, Switzerland ranked second to last in terms of availability of health data. This study revealed that only 14% of health datasets are regularly linked or integrated for research and statistics, highlighting the problem that Switzerland lacks connections between different health institutions when it comes to data sharing and monitoring [13].

There are several relevant bodies involved in the collection of agricultural, occupational and public health data at the federal, cantonal and local or private level in Switzerland (fig. 1). Nevertheless, there is currently no centralised and standardised database on workers' exposures to PPPs, or a national register of negative effects due to occupational PPP exposure. This lack of knowledge makes it difficult to design and implement epidemiological research, promote coordination among stakeholders, or to understand the need for prevention efforts. As such, the objective of this research was to better understand the state of the knowledge regarding health effects due to occupational PPP exposures in Switzerland. As part of this larger objective, an information flow map was developed to better define potential strategies for the improvement of a vigilance system for PPP related health effects.

Figure 1: Overview of relevant stakeholders in Switzerland at the federal, cantonal, and local/private level with regard to collection of data on agricultural workers, including PPP use and exposures, and occupational and public health indicators related to adverse health effects. These stakeholders may be involved in PPP regulation and risk assessment (e.g., SECO, FOAG, FOPH), implement agricultural policies (e.g., SAVI, Prometerre SA, SSP of VAUD, Agroscope), provide health insurance (e.g., SUVA, private insurance companies), provide education and advisory services for workers (e.g., SPAA, SUVA, AGRIDEA, IST) as well as healthcare to patients (e.g., medical care providers, IST), or, conduct research or gather/analyze existing data (e.g., IST, FOS). We contacted all the stakeholders presented in figure 1 for an interview.



Methods

Research was conducted between November 2016 and July 2017. Due to differences between cantons in regards to legal mandates and health data protocols, we restricted research to the canton of Vaud (Vaud). This canton was particularly interesting owing to the high concentration of vineyards and orchards, and because it is home to one of the region's largest university hospitals (Lausanne University Hospital).

Mapping study and stakeholder interviews

As we were aware that a national database of information on occupational PPPs exposure did not exist at the time of undertaking the research, a mapping study was conducted because of its utility in reviewing multifaceted characteristics of a research question [14]. Mapping focuses not only on research findings, but also on qualitative descriptors that reveal relationships and linkages between resulting data and information flow [14]. Our mapping study consisted of iterative reviews of press and media articles, as well as grey and peer-reviewed literature. In addition, semistructured interviews were used to collect information from stakeholders and took place between October 2016 and January 2017 (the stakeholder interview form is available in appendix 1). This first research phase sought to identify linkages between the different stakeholders depicted in figure 1 in order to comprehensively map existing information flow systems in regards to occupational PPP exposure and health effects.

Clinical record investigation

The Institute for Work and Health (IST) provides specialised medical consultations for workers with health concerns that may be linked to professional activity. IST occupational physicians conduct health examinations and record the patient's work history, which may be supplemented by analysis of safety data sheets and a workplace visit. From the gathered information, the occupational physician will determine the imputability of the pathology to occupational exposures, suggest preventive workplace measures together with an occupational hygienist, and advise workers on follow-up procedures such as a formal occupational disease claim to the relevant health insurance. The IST medical department analysed patient files and provided an anonymous summary of all agricultural workers who had visited the IST between April 1993 and January 2017 with a health concern and occupational exposure to PPPs.

Stakeholder workshop

Based on information collected during the first research phase, a stakeholder workshop was organised in which focus group discussions could investigate more precisely the research questions at hand. Workshop participants included representatives of federal and cantonal authorities, foundations, universities, family physicians and specialists, occupational physicians, private insurance companies, SUVA (the Swiss National Accident Insurance Fund) and agricultural organisations. The objectives of the workshop were to: present the current situation and describe examples of registries used to collect data on the health effects of PPPs; identify barriers in collecting occupational health data; identify existing stakeholders that could develop a registry on effects related to PPPs; and define recommendations to improve the collection of PPP-related health effects.

Results and discussion

Overall, our investigations revealed that a significant lacuna of information currently exists for both exposure data and health effect indicators related to occupational PPP exposures in Switzerland. Consolidated results from the mapping study and stakeholder interviews (19 conducted in total) were used to map the informational flow related to PPP exposure and health effects, and to better characterise the barriers that exist for data collection and analysis. Results revealed three distinct areas of importance: (1) occupational PPP exposure scenarios; (2) reporting of PPP used; and (3) reporting pathways of different PPP-related health effects (fig. 2).

