Respiratory health and acute pesticide intoxications

among workers in the flower farm industry in Ethiopia

Amare Workiye Nigatu

Thesis for the degree of philosophiae doctor (PhD)
at the University of Bergen

2017

Date of defence: 30 May 2017

Year: 2017

Title: Respiratory health and acute pesticide intoxications among workers in the flower farm industry in Ethiopia

Author: Amare Workiye Nigatu

Print: AiT Bjerch AS / University of Bergen

Scientific environment

This study focused on the respiratory health and acute pesticide intoxications related to the flower industry. It was conducted at the Research Group for Occupational and Environmental Medicine and Centre for International Health (CIH), Department of Global Public Health and Primary Care, University of Bergen. The research group at CIH has also collaborated with Addis Ababa University, Ethiopia during the study under the NORHED project.

Acknowledgements

My heartfelt thanks to my God for giving me this noble opportunity and helping me all the way throughout my study.

My gratitude goes to the Norwegian Educational Loan Fund (Statens lånekasse) for the financial support to undertake my studies and my stay in Norway.

To my supervisors, Bente Elisabeth Moen and Magne Bråtveit, I truly lack the words to express my deepest and heartfelt thanks for everything you have done for me during my PhD work. Thank you for your trust and for giving me the opportunity to pursue my PhD under your supervision. It has been a great privilege for me to have you as my supervisors; thank you for providing me with all the support and guidance that has resulted in successful completion of my study.

I would like to express my sincere gratitude to Wakgari Deressa. Your support was instrumental in carrying out this study, especially during the difficult time of my fieldwork.

I owe my special thanks to Vegard M Hanssen, for the excellent collaboration we had together and that provided insight into the subsequent work.

To all staff members at the Department for Global Public Health and Primary Care, including the Centre for International Health, my sincere thanks for all the support you have given me during my study. Special thanks go to all staff members at the Research Group for Occupational and Environmental Medicine. I have enjoyed the privilege of benefitting from your contributions during our weekly scientific meetings. Most of all, my sincere thanks go to Gunhild Koldal for the support you have provided me throughout my study period.

To my wife, Selamawit Debebe, Enatye I lack the proper words to describe my deepest gratitude and respect for the patience and support you have given me throughout my study period. To my children, Elnathal, Edilawit and Betselot, I love you and thank you for allowing me to focus on my study and for your patience despite my long absence from home.

To my late brothers and parents, I wish we could have celebrated this special occasion together. Your long-standing wish has finally come true. I now feel fulfilled. Rest in peace!

To my friends, Zeyede, Ebba, Endris, Yonas, Gulelat,Zelalem, Lule, Sisay and others whom I have not mentioned by name, my heartfelt thanks for your advice and inspiration. I would like to offer special thanks to Zeyede for connecting me with my supervisors, a connection which led to the beginning of my PhD study opportunity. I believe we have successfully completed our shared goal in our academic career.

Finally, my sincere gratitude goes to my study participants and farm managements for their cooperation and willingness to participate in the study, without which this study would not have been impossible.

Abstract

Background: The flower industry in Ethiopia is a rapidly growing economic activity involving tens of thousands of workers. On these farms, roses are cultivated inside greenhouses, which are characterized by elevated temperature, humidity, poor ventilation and frequent use of pesticides.

Pesticides of different types are widely used by the flower industry in Ethiopia to enhance the growth of flowers. Workers in the flower industry are frequently exposed to organic dust from the flowers and the soil, including endotoxins, and to pesticides, which may result in adverse health effects. In addition, residents in the immediate area may risk increased exposure to pesticides through the proximity of their homes to the flower farms. Several studies have shown a high prevalence of respiratory symptoms and acute pesticide intoxications among agricultural workers. Few of these studies focus on greenhouse workers. Despite its great importance to the country's economy, the working conditions and health status of the workers in the Ethiopian flower industry are not thoroughly documented.

Objectives: The aims of this study were to describe working conditions on flower farms, to determine personal dust and endotoxin exposure levels, assess self-reported symptoms and acute pesticide intoxications (API), and to study respiratory inflammation by measuring exhaled nitric oxide among flower farm workers and residents living close to the farms. In addition, we aimed to determining work-related risk factors of API.

Methods and materials: This project was conducted via three separate studies between 2012 and 2014 in selected Ethiopian flower farms and among the residents grouped according to their living proximity to one of the flower farms. In the first study, a work place survey was performed on three flower farms using a structured checklist. In addition, interviews were made, obtaining respiratory, neurological and dermal symptoms using the British Medical Research Council (BMRC) questionnaire, and a standardized questionnaire instrument of subjective health

complaints among flower farm workers (n=213) and a control group of supermarket workers (n=60).

In the second study, respiratory symptoms were assessed in an interview using the BMRC questionnaire among 248 female workers in four flower farms. The mean age, and years at work for the participants were 24 and 2 years, respectively. Measurements of exhaled nitric oxide were performed according to the American Thoracic Society and European Respiratory Society recommendations (n=108) using a portable electrochemistry-based sensor. Full-shift personal exposure to endotoxin was measured in samples of “total” dust in the environment, collected from the workers’ breathing zone (n=75).

In the third study the prevalence of API was assessed among residents (n=516) living in the surrounding area of a large flower farm. Participants (mean age 30 years) were grouped according to their residence proximity to a large flower farm; living within 5 km, and 5–12 km away, respectively, from the flower farm. In structured interviews, we asked participants to report their exposure to pesticides and if they had experienced health symptoms within 48 hours of the exposure to the pesticides during the previous year. Those who had experienced this, and reported two or more typical pesticide intoxication symptoms at the time, were considered as having had API.

In addition, risk factors of API were assessed among the residents who were either flower farm workers or small-scale farmers (n=440).

Results: Workers at the flower farms generally had higher prevalence of respiratory, neurological and dermal symptoms than controls. Female workers inside the greenhouses had significantly higher prevalence of chronic respiratory and dermal symptoms than women working outside the greenhouses. Limited access to personal protective equipment (PPE) and unsafe pesticide routines were observed in all the flower farms examined. Greenhouse workers had higher endotoxin exposure than workers outside greenhouses, but the levels were relatively low, compared to European standards. The concentration of FeNO ranged from 5 to 166 ppb with a GM of 14 ppb. Only two workers had FeNO concentrations above 50 ppb, a level that often indicates the presence of asthma. FeNO was not different among those working inside and outside the greenhouses.

The residents who live nearby and worked on the flower farm had significantly higher prevalence of API (56%) than did the residents living nearby but who did not work in the flower farm (16%). Flower farm workers had a higher risk of API than did small-scale farmers (PR=4.5, 95% CI: 3.20, 6.35). Lack of safety training, not following pesticide label instructions and not bathing after pesticides were used were significant risk factors for API among flower farm workers. Among small-scale farmers, none of the risk factors were significantly associated with API.

Conclusion: The study revealed a high prevalence of self-reported respiratory, dermal and neurological symptoms and API among the workers on the flower farms. Lack of pesticide safety training, not following pesticide labels and poor personal hygiene measures were significant risk factors associated with API among flower farm workers. Dust or endotoxin levels were low and inflammation in the airways of the workers was not revealed when measured by exhaled NO.

List of publications

I. Hanssen VM, Nigatu AW, Zeleke ZK, Moen BE, Bratveit M (2012) High prevalence of respiratory and dermal symptoms among Ethiopian flower farm workers. Arch Environ Occup Health; 15:15

II. Nigatu AW, Bratveit M, Deressa W, Moen BE (2015) Respiratory symptoms, fractional exhaled nitric oxide & endotoxin exposure among female flower farm workers in Ethiopia. J Occup Med Toxicol.; 10:8

III. Nigatu AW, Bråtveit M, Moen BE (2016) Self-reported acute pesticide intoxications in Ethiopia. BMC public health; 16 (1): 1-8

IV. Nigatu AW, Bratveit M, Moen BE. Work-related risk factors of acute pesticide intoxication among workers at flower and small-scale farms. (Submitted 2017)

Abbreviations

ODTS	Organic Dust Toxic Syndrome
EU	Endotoxin Unit
API	Acute Pesticide Intoxication
WHO	World Health Organization
DDT	Dichloro-Diphyenyl-Trichloroethane
COPD	Chronic Obstructive Pulmonary Disease
GM	Geometric Mean
FeNO	Fractional exhaled Nitric Oxide
LAL	Limulus amebocyte Lysate
L	Liter
LOQ	Limit of Quantification
SKC	Side Kick Casella
USA	United States of America
PPE	Personal Protective Equipment
PPB	Part Per Billion
SPSS	Statistical Package for Social Sciences
OR	Odds Ratio
CI	Confidence Interval
PR	Prevalence Ratio
CFC	Closed Face Cassettes
EHDA	Ethiopian Horticulture Development Agency
FMOLSA	Federal Ministry of Labor and Social Affairs
RBOLSA	Regional Bureau of Labor and Social Affairs

Contents

1. Introduction

1.1 Flower cultivation in Ethiopia

1.1.1 Historical perspective of flower farms in Ethiopia

Flower cultivation is one of the booming industries in Ethiopia. The two flower farms, Meskel flower and Ethio–flora, were the first that started activities in the year 1997 on a few hectares of land (1). However, owing to the favourable government investment policy, the prevailing suitable climatic conditions for the growth of flowers and the abundant cheap labour in Ethiopia, the flower industry has been growing rapidly over the past years. For instance, according to the data from the Ethiopian horticulture development agency (EHDA), the number of horticultural farms that produce flowers, vegetables and fruits for export has increased to more than 120 companies (2). Seventy percent of these companies are engaged in the cultivation of flowers and export to over 100 markets globally mainly to the Netherlands, Germany, Saudi Arabia and Norway. Currently Ethiopia is the second largest exporter of flowers in Africa, next to Kenya.

Flower export is one of the main sources of foreign exchange earnings of the Ethiopian economy. Based on the information obtained from EHDA, the amount of foreign currency earnings has been increasing over the years (Figure 1).

The sector has created significant employment opportunities for the local people. Based on the information gathered from EHDA, the horticulture sector as a whole (flower, vegetables and fruits production) employed about 131,495 workers in 2015/16, of which 46,000 workers are employed in the flower industry. Furthermore, the government has expansion plan for the horticulture sector, which will presumably increase the number of workers involved in the cultivation of flowers dramatically.

Like in most agricultural activities, there is an extensive and wide variety of pesticides used for the cultivation of flowers in Ethiopia (3). Consequently, there are increasing concerns about its environmental and human health effects.

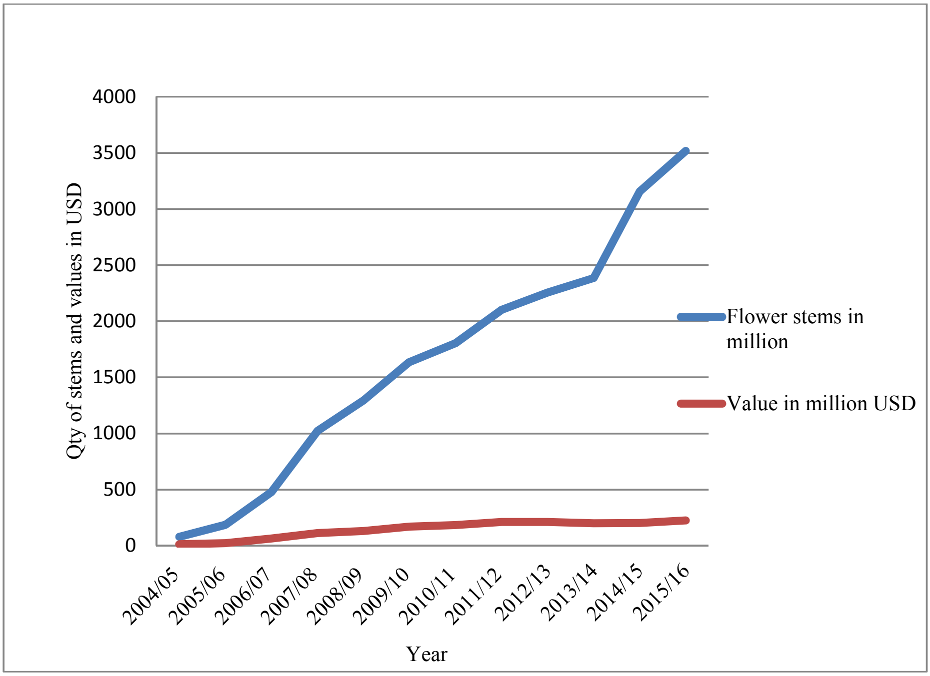


Figure 1: Flower export quantity and value performance 2004/05 – 2015/16 (Source: EHDA)

1.1.2 Impact on the population

The great majority of the workforce involved in the flower industry are women. In view of the government investment policy and the future expansion plan of the sector, the number of workers engaged in flower cultivation will presumably increase dramatically. Thus the sector plays and will continue to play a pivotal role in the country's economic growth. Nonetheless, unless adequate attention is paid to the working conditions and workers' health, there may be negative health impacts on the population, particularly among the employees working in this industry. Poor working conditions together with possible occupational exposure to bioaerosols including organic dust/endotoxin, and exposure to pesticides can have serious health effects. The health effects may range from acute to chronic health effects including respiratory health effects and acute intoxications.

1.1.3 Ethiopian labour legislation

Ethiopia has ratified ILO's core labour and technical conventions, including the Occupational Safety and Health Convention that are essential to protect workers' rights. Despite the ratification of the international labour conventions and the adaptation of a national labour proclamation, legislation to regulate the working environment is inadequate and the authorities have a very limited capacity to conduct regular work place surveillance in Ethiopia.

The Federal Government of Ethiopia has adopted a proclamation for the registration and control of pesticides (Proclamation No. 674/2010) that requires the registration of all pesticides imported and/or exported; labelling of all pesticides in both English and Amharic languages; and employers must ensure the occupational safety of their employees (4). Nevertheless, there seems to be a weak implementation in the enforcement of such regulations to ensure the health and safety of workers in different work environment, including flower farms.

1.2 Work on flower farms

Work on the flower farms comprises different activities such as work inside greenhouses, packing, transport and storage, pesticide spraying and chemical fertigation. The female workers are mainly engaged in culturing, cutting and weeding flowers inside greenhouses or trimming and packing flowers in a packhouse. There are few men in this industry; men either work as sprayers or are engaged in other activities including greenhouse maintenance, transportation of harvested flowers as well as waste disposal activities.

1.2.1 Work in greenhouses

Flowers are cultivated inside greenhouses made of plastic materials. The number and size of greenhouses vary according to the size of individual farms. The greenhouses have an opening at the top of the roof for natural ventilation and side curtains that can be opened when the temperature is too high.

Work inside greenhouses involves culturing, weeding and cleaning of flowerbeds, and harvesting of roses, and is mainly performed by women. They carry bundles of roses to the main paths in the greenhouse from where the roses are transported in buckets to a cold room for storage (Figure 2). The female workers inside the greenhouses, compared to workers outside, presumably have greater risk of exposure to various agents including organic dusts and pesticides due to the nature of their work. The extensive and frequent use of pesticides in the farms, and direct contact with flowers is likely to increase the risk of exposure to pesticides.

Figure 2 Flower harvesting inside a greenhouse

1.2.2 Pesticide spraying

All the sprayers on the flower farms are normally male workers and there are usually not more than 15 sprayers per farm. Pesticide sprayers have presumably the highest risk of exposure to pesticides (Figure 3) compared to other flower farm workers. Pesticides are usually mixed and sprayed manually using spray lances while

walking into the spray mist instead of walking backwards, which is likely to increase the exposure. However, sometimes pesticides are mixed centrally in an open large container inside the greenhouses and distributed through pipes to the flowerbeds. The sprayers also clean and maintain spraying equipment after the daily spraying activities.

Figure 3: Sprayers back from morning spraying activity

1.2.3 Work in packhouse

The female workers in the packhouse have various tasks, including bundling, quality control and packing of the flowers (Figure 4).

Figure 4: Flower being packed inside a packhouse

1.3 Work on small-scale farms

It has been estimated that over 85% of the Ethiopian population live in rural areas and depend on agriculture as a means of livelihood. The great majority of the farmers are engaged in small-scale farming practices characterized by cultivation of a small piece of land meant for household subsistence farming. The small-scale farms in our study area mostly grow crops such as maize, wheat and sorghum.

Work on small-scale farms generally involves seed planting, weeding, harvesting, fertigation as well as pesticide application. The farm owners usually perform most of these activities except pesticide application, which is mostly done by local sprayers who provide such services for small-scale farms in the study area.

1.4 Risk factors of acute pesticide intoxication related to work on flower farms

Agricultural workers are potentially exposed to a wide range of hazardous agents that can be inhaled. Pesticides may cause adverse neurological and respiratory health effects (5, 6). In addition, they could be exposed to allergens and irritants in dust and vapour. Airborne dust could include fungi, bacteria, viruses and endotoxin (7-9). Dermal effects are also reported among agricultural workers including itching or redness of the skin, while neurological effects could include difficulty concentrating, blurring of vision and depression (10, 11).

1.4.1 Exposure to organic dust and endotoxin on flower farms.

Organic dust consists of airborne particles derived from plants or animals and may consist of flower pollen, flour, and wood dust. Exposure to organic dust through inhalation may cause different health effects including organic dust toxic syndrome (ODTS), hay fever and airway inflammation, which might be presented as asthma among the workers (12-14).