Part 1: Occupational PPP exposure

Exposure is largely dependent on work tasks, and whether an individual is an "operator" or a "worker". Operators handle, mix/load the PPPs; operate and repair application machinery; and empty/clean machinery after use. Workers are exposed when re-entering an agricultural area to conduct various tasks after PPP application, such as pruning and harvesting. The main risks for PPP exposure are due to noncompliance with protection requirements, such as the lack, or incorrect use of personal protective equipment (PPE). Results from the mapping study and stakeholder interviews revealed that a majority of Swiss agricultural workers do not take proper precautions for PPE use for a variety of reasons [15]. PPE represents a significant cost to farm owners, many of whom are not incentivised to purchase or replace materials. In some cases, individual PPE pieces may be purchased in lieu of an entire "PPE kit". These pieces may not always be well suited for the work task, and can increase the exposure risk. PPE may also be uncomfortable or burdensome, and some farmers are concerned that PPE may harm the agriculture image among the general population in regards to the use of toxic substances. Finally, interviews revealed that there is a generally low level of risk perception among agricultural workers when it comes to PPP exposures. The Federal Office of Statistics has retrievable data for number of employees in agricultural operations by year and Canton, but this figure is not defined for precise job-titles (owner vs operator vs worker). Caution must be used when using job titles as exposure surrogates because they may not be predictive for PPP exposure [16].

Part 2: Reporting of PPPs used

It was not possible to quantify the amount of PPPs used in Vaud for agricultural operations. However, it was possible to better understand where this information could be retrieved. By federal mandate from the Federal Office of Agriculture, each farm owner is required to keep a PPP use diary (Journal d'Exploitation), which contains information on the PPP applied, amount used and time of application. Each farm operator must record PPP use data and keep records for 6 years. Prometerre SA (Association vaudoise de promotion des métiers de la terre) is mandated

by the Service of Agriculture and Viticulture (SAVI) to inspect Vaud agricultural operations and PPP diaries. The results of the inspections are provided to SAVI, who establishes sanctions if necessary. In this way, farm operators have a clear incentive to keep PPP diaries up to date. However, Prometerre SA does not treat the data in a way that can be shared for informational purposes (e.g., volume of PPPs used). The fact that PPP diaries are handwritten and not digitised creates an additional barrier for data analysis and sharing. It was revealed that, whereas SAVI maintains a database with information on PPP use and application, these data are not publicly accessible. Moreover, this database does not contain any information on exposure or on resulting health effects. Interviews with SAVI representatives indicated that there is no known systematic mechanism for reporting PPP-related health effects among farmers.

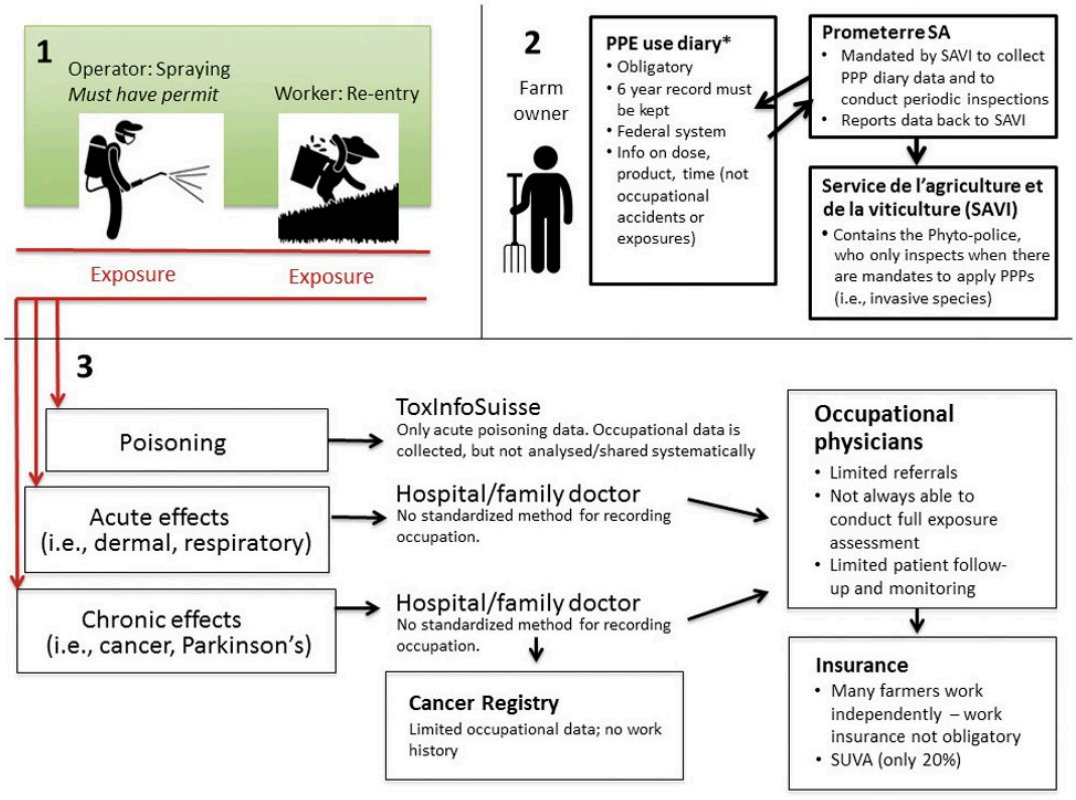
Part 3: Reporting of PPP-related health effects