Endotoxins are cell-wall components of gram-negative bacteria that are released when the cell disintegrates (15, 16). Inhalation of endotoxin has been associated with respiratory health effects including nose and throat irritation, tightness of the chest, coughing, shortness of breath, wheezing, acute airway restriction and inflammation (17-22). Agricultural workers might be exposed to high concentrations of endotoxin due to the organic materials they deal with (23). Greenhouse workers at flower farms might be higher exposed to organic dust and pesticides than those working outside the greenhouses. This might be due to the prevailing working conditions in the relatively enclosed areas with elevated temperature, low air ventilation rate and high humidity (24). Studies among flower growers inside greenhouses in Europe reported endotoxin exposure levels ranging from 2.9 EU/m^3 up to 44 EU/m^3 (24-26). Another study among cucumber and tomato growers in greenhouses reported considerably higher endotoxin exposure (median = 320 EU/m^3) (27).

1.4.2 Pesticides

Definition and use of pesticides

A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest caused by insects, unwanted plants (weeds), mice and other animals, fungi, bacteria and viruses. There are different types of pesticides and the major ones include insecticides, herbicides and fungicides.

Pesticides are widely used in the agriculture sector globally. In less developed countries the use of pesticides is increasing, which may result in increased risk of exposure (28). Moreover, pesticides are also used for domestic purposes to prevent and control household pests such as mouse, fleas, bed bugs, and mosquitoes.

Pesticide classification based on hazard levels

The WHO has classified pesticides based on their inherent hazards and acute toxic effects; extremely hazardous (Ia), highly hazardous (Ib), moderately hazardous, slightly hazardous and unlikely to present acute hazard (29). In Ethiopia a wide variety of pesticides are intensively (623 kg/hectare/year) used on the flower farms (3). Commonly used pesticides on flower farms in Ethiopia are organophosphate and carbamates. The use of organochloride pesticides such as dichloro-diphyenyl-trichloroethane (DDT) and endosulfan was also reported among small-scale irrigation farm workers in Ethiopia (3).

Exposure to pesticides on flower farms and small-scale farms

Pesticide exposure occurs both among agricultural workers in the open fields, like on the typical small-scale farms of Ethiopia, and in large-scale greenhouses (30-32). Workers who mix, load, transport and apply formulated pesticides are generally considered the group with highest exposure to pesticides due to the nature of their work and therefore they are at greater risk of developing API (33, 34). In addition, the greenhouse workers in the horticulture sector who do not apply pesticide themselves are presumably exposed to pesticides. Furthermore, most of the workers on the flower farms in Ethiopia live close to the flower farms and they might be exposed to pesticides due to the proximity of their homes to these farms. A study in the USA suggested that rural residents could be exposed to pesticides through the proximity of their homes to agricultural fields (35).

Studies have shown that several factors may affect the workers' exposure to pesticides (33, 36-38). Such factors are, for instance, poor working conditions, inappropriate handling and storage of pesticides, lack of training on safe pesticide use and workers' hygiene practices. Provision of continuous safety training on pesticide use among Indian farmers was shown to increase their awareness and reduce the number of pesticide intoxication cases (39, 40). The intensity and frequency of pesticide use are also very important factors that affect the exposure (34). Inadequate use of personal protective equipment (PPE) and poor pesticide handling and storage were found to be associated with increased risk of exposure to pesticides (41-43).

1.5 Health effects related to dust and pesticides

The health effects of exposure to pesticides and dust are generally categorized as acute and chronic. Acute effects occur during or shortly after the exposure, while chronic effects develop over time.

Generally, in agricultural settings, exposure to pesticides primarily occurs via inhalation for several pesticide types, but pesticide exposure may also occur through dermal exposure or ingestion.

1.5.1 Acute pesticide intoxication

In the present study we define acute pesticide intoxication (API) as self-reported symptoms or adverse health effects due to suspected or confirmed exposure to pesticides within 48 hours after the exposure (44). Exceptions to this definition are warfarines, superwarfarins and coumarins, of which the onset of symptoms may be delayed and develop more than 48 hours after the exposure (44).

The health effects from acute intoxications could be localized affecting a particular body part like dermal and ocular effects, or could lead to systemic health effects such as respiratory, neurological, cardiovascular and gastrointestinal systems. The severity of symptoms due to acute intoxications could be low, moderate, high or fatal depending on the degree and duration of exposure to pesticides. Pesticide intoxication, for instance can start with a light cough and airway irritation at low levels of exposure. However, at higher levels of exposure and prolonged exposure, the symptoms may develop into chest pain and difficulty breathing and end up with lung oedema, respiratory arrest and death (44). Low levels of exposure also may lead to the development of mild neurological symptoms such as dizziness and profuse sweating; and with higher levels of exposure and longer period of exposure, the symptoms become severe (blurred vision and confusion) and may ultimately lead to coma, paralysis and death (45, 46).

High prevalence of API has been reported by several studies conducted among agricultural workers in developing countries (47-49). However, most of the studies are about general agricultural workers, and not flower farm workers. To our knowledge, there are no studies that focus on the magnitude of API among flower farm workers. Studies from the past ten years show that the most frequent symptoms reported among farmers with API include respiratory, neurological and dermal symptoms (Table 1). These studies, except the one conducted among greenhouse workers in the Philippines, were all done among general farmers practising farming in the open field. Generally, most of these studies reported a high prevalence of API, with the study in Tanzania reporting the highest prevalence of API. The use of different definitions of API in these studies likely explains some of the differences in the prevalence of API among the studies listed (Table 1).

Table 1 Overview of studies on acute pesticide intoxication and related symptoms reported among flower farm and other types of farm workers*.

Year	Author(s)	Country	Group of workers included	Persons studied	Prevalence of API and different symptoms	Reference
2007	Del Pardo-Lu	Philippines	Flower farm workers in greenhouses	102	API (24%); general symptoms (weakness, fever, lethargy, 64%); headache (48%); cough (40%); blurred vision (36%)	(46)
2011	Zhang et al.	China	Farm workers	910	API (9%)	(43)
2012	Lee et al.	South Korea	Farm workers	1958	API (25%); nausea (12%); dizziness (12%); skin irritation (11%) and headache (10%)	(50)
2014	Lekei et al.	Tanzania	Farm workers	121	API (93%) – past life time exposure; skin irritation (55%); excessive sweating (36%); eye irritation (50%); breathing with difficulty (33%); excessive salivation (36%); headache (55%); dizziness (40%)	(36)
2006	Recena et al.	Brazil	Farm workers	250	API (26%); Headache (31%); dizziness (19%); vomiting (17%)	(51)
2011	Ncube et al.	Jamaica	Farm workers	359	API (16%); burning skin (13%); headache (12%); itching eyes (11%); blurred vision (11%); twitching eyelids (7%) and muscle cramp (5%)	(52)
2010	Jensen et al.	Cambodia	Aquatic farmers	89	Headache (55%); blurred vision (26%); excessive sweating (15%); shortness of breath (12%); (dizziness (57%); dry throat (69%); itchy skin (25%)	(53)

*: All studies were cross-sectional

1.5.2 Respiratory health

Occupational exposure to organic dust/endotoxin and pesticides has been linked to acute and chronic respiratory symptoms (54). While a large number of studies exist on respiratory health effects among agricultural workers, very few of these studies have focused on the possible effects of pesticide exposure (Table 1).

Occupational exposure to pesticides has been associated with adverse respiratory health effects such as increased risk of chronic bronchitis, rhinitis, asthma and chronic obstructive pulmonary disease (COPD) (55-58). Studies among greenhouse workers in Croatia and Turkey reported high prevalence of respiratory symptoms such as rhinitis, phlegm, bronchitis, dyspnea, chest tightness and nose dryness (11, 59). Exposure to organochlorine (heptachlor) and organophosphate pesticides were reported to have a strong association with chronic bronchitis (56), and other respiratory effects such as shortness of breath and wheezing (60). A recent study done among commercial farm workers in Ethiopia reported adverse respiratory health, increased risk of chronic cough, and shortness of breath and lung function decline (5).

Endotoxin exposure among greenhouse workers has been associated with high prevalence of respiratory symptoms (7). Exposure to endotoxin is linked to airway inflammation, and this has been assessed through a non-invasive method by measuring fractional exhaled nitric oxide (FeNO) in different work settings (61). Several methods for examining indications of inflammation in the airways have been developed. Measurement of FeNO, or exhaled NO, is recognized as a reliable marker of eosinophilic airway inflammation (62). NO is a signalling molecule in a wide variety of biological processes. Increased exhaled NO is related to respiratory inflammation in asthma (62-64). To our knowledge there is no previous study reporting on the FeNO levels among flower farm workers.

2. Rationale and objectives of the study

2.1 Rationale

There are few studies done globally on respiratory health and acute pesticide intoxications among workers on flower farms. Some of these studies are done in Ethiopia, because of the flower farming's importance to the country's revenue (3, 5, 65). The flower industry in Ethiopia is growing at a very fast rate and tens of thousands of people are employed in the sector. Currently Ethiopia is the second largest exporter of flowers in Africa next to Kenya. However, limited information exists about the working conditions and the workers' health on flower farms in Ethiopia.

Exposure to airborne pollutants, particularly exposure to organic dust/endotoxin and pesticides, and the associated risk of respiratory effects and acute pesticide intoxications among the workers in the flower farms should be further investigated.

It is known that exposure to pesticide and organic dust might cause severe adverse health effects that result in impaired health and human suffering. Pesticide intoxications are very dangerous to people and can be lethal. Respiratory health effects can be minor, like symptoms from nose and mild irritations in the airways, but they might also be very serious, causing disability and reduced quality of life. The symptoms are serious in particular in countries like Ethiopia, where it is difficult to get medical treatment and medication in many geographical locations. These health problems are very costly to the society because of the associated disability, medical expenses, work absenteeism and reduced productivity. However, the adverse health effects that might be caused by these factors in the work places can be prevented with proper knowledge of the working conditions and the prevailing hazards, and implementation of good practices. At present, Ethiopia has few possibilities of controlling and improving the work place situations; the country has few regulations in the area of the working environment that are enforced and implemented at the work sites.

Therefore there is a critical need to conduct studies in this area in order to gain information on the national occupational health and safety problems related to the rapidly growing flower industry; to reveal the actual status and provide scientific basis to set priorities for occupational health and safety policies that can be used to implement preventive and control measures.

2.2 Objectives of the study

2.2.1 General objective

- To obtain more knowledge on respiratory health and acute pesticide intoxications in relation to work in the flower industry in Ethiopia.

2.2.2 Specific objectives

- To describe the working conditions on flower farms including assessment of endotoxin exposure levels.
- To assess the prevalence of dermal, neurological and respiratory symptoms among flower farm workers.
- To measure fractional, exhaled nitric oxide as a possible measure of respiratory inflammation among flower farm workers.
- To assess the prevalence of acute pesticide intoxications and related risk factors of such intoxications in a population living in an area where a flower farm is located.

3. Methods

3.1 Study area

This study was conducted in Ethiopia, as this country has a large and growing flower farm industry. These flower farms mainly cultivate roses inside greenhouses; and export their products to Europe and the US.

Oromia regional state was chosen since the great majority of the flower farms in Ethiopia are found in this region (Figure 5). The flower farms are located in the East, South and Northwest of the capital Addis Ababa. A total of four flower farms from the main rose cultivating geographical areas of Oromia regional state (Hollota/Addis-Alem, Debrezeit and Zeway areas) were chosen. Due to practical reasons such as location and accessibility, the farms were selected based on sampling convenience.

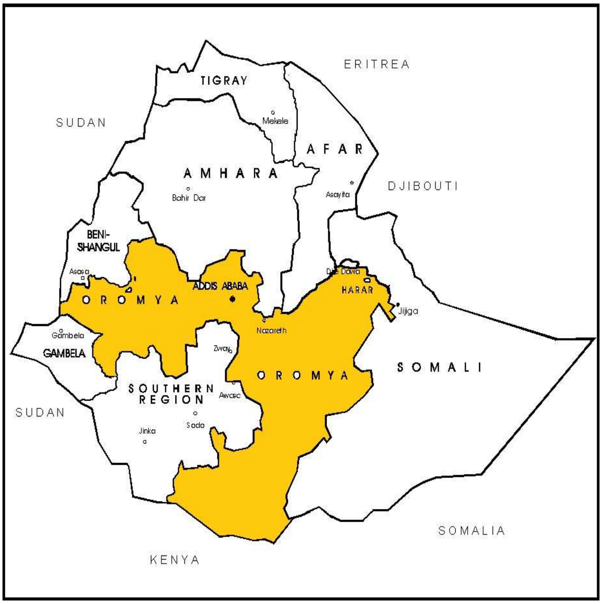


Figure 5: Map of the study areas and location of flower farms

3.2 Study design and study populations

This study consisted of three cross-sectional studies. Because of the high turnover of workers on the flower farms, longitudinal studies were not suitable at the time of the study.

Flower farm workers and the residents living close to a flower farm were the study populations (Figure 6); the participants in each of the studies are described below.

1. Study I (2012) was conducted on three flower farms that were selected based on the estimated number of workers required for the study. Greenhouse workers, sprayers, packing, storage, transport and cold room workers in three flower farms were invited to participate. A control group of supermarket workers from 19 supermarkets in a nearby town in Oromia region was chosen.
2. Study II (2013) was conducted on four flower farms. We chose four flower farms in order to get the required number of workers based on the estimated sample size. Out of the four flower farms chosen in Study II, three of them were the same farms as in Study I. Female workers who work inside greenhouses and in the packhouse (outside greenhouse) on these farms were included in the study. Personal endotoxin exposure and FeNO measurements were performed on two of the selected farms.
3. Study III (2014) was a population study performed among the residents living in an area close to a large flower farm. We had to revise the original plan to perform Study III in a work place setting, due to the serious challenges encountered during the first two studies where we were totally denied access to one of the flower farms (study I), while the others barely cooperated after a long discussion with the farms management. Thus, access to the flower farms and willingness to cooperate for research purpose was extremely limited
   The residents in study III were grouped according to their living proximity to the nearby flower farm.

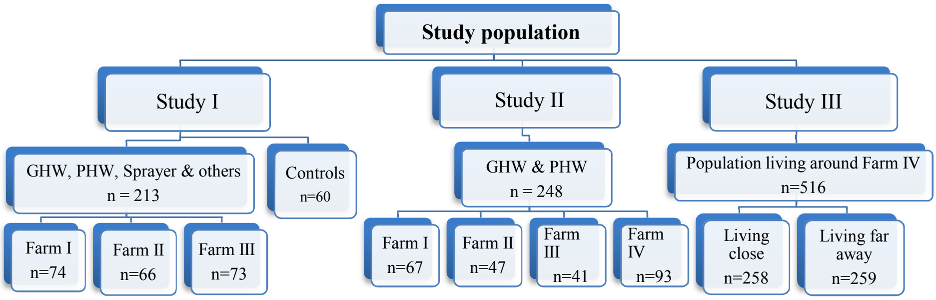


Figure 6 Schematic diagram of the study population. GHW: Greenhouse workers; PHW: packhouse workers

3.3 Sample size

In the first study, sample size was estimated based on the prevalence of chest tightness (18%) reported among greenhouse workers and 5% among controls (11). In order to find a difference between the groups we needed 250 and 50 participants in the exposed and control groups, respectively to achieve a statistical power of 80% at a significance level of $p<0.05$. We chose to have a relatively low number in the control group, as we expected it to be difficult to motivate these persons for participation.

In the second study, the sample size was calculated based on the prevalence of shortness of breath (70%) among Ethiopian flower farm workers (66). A total of 248 individuals (divided in two groups of 124 participants each: inside vs. outside greenhouse) were needed to achieve a statistical power of 80% at $p<0.05$.

For personal endotoxin samples, we followed Rappaport and Kupper's recommendations for exposure studies: 10–20 measurements per observational group, i.e., two measurements of 5–10 randomly selected individuals per group (67).

Endotoxin samples from 46 workers from Farm I, & II were taken, out of which 29 of the workers had repeated measurements.

In the third study based on the prevalence of excessive sweating (25%), which is a typical symptoms of organophosphate poisoning, a sample size of 520 individuals (divided in two groups, i.e., living close vs. far away) was needed to achieve a statistical power of 80% at $p<0.05$ (68).

Study participants

Study I: In the first study, a total of 213 workers from three flower farms were invited to participate. All "cutters and weeders" from 3–4 randomly selected greenhouses from each flower farm were invited, while sprayers, packing, storage, transport and cold room workers were randomly selected from a list provided by the farm managements and invited to participate. In one of the flower farms, the farm management did not facilitate selection of sprayers.

The participating workers were divided into subgroups based on assumed exposure levels to chemical and biological hazards. Female workers were divided into two groups: "Cutters and weeders" who worked inside greenhouses were assumed to have a higher degree of exposure than "Other workers" who did not work inside the greenhouse. "Cutters and weeders" worked culturing, weeding, harvesting and transporting the harvested roses to the main path in the greenhouses. Female "other workers" had various tasks including bundling, quality control and packing of the flowers inside the packhouse. Of the male workers, sprayers were considered as highly exposed to pesticides, while the remaining males were grouped as "Other workers" who worked outside the greenhouse were assumed to have lower exposure.

A control group of 60 workers from supermarkets or small shops and who had no direct occupational exposure to chemicals or biological hazards were chosen from a nearby town in the Oromia region. They were also chosen because they were assumed to have socioeconomic status similar to that of the flower farm workers. Supermarkets were chosen at random along two main roads in the town; and all workers present were invited to participate. Supermarkets with only one worker were excluded to avoid any interruption of their work due to the interview. The response rate was 99.5% among those invited.

Study II: A total of 248 female workers from four flower farms were invited to participate. The female workers on the selected farms were grouped into two observational groups based on their workstation, inside vs. outside greenhouses. We planned to have an equal number of workers from each of the farms as well as from inside and outside greenhouses, and thus overall 122 and 126 workers participated from inside and outside greenhouses, respectively. Participants from Farm II and III were randomly selected from the personnel registration book, while on Farms I and IV, workers were selected in collaboration with the farm managements. The response rate was 100%.

The participants from Farms I & II also participated in endotoxin sampling and FeNO measurements, which were performed in this study only.

Study III: A total of 516 residents living in the surrounding areas of one of the largest flower farms in Ethiopia employing over ten thousand workers participated in the third study (Paper 3 & 4). In Paper 4, of the 516 individuals who participated in the third study, 440 individuals who were either flower farm or small-scale farm workers were included. The households were grouped according to their living proximity (living close vs. far away) from the flower farm; <5 & 5–12/ kilometres from the flower farm, respectively. The 5-km cut-off point was decided based on our observations of the study area. Most of the working population on the flower farms live within a distance of 0-5 km from the flower farm while those living within 5–12 km are mainly involved in small-scale private farming. The12-km cut-off point was chosen to exclude the residents living in the villages right after the 12-km mark as they mostly worked at a pesticide factory. Cluster sampling was used, where a village, which is the smallest administrative unit, was considered as a cluster. The number of households in a village varied considerably, ranging from 40 to 100 households (about 200 to 500 inhabitants) per village; and the villages closer to the flower farm were much larger than those located further away. All the villages located within 0–12 km from the flower farm, formed the sampling frame: a total of 68 villages; 23 were located < 5 km away and 45 were located 5–12 km away. A total of 11 villages (4 close and 7 far) out of 68 villages were randomly selected. All the households in each of the selected villages were invited to participate in the study. The response rate for this study was 99%; the remaining four households did not participate, as they were not available during the interview time. A complete mapping of the area including a list of villages and households was created based on information from the local authorities and from a research project run by researchers from Bergen and Addis Ababa University (69).

3.4 Interview

In Study I, a modified version of BMRC questionnaire and a part of a standardized questionnaire instrument for subjective health complaints (SHC) (70) was used to assess chronic respiratory symptoms, and health complaints, respectively, for the previous 30 days (Table 2).

In Study II, BMRC questionnaire and questions about upper airway symptoms (runny nose, sneezing and blocked nose) (71) were used.

In Study III, a structured interview guide developed from previous similar studies was used to assess API, and associated risk factors of API among residents living close to the largest flower farm (43, 44, 50, 72).

All the questionnaires were translated from English into the local language (Amharic and Afan Oromo in Studies I and II, respectively) and back to English for consistency, and making no changes in the text. Since the majority of the participants had a lower education level, questionnaires were not distributed among the participants. A trained data collector administered the questionnaire in the first study, and in the second study, the principal investigator did the interview. For Study III, five health workers (nurses and public health officers) who were familiar with the area conducted the interview.

Table 2 An overview of the studies and assessments performed in the three studies

Study	Year	Farm	Interview	Work place survey	Endotoxin sampling (n)	FeNO measurements (n)
Study I	2012	Farm I, II & III	Respiratory, dermal & neurological symptoms Subjective health complaints	Walk-through with checklist		
Study II	2013	Farm I	Respiratory symptoms		39	63
		Farm II	Respiratory symptoms		36	45
		Farm III & IV	Respiratory symptoms			
Study III	2014	Residents living around Farm IV	Health problems API & risk factors of API			

3.4.1 Assessment of respiratory, neurological and dermal symptoms

Chronic respiratory symptoms (cough, shortness of breath, wheezing); neurological symptoms (headache, sleep problems, dizziness, anxiety and depression); and dermal symptoms (rash on hands and rash on skin other than hands) symptoms were assessed

among workers on the selected flower farms (Study I, 2012) using a structured questionnaire (appendix II). The questions included background characteristics such age, gender, educational level (years in school), current job in the flower farm (cutting, weeding, spraying, packing, or other work), number of hours spent spraying the last week, employment history (months worked in the farm; previous work in other agriculture & duration worked; currently working in other agriculture; cooking facilities at home (biomass, charcoal, kerosene, electricity, or combination of these), present smoking (yes/no); number of cigarettes/day and duration of smoking and previous disease including chest injury, heart trouble, bronchitis, pneumonia, pulmonary tuberculosis, and any other chest trouble.

3.4.2 Assessment of chronic respiratory symptoms

Because of the high prevalence of respiratory symptoms found in Study I (2012), we focused on respiratory symptoms in Study II (2013). All participants who agreed to take part in the second study (2013) were also interviewed on socio-demographic characteristics: job profile, age and education; previous respiratory illnesses; cooking fuel use; smoking habits; chronic respiratory symptoms; upper airway symptoms (runny nose, sneezing and blocked nose) and PPE use (appendix IV).

3.4.3 Assessment of acute pesticide intoxication (API)

The participants in the API-study (Study III) were interviewed on socio-demographic information: age, sex and education, current job, work experience, pesticide use and experienced health problems within 48 hours of exposure to pesticides in the last year, and whether the exposure to pesticides occurred through occupational exposure as flower farm workers or as small-scale farmers or by household pesticide use for pest control.

The respondents, who explained a plausible description of pesticide exposure and reported having experienced health problems within 48 hours of the exposure once or several times during the past year were asked to state the health symptoms they had. The interviewers then ticked-off the symptoms they mentioned from the list in the interview guide. In this study we used WHOs standard case definition matrix for possible API to guide our API definition, which requires that the case should meet the following criteria, i.e., a plausible description of the exposure, two or more subjective symptoms reported, and temporal cause-effect relationship (44). The respondents who presented a plausible description of exposure and reported to have experienced two or more of these symptoms within 48 hours of the exposure to pesticides once or several times the past year were considered to have suffered API.

3.4.4 Assessment of risk factors of acute pesticide intoxication

The participants in the third study were interviewed on work-related risk factors: do you know the type of pesticides used? (yes/no); do you read pesticide labels? (yes/no); do you follow pesticide label instructions? (not at all/sometimes/always); did you had training on safe pesticide use? (yes/no); do you consider wind direction while spraying pesticides? (yes/no); do you use personal protective equipment? (yes/no); type of PPE used (clothing/gloves/boots/mask); empty pesticide container handling (dispose properly/reuse/sale); proper pesticide storage (yes/no); do you wash your hands with soap immediately after contact with pesticides? (never/sometimes/always); do you take bath immediately after contact with pesticides? (never/sometimes/always); how long do you stay away before entering to pesticide sprayed areas?

3.5 Workplace survey

A walk-through survey was conducted on the three flower farms using a structured health and safety checklist (Study I, 2012) (Appendix III). The principal investigator along with representatives of the farms' management did the workplace survey in each of the three farms. The checklist was adapted from the standard International Labour Organization (ILO) checklist, the guidelines in the Flower Label Program (FLP), the standards from the Fair-trade Labeling Organizations International and on compliance criteria of the FLO-CERT (73-75). The variables in the checklist included farm infrastructure: drinking water and sanitary facilities; accessibility to PPE, PPE use, washing and storage of PPE; pesticide products, pesticide storage, administrative control of pesticides, pesticide mixing facilities, spraying procedures, re-entry intervals into sprayed greenhouses and job rotation.

3.6 FeNO measurements

Exposure to organic dust has been shown to cause airway inflammation and cause health problems like asthma. Indications of such effects can be assessed by a non-invasive approach by measuring the fraction of nitric oxide in the exhaled air (FeNO). This is a more objective measure of inflammation than an interview of symptoms. However, this type of examination has limitations as it mainly measures eosinophilic inflammation, and to a lesser extent, other types of inflammatory reactions.

FeNO was assessed as a marker of airway inflammation among female flower farm workers in Study II (Figure 7). The eligibility criteria for the selection of study participants for FeNO measurement were non-smoking and not being on any medication.

The measurements were done using a portable electrochemistry-based sensor (NIOX MINO; Aerocrine AB, Solana, Sweden) in accordance with the American Thoracic Society & European Respiratory Society recommendations on online measurement of FeNO (76, 77). This was chosen because it is simple and easy to use in field. One measurement was taken for each person in a sitting position during the working day between 10:00 and 15:00 hours, and the results are expressed as part per billion (PPB). Studies have shown that a single measurement using NIOX MINO is adequate (78).

The mean ambient NO, temperature and relative humidity in the room where the FeNO measurements were performed were registered daily as these factors may affect the FeNO measurement; below 5 ppb, 22 ^{0}C (18–28 ^{0}C) and 70%, respectively. According to the ATS clinical guidelines, FeNO levels in adults that are less than 25 ppb are considered normal, 25-50 ppb are deemed intermediate values, while levels above 50 ppb are considered high values which might be related to airway inflammation (79).

Figure 7: Measurement of fractional exhaled nitric oxide

3.7 Exposure assessment and laboratory analysis

Personal endotoxin air samples were collected in Study II (Figure 8). Because of the high prevalence of respiratory symptoms found among the workers on the flower farms in Study I (2012), we decided to measure the level of personal endotoxin exposure at the flower farms (Table 2).

Figure 8: Personal endotoxin sampling inside packhouse

3.7.1 Endotoxin sampling and analysis

Full-shift personal endotoxin air samples were collected on two farms (inside vs. outside greenhouses) only, because of limited funds available for analyses. Sampling was performed in the workers' breathing zone (Figure 9) using Side Kick Casella (SKC) pump at a flow rate of 2 L/minute connected to 25-mm closed-face conductive Millipore cassettes containing glass fibre filter with 0.2-μm pore size for sampling of the "total dust" fraction. The pumps were calibrated using a Rotameter every day before starting the measurement and the flow rate was measured at the end of the measurements. Two samples were excluded due to a reduction in airflow of more than 10% during the sampling day.

Filters were kept cold at about 4 ^{0}C inside a box filled with ice bags until the samples were transported to Norway and then to Sweden for analysis at Lund University Medical Laboratory. The samples were transported as hand luggage on the flights, and were outside the cold box for a total of about 15 hours.

The glass fibre filters were immersed into 0.05% Tween-20 pyrogenic free water and shaken on a rotary shaker for 1 hour. Endotoxin extracts were analysed using kinetic chromogenic Limulus amebocyte Lysate (LAL) Assay (80).

The results were expressed as Endotoxin Unit per cubic meter (EU/m^3). Totally, 27 samples had endotoxin values below Limit of Quantification (LOQ), which was set to 10 EU/m^3 by the laboratory. The measurements below LOQ were set as LOQ/$2^{1/2}$ in the data handling, which has been suggested when less than 50% of the samples are non-detectable and the geometric standard deviation is below 3.0 (81).

Currently there is no occupational exposure limit value for endotoxin in Ethiopia, however, a health-based recommended value for endotoxin, 90 EU/m3 air in the inhalable dust fraction was suggested by the health council of the Netherlands. Thus, in this study we used this reference value to compare our findings (24).

Figure 9: Personal endotoxin exposure sampling inside greenhouse

3.8 Statistical analysis

Data were analysed using SPSS version 21. Categorical variables were compared using chi-square and Fisher's exact tests. Continuous variables were compared using independent t-test between different groups. The prevalence ratio of categorical variables was calculated using generalized linear-binary regression model (Papers III and IV), and adjusted for age, gender and education. Mantel-Haenszel statistics were used to compare the risk factors between flower farm workers and small-scale farmers (Paper IV).

The distribution of endotoxin and FeNO data were skewed, and were therefore log-transformed in order to compare the levels between groups (Paper II).

A linear mixed-effects model was used to analyse the determinants of endotoxin exposure among the female workers to account for repeated measurements from individual workers. The individual workers were included in the model as a random factor. The farms (Farm I vs. Farm II) and workstation (inside vs. outside greenhouses) were set as fixed factors. Data were adjusted for educational level when comparing the groups.

3.9 Ethics

The research proposal was submitted and approved by the Regional Committees for Medical and Health Research Ethics, Norway and Oromia Regional State Health Bureau Committees for Health Research Ethics, Ethiopia. All the participants were informed about the purpose of the study and gave written consent to participate.

4. Summary of Results

4.1 Paper 1

Flower farm workers on the three flower farms studied, had a generally higher prevalence of respiratory, neurological and dermal symptoms than the controls. Controls were supermarket workers, reporting very low occurrence of all symptoms.

Female workers inside the greenhouse had significantly higher prevalence of coughing in the morning (44%; OR_{adj}: 2.7), coughing during the day/at night (39%; OR_{adj}: 2.2), coughing with sputum in the morning (29%; OR_{adj}: 2.5), and shortness of breath hurrying (71%; OR_{adj}: 2.1) compared to women working outside the greenhouses. They also had more dermal symptoms than those working outside the greenhouses. Among the female flower farm workers inside the greenhouse, 71% reported that they always used gloves vs. 41% among those working outside the greenhouses.

Male sprayers had a higher prevalence of all respiratory symptoms than did other male workers, but the difference was not significant.

Among the 87 pesticides observed, we were able to identify 64 on the basis of product name. All the farms had organophosphate and carbamate pesticides in their pesticide stores. Two of the farms had pesticides in WHO hazard class Ib (very hazardous), including pyrethroid and carbamate pesticides. WHO hazard class II constituted a large proportion of the pesticide repository on all farms. Open pesticide stores were observed on some of the farms. Pesticides are mixed either inside open rooms or in open pools inside the greenhouse and distributed through pipes to flowerbeds for spraying. No safety precautions were observed except a general health and safety poster.

Pesticides were sprayed manually using spray lances; and the sprayers were observed walking into the spray cloud. Re-entry time after spraying pesticides was said to be in compliance with WHO recommendations on some of the farms. However, it was reported that spraying could occur when other workers (cutters and weeders) stayed inside the greenhouse.

In general, there was limited use of PPE among the workers. Waterproof clothing, rubber boots, goggles and respiratory protection with filter type A2 for organic vapours were used among sprayers on one of the farms; while the sprayers on other farms used cotton overall, plastic apron and rubber boots and a cotton balaclava to protect face and mouth.

4.2 Paper 2

Personal endotoxin exposure on the two farms (Farms I and II) was relatively low, with a geometric mean of 22.8 EU/m^3. Only one of the samples had endotoxin levels above the recommended health-based exposure limit of 90 EU/m^3 in inhalable dust. The endotoxin exposure inside the greenhouses was significantly higher than outside the greenhouses. The greenhouse workers in Farm I were the subgroups with the highest endotoxin exposure (GM = 37.8 EU/m^3).

The mean age and years at work for the participants in this study were 24 and 2 years, respectively. None of the female workers in the four farms reported use of respiratory protective devices. Female workers inside the greenhouse had higher prevalence of blocked nose (21%) compared to those working outside the greenhouses (9%) (OR_{adj}: 2.4, 95% CI: 1.1 – 5.2).

The FeNO-values ranged from 5 to 166 ppb with a GM of 14 ppb. Only two of the workers had levels above 50 ppb, which is the level often used to indicate the presence of asthma. The mean FeNO of those working inside and outside the greenhouses did not differ significantly.

4.3 Paper 3

The prevalence of self-reported symptoms, defined as API, among the residents living in the surrounding area of one of the largest flower farms in Ethiopia was 26%.

The residents living close to this flower farm had significantly higher self-reported API (42%) than those living far away (11%) (adjusted PR; 3.2; 95% CI; 2.2 – 4.8). The subgroup living close to, and working on the flower farm had significantly higher prevalence of API (56%) than the subgroup living close to, and did not work in the flower farm (16%) (adjusted PR; 3.0; 95% CI; 1.8 – 4.9). There was no difference in API prevalence between the residents living far away (11%) and those living close to the flower farm, but did not work there (16%).

Pesticide exposure at the flower farm was related to 68% of the API cases followed by 16% and 15% API cases related to household and small-scale farmers' exposure to pesticide, respectively. There were significant differences in API prevalence among the different job groups in the flower farm; greenhouse workers had the highest API prevalence (57%). The prevalence of API among small-scale farmers in the study area was 12%.

4.4 Paper 4

This paper reports on the risk factors of API based on the findings of Paper 3, but only participants from 440 of the households were included, i.e., those who are either flower farm workers or small-scale farmers.

A total of 126 (29%) had symptoms corresponding with the API definition during the previous year. The age of participants was inversely associated with the risk of API, i.e., the youngest workers had an increased risk of API compared to the older ones. Of those working at the flower farm 56% had API, compared to 12% among small-scale farmers. Among flower farm workers, the sprayers and the greenhouse workers had the highest risk of API (adjusted PR; 2.6; 95% CI; 1.2 – 5.5 and 2.2; 95% CI; 1.0 – 4.8) followed by the packhouse workers (adjusted PR; 1.9; 95% CI; 0.9 – 4.5) when using other workers as the reference.

Nearly one-third of the flower farm workers (32%) and 5% of the small-scale farmers reported having had safety training on pesticide use. However, similar proportions of flower farm workers and small-scale farmers reported having read pesticide labels

(15% and 18%) and having followed the advice on the pesticide label (18% and 17%), respectively.