Potential health outcomes were grouped into three main categories: poisonings; acute health effects; and chronic disease. Information on PPP poisonings comes from the national poison control centre, Tox Info Suisse, which has a specific exposure category called "occupational", as well as a category for "agricultural/horticultural agents". If known, the product name and composition are recorded. Since 1995, Tox Info Suisse received 1247 calls related to occupational exposures with agricultural/horticultural agents. However, PPPs are in the same category as manure pit/silo gases, which are known to cause poisonings, and whether these types of poisonings occur more frequently than PPP poisonings should be investigated. Moreover, as poisoning cases are voluntarily reported, underreporting must be taken into consideration.

Aside from poisonings, the reporting of acute effects (e.g., dermal or respiratory irritations), and chronic diseases (e.g., cancers or neurological diseases) was investigated. In these scenarios, it is likely that workers consult their family doctor or visit a clinic or hospital. Thus, it would be most pertinent to contact local physicians, clinics and hospitals to collect the health data. However, it was revealed that in most cases, physicians do not collect a patient's profession in a standardised way. Furthermore, general practitioners (GPs) may not suspect that health effects are linked to occupational exposure, and as such, there is generally no systematic transfer of the patient to an occupational physician. Vaud does have an operating cancer registry and the database records "occupation", but it does not capture information related to work history, thus eliminating knowledge of potential exposures. Unfortunately, it is foreseen that the entrance of a new law [17] will altogether eliminate the practice of reporting profession in Swiss cancer registries.

When a health effect is deemed to be caused by an occupational exposure, the patient or physician can apply for a work insurance claim. It is thus logical that insurance bodies, such as SUVA, could have occupational health data. However, these data provide only a small glimpse into the

Figure 2: Information flow diagram of the generalised process of occupational PPP exposures and resulting health effects. Part 1 demonstrates occupational exposure scenarios; part 2 describes the reporting of PPP use; and part 3 traces the reporting pathway of different health effects, from clinical assessment to insurance claims. *Translated from French (*Journal d'exploitation*; JE).



problem, as approximately 80% of agricultural workers in Switzerland work independently and therefore are not insured by SUVA [18, 19]. Retrieving data from insurance companies remains problematic as a result of a lack of precise recording mechanisms, and because of data privacy.

Clinical record investigation

From April 1993 and January 2017, six cases of adverse health effects and occupational PPP exposures were reported to IST: three cases of respiratory health effects, two cases of neurological health effects, and one dermatological health effect (table 1). Workers were concomitantly exposed to multiple active substances (range: 2–12, average 6.5), making it difficult to ascertain a direct link between exposure and resulting health effect. Evidence from epidemiological studies has shown occupational exposure to PPPs to be associated with respiratory effects [20], neurological effects [21, 22], and dermatological effects [23, 24]. All cases were referred to IST via physicians, either generalists or specialists. There were three cases in which IST advised patients to make an occupational disease claim. Overall, the number of reported cases in 24 years compared with the number of workers likely to be occupationally exposed to PPPs in the French-speaking cantons of Switzerland is very low. This highlights the need to collect better data and to develop a standardised and centralised registration system for exposed agricultural workers suffering from PPP-related health effects.