Flower farm workers who had no safety training, did not follow pesticide label instructions and did not bathe immediately after contact with pesticides had increased risk of API (PR; 8.9; 2.4 and 1.6, respectively). These factors significantly increased the risk of API among flower farm workers but not among small-scale farmers.

5. Discussion

5.1 Main discussion

This study reports high prevalence of self-reported symptoms and API among the workers in the flower farms. This high prevalence indicates that the symptoms are related to hazardous agents in the working environments on the flower farms. The prevailing poor working conditions observed on the flower farms during the workplace surveys further support this. The lack of safety training on pesticide use, failure to follow pesticide labels and poor personal hygiene practice were found to be among the risk factors associated with increased risk of API among workers at the flower farms. Thus, pesticide exposure related to work on the flower farms seems to be a major problem. On the other hand, examination of personal endotoxin exposure and respiratory health revealed low levels of endotoxin exposure and low FeNO measurements among the workers at the flower farms.

5.1.1 Acute pesticide intoxications

The prevalence of symptoms attributable to API during the previous 12 months among the participants from the households was 26%, and it was highest in the population living close to the flower farm and working on the farm (56%). The most frequent symptoms reported, neurological and respiratory symptoms, are typical symptoms of exposure to organophosphorous and carbamates (44), which were reported to be the pesticides predominantly used in the flower farms.

Flower farm workers in our study had higher prevalence of API (56%) than cut-flower workers (23.5%) in the Philippines (46). The later study reported on respondents' illness experiences due to pesticides during the previous year, whereas we asked for health problems experienced within 48 hours of exposure to pesticides in the last year, which might partly explain the observed difference.

The prevalence of API among the residents in our study is similar to the findings in a study among farmers in South Korea (24.7%) (50). A population-based survey in

Central America reported low prevalence of API (2% and 2.3%) (49, 82). These differences might be explained by the different study designs. Unlike the studies in Central America, our study should not be considered as a general population study since it comprised a high fraction of flower farm workers as well as small-scale farmers. Moreover, the studies from Central America asked for self-reported cases of API within the first 24 hours of exposure to pesticides, while in our study we asked for symptoms within the first 48 hours.

The prevalence of API among small-scale farmers in our study (12%) is slightly higher than reported among Chinese farmers (8.8%). However, the Chinese study also reported on API cases occurring within the first 24 hours of exposure to pesticides vs. 48 hours in our study (43). A study among small-scale farmers in Tanzania reported much higher prevalence of API (93%) (36), but in that study the researchers asked for "past lifetime acute pesticide poisoning experienced" whereas we asked for the experience during the previous year.

Our study indicated that residence close to the flower farm was not as such associated with increased prevalence of API. The higher risk of API among the residents living close to the flower farm in our study was associated with being employed on the flower farm. This was evident since the subgroup living close to the flower farms and working there had significantly higher API compared to those living close to but not working on the flower farm. This is further supported by the absence of difference in the prevalence of API between the subgroups living close to the flower farm and not working there vs. those living far away, after adjusting for being small-scale farmers. One might assume that pesticides would be more accessible among the residents closer to the flower farm, causing higher prevalence of API. We have no information about the accessibility of pesticides in this group of residents, and easily accessible pesticides might not be a problem in the examined population. Pesticides are expensive and are not likely to "disappear" from the farms without being noticed. Our findings are in contrast to previous studies that have reported increased exposure to pesticides with decreasing distance between the households to the farms (37, 83).

However, those studies dealt with children of agricultural workers, and not industrial flower farms.

5.1.2 Airway inflammation and respiratory symptoms

The prevalence of respiratory symptoms among flower farm workers in the present study was higher than among the controls (Paper 1). Similar results were previously reported in a study of greenhouse flower workers in Croatia (11). The prevalence of coughing in the morning (35%), coughing during day or at night (31%), coughing with sputum in the morning (22.4%) and coughing with sputum at day or night time (20%) among female workers was similar to the results in greenhouses mainly producing flowers in Croatia (chronic cough 22.9%), among male and female flower farm workers in the Philippines (cough 40.2%) and Turkey (cough 31.5%) (11, 46, 59).

Female flower farm workers inside greenhouses in our study had more respiratory symptoms compared to those working outside the greenhouses (Papers 1 and 2). The prevalence of blocked nose, which is most likely a symptom of rhinitis, was significantly higher among female workers inside greenhouse (21%) than that of those working outside the greenhouses (9%). This is slightly lower than reported in a study among male and female Spanish greenhouse flower workers (31%) (55). This difference may be explained by the use of different terms to refer to the nose symptoms. The term rhinitis is broad, and more people may have reported this than the more specific symptom blocked nose. It has been suggested that rhinitis precedes asthmatic conditions (84), which might indicate a possible risk of developing asthma among the workers inside the greenhouse. However, this requires future studies to be confirmed.

The prevalence of respiratory and other symptoms were generally higher in Paper 1 (2012) than in Paper 2 (2013) for most of these symptoms. This could be explained partly by the difference in the levels of relevant exposure during the two studies. However, we did not measure the levels of exposure in any of these studies except for endotoxin exposure in Paper 2.

The geometric mean FeNO level in the present study was 13.9 ppb, which is considered to be low (79). This is similar with the findings of a study among female agriculture workers in the Netherlands (11.4 ppb) (22). Studies done among asthmatics have shown elevated levels of FeNO (85, 86). However, airway inflammation associated with increased FeNO was not detected in the examined population. On the other hand, although we found low FeNO levels in our study, it may not necessarily mean that these types of workers do not have any risk of asthma or respiratory problems. Asthma might also develop among workers with longer working periods on the flower farms; our study included relatively young people, with short work time experience on the flower farms.

Various exposures on the flower farms might be associated with respiratory symptoms found in this study. The low personal endotoxin exposure found in the present study is unlikely to explain the high prevalence of respiratory symptoms. The symptoms might instead be related to exposure to other hazardous agents such as fungi or pesticides (6, 9). Occupational exposures to pesticides are known to give adverse respiratory effects, such as chronic bronchitis, rhinitis, asthma and chronic obstructive pulmonary disease (COPD) (55, 56, 87). For instance, occupational exposure to organophosphate has been linked to respiratory effects such as coughing, shortness of breath and wheezing in addition to lung dysfunction (60, 88). The high prevalence of respiratory symptoms in the present study might be related to the pesticides used in the flower farms. However, the present study is based on a cross-sectional survey with limitations to establish a causal relationship between exposure and health effects, and we have no pesticide exposure measurements to confirm this possibility.

5.1.3 Endotoxin exposure

The present study has shown that the personal endotoxin exposure level among the female flower farm workers was low (GM = 22.8 EU/m^3). Greenhouse workers had significantly higher personal endotoxin exposure than the workers outside the greenhouses. However, the endotoxin samples, except one, were below the Dutch recommended health-based limit value (90 EU/m^3) for endotoxin (89). Nevertheless, the mean personal endotoxin exposure in the present study was higher than reported in a study among flower/ornamental growers inside European greenhouses (GM = 2.9; range: 0.4 – 101.4 EU/m^3) (25). The difference might also be due to the type of plants grown. In our study, the farms grow only roses, while in the European greenhouses, in addition to roses, they grow other types of plants (gerbera jamesonii, dianthus caryophyllus, ornamental and other plants). Similar or slightly higher personal endotoxin exposure were reported among Dutch and Danish flower growers inside greenhouses (GM = 27 and 44 EU/m^3, respectively) (24, 26). The differences may be due to the differences in the samplers used, i.e., in the present study ”total” dust sampler was used, while in Dutch and Danish studies inhalable dust samplers, which have been reported to sample 1.5 – 4 times more dust, were used. Direct comparison of the obtained results with other studies and the Dutch limit value could be difficult since the total dust sampler in our study presumably collected lower amounts of endotoxin than were present in the inhalable dust fraction (90). Considerably higher endotoxin exposure was reported among employees in greenhouses working with cucumbers and tomatoes (median = 320 EU/m^3), which might be caused by the different type of plants cultivated. Plants with larger leaf area index (the ratio of total upper leaf surface of vegetation to the surface area of the land on which the vegetation grows) than roses might yield higher endotoxin levels because of the high endotoxin concentration found on the leaves (27).

5.1.4 Risk factors of API

Workers at the flower farm had 4.5 times higher risk of API compared to workers on small-scale farms. This difference in the risk of API between flower farm workers and small-scale farmers might be related to the difference in the frequency of pesticide application. Pesticides were applied more frequently, almost every day, in the flower farms, which may result in more pesticide exposure possibilities among flower farm workers. Pesticides were applied less frequently in the small-scale farms, about 3-4 times a year.

Among flower farm workers in the present study, greenhouse workers and sprayers had a higher risk of API compared with the reference group, “other” flower farm workers. Similarly, a study among Korean farmers reported a higher risk of pesticide intoxication among greenhouse farmers compared to non-greenhouse farmers, though not significant (91).

Work-related risk factors, including lack of training on safe pesticide use, not following pesticide labels and not taking a bath immediately after contact with pesticides, were all significantly associated with API among flower farm workers but not among small-scale farmers. This could be related to the scarce resources available to train farm workers in safe pesticide use and to provide adequate water supply for hygiene measures.

Approximately one-third (32%) of the flower farm workers in our study reported having had training in safe pesticide use. This is similar to the finding of a study (35%) among large-scale, closed-greenhouse workers in Ethiopia; the training was reportedly provided by the Ethiopian Horticultural Producers and Export Association (EHPEA) (3). Our finding is also somewhat similar to the results of studies done among farmers in Bolivia and Jamaica (47, 52). One might expect this since most of these nations lack the necessary resources to train farm workers in safe pesticide use. The lack of safety training in pesticide use was associated with increased risk of API among flower farm workers. Provision of such training in safe pesticide use, may have a preventive effect from possible pesticide exposure on the flower farms. Similarly, a study among Indian farmers reported a reduced number of pesticide intoxication cases following continuous safety training in pesticide use (39, 40).

Failure to follow pesticide labels is a risk factor associated with higher prevalence of API among flower farm workers in the present study. Similar findings were reported in studies conducted among farmers in Korea and China (42, 43, 92). However, the studies in Korea and China involved farmers in general, and these comprise different groups than the flower farm workers in our study. We did not find similar studies among flower farm workers to compare with our result.

A low proportion of flower farm workers (39%) in our study practice hygiene measures, i.e., bathe after contact with pesticides. Another study reported similar results (32%) among large-scale greenhouse workers in Ethiopia (3). Our findings show a lower percentage of practice of hygienic measures than reported among farmers in Bolivia and Cambodia, where 69% and 98%, respectively practise bathing after handling pesticides (47, 93).

Only 59% of flower farm workers in the present study reported having used some kind of PPE (clothing, boots, gloves or mask), but PPE use was not significantly associated with the risk of API among flower farm workers in our study. Contrary to our finding, previous studies among farmers showed that proper PPE use was related to reduced risk of API (42, 94). The use of inappropriate PPE among flower farm workers in our study might have provided poor protection from possible pesticide exposure.

5.2 Methodological discussion

5.2.1 Study design and setting

This study was conducted using a cross-sectional design involving flower farm workers as well as residents living in the surrounding area of one of these flower farms. Most of the flower farm workers had short work experience due to the high turnover in the flower farms, thus a longitudinal design was not feasible for this group of workers. The cross-sectional design makes it difficult to conclude that there is a causal relationship between possible occupational exposure and the high prevalence of symptoms and API.

Inclusion of the residents living in the surrounding area of the flower farm (Study III) has enabled us to get information about the workers without entering the flower farms. When present at the workplace, the fear of losing their job might limit the information the workers were willing to contribute.

5.2.2 Internal validity

Internal validity refers to how accurate the findings of an observation represent the actual information of the particular group under study (95). In this study, factors like participation, selection, information bias, confounders and methods used are discussed.

Participation rate

The participation rates in our studies were high, and the reason for the high response rate could possibly be due to the close cooperation between the investigator and the residents. The high response rate may permit us to assume that the results have high validity within the workers in the studied farms and the residents.

Selection bias

Selection bias could occur when there is a systematic difference in characteristics between the people selected for the study and those who are not. Healthy worker effect is a common selection bias in occupational epidemiology, which is overrepresentation of healthy persons in occupational settings compared to the general population (95). A healthy-worker effect may occur either because of hiring healthy workers (selection in), or when workers quit jobs because of work-related ill health (selection out) (96, 97). These types of biases might result in an underestimation of work-related diseases that occur in work environments. In our study, there might be a healthy-worker effect because most of the workers on the flower farms were young and had brief work experience due to high turnover.

The participants from the flower farms were either randomly selected or were all included, which reduced the risk of selection bias (Study I & II). The selection was carried out without prior knowledge of the participants' health status. However, on two farms, the managers influenced the selection of the workers, and they might have picked the healthiest workers. Nonetheless, it was not likely that the managers knew all the details about the workers' health. In Study III, the villages were randomly selected, and the sample presumably represents the residents living in the area surrounding the flower farm.

Most of the workers in our study at the flower farms had brief work experience, and this may have reduced the possibility of detecting health problems related to the working environment. However, short work experience was a trait of works on all flower farms and the healthy-worker effect may have been present in the whole study.

Information bias

Information bias may occur due to misclassification of information, which occurs whenever study subjects are erroneously grouped with respect to their exposure or health status (95, 98). Information bias could be either random/differential or non-differential and may be a result of the observer and the study participants. Differential misclassification bias may underestimate or overestimate the association between the exposure and health outcome whereas non-differential bias results in a bias towards the null hypothesis (no difference). In our study, since most of the participants had a low-level education, personal interviewing was the preferred method rather than a self-administered interview conducted by the workers themselves. There is a possibility that this may have introduced interviewer bias. However, we used a standardized questionnaire; and the interviews were performed by a trained data collector (Study I), and by the principal investigator (Study II) in order to reduce the interviewer bias. In Study III, since we asked for API symptoms in the previous year, some recall bias might have been present. However, we used interview instruction, which presumably minimized the recall bias.

Workplace surveys may affect the information obtained from the workers due to fear of losing jobs. However, in our study, since the workers were informed about the confidentiality of personal information and that the results were given at group levels, we expect that the effect of this should be reduced.

In study III, there might be some information bias, because some of the respondents might not have worked in the field themselves and might not have been exposed to pesticides. However, in rural settings like in our study, farming is a family business and it is therefore likely that family members could possibly be exposed to pesticides.

Confounding

Confounding refers to a situation when there are external variables that are associated with the exposure and health outcome of a study population. Confounding could mask the true association between the exposure and the health outcome under study. The effect of confounding occurs when such external factors are unequally distributed between the different observation groups during the study (95, 98).

In our study, variables like age, education and gender were different for farm workers and small-scale farmers. The effects of these variables were adjusted in our statistical analysis. However, there might be other factors not investigated, like different work context and control over one's work. The influence of such factors were not taken into account.

Health assessment

Questionnaire

Self-reported neurological, dermal and chronic respiratory symptoms were assessed using standardized questionnaire instruments of SHC and BMRC. Questionnaire-based surveys have been reported to have limitations in underreporting and over-reporting both in interviews and self-administered questionnaires (99). The questionnaire was translated from English to Amharic, since English is uncommon in Ethiopia. As the method has not been validated among the Ethiopian population, it may have led to misreporting of certain symptoms. For instance, the workers may have misunderstood the symptoms of heart problems including dyspnea, and we had to explain it during the interview. A high prevalence of the symptom "heart trouble" was reported in Paper 1, which seems very unlikely in this young population. However, the other expressions of symptoms are better known and exist in the Ethiopian language, and should therefore be more reliable and correctly understood by the workers.

In Study III, the workers themselves described the symptoms they had although they might not have known the name of all symptoms they had. However, alternatives to this method were difficult to find. Objective measures of API would have required hospital studies. For instance, a case-control study could have been planned. This would have meant that all health-related offices in an area had to be instructed to put in place a systematic gathering of data for a longer period, or similar planning in a hospital. This kind of planning is difficult in Ethiopia, where there are few hospitals and a number of unregistered health workers, as well as lack of registers for such data. In this situation, an interview was considered the most feasible approach.

Measurement of fractional, exhaled nitric oxide

The measurements of FeNO were performed using a simple NIOX MINO device, since we presumed the workers develop inflammation in the airways because of exposure to the dust/endotoxin. FeNO a non-invasive and easy to measure in fields, whereas other methods are more complicated.

Other objective methods could have been X-rays to look for lung tissue changes or and blood samples to assess immunological variables such as neutrophils and eosinophils. However, these methods were not used in this study because of the limitations related to the availability of laboratory and X-ray machine in the study site. Spirometry could have been used as well, but we considered the chance of detecting lung function changes to be minor in such a young population. In addition, the spirometry measurements would have been difficult to implement, as the flower farms were very sceptical towards the use of instruments, and we decided to examine only the exhaled NO.

The drawback of FeNO is that it is best in showing eosinophilic types of allergic inflammation reactions, and this condition might not have been present among the workers (61).

Assessment of endotoxin exposure

Full-shift personal endotoxin exposure was assessed using closed face cassettes (CFC) for sampling of the total dust fraction. The use of total dust sampler in our study has presumably underestimated the mean endotoxin exposure level compared to inhalable samplers. Inhalable dust samplers were reported to sample 1.5–4 times more dust than the total dust samplers used in our study (90). Still, the endotoxin levels are likely to have been low also with a sampler complying more closely with the inhalable convention.

The endotoxin exposure levels were calculated by dividing the endotoxin amount by the volume of air that has passed through the filter. A high fraction of endotoxin samples (27) in our study was below the limit of quantification (LOQ), which was set at 10 EU per filter by the laboratory. The samples below the LOQ were set as $LOQ/2^{1/2}$ in further data analysis. The high fraction of samples below LOQ may have affected estimates of mean exposure and the fixed factors in the mixed-effects model, but presumably, it did not affect the main findings.

Endotoxin samples storage and transportation was a challenge. The samples are supposed to be kept at low temperature from the moment the samples are collected until delivered to laboratory for analysis. We managed to keep the cold temperature of the collected samples in Ethiopia until delivered to Norway and then Sweden by keeping it inside a cold box filled with bags of ice. A literature review on workplace measurements of endotoxin in bioaerosols suggested a delivery of samples to laboratory within 24 hours after collection (100). Since there is no accredited laboratory in Ethiopia we did not manage to meet this criterion, but the samples were kept at low temperature.

Pesticides exposure

Pesticides were not measured in this study. This was because a large number of pesticides were used in the flower farms, shifting in type. Detailed knowledge about the pesticide use is necessary for planning and performance of pesticide measurements, and we did not have sufficient knowledge to plan this type of a study. A study among applicators and re-entry workers of large-scale greenhouses in Ethiopia revealed higher exposure to pesticides based on a semi-quantitative exposure assessment compared to other farming systems (65). However, such studies are clearly needed; hopefully, they will be conducted in the future.

Instead of measurements, we observed the pesticide use on the farms. Unsafe routines including limited access to PPE, poor management of pesticides and faulty pesticide spraying procedures were observed in the flower farms. Occupational exposure to pesticides among agricultural workers is affected by several factors including poor working conditions, pesticide mishandling and non-compliance with safety procedures (31, 101).

The pesticides mostly used in the Ethiopian flower farms include organophosphate and carbamate. Exposure to these types of pesticides were shown to be associated with respiratory and neurological symptoms (44).

5.2.3 External validity

This study was conducted among workers at flower farms that cultivate roses (Papers 1 and 2); and the residents living in the surrounding area of one these flower farms (Papers 3 and 4). The flower farms in this study presumably represent other flower farms producing roses in Ethiopia. This is because the farms were selected to represent the main rose cultivating geographical areas (Holleta/Addis Alem, Debrezeit and Zeway) in Ethiopia, where the majority of the flower farms are located. Additionally, the sizes and production scales of the selected flower farms ranged from relatively small farms with a few hundred workers to large ones involving more than ten thousand workers. Moreover, because of the lack of adequate legislation, weak workplace monitoring and legal enforcement in Ethiopia, the flower farms are likely to have similar working environments. Thus, the findings of this study are presumably applicable to other flower farms in Ethiopia. Moreover, the findings are probably also applicable to flower farms of a similar nature in other countries where workers cultivate roses inside greenhouses under similar working conditions. East African countries including Kenya, Tanzania and Uganda are widely engaged in the cultivation of roses, and presumably, they do so under similar working environments as the farms in Ethiopian. The occurrences of API among the workers at the flower farms in the present study might be found in the flower farms of the East African countries. For instance a high prevalence of self-reported respiratory, neurological and dermal symptoms were found among planters, weeders and harvesters working on horticulture farms in Kenya (102).

6. Conclusion and recommentations

6.1 Conclusion

- This study revealed that the current working conditions on the flower farms in Ethiopia are not optimal, and they present health and safety challenges to their employees.
  Endotoxin exposure was low, with the highest levels among the workers inside greenhouses.
- A high prevalence of self-reported respiratory, dermal and neurological symptoms was reported among the workers on the flower farms.
- FeNO-levels were low, and there were few workers with objective signs of airway inflammation as indicated by FeNO levels.
- The prevalence of self-reported API among flower farm workers was high. Work on flower farms was associated with API. Lack of pesticide safety training, failure to follow pesticide labels and poor personal hygiene measures were significant risk factors associated with API among flower farm workers.

6.2 Recommendations

We observed several insufficiencies related to the working environments on the flower farms. Based on these findings and the information about possible risk factors for API, the following are suggested:

- Have correct and understandable labelling, and standard operation procedures of pesticide use in all the farms to ensure safe pesticide handling during mixing, spraying and storage to prevent workers' exposure
- Provide sufficient and appropriate PPE supported with training on proper PPE use for the workers
- Improve the working conditions, including the availability of washing facilities at the flower farms to ensure that workers have access to these facilities and minimize possible exposure to pesticides at workplace

- Provide training on pesticide safety for all workers at the flower farms prior to employment and regularly afterwards as necessary

Further examination of the working conditions and the health effects among flower farm workers:

- Investigate possible occupational exposure to pesticides and to other components in bioaerosols including fungi and bacteria
- Even though long term studies might be difficult in this setting, a larger follow-up study to include more flower farms in area should be performed to investigate the effect of longer employment and exposure time and health effects
- Examine validity of questionnaires/interviews in Ethiopian populations
- Conduct case control studies

Moreover, there should be regular workplace inspection activities, by the Federal Ministry of Labour and Social Affairs (FMOLSA) and Regional Bureaus of Labour and Social Affairs (BOLSA), to assess and monitor the working conditions and related workplace risks to protect the workers' health.

7. References

1. Kassa N. Floriculture Industry in Ethiopia: Trends, Prospects and Challenges. Jimma University College of Agriculture and Veterinary Medicine; 2006.
2. Agency EHD. Ethiopian horticulture sector statistics bulletin. Ethiopian Horticulture Development Agency, 2012.
3. Negatu B, Kromhout H, Mekonnen Y, Vermeulen R. Use of Chemical Pesticides in Ethiopia: A Cross-Sectional Comparative Study on Knowledge, Attitude and Practice of Farmers and Farm Workers in Three Farming Systems. Ann Occup Hyg. 2016;60(5):551-66.
4. Ethiopia FDRo. Pesticide Registration and Control Proclamation. Proclamation No 674/2010. Addis Ababa2010.
5. Negatu B, Kromhout H, Mekonnen Y, Vermeulen R. Occupational pesticide exposure and respiratory health: a large-scale cross-sectional study in three commercial farming systems in Ethiopia. Thorax. 2016.
6. Hernandez AF, Casado I, Pena G, Gil F, Villanueva E, Pla A. Low level of exposure to pesticides leads to lung dysfunction in occupationally exposed subjects. Inhal Toxicol. 2008;20(9):839-49.
7. Adhikari A, Gupta J, Wilkins JR, 3rd, Olds RL, Indugula R, Cho KJ, et al. Airborne microorganisms, endotoxin, and (1-->3)-beta-D-glucan exposure in greenhouses and assessment of respiratory symptoms among workers. Ann Occup Hyg. 2011;55(3):272-85.
8. Madsen AM. Airborne endotoxin in different background environments and seasons. Ann Agric Environ Med. 2006;13(1):81-6.
9. Hansen VM, Winding A, Madsen AM. Exposure to bioaerosols during the growth season of tomatoes in an organic greenhouse using Supresivit (Trichoderma harzianum) and Mycostop (Streptomyces griseoviridis). Appl Environ Microbiol. 2010;76(17):5874-81.
10. Stallones L, Beseler C. Pesticide illness, farm practices, and neurological symptoms among farm residents in Colorado. Environ Res. 2002;90(2):89-97.
11. Zuskin E, Schachter EN, Mustajbegovic J. Respiratory function in greenhouse workers. Int Arch Occup Environ Health. 1993;64(7):521-6.
12. Liebers V, Raulf-Heimsoth M, Bruning T. Health effects due to endotoxin inhalation (review). Arch Toxicol. 2008;82(4):203-10.
13. Von Essen S, Robbins RA, Thompson AB, Rennard SI. Organic dust toxic syndrome: an acute febrile reaction to organic dust exposure distinct from hypersensitivity pneumonitis. J Toxicol Clin Toxicol. 1990;28(4):389-420.
14. Smit LA, Zuurbier M, Doekes G, Wouters IM, Heederik D, Douwes J. Hay fever and asthma symptoms in conventional and organic farmers in The Netherlands. Occup Environ Med. 2007;64(2):101-7.
15. Paba E, Tranfo G, Corsetti F, Marcelloni AM, Iavicoli S. Indoor exposure to airborne endotoxin: a review of the literature on sampling and analysis methods. Industrial health. 2013;51(3):237-55.

16. Dutkiewicz J, Cisak E, Sroka J, Wojcik-Fatla A, Zajac V. Biological agents as occupational hazards - selected issues. Ann Agric Environ Med. 2011;18(2):286-93.
17. Schwartz DA, Thorne PS, Jagielo PJ, White GE, Bleuer SA, Frees KL. Endotoxin responsiveness and grain dust-induced inflammation in the lower respiratory tract. The American journal of physiology. 1994;267(5 Pt 1):L609-17.
18. Rylander R. Endotoxin in the environment--exposure and effects. Journal of endotoxin research. 2002;8(4):241-52.
19. Wang XR, Eisen EA, Zhang HX, Sun BX, Dai HL, Pan LD, et al. Respiratory symptoms and cotton dust exposure; results of a 15 year follow up observation. Occup Environ Med. 2003;60(12):935-41.
20. Thorn J. The inflammatory response in humans after inhalation of bacterial endotoxin: a review. Inflammation research : official journal of the European Histamine Research Society [et al]. 2001;50(5):254-61.
21. Thorne PS, Kulhankova K, Yin M, Cohn R, Arbes SJ, Jr., Zeldin DC. Endotoxin exposure is a risk factor for asthma: the national survey of endotoxin in United States housing. Am J Respir Crit Care Med. 2005;172(11):1371-7.
22. Smit LA, Heederik D, Doekes G, Wouters IM. Exhaled nitric oxide in endotoxin-exposed adults: effect modification by smoking and atopy. Occup Environ Med. 2009;66(4):251-5.
23. Lee SA, Adhikari A, Grinshpun SA, McKay R, Shukla R, Reponen T. Personal exposure to airborne dust and microorganisms in agricultural environments. J Occup Environ Hyg. 2006;3(3):118-30.
24. Thilsing T, Madsen AM, Basinas I, Schlunssen V, Tendal K, Baelum J. Dust, endotoxin, fungi, and bacteria exposure as determined by work task, season, and type of plant in a flower greenhouse. Ann Occup Hyg. 2015;59(2):142-57.
25. Radon K, Danuser B, Iversen M, Monso E, Weber C, Hartung J, et al. Air contaminants in different European farming environments. Ann Agric Environ Med. 2002;9(1):41-8.
26. Spaan S, Wouters IM, Oosting I, Doekes G, Heederik D. Exposure to inhalable dust and endotoxins in agricultural industries. J Environ Monit. 2006;8(1):63-72.
27. Madsen AM, Hansen VM, Nielsen SH, Olsen TT. Exposure to dust and endotoxin of employees in cucumber and tomato nurseries. Ann Occup Hyg. 2009;53(2):129-38.
28. Atreya K. Pesticide use knowledge and practices: a gender differences in Nepal. Environ Res. 2007;104(2):305-11.
29. Chemicals I-OPftSMo, Organization WH. WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009. World Health Organization; 2010.
30. Lopes Soares W, Firpo de Souza Porto M. Estimating the social cost of pesticide use: An assessment from acute poisoning in Brazil. Ecological Economics. 2009;68(10):2721-8.
31. Maroni M, Fanetti AC, Metruccio F. Risk assessment and management of occupational exposure to pesticides in agriculture. Med Lav. 2006;97(2):430-7.
32. Wilson C, Tisdell C. Why farmers continue to use pesticides despite environmental, health and sustainability costs. Ecological Economics. 2001;39(3):449-62.

33. Damalas CA, Eleftherohorinos IG. Pesticide exposure, safety issues, and risk assessment indicators. Int J Environ Res Public Health. 2011;8(5):1402-19.
34. Fenske RA, Day EW. Assessment of Exposure for Pesticide Handlers in Agricultural, Residential and Institutional Environments. Occupational and Residential Exposure Assessment for Pesticides: John Wiley & Sons, Ltd; 2005. p. 11-43.
35. Ward M, Lubin J, Giglierano J, Colt J, Wolter C, Bekiroglu N, et al. Proximity to crops and residential exposure to agricultural pesticides in Iowa. Environ Health Perspect. 2006;114:893 - 7.
36. Lekei EE, Ngowi AV, London L. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC public health. 2014;14:389.
37. Loewenherz C, Fenske RA, Simcox NJ, Bellamy G, Kalman D. Biological monitoring of organophosphorus pesticide exposure among children of agricultural workers in central Washington State. Environ Health Perspect. 1997;105(12):1344-53.
38. Henao S, Arbelaez MP. Epidemiologic situation of acute pesticide poisoning in Central America, 1992-2000. Epidemiol Bull. 2002;23(3):5-9.
39. Mancini F, Jiggins JL, O'Malley M. Reducing the incidence of acute pesticide poisoning by educating farmers on integrated pest management in South India. Int J Occup Environ Health. 2009;15(2):143-51.
40. Sam KG, Andrade HH, Pradhan L, Pradhan A, Sones SJ, Rao PG, et al. Effectiveness of an educational program to promote pesticide safety among pesticide handlers of South India. Int Arch Occup Environ Health. 2008;81(6):787-95.
41. Issa Y, Sham'a FA, Nijem K, Bjertness E, Kristensen P. Pesticide use and opportunities of exposure among farmers and their families: cross-sectional studies 1998-2006 from Hebron governorate, occupied Palestinian territory. Environmental health : a global access science source. 2010;9:63.
42. Kim JH, Kim J, Cha ES, Ko Y, Kim DH, Lee WJ. Work-related risk factors by severity for acute pesticide poisoning among male farmers in South Korea. Int J Environ Res Public Health. 2013;10(3):1100-12.
43. Zhang X, Zhao W, Jing R, Wheeler K, Smith GA, Stallones L, et al. Work-related pesticide poisoning among farmers in two villages of Southern China: a cross-sectional survey. BMC public health. 2011;11:429.
44. Thundiyil JG, Stober J, Besbelli N, Pronczuk J. Acute pesticide poisoning: a proposed classification tool. Bulletin of the World Health Organization. 2008;86(3):205-9.
45. Fleming LE, Gomez-Marin O, Zheng D, Ma F, Lee D. National Health Interview Survey mortality among US farmers and pesticide applicators. Am J Ind Med. 2003;43(2):227-33.
46. Del Prado-Lu JL. Pesticide exposure, risk factors and health problems among cutflower farmers: a cross sectional study. Journal of occupational medicine and toxicology (London, England). 2007;2:9.
47. Jørs E, Morant RC, Aguilar GC, Huici O, Lander F, Bælum J, et al. Occupational pesticide intoxications among farmers in Bolivia: a cross-sectional study. Environmental health : a global access science source. 2006;5.

48. Jeyaratnam J, Lun KC, Phoon WO. Survey of acute pesticide poisoning among agricultural workers in four Asian countries. Bulletin of the World Health Organization. 1987;65(4):521-7.
49. Corriols M, Marín J, Berroteran J, Lozano LM, Lundberg I. Incidence of Acute Pesticide Poisonings in Nicaragua: A Public Health Concern. Occupational and Environmental Medicine. 2009;66(3):205-10.
50. Lee WJ, Cha ES, Park J, Ko Y, Kim HJ, Kim J. Incidence of acute occupational pesticide poisoning among male farmers in South Korea. Am J Ind Med. 2012;55(9):799-807.
51. Recena MC, Caldas ED, Pires DX, Pontes ER. Pesticides exposure in Culturama, Brazil--knowledge, attitudes, and practices. Environ Res. 2006;102(2):230-6.
52. Ncube NM, Fogo C, Bessler P, Jolly CM, Jolly PE. Factors associated with self-reported symptoms of acute pesticide poisoning among farmers in northwestern Jamaica. Arch Environ Occup Health. 2011;66(2):65-74.
53. Jensen HK, Konradsen F, Jørs E, Petersen JH, Dalsgaard A. Pesticide Use and Self-Reported Symptoms of Acute Pesticide Poisoning among Aquatic Farmers in Phnom Penh, Cambodia. Journal of Toxicology. 2011;2011:8.
54. Zock JP, Hollander A, Heederik D, Douwes J. Acute lung function changes and low endotoxin exposures in the potato processing industry. Am J Ind Med. 1998;33(4):384-91.
55. Riu E, Monsó E, Marin A, Magarolas R, Radon K, Morera J, et al. Occupational risk factors for rhinitis in greenhouse flower and ornamental plant growers. American journal of rhinology. 2008;22(4):361-4.
56. Hoppin JA, Valcin M, Henneberger PK, Kullman GJ, Umbach DM, London SJ, et al. Pesticide use and chronic bronchitis among farmers in the Agricultural Health Study. Am J Ind Med. 2007;50(12):969-79.
57. Salameh PR, Waked M, Baldi I, Brochard P, Saleh BA. Chronic bronchitis and pesticide exposure: a case–control study in Lebanon. European journal of epidemiology. 2006;21(9):681-8.
58. Mamane A, Baldi I, Tessier J-F, Raherison C, Bouvier G. Occupational exposure to pesticides and respiratory health. European Respiratory Review. 2015;24(136):306-19.
59. Ergonen AT, Salacin S, Ozdemir MH. Pesticide use among greenhouse workers in Turkey. J Clin Forensic Med. 2005;12(4):205-8.
60. Fieten KB, Kromhout H, Heederik D, van Wendel de Joode B. Pesticide exposure and respiratory health of indigenous women in Costa Rica. Am J Epidemiol. 2009;169(12):1500-6.
61. Quirce S, Lemiere C, de Blay F, del Pozo V, Gerth Van Wijk R, Maestrelli P, et al. Noninvasive methods for assessment of airway inflammation in occupational settings. Allergy. 2010;65(4):445-58.
62. Sandrini A, Taylor DR, Thomas PS, Yates DH. Fractional exhaled nitric oxide in asthma: an update. Respirology. 2010;15(1):57-70.
63. Barnes PJ, Belvisi MG. Nitric oxide and lung disease. Thorax. 1993;48(10):1034-43.