Workshop results

A total of forty participants attended the one-day workshop. The attendance and active participation of numerous stakeholders with different mandates represented a positive result, providing evidence that this research question marked an important issue for Swiss health research and policy. To the authors' knowledge, this workshop was first time that such a broad stakeholder group was brought together to discuss the importance of improving the reporting of PPP-related health effects for agricultural workers. However, discussion during the workshop revealed that, although there are numerous stakeholders that work efficiently in their own mandate, collaboration is limited, especially when it comes to occupational exposures and health indicators. This lack of collaboration hampers knowledge exchange and linkages of potentially relevant epidemiological data. It was emphasised that occupational PPP exposure and determination of resulting health effects is a cross-cutting issue, and therefore demands increased collaboration between various institutional actors at the federal, cantonal, and local levels. Workshop proceedings, including a list of participants, can be accessed at: http://www.i-s-t.ch/fileadmin/documents/Documents/1_-_L_Institut/Ev%C3%A9nements/PesticideWorkshopRapport_Final_forupload_v2.pdf

Recommendations: the way forward

The collection, reporting and evaluation of occupational health effects has the potential to improve the health and safety of PPP users by reducing the likelihood of adverse events, as well as to mitigate the consequences of such events [25]. The European Food Safety Authority (EFSA) defines this continuous process as "phytopharmacovigilance", which is distinct from monitoring and surveillance, as it implies a process of close and constant attention, specifically to post-marketing events related to PPP use [25]. Phytopharmacovigilance can be used to identify emerging PPP risks, estimate the magnitude of PPP related health effects and evaluate the need for intervention and prevention efforts. PPPs in Switzerland go through pre-marketing authorisation procedures and include recommendations for worker protection [15], but such protocols do not address all environmental conditions, PPP mixtures, chronic exposure patterns and other parameters that can be encountered. As such, vigilance serves as a warning system of effects not detected during the risk assessment process. A well-documented vigilance system can establish routine medical follow-up of people at risk, and document interventions and/or treatments as well as their efficacy. In turn, this critical information can inform the design of preventive campaigns, guide policy decisions, and improve the quality and performance of the public health system. Improving the health of agricultural workers through targeted prevention also makes economic sense by reducing the need for costly medical interventions necessary for the treatment of chronic diseases.

Exploit existing data sources to enhance knowledge on exposures

The first logical step towards effective phytopharmacovigilance in Switzerland would be the assessment and exploitation of existing data sources to better characterise PPP exposures, in order to more accurately predict health effects. Existing modalities such as PPP diaries can be easily improved without developing a new and costly system. PPP diaries can be collected and analysed systemically to better understand the level of PPPs used in each region and crop type. These data can be used to develop more accurate occupational risk models, and would in turn inform targeted prevention strategies. To overcome the current limitations of PPP diaries, their objective should be enlarged to gather epidemiological exposure data, and they should be digitalised and anonymised in order to ease centralisation of data and reduce paperwork for farmers. Increased data on exposure indicators could provide the first steps towards a more accurate assessment of potential health effects at the population level. In particular, with regional information on exposures from PPP diaries, new linkages could be made with local medical centres to better account for related health effects. Such strategies, which adopt geographical information systems (GIS) methodologies, could provide novel and specific data on PPP exposures and subsequent disease – not only for human health but also for environmental issues.

Develop epidemiological research studies on PPP-related health effects

One way to increase knowledge on PPP exposure and related health effects is to conduct targeted surveys on specific exposures and to investigate the potentially related health problems among agricultural workers. Data from the Swiss Health Survey and the Swiss Labour Force Survey could be linked to better assess health at the population level by occupational activity and job tasks. In addition, data from the Swiss General Population Census could be

used to construct the first-ever Swiss cohort of agricultural workers. Setting up such a prospective cohort would enable occupational epidemiologists to conduct cause-specific morbidity and mortality studies and to launch nested case-control studies on specific diseases. With further improvement of data linkages, it should also be possible to investigate specific sub-populations of this cohort, such as spouses and children of workers. Linkage of this cohort with data from cancer registries would provide an additional valuable parameter for epidemiological cancer research.

Table 1: Medical consultation summaries of six patients reporting occupational exposure to PPPs and adverse health effects (assessed from all patient files at the Institute of Work and Health from April 1993 to January 2017).