64. Barnes PJ. Pathophysiology of allergic inflammation. Immunological reviews. 2011;242(1):31-50.
65. Negatu B, Vermeulen R, Mekonnen Y, Kromhout H. A Method for Semi-quantitative Assessment of Exposure to Pesticides of Applicators and Re-entry Workers: An Application in Three Farming Systems in Ethiopia. Ann Occup Hyg. 2016;60(6):669-83.
66. Hanssen VM, Nigatu AW, Zeleke ZK, Moen BE, Bratveit M. High prevalence of respiratory and dermal symptoms among Ethiopian flower farm workers. Archives of environmental & occupational health. 2014;15:15.
67. Rappaport SM, Kupper LL. Interpreting Levels of Exposures to Chemical Agents. Patty's Industrial Hygiene: John Wiley & Sons, Inc.; 2001.
68. Zyoud SH, Sawalha AF, Sweileh WM, Awang R, Al-Khalil SI, Al-Jabi SW, et al. Knowledge and practices of pesticide use among farm workers in the West Bank, Palestine: safety implications. Environmental health and preventive medicine. 2010;15(4):252-61.
69. Deressa W, Loha E, Balkew M, Desalegne A, Gari T, Gebremichael T, et al. Combining long-lasting insecticidal nets and indoor residual spraying for malaria prevention in Ethiopia: study protocol for a cluster randomized controlled trial. Malar J. 2014;13(1):1-.
70. Eriksen HR, Ihlebaek C, Ursin H. A scoring system for subjective health complaints (SHC). Scand J Public Health. 1999;27(1):63-72.
71. Wasserfallen JB, Gold K, Schulman KA, Baraniuk JN. Development and validation of a rhinoconjunctivitis and asthma symptom score for use as an outcome measure in clinical trials. The Journal of allergy and clinical immunology. 1997;100(1):16-22.
72. Litchfield M. Estimates of Acute Pesticide Poisoning in Agricultural Workers in Less Developed Countries. Toxicol Rev. 2005;24(4):271-8.
73. FLO-CERT. Public Compliance Criteria List-Hired Labour. Bonn: FLO-CERT; 2011.
74. (FLO) FLOI. Faire-trade Standards for Flowers and Plants for Hired Labour. Bonn: Fairetrade InternationalFaire; 2009.
75. Branch ILOSADIA. Employment and Working Conditions in the Ecuadorian Flower Industry. 1999.
76. Alving K, Janson C, Nordvall L. Performance of a new hand-held device for exhaled nitric oxide measurement in adults and children. Respir Res. 2006;7:67.
77. ATS/ERS. Recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. Am J Respir Crit Care Med. 2005;171(8):912-30.
78. Menzies D, Nair A, Lipworth BJ. Portable exhaled nitric oxide measurement: Comparison with the "gold standard" technique. Chest. 2007;131(2):410-4.
79. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (FENO) for clinical applications. American journal of respiratory and critical care medicine. 2011;184(5):602-15.

80. Lane SR, Nicholls PJ, Sewell RD. The measurement and health impact of endotoxin contamination in organic dusts from multiple sources: focus on the cotton industry. Inhal Toxicol. 2004;16(4):217-29.
81. Hornung RW, Reed LD. Estimation of Average Concentration in the Presence of Nondetectable Values. Applied Occupational and Environmental Hygiene. 1990;5(1):46-51.
82. Murray D, Wesseling C, Keifer M, Corriols M, Henao S. Surveillance of pesticide-related illness in the developing world: putting the data to work. Int J Occup Environ Health. 2002;8(3):243-8.
83. Simcox NJ, Fenske RA, Wolz SA, Lee IC, Kalman DA. Pesticides in household dust and soil: exposure pathways for children of agricultural families. Environ Health Perspect. 1995;103(12):1126-34.
84. Storaas T, Steinsvag SK, Florvaag E, Irgens A, Aasen TB. Occupational rhinitis: diagnostic criteria, relation to lower airway symptoms and IgE sensitization in bakery workers. Acta oto-laryngologica. 2005;125(11):1211-7.
85. Alving K, Weitzberg E, JM. L. Increased amount of nitric oxide in exhaled air of asthmatics. Eur Respir J. 1993(6):1368-70.
86. Gratziou C, Lignos M, Dassiou M, C. R. Influence of atopy on exhaled nitric oxide in patients with stable asthma and rhinitis. Eur Respir J. 1999(14):897-901.
87. Salameh PR, Waked M, Baldi I, Brochard P, Saleh BA. Chronic bronchitis and pesticide exposure: a case-control study in Lebanon. European journal of epidemiology. 2006;21(9):681-8.
88. De Silva HJ, Samarawickrema NA, Wickremasinghe AR. Toxicity due to organophosphorus compounds: what about chronic exposure? Transactions of the Royal Society of Tropical Medicine and Hygiene. 2006;100(9):803-6.
89. Health Council of the Netherlands. Endotoxins. Health-based recommended occupational exposure limit. The Hague: Health Council of the Netherlands; 2010.
90. Martin JRJ, Martin DMD. Comparison of Total Dust/Inhalable Dust Sampling Methods for the Evaluation of Airborne Wood Dust. Applied occupational and environmental hygiene. 1998;13(3):177-82.
91. Lee JY, Park JH, Kim D. A Survey on Physical Complaints Related with Farmers' Syndrome of Vinylhouse and Non-vinylhouse Farmers. Korean J Prev Med. 1994;27(2):258-73.
92. Tu ZB, Cui MJ, Yao HY, Hu GQ, Xiang HY, Stallones L, et al. [A case-control study on the risk factors of work-related acute pesticide poisoning among farmers from Jiangsu province]. Zhonghua liu xing bing xue za zhi = Zhonghua liuxingbingxue zazhi. 2012;33(4):382-5.
93. Jensen HK, Konradsen F, Jors E, Petersen JH, Dalsgaard A. Pesticide Use and Self-Reported Symptoms of Acute Pesticide Poisoning among Aquatic Farmers in Phnom Penh, Cambodia. J Toxicol. 2011;2011:639814.
94. Bell EM, Sandler DP, Alavanja MC. High pesticide exposure events among farmers and spouses enrolled in the Agricultural Health Study. Journal of agricultural safety and health. 2006;12(2):101-16.
95. Bonita R, Beaglehole R, Kjellstrom T. Basic epidemiology. 2nd ed. Geneva: World Health Organization; 2006.

96. Li C-Y, Sung F-C. A reveiw of healthy worker effect in occupational epidemiology. Occup Med. 1999;49(4):225-9.
97. Pearce N, Checkoway H, Kriebel D. Bias in occupational epidemiology studies. Occup Environ Med. 2007;64(8):562-8.
98. Hennekens CH, Buring JE. Epidemiology in Medicine. SL M, editor. Philadephia: Lippincott Williams & Wilkins; 1987.
99. Bowling A. Mode of questionnaire administration can have serious effects on data quality. J Public Health (Oxf). 2005;27(3):281-91.
100. Duquenne P, Marchand G, Duchaine C. Measurement of endotoxins in bioaerosols at workplace: a critical review of literature and a standardization issue. Ann Occup Hyg. 2013;57(2):137-72.
101. Ye M, Beach J, Martin JW, Senthilselvan A. Occupational pesticide exposures and respiratory health. Int J Environ Res Public Health. 2013;10(12):6442-71.
102. Tsimbiri PF, Moturi WN, Sawe J, Henley P, Bend JR. Health Impact of Pesticides on Residents and Horticultural Workers in the Lake Naivasha Region, Kenya. Occupational Diseases and Environmental Medicine. 2015;3(02):24.

APPENDICES

APPENDIX I: Consent form for participation

We ask you to consent to participate in a research study related to work in the flower industry and health. The aim of this study is to study work with the flowers and how this affects the health. This study will help us come up with recommendations on how to improve the work environment, if needed.

We are going to interview you on your demographic characteristics and some questions on health. Please answer the questions as frankly and accurately as possible.

Your participation in this interview and every aspect of this study is completely voluntary.

Those reporting serious diseases will be given advice how to find needed medical treatment.

When this study ends in 2014 information from the questionnaire will be stored anonymously in a secured database.

ALL INFORMATION OBTAINED IN THIS STUDY WILL BE KEPT CONFIDENTIAL AND USED FOR MEDICAL RESEARCH ONLY.

CONSENT FORM

I agree to participate in this study

Date __________________ Signature __________________

APPENDIX II

QUESTIONNAIRE FOR ASSESSING HEALTH AMONG FLOWER INDUSTRY WORKERS IN ETHIOPIA

Date: ___________

Section A: General information

Name of the plant: _____________

Name of the respondent: __________________________

1. Identification number: _____________
2. Date of birth: ______________ (day/month/year) in GC
3. Age in years __________
4. Sex 1[male] 2[female]
5. Education level by school years [0] none 1[1-4] 2[5-8] 3[9-10] 4[11-12] 5. [University]

Section B: Occupational history

6. For how long have you been working in this plant (months and years) _____/_____
7. Have you ever worked in other kinds of agriculture 1[yes] 2[no]
8. If yes, for how long have you worked in any of the following types of work (years)
a Other flower plant [____] b Other green house [____] c Farming [____] d others [mention]
____
9. What kind of job do you have in this flower plant?

a. Flower cutting [___]
b. Weeding [___]
c. Spraying pesticides [___]
d. Packing flowers [___]
e. Other work [___]

Section C: Health

I am going to ask you some questions about your health. I would like you to answer Yes or No to these first questions.

10. Do you usually cough first thing in the morning 1. [Yes] 2. [No]

11. Do you usually cough during the day or at night? 1. [Yes] 2. [No]

12. Do you usually cough with sputum first thing in the morning? 1. [Yes] 2. [No]

13. Do you usually cough with sputum during the day or at night? 1.[Yes] 2. [No]

14. Are you troubled by shortness of breath when hurrying on ground level? 1. [Yes] 2. [No]

15. Are you troubled by shortness of breath when walking up slight hill? 1.[Yes] 2. [No]

16. Do you get shortness of breath walking with other people of your own age on level ground? 1.[Yes] 2. [No]

17. Have you had attacks of wheezing in your chest at any time? 1.[Yes] 2. [No]

18. If yes, how long have you had wheezing in your chest? _________________months and/or years

These question concerns the last 30 days (month). To what extent did you have these symptoms:

19. Headache Never /Mild /Moderate/ Severe
20. Sleep problems Never /Mild /Moderate/ Severe
21. Tiredness (more than normal) Never /Mild /Moderate/ Severe
22. Dizziness Never /Mild /Moderate/ Severe
23. Anxiety Never /Mild /Moderate/ Severe
24. Depression Never /Mild /Moderate/ Severe
25. Rash on hands Never /Mild /Moderate/ Severe
26. Rash on skin other than hands Never /Mild /Moderate/ Severe

Please rate the severity of the following symptoms since you started work today. Choose the appropriate severity score at the location you think corresponds to the importance of your symptoms.

27. Airway symptoms

[1] Cough Never /Mild /Moderate/ Severe/ Very severe:
[2] Shortness of breath Never /Mild /Moderate/ Severe/ Very severe:
[3] Wheezing Never /Mild /Moderate/ Severe/ Very severe:

28. Nasal symptoms

[1] Stuffy nose Never /Mild /Moderate/ Severe/ Very severe:
[2] Runny nose Never /Mild /Moderate/ Severe/ Very severe:
[3] Sneezing Never /Mild /Moderate/ Severe/ Very severe:

29. Eye symptoms

[1]Red eyes Never /Mild /Moderate/ Severe/ Very severe:
[2]Sore eyes Never /Mild /Moderate/ Severe/ Very severe:
[3]Running eyes Never /Mild /Moderate/ Severe/ Very severe

30. Skin symptoms
Itching of skin Never /Mild /Moderate/ Severe/ Very severe

Section D: Previous diseases

Have you ever had any of the following?

31. An injury/operation affecting your chest. 1. [Yes] 2 [No]
32. Heart trouble 1. [Yes] 2 [No]
33. Bronchitis 1. [Yes] 2 [No]
34. Pneumonia 1. [Yes] 2 [No]
35. Pulmonary tuberculosis 1. [Yes] 2 [No]
36. Any other chest trouble? 1. [Yes] 2 [No] SPECIFY _______________________________

Section E: Tobacco smoking

37. Have you ever smoked cigarettes? 1. [Yes] 2 [No]
38. Do you now smoke cigarettes? 1. [Yes] 2 [No]
39. For how long have you being smoking [__]__] years
40. How many cigarettes do you normally smoke per day now? [__]___] number

41. How long ago did you give up cigarette smoking? [__]__] years
42. How many cigarettes did you normally smoke when you smoked earlier? [__]___] number

Section F: Personal protective equipment

43. Do you use gloves at work? Yes, always / Most of the time/Sometimes/ Seldom /Never

44. If you use gloves, at which work activity do you use them?_________________________________

45. If the person answers “seldom or never”, why? Select the most appropriate reason for not using gloves:

1. Not available
2. Not comfortable to wear
3. Do not offer enough protection of the skin
4. It is not necessary
5. Any other reason __________________

47. Do you use respiratory equipment at work? Yes, always / Most of the time/Sometimes/ Seldom /Never

48. If you use respiratory equipment, at which work activity do you use this?_________________________

49. If the person answers “seldom or never”, why? Select the most appropriate reason for not using respir- atory protective device:

1. Not available
2. Not comfortable to wear
3. Do not offer enough protection against the dust
4. The dust is not harmful
5. Any other reason __________________

Thank you!

APPENDIX III

Checklist for walk-trough survey in Flower Greenhouse

Flower plant	
Contact person	
Established	
Date	
Nr. of employees	
Nr. of greenhouses	

Hectares	
Shifts	
Annual production	
Owners	
Certification	
Other • Inspections • Historical assessment/changes made	

Greenhouse			
		Cutting & Cultivating	Spraying
Safety poster • Language			
Safety sheets • Language			
Ventilation	Mechanical		
	Natural		
	Local exhaust		
Working teams • Number of workers per team • Number of teams			
Work duration			
How often			
Re-entry interval			
PPE	Gloves		
	Glasses		
	Mask		
	Overall		

	Boots		
	Storing		
Tap-water			
Workers gender			
Other • Spraying equipment • Distance between rows • Fertilizer in irrigation • Drainage for waste water • Post-harvest treatment/chemicals			

Pesticide mixing room		
		Pesticide mixing
Safety poster • language		
Safety sheets • language		
Ventilation	Mechanical	
	Natural	
	Extraction arms	
Working teams • Number of workers pr team • Number of teams		
Work duration		
How often		
Re-entry interval		
PPE	Gloves	
	Glasses	

	Mask	
	Overall	
	Boots	
	Storing	
Tap-water		
Workers gender		
Other • Admission • Associated dispensary • Cleaning procedures • Storing containers • Mixing procedures • Mixing equipment • Drainage for waste water		
Irrigation and fertilizer room		
		Fertilizer mixing
Safety poster • language		
Safety sheets • language		
Ventilation	Mechanical	
	Natural	
	Extraction arms	
Working teams • Number of workers pr team • Number of teams		
Work duration		
How often		

Re-entry interval				
PPE	Gloves			
	Glasses			
	Mask			
	Overall			
	Boots			
	Storing			
Tap-water				
Workers gender				
Other • Types of fertilizer(g/l/s) • Application systems • Admission • Associated dispensary • Cleaning procedures • Storing containers • Mixing procedures • Mixing equipment • Drainage for waste water				
Packing and storing house				
		Making bundles	Cold storing	Other
Safety poster • language				
Safety sheets • language				
Ventilation	Mechanical			
	Natural			
	Extraction arms			

Working teams • Number of workers per team • Number of teams				
Work duration				
How often				
Re-entry interval				
PPE	Gloves			
	Glasses			
	Mask			
	Overall			
	Boots			
	Storing			
Tap-water				
Workers gender				
Other Cold room temp.				
Other areas				
Safety poster • language				
Safety sheets • language				
Ventilation	Mechanical			
	Natural			

	Extraction arms		
Working teams • Number of workers pr team • Number of teams			
Work duration			
How often			
Re-entry interval			
PPE	Gloves		
	Glasses		
	Mask		
	Overall		
	Boots		
	Storing		
Tap-water			
Workers gender			

Additional questions	
Describe the:	For the Health and Safety officer to answer
Health and safety training provided • To which groups? • How often? • Training focus on?	
Health and safety policy of the company • Points of priority on health and safety • Risk assessment	

Health services available • Acute illness/fist-aid procedures • Recordings of ill-health related to work o Tests being conducted?	
Internal controll of implementation of code of practice	
Inspections conducted • By who?	
Social security scheme provided to the employees	
Housing of the workers	
Sanitary facilities	
Drinking water	
Eating place for the workers	
Washing facilities	
Use and accessibility of personal protection equipment (PPE)	
Recordings of pesticide use • Types, list available? • Amounts	
Hierarchy of health and safety responsibility	
Most frequent pests to roses	
Most frequent human illness	
Additional information	

APPENDIX IV

QUESTIONNAIRE FOR ASSESSING RESPIRATORY HEALTH PROBLEMS AMONG CUT FLOWER WORKERS IN ETHIOPIA

Date of interview: ____/___/___ (DD/MM /YEAR)

Name of the farm: ________________________

Section A: Socio-demographic data

1. ID Number ______________

2. Name ______________________

3. Date of Birth __/__/_____ (day/month /year)

5. Age in years_______

6. Sex: [1] Male [2] Female

7. Education levels by school years

[0] none 1[1-4] 2[5-8] 3[9-10] 4[11-12]

5. [University]

8. Marital status:

[1] Single [2] Married [3] Cohabit [4] Separated /Divorced [5] Widowed

Section B: Occupational history

9. For how long have you been working in this flower farm (months and years) _____/_____

10. What kind of job do you have in this flower plant?

1. Flower cutting [___] 2. Weeding [___] 3. Spraying pesticides [___]

4. Packing flowers [___] 5. Other work [___]

11. Have you ever worked in other kinds of agriculture 1[yes] 2[no]

12. If yes, for how long have you worked in any of the following types of work (years)

1. Other flower plant [____] 2. Other greenhouse [____]

3. Farming [____] 4. Others [mention] ________________________

Section C: Respiratory symptoms: please answer yes or no to the following questions

Cough

13. Do you usually cough first thing in the morning (Clearing of throat is not applicable)?

1. [Yes] 2. [No]

14. Do you usually cough during the day or at night? 1. [Yes] 2. [No]

If yes to any of the above:

15. Do you usually cough as much as 4-6 times a day for 4 or more days in a week?

1. [Yes] 2. [No]

16. Do you cough like this on most of days for as much as 3 consecutive months or more in a year? 1. [Yes] 2. [No]

Cough with sputum production

17. Do you usually cough with sputum first thing in the morning? 1. [Yes] 2. [No]

18. Do you usually cough with sputum during the day or at night? 1. [Yes] 2. [No]

If yes to any of the 17 & 18:

19. Do you usually cough with sputum as much as 4-6 times a day, or 4 or more days in a week? 1. [Yes] 2. [No]

20. Do you cough with sputum on most of days for as much as 3 consecutive months or more in a year? 1. [Yes] 2. [No]

Breathlessness (Dyspnea)

21. Are you troubled by shortness of breath when hurrying on level ground or walking up slight hill? 1. [Yes] 2. [No]

22. Do you get shortness of breath walking with other people of your own age on level ground? 1. [Yes] 2. [No]

If yes to any of question 21 & 22:

23. Do you ever have to stop for breath when walking at your own pace on level ground?

1. [Yes] 2. [No]

Wheezing

24. Have you had attacks of wheezing in your chest at any time? 1. [Yes] 2. [No]

25. How long do you have wheezing in your chest? ______/_____ (Year/Month)

26. Do you usually experience chest tightness while at work or just after work?

1. [Yes] 2. [No]

27. For how long do you have this problem? _____/______ (Year/Month)

Sinusitis

Have you ever had problem with:

28. Sneezing (when you don't have cold or flu) 1. [Yes] 2. [No]

29. Runny nose (when you don't have cold or flu) 1. [Yes] 2. [No]

30. Blocked nose (when you don't have cold or flu) 1. [Yes] 2. [No]

29. In the past 12 months have you had a problem with recurrent nasal fluid or a runny or blocked nose (when you don't have a cold or flu)? 1. [Yes] 2. [No]

Section D: History of Past chest illness

Have you ever had or been treated for any of the following illnesses?

30. Injury or operation affecting your chest [1] Yes [2] No [3] Don't know

31. Bronchitis [1] Yes [2] No [3] Don't know

32. Pneumonia [1] Yes [2] No [3] Don't know

33. Pulmonary Tuberculosis [1] Yes [2] No [3] Don't know

34. Asthma [1] Yes [2] No [3] Don't know

35. Other(s) (specify) ____

Section E: Medication History

36. Do you currently use any drugs for treatment of your chest? [1] Yes [2] no

37. If yes which drugs do you currently use for your chest?

a) Antibiotics 1] Yes [2] no

b) Anti TB [1] Yes [2] no

c) Steroids [1] Yes [2] no

d) Others (specify) ________________________________

Section F: Tobacco smoking

38. Have you ever smoked cigarettes? 1. [Yes] 2 [No]

If no, go to section F

39. Do you now smoke cigarettes? 1. [Yes] 2 [No]

If No, go to question 41

40. For how long have you being smoking ________/_______ Months/Years

41. How many cigarettes do you normally smoke per day now? [__]___] number

42. How long ago did you give up cigarette smoking? [__]__] years

43. How many cigarettes did you normally smoke before you gave up smoking? [_____] number of cigarettes

Section G: Personal protective devices

44. Do you usually wear respiratory protective devices while at work? 1[yes] 2[no]

If yes, go to question 45; If No, go to question 46

45. Which of the respiratory protective device do you use?

1. Mask respirator

2. Full face piece respirator

3. Powered respirator

4. Breathing apparatus

46. Select the most appropriate reason for not using respiratory protective device

1. Not available

2. Not comfortable to wear

3. Do not offer enough protection

4. There is not harmful substance

5. Any other reason ___________________

47. Do you usually wear/use gloves? 1. Yes 2. No

48. If no (Q47), select the most appropriate reason for not using gloves

1. Not available

2. Not comfortable to wear

3. Do not offer enough protection

4. There is not harmful substance

5. Any other reason ___________________

II

Nigatu *et al. Journal of Occupational Medicine and Toxicology* (2015) 10:8
DOI 10.1186/s12995-015-0053-x

JOURNAL OF OCCUPATIONAL MEDICINE AND TOXICOLOGY

RESEARCH Open Access

Respiratory symptoms, fractional exhaled nitric oxide & endotoxin exposure among female flower farm workers in Ethiopia

Amare W Nigatu[1*], Magne Bråtveit[1], Wakgari Deressa[2] and Bente E Moen[1]

Abstract

Background: Greenhouse workers are exposed to organic dusts, and they are thereby at risk of developing airway disorders. This study aims to measure personal endotoxin exposure, assess respiratory symptoms and measure fractional exhaled nitric oxide (FeNO) among female flower farm workers in Ethiopia.

Methods: A cross-sectional study involving female workers (n = 248) from four flower farms was conducted. The workers were interviewed for respiratory symptoms using a standard questionnaire. Workers from two of these farms also participated in personal endotoxin sampling (46 workers, 75 measurements) on glass fiber filters (0.2 μm pore size) inside conductive 25 mm Millipore cassettes for sampling of the "total dust" fraction. They also participated in FeNO (n = 114) measurements with a portable electrochemistry-based sensor. Chi-square and independent t-tests were used to compare categorical and continuous variables respectively. A mixed-effects model was used to analyze exposure determinants.

Results: Endotoxin exposure had a geometric mean (GM) of 22.8 endotoxin units (EU)/m^3 with a maximum of 180 EU/m^3. Greenhouse workers had significantly higher endotoxin exposure than workers outside the greenhouses (GM = 26.7 vs. 19.3 EU/m^3 respectively; $p < 0.05$). The mean age of the workers was 24 years, and their mean working time in the flower farm was 21 months. Greenhouse workers had higher prevalence of self-reported respiratory symptoms than those outside greenhouses. However, after adjusting for education only blocked nose remained significant. The FeNO concentration ranged 5–166 ppb (GM = 14 ppb). Two workers had FeNO concentration above 50 ppb. FeNO levels differs significantly between the farms but there was no difference between workers inside and outside greenhouses.

Conclusion: Greenhouse workers at flower farms had higher prevalence of blocked nose than workers outside, which may indicate the presence of rhinitis. Endotoxin exposure was low. There were few workers with objective signs of airway inflammation; this might be because the mean working time in the greenhouses was only two years. We suggest further studies to evaluate the effect of longer employment and exposure time as well as to investigate possible exposure to pesticides and other components in the bio-aerosols.

Keywords: Endotoxin exposure, Respiratory symptoms, Fractional exhaled nitric oxide, Greenhouse, Flower farm

Background

The cultivation of roses inside greenhouses is a rapidly growing economic activity in Ethiopia, and covers 120 hectares of land with over 50,000 workers [1]. The greenhouses are characterized by elevated temprature, humidity and poor ventilation [2-4]. Pesticides of different types, chemical fertilizers and to some extent biological agents are widely used to enhance the growth of flowers [5].

It is likely that people in the agriculture sector are exposed to organic dusts during their daily routines [6-8]. Part of the agriculture process involves work in greenhouses, including cultivation of flowers and vegetables. Because of the enclosed space and poor ventilation, greenhouse work might also be associated with high exposure levels to organic dust [9]. Several studies among greenhouse workers have shown high prevalence of respiratory symptoms such as chronic cough, dyspnea,

* Correspondence: Amare.Nigatu@igs.uib.no
[1]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway
Full list of author information is available at the end of the article

chest tightness and rhinitis, as compared to controls [2,10-12]. In 2012 we conducted a study among flower farm workers in Ethiopia and found that workers inside the greenhouse had significantly higher self-reported prevalence of chronic respiratory symptoms compared to workers outside the greenhouse as well as compared to a control group of supermarket workers [13]. No objective measurements of occupational exposure or respiratory health were performed in that study.

The organic dust in greenhouses has many components such as fungal spores, bacteria, and endotoxins [4,14,15]. Endotoxins are a cell-wall component of gram-negative bacteria, and can be inhaled by workers [16,17]. It is suggested that they are involved in the development of respiratory disorders such as obstructive lung disease [17]. As many of the Ethiopian farm workers had respiratory symptoms, which can be considered typical for airway obstruction [9,13], we decided to measure endotoxin exposure levels in their work environment.

Adverse respiratory effects due to organic dust exposure might be associated with eosinophilic inflammation and increased fractional exhaled nitric oxide (FeNO) among workers [18]. The measurement of FeNO involves a simple and non-invasive method. The technique uses a portable device. This gives fast and reliable results in the field [19]. Occupational exposure to organic dust and measurement of FeNO in the agricultural sector has been used in the Western countries to study several work settings [20]. However, few of these studies are conducted among greenhouse workers [4,11]. Moreover, there is no information about endotoxin exposure and FeNO among flower farm workers in Ethiopia.

The objective of the present study was to evaluate the exposure to endotoxins; to assess the prevalence of respiratory symptoms and to measure FeNO among female workers inside and outside greenhouses in flower farms in Ethiopia.

Methods and materials

Study design and study settings

A cross-sectional study was conducted from July to October 2013 in four flower farms in the three main geographical areas for cultivation of roses in Ethiopia (Hollota/Addis-Alem, Debrezeit and Ziway areas). Due to practical reasons such as location and accessibility, we used convenient sampling to select the farms. The workers in each of the farms were divided into two observational groups based on their workstation (inside vs. outside greenhouses) for an interview, FeNO measurement and endotoxin sampling under their normal working conditions. All the four farms were included in the assessment of respiratory symptoms, but due to limited resources only two farms were included in the measurements of endotoxin and FeNO. The farms were visited before the actual data collection and the farm managements were informed about the purpose of the study.

The farms only grow roses, and vary in size from 5–51 hectares, while the total number of workers ranged from 350 to 1,300 (Table 1). The production rate is relatively constant, but at times there is peak production to meet increased demands. All the farms use chemical fertilizers and pesticides to enhance the growth of flowers and to control pests. In addition, Farm I also uses mites as biological control, however, we did not collected information on the types of mites used. The pesticides are manually mixed at a central location inside greenhouses and distributed through pipelines. The sprayers use a nozzle or sprayer gun to spray the pesticide. In all the farms, except Farm IV, spraying takes place in the morning during which time the other greenhouse workers are relocated to other greenhouses until the spraying is completed. In Farm IV spraying is done late in the afternoon after all greenhouse workers have completed their work and left the farm.

The great majority of the workers are females, who either harvest and weed flowers inside greenhouses or trim and pack roses in a pack-house before storage in a cold room until transporting them to Addis Ababa for export. The few men work as pesticide sprayers and also perform other activities including repairing the greenhouses, collecting and disposing of wastes as well as transporting harvested flowers.

Study participants

Female workers from the selected farms participated in the study. Based on the prevalence of shortness of breath (70%) among Ethiopian flower farm workers [13], a total of 248 participants (divided in two groups, i.e., inside vs. outside greenhouse) were needed to achieve 80% statistical power with significance level set to $P < 0.05$. The plan was to have equal number of workers from each of the four farms as well as from inside and outside greenhouses, and overall 122 and 126 workers participated from inside and outside greenhouses, respectively. The same participants from Farm I & II ($n = 114$) were also invited to participate in the FeNO measurements. Participants were randomly selected by the researcher from the personnel registration book in Farm II & III, while in Farm I & IV, the selection was done together with the farm administration. The principal investigator did all the interviews and the FeNO measurements in a separate room inside the farm compound. The FeNO instruction was sometimes done in groups of 2–4 workers.

Interview

A part of the standardized questionnaire from the British Medical Research Council (BMRC) on respiratory health was used to assess chronic respiratory symptoms. The

Table 1 Description of the flower farms and workers participated in the study

Farm characteristics	Farm ID			
	I	II	III	IV
Farm size (hectares)	51	12	5	41
Number of greenhouses	21	7	3	5
Number of pack-houses	2	1	1	2
Number of workers	1,300	700	350	1295
Sample Size				
Interview	67	47	41	93
FeNO measurement	67	47	NA	NA
Endotoxin measurement	25	21	NA	NA
Pest control methods	CP, BA	CP	CP	CP
Pesticide spraying time	6:00–10:00 AM	6:00–10:00 AM	6:00–10:00 AM	3:00–6:00 PM
Flower cultivated	Roses	Roses	Roses	Roses

NA: Not Applicable; CP: Chemical Pesticides; BA: Biological Agents.

questionnaire was adapted to the Ethiopian context, and translated from English to the local language; the symptoms included cough first thing in the morning, day/night time cough, shortness of breath, chest tightness and wheezing as well as previous diseases such as bronchitis, pulmonary TB, asthma and chest injury (yes/no). In addition, questions about upper airway symptoms (runny nose, sneezing and blocked nose) were also included [21]. Moreover, previous flower farm experience (months), socio-demographic characteristics such as age, education (years in school), types of job (cutter & weeder, packing, deleafing, grading, quality control), present and previous smoking habits (yes/no) and the use of Personal Protective Equipment: gloves and respiratory protective device (yes/no) were also asked.

FeNO measurement

FeNO measurements were taken for each person in a sitting position during the working day between 10:00 and 15:00 hours, using a portable electrochemistry-based sensor (NIOX MINO; Aerocrine AB, Solana, Sweden) in accordance with the American Thoracic Society & European Respiratory Society recommendations for online measurement of FeNO [22,23]. The mean ambient NO, room temperature and relative humidity of the room where FeNO measurement performed were registered daily; below 5 ppb, 22°C (18 – 28°C) and 70%, respectively.

Endotoxin sampling and analysis

Full-shift personal endotoxin air samples were collected in the two selected farms (inside vs. outside greenhouses). The number of endotoxin samples was based on the Rappaport and Kupper's recommendations for exposure studies; 10–20 measurements per observational group, two measurements of 5–10 randomly selected individuals per group [24]. Totally 46 female workers were invited for sampling; 25 from Farm I, and 21 from Farm II. Among these, 31 workers had repeated samples.

Sampling was performed from the workers' breathing zone during the summer months, which is a rainy season in Ethiopia. Side Kick Casella Pump at a flow rate of 2 L/minute connected to 25 mm closed-face conductive Millipore cassettes containing a glass fiber filter with 0.2 μm pore size was mounted onto each worker for sampling of the "total dust" fraction. The mean sampling times were 350 (275 – 425) minutes and 358 (240 – 405) minutes for Farm I and II, respectively. The pumps were calibrated using a Rotameter every day before starting the measurement, and the air flow rate was also measured at the end of the measurements. Two samples were excluded due to a reduction in air flow of more than 10% during the sampling day. Filters were kept cold at about 4°C inside a box filled with ice bags until the samples were transported to Norway and then to Sweden for analysis at Lund University Medical Laboratory. The samples were transported as hand luggage on the flights, and were outside the cold box for a total of about 15 hours. The glass fiber filters were immersed into 0.05% Tween-20 pyrogenic free water and shaken on a rotary shaker for 1 h. Endotoxin extracts were analyzed using kinetic chromogenic Limulus amebocyte Lysate (LAL) Assay. The results were expressed as Endotoxin Unit (EU) per filter. A total of 27 samples had endotoxin values below the Limit of Quantification (LOQ), which was set to 10 EU per filter by the laboratory. In calculations of exposure levels (EU/m^3), the amount of endotoxins on the respective filters were divided by the air volume that had passed through that filter. The measurements below LOQ were set as $LOQ/2^{1/2}$ in further data handling. This cut-off level has been suggested when less than 50% of the data are nondetectable, and the geometric standard deviation is below 3.0 [25]. The resulting limit of detection (LOD) for the endotoxin exposure corresponding to the 27 samples < LOQ varied from 8.7 to 14.7 EU/m^3 due to different air volumes.