Case	Patient details	Work tasks	Exposure		Outcome	Diagnosis
			Product name	Active substance (CAS number)		
1	Horticulture apprentice, female, age 18	Watering plants; transplanting; weeding; making seedbeds	Mapro® Indar®	Fluazinam (CAS 79622-59-6) Fenbuconazole (CAS 114369-43-6)	Emergency room visit due to irritation of upper airways and dyspnoea	Respiratory reaction due to allergy or irritation after inhalation of a fungicide. IST advised claiming for occupational illness, but result unknown; work leave
2	Farmer, male, age 52	Production of cereal crops	Exelor® Round up® Harmony sx®	Mecoprop-P-DMA (CAS 66423-09-4) 2,4-D DMA (CAS 2008-39-1) 4-chloro-2-methylphenol (CAS 1570-64-5) Glyphosate (CAS 1071-83-6) Thifensulfuron methyl (CAS 79277-27-3)	Worsening of chronic bronchitis. Skin rash following contact with milking cleansers or cows' urine	Obstructive bronchopneumopathy. IST advised claiming for occupational illness, but occupational illness not declared owing to lack of insurance.
3	Farmer, male, age 54	Production of cereal crops and potatoes	Fénican® Banaril ® Brasan Trio®	Diuron (CAS 330-54-1) Terbuthylazine (CAS 5915-41-3) Pendiméthaline (CAS 40487-42-1) Chlorotoluron (CAS 15545-48-9) Napropamide (CAS 15299-99-7) Diméthachlore (CAS 50563-36-5) Clomazone (CAS 81777-89-1) Oxirane (methyl, polymer) (CAS 75-21-8)	Chronic cough, nonspecific bronchial reactivity.	Multifactorial chronic cough: organic dust syndrome, gastro-oesophageal reflux, possible allergic contribution. Clinical improvement since home heating with oil instead of wood and treatment of gastro-oesophageal reflux.
4	Farmer, male, age 49	Production of cereal crops	Banvel-extra® Omya Picobello® Olymp 10 EW® Banvel M®	MCPA DMA (CAS 2039-46-5) Mecoprop-P-DMA (CAS 66423-09-4) Dicamba-dimethylamine (CAS 2300-66-5) 4-chloro-2-methylphenol (CAS 1570-64-5) Clopyralid (CAS 1702-17-6) Triclopyr-butotyl (CAS 64700-56-7) Flusilazole ISO (CAS 85509-19-9) 1,2-benzisothiazolin-3-one (CAS 2634-33-5) MCPA-K (CAS 5221-16-9) MCPA (CAS 3653-48-3), Dicamba-potassium (CAS 10007-85-9) Dicamba-sodium (CAS 1982-69-0) 4-chloro-2-methylphenol (CAS 1570-64-5)	Polymyositis evolving for 4 years	No correspondence between pathology and occupational exposures.
5	Horticulture worker, male, age 19	Treatment of plants with various PPPs	Marshal 25 EC® Vertimec® Apollo 50 SC® Mapro®	Carbosulfan (CAS 55285-14-8) Abamectine (CAS 65195-55-3) Clofentezin (CAS 74115-24-5) Fluazinam (CAS 79622-59-6)	Contact dermatitis of exposed body parts after working with phytosanitary agents	Professional contact dermatitis to phytosanitary agents; IST advice to declare occupational disease with insurer.
6	Gardener, male, age 39	Treatment of plants with various PPPs	Fux tril® Garlon 3A® Round up® Zolone® Dodene® Veralin®	Triclopyr (CAS 55335-06-3) Bendiocarb (CAS 22781-23-3) Glyphosate (CAS 1071-83-6) Phosalone (CAS 2310-17-0) Tebuconazole (CAS 107534-96-3) Bixafen (CAS 581809-46-3) Diazinon (CAS 333-41-5)	Half body fluctuating sensorimotor deficit. First episode in the spring of the consultation year	No accountability, no declaration of occupational disease.

Such cohorts have existed for decades in several countries [26, 27], attesting to their effectiveness as health surveillance and epidemiological research infrastructure.

Emphasise occupational health among medical professionals

Accurate and standardised data on incidence and prevalence of health effects from a broad range of medical institutions is critical towards the operation of a successful vigilance system. However, physicians – both GPs and specialists – often do not collect the profession of patients, or if they do, not in a standardised way. Any vigilance system must therefore strengthen medical reporting efforts through increased awareness among GPs. Targeted continuing education should focus on occupational health indicators in order to help GPs better recognise symptoms from PPP exposures, and to emphasise the importance of referrals to occupational physicians when in doubt. The importance of incorporating occupational and environmental health into primary care education and practice has been long recognised in other countries [28].