Ethics

The research proposal was submitted and approved by the Ethical committees both in Norway and Oromia Regional State Health Bureau, Ethiopia. All the participants were informed about the purpose of the study and written consent was obtained.

Statistical analysis

The data was plotted into SPSS version 21 and analyzed using descriptive statistics. The distribution of endotoxin and FeNO data were skewed, and were therefore log-transformed in order to compare the levels between the groups. Chi-square test for categorical variables, and independent t-tests for continuous variables were used to test differences between the groups. The significance level was set to 0.05. A linear mixed-effects model was used to analyze the determinants of endotoxin exposure among the female workers, since we had repeated measurements of endotoxins on several of the workers. The individual female participants were included in the model as random effects. The farms (Farm I vs. Farm II) and workstation (inside vs. outside greenhouses) were set as fixed effects. Logistic regression was used to test differences in symptoms between groups by adjusting for education. Education was the only potential confounder among those tested that was significantly different between workers inside vs. outside greenhouses.

Results

Characteristics of the study participants

The workers were categorized by workstation based on whether they work inside the greenhouse or not. The response rate for the interview was 100%. The mean age of all female workers was 24 years (range 14 – 60 years). There were no differences in age, previous respiratory diseases and duration of work experience between inside and outside greenhouse workers (Table 2). Workers outside the greenhouse had significantly higher education than those working inside (Table 2). None of the female workers were current smokers or had any previous history of smoking. The majority of the workers (97%) used biofuel (wood, cow dung & charcoal) as energy source for cooking and other domestic purposes. A quarter of the participants had domestic animals, and 7% shared their living space with the animals.

Table 2 Characteristics of the female flower farm workers by workstation (inside vs. outside greenhouse)

N	IGH	OGH
	122	126
Years of age		
Mean (Range)	24 (14 – 48)	23 (16 – 60)
Cooking energy N (%)		
Biofuel-wood-dung-wood-charcoal	119 (98)	122 (97)
Kerosin	2 (1.6)	4 (3)
Both	1 (0.8)	0
Educational level N (%)		
No Education (0–4 school years)	55 (45)	25 (20)*
Education (>5 school years)	67 (55)	101 (80)
Work experience in Months		
Mean (range)	21 (1–96)	22 (1–96)
Previous Agricultural experience N (%)	28 (23)	38 (30)
Previous Agricultural experience in months Mean (SD)	20 (18)	8 (8)
Domestic animals N (%)	27 (22)	34 (27)
Shared room with domestic animals	7 (6)	10 (8)
Pesticide use N (%)		
For household pests[a]	52 (43)	60 (50)
For mosquito control	23 (19)	28 (22)
Previous diseases N (%)		
Chest injury/operation	1 (0.8)	0
Bronchitis	9 (7.4)	12 (9.5)
Pneumonia	3 (2.5)	4 (3.2)
Pulmonary TB	1 (0.8)	2 (1.6)
Asthma	4 (3.3)	3 (2.4)
Smoking		
Current & Previous smokers	None	None

IGH: Inside Greenhouse; OGH: Outside Greenhouse; *Pearson chi-square test, $P < 0.001$; [a]Fleas, bed bugs, lice, mice.

Endotoxin exposure measurements

The personal endotoxin exposure ranged from < LOD to 180 EU/m^3 with a geometric mean of 22.8 EU/m^3 (Table 3). Only one of the samples exceeded the Dutch recommended health-based exposure limit value for endotoxins in inhalable dust of 90 EU/m^3 [26]. The endotoxin exposure inside the greenhouses was significantly higher than outside the greenhouses ($p < 0.05$) (Table 3). Workers in Farm I had significantly higher endotoxin exposure than workers in Farm II (GM = 29.2 Vs. 17.3 EU/m^3; $P < 0.01$). The greenhouse workers in Farm I were the subgroup with the highest endotoxin exposure (GM = 37.8 EU/m^3) (Table 3).

The day-to-day endotoxin exposure variability (within workers) was higher than the between worker variability (Table 4). In a mixed-effects model analysis, the fixed

Table 3 Personal endotoxin exposure among female flower farm workers according to farm (I or II) and workstation (inside vs. outside greenhouse)

Farm ID	Workstation	Nw	Ns	Ns <LOD	Endotoxin (EU/m3)		
					AM	Range[a]	GM (GSD)
Farm I	IGH	10	19	2	47.3	9.2 – 180	37.8 (2.0)*[b]
	OGH	15	20	8	28.2	10.0– 64.6	22.9 (2.0)
	Total	25	39	10	37.5	9.2 – 180	29.2 (2.1)**[c]
Farm II	IGH	12	19	8	24.9	8.7 – 60.9	18.9 (2.1)[ns,b]
	OGH	9	17	9	17.1	9.1 – 34.7	15.8 (1.5)
	Total	21	36	17	21.3	8.7 – 60.9	17.3 (1.9)
Total	IGH	22	38	10	36.1	8.7 – 180	26.7 (2.2)*[b]
	OGH	24	37	17	23.1	9.1 – 64.6	19.3 (1.8)
	Total	46	75	27	29.7	8.7 – 180	22.8 (2.1)

Independent sample t-tests were used to compare groups.
EU/m^3: Endotoxin Units per cubic meter; Nw: Number of workers; Ns: Number of sample; <LOD: Below Limit of Detection; AM: Arithmetic Mean; GM: Geometric Mean; GSD: Geometric Standard Deviation; IGH: Inside Greenhouse; OGH: Outside Greenhouse (packhouse); **P < 0.01, *P < 0.05, ns = not significant, [a]The lowest exposure in all subgroups are estimated values for results below LOD; [b]Comparing samples inside and outside greenhouses; [c]Comparing Farm I and Farm II.

factors workstation and farm, explained 17% of the total variance in endotoxin exposure (Table 4). The fixed factors explained parts of the between-worker variance only. Work in Farm I was associated with 1.7 times higher personal exposure to endotoxin compared to Farm II, while those working inside the greenhouse had 1.4 times higher exposure than those working outside.

Use of Personal Protective Devices (PPD)

None of the female workers in any of the four flower farms used any type of Respiratory Protective Devices (RPD). Almost all (99.6%) of the workers indicated the reason for not using RPD was because it is unavailable or not provided at the work place. Gloves at work were used by 64% of all female workers (78% and 50% among inside and outside greenhouse workers respectively) with significant differences between the farms (p < 0.01). The reported reason for not using gloves was mainly because gloves were not available or provided.

Prevalence of chronic respiratory symptoms

Among all invited workers in the four farms shortness of breath (53%), chest tightness (27%) and morning cough (25%) were the most frequently reported symptoms (Table 5). Morning cough, runny nose and blocked nose were significantly higher among greenhouse workers compared to those working outside (Table 5). When adjusting for education by logistic regression analyses, only the prevalence of blocked nose remained significantly higher among workers inside greenhouses. The prevalence of morning cough and day/night time cough with sputum were significantly different among the four flower farms (p = 0.009 & 0.028 respectively), while the other symptoms did not differ among these groups. Farm I had the highest prevalence for most of the symptoms (results not shown). When comparing results of Farm I & II, where we also have measurements of personal endotoxin exposure and Fractional exhaled Nitric Oxide (FeNO), Farm I has relatively higher prevalence for most of the symptoms. The prevalence inside the greenhouse was higher than outside for most of the symptoms. Due to small numbers, the groups inside and outside the greenhouse in these two farms were not statistically compared after stratification by farm.

Fractional exhaled Nitric Oxide (FeNO)

A total of 114 female flower workers from Farm I & II participated in measurements of Fractional exhaled Nitric Oxide (FeNO), and valid results were obtained from 108 of these.

Among all participants FeNO ranged from 5 to166 ppb with a GM of 14 ppb (Table 6). Only two workers (1.8%) had FeNO concentration greater than 50 ppb, a level often used to indicate the presence of asthma [27]. The mean FeNO of those working inside and outside the greenhouses did not differ significantly, either among workers in Farm I and Farm II together or within each

Table 4 Linear mixed-effects model for the $\log_e$-transformed personal endotoxin exposure levels of female workers

	Endotoxin (EU/m^3)		
	Random-effects Model β (SE)	Mixed-effects Model β (SE)	Effect (e^{β})
Intercept	3.14 (0.09)**	2.67 (0.15)**	
Workstation (OGH = 0 & IGH = 1)		0.35 (0.16)*	1.4
Farm ID (Farm II = 0 & Farm I = 1)		0.53 (0.16)**	1.7
WWδ (SE)	0.35 (0.09)	0.35 (0.09)	
BWδ (SE)	0.17 (0.09)	0.08 (0.08)	
% of explained variance		17%	

SE: Standard Error; β: Regression Coefficient; IGH: Inside Greenhouse; OGH: Outside Greenhouse; WWδ: Within Worker Variance; BWδ: Between Worker Variance; **P < 0.01, *P < 0.05.

Table 5 Prevalence of respiratory symptoms by workstation (inside vs. outside greenhouse)

	Workstation			Adjusted OR (95% CI)[a]
	Total	IGH	OGH	
	N = 248	N = 122	N = 126	
	n (%)	n (%)	n(%)	
Morning cough	63 (25)	38 (31)*	25 (20)	1.19 (0.63, 2.26)
Cough day/night time	41 (17)	23 (19)	18 (14)	1.08 (0.53, 2.21)
Cough 4–6 days a week	47 (19)	29 (24)	18 (14)	1.31 (0.66, 2.64)
Cough more days in 3 months	18 (7)	11 (9)	7 (6)	1.11 (0.39, 3.13)
Morning cough with sputum	39 (16)	22 (18)	17 (14)	1.03 (0.49, 2.14)
Cough day/night time with sputum	19 (8)	11 (9)	8 (6)	1.15 (0.43, 3.09)
Cough 4–6 days a week with sputum	25 (10)	15 (13)	10 (8)	0.99 (0.39, 2.45)
Cough more days in 3 months with sputum	11 (4)	7 (6)	4 (3)	1.01 (0.27, 3.79)
Shortness of breath walking on level ground/slight hill	131 (53)	60 (49)	71 (56)	0.65 (0.38, 1.09)
Shortness breath walking own pace	38 (15)	22 (18)	16 (13)	1.16 (0.56, 2.43)
Wheezing	40 (16)	20 (16)	20 (16)	0.69 (0.33, 1.46)
Chest tightness	66 (27)	34 (28)	32 (25)	0.89 (0.49, 1.62)
Sneezing	70 (29)	32 (26)	38 (30)	0.74 (0.42, 1.33)
Runny nose	48 (19)	30 (25)*	18 (14)	1.74 (0.89, 3.39)
Blocked nose	36 (15)	25 (21)**	11 (9)	2.36 (1.08, 5.17)

The groups were compared using chi-square tests and logistic regression, while adjusting for education.
N: Total number of samples; n: number of cases with the symptom; **$P < 0.01$ & *$P < 0.05$ (unadjusted chi-square tests); [a]95 percent confidence interval.

of the farms (Table 6). Workers in Farm I had significantly higher mean FeNO than in Farm II (GM = 15.8 ppb and 11.8 ppb; P = 0.009) respectively (Table 6). When excluding the two values above 50 ppb, the statistical differences between the groups did not change.

Discussion

Our study indicated that endotoxin exposure and FeNO levels were low while there were high prevalences of self-reported respiratory symptoms among the female workers in the flower farms. Greenhouse workers had significantly higher endotoxin exposure and reported more symptoms than workers outside greenhouses. However, after adjusting for education, only blocked nose remained significant. FeNO levels differed significantly between the farms but there was no difference comparing inside vs. outside greenhouse workers.

Table 6 Mean FeNO level according to workstation (inside vs. outside greenhouse) and farm among the female flower farm workers

Farm ID	Workstation	N	AM	Range	Ns > 50 ppb	GM	GSD
Farm I	IGH	26	16.5		0	15.3	1.47
	OGH	37	21.4		1	16.2	1.93
	Total[a]	63	19.4	5-166	1	15.8*	1.75
Farm II	IGH	23	17.2		1	12.8	1.95
	OGH	22	12.3		0	10.8	1.65
	Total[a]	45	14.8	5-107	1	11.8*	1.82
Total	IGH	49	16.8		1	14.1	1.72
	OGH	59	18.0		1	13.9	1.88
	Total	108	17.5	5-166	2	13.9	1.81

[a]Independent *t*-test; *$P < 0.01$ when comparing Farm I and II; Ns: Number of samples; IGH: Inside Greenhouse; OGH: Outside Greenhouse (packhouse).

All the endotoxin samples, except one, were below the Dutch recommended health-based exposure limit value (90 EU/m^3) [26]. Nevertheless, the mean endotoxin exposure was higher than reported for flower/ornamental growers inside European greenhouses (GM = 2.9; range 0.4-101.4 EU/m^3) [28]. Studies among Dutch and Danish flower growers in greenhouses reported similar or slightly higher endotoxin exposure (GM = 27 & 44 EU/m^3 respectively) [20,29]. In those studies they used inhalable dust samplers which have been reported to sample 1.5-4 times more dust by mass than the "total" dust samplers used in the present study [30]. Thus, it is difficult to directly compare the obtained results with other studies and with the Dutch limit value since the total dust samplers in our study presumably collected lower levels of endotoxins than were present in the inhalable dust fraction. A study among cucumber and tomato employees in greenhouses reported considerably higher endotoxin exposure (median = 320 EU/m^3) which might be partly due to the larger leaf areas of these plants [9]. Greenhouse workers in Farm I had the highest endotoxin exposure of all the groups in both farms.

Use of biological pest control method in Farm I might have contributed to the higher exposure, as this is the only apparent difference between the farms. One may speculate whether biological pest control combined with less use of pesticides could be related to this differences in exposure.

The day-to-day variance was higher than the between worker variance for the endotoxin exposure. One reason might be temporary relocation of workers to other greenhouses during spraying. However, we did not systematically register the relocation times. The fixed factors in the mixed-effects model only explains the between-worker variability in endotoxin exposure, which is logical since the individual worker did not change workstation (inside/outside greenhouse) or farm.

The greenhouse workers had higher prevalence for most symptoms than workers outside. However, when we adjust for education, only the prevalence of blocked nose, which is most likely a symptom of rhinitis, was significantly higher. This is similar to the findings in Croatia that female greenhouse workers had higher prevalence of respiratory symptoms than controls [2]. However, the prevalence of rhinitis in the Croatian study was higher (42%) than for blocked nose in the present study (21%). This difference may be explained by the use of different terms describing nose symptoms. The term rhinitis is broad, and more people may have reported this symptom than the more specific symptom blocked nose. Rhinitis is known to precede asthmatic conditions [31], which might mean that the workers inside greenhouses could be at risk of developing asthma. However, only surveys over a longer time can support this. The results in the present study are also partly consistent with our previous study [13], showing high prevalence of respiratory symptoms, including blocked nose. However, in that study a different control group was used. The low endotoxin exposure in the present study is not likely to explain the respiratory symptoms, and might rather be related to other components in the bioaerosol including fungi or pesticides [3,15]. Studies on greenhouse workers in Oman [32] and Turkey [33] reported prevalence of cough of 30% and 31%, respectively. The higher prevalence in these two studies than in the present study (19% of day/night time cough), might be explained by the higher age (78% over 30 years), cigarette smoking (19.8%) and longer work experience (73% over 7 years) of the workers in the Oman study. It might be possible that longer work experience with longer exposure time cause more respiratory health problems than we have been able to demonstrate.

This relatively high prevalence of shortness of breath, chest tightness and wheezing, even in the young worker population in our study, might be partly due to unknown factors such as reporting errors or living conditions. Over a quarter of the workers had domestic animals, which may also expose them to dust and allergens.

The mean FeNO in our study was GM = 13.9 ppb, which is considered to be low [34]. A study among endotoxin exposed female agricultural workers also found to be low FeNO (GM = 11.4 ppb) [35]. Previous studies of asthmatics have shown elevated FeNO levels [36,37]. Although we found low FeNO level in our study, it may not necessarily mean that these workers do not have any risk of asthma or other respiratory problems.

Strength and limitation

Strengths of the present study are that objective measurements were done both for endotoxin exposure and FeNO. Moreover, the subgroups (inside vs. outside greenhouses) were comparable for most variables except education, which we controlled for in the analysis.

However, it is a weakness that we only measured endotoxin exposure during one summer (rainy and wet). This may not represent the winter (sunny and dry) exposure. A high fraction of the endotoxin samples had values below the limit of quantification at the laboratory. The high fraction of these low levels has presumably influenced the estimates of mean exposures and the fixed factors in the mixed-effects model, but presumably they did not affect the main findings. Pesticides and fertilizers of different types were widely used in the flower farms [13], but we were unable to measure these exposures in this study. There might be a healthy worker effect as most workers had short work experience due to high turnover. In addition, the administration may have picked the healthiest workers for examination. However, the administrative personnel was not likely to know all the details of the workers' health.

Conclusion

Greenhouse workers in flower plants had higher prevalence of blocked nose than those outside greenhouses, which may indicate the presence of rhinitis. Endotoxin exposure was low, but the levels were highest inside the greenhouses. There were few workers with objective signs of airway inflammation, but most workers had only been working in the greenhouses for two years. Further studies should be performed in the rose farms to evaluate the effect of longer employment and exposure time as well as to investigate possible occupational exposure to pesticides and other components in the bioaerosol.

Abbreviations

FeNO: Fractional