Increase collaboration among stakeholders

A central obstacle remains the lack of coordination between institutional stakeholders when it comes to data sharing and collaborative vigilance efforts. Indeed, this barrier is not limited to Switzerland but rather represents a trend of sectoral specialisation characteristic of modern governments, in which organisations are governed by their own priorities and operating mode [29]. Such situations often lead to departmentalism and the production of standalone data that remain within an organisation's policy silo [30]. The incidence of PPP-related health outcomes represents a highly complex condition for public health and occupational health vigilance. In fact, the US Centers for Disease Control and Prevention recommends that phytopharmacovigilance requires experts from a broad range of backgrounds, including toxicology, epidemiology, medicine, data management, occupational and environmental health, occupational hygiene, integrated pest management and health education [31]. This issue requires a shift from traditional sectoral specialisation to a collaborative government approach in order to be effectively addressed, and to ensure that evidence-based decisions are made in order to protect worker populations.

Bringing it all together

There is increasing evidence that PPP exposure may be associated with chronic neurodegenerative diseases and selected cancers [2]. To address the burden of chronic disease nationwide, an increased focus on preventing its onset as well as monitoring its progression is needed. However, without an effective vigilance system and occupational epidemiological research in place, there is a severely limited understanding of this potential problem as well as ways to mitigate adverse consequences at the population level. This situation presents a unique dilemma, where the lack of quantified evidence of a problem hampers political will to establish a vigilance system. Such a vigilance system is coincidentally the first step towards establishing the magnitude of this potential occupational health problem for Swiss agricultural workers.

In September 2017, the Swiss Federal Council adopted the Action Plan for Risk Reduction and Sustainable Use of Plant Protection Products. The Action Plan proposes that PPP related risks should be halved and alternatives to chemical methods should be encouraged. The Federal Council set clear objectives in this plan; now, appropriate measures must be introduced to meet these objectives. The recommendations of this investigation should be integrated into this action plan to promote the health and safety of the Swiss agricultural workforce.

Finally, it important to highlight that these results extend well beyond agricultural PPP exposures and occupational health indicators. The widespread use of PPPs in Switzerland means that the general public is at risk for exposure, including vulnerable populations such as pregnant women and children. This is especially concerning given that a high number of PPPs can be found in watercourses in Switzerland [32]. As such, it is clear that the development of an effective phytopharmacovigilance system would benefit not only occupationally exposed workers, but also the broader population.

Conclusion

There is a general lack of information concerning occupational PPP exposures and resulting health effects for Swiss agricultural workers. Because of increasing evidence of a potential link between PPP exposure and health effects, it is imperative that increased research is conducted on this topic in Switzerland. It is also crucial that stakeholders from different fields of expertise coordinate actions to develop a standardised and centralised system for collecting health data of agricultural workers. Our study is the first to investigate the health effects linked to PPP exposure among the Swiss agricultural population. The recommendations presented in this paper would help promote a safer and healthier agricultural workforce in Switzerland, as well as the population at large.

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Potential competing interests

The authors declare no conflict of interests.

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Appendix 1

Semi-structured stakeholder interviews – interview and recording form

Note: This interview form presents an outline of questions to pose to stakeholders. However, given the semi-structured nature of this methodology, use the questions as a way to guide the discussion, and allow the interview to broaden its scope or perspective to develop pertinent ideas and themes.

Interview form

Question / variable	Response
1. Descriptive	
1.1 Name of Interviewee	
1.2 Institute	
1.3 Position	
1.4 Date	
1.5 Interview location	
2. Exposure information	
2.1 In your opinion, which PPPs are of most interest for occupational exposures in Switzerland?	
2.2 Do you have information, data or research on the types and amounts of PPPs used in Canton Vaud or Switzerland?	
2.3 In your opinion, what types of crops are most pertinent for occupational PPP exposures?	
2.4 In your opinion, what types of tasks are most pertinent for occupational PPP exposures?	
2.5 What organisations or contacts would be pertinent to contact in order to obtain more information, data or research on occupational PPP exposures in Switzerland?	
3. Health effects	
3.1 In your opinion, which health effects are the most important to consider following occupational PPP exposures in Switzerland?	
3.2 Do you have information, data, or research on the health effects following occupational PPP exposure in Switzerland?	
3.3 What organisations or contacts would be pertinent to contact in order to obtain more information, data or research on the health effects following occupational PPP exposures in Switzerland?	
4. Additional information	
4.1 What other information can be useful towards uncovering more information about occupational PPP exposures and resulting health effects in Switzerland?	
4.2 What are your recommendations in regards to the next steps for this research?	
4.3 Any final comments, questions, suggestions?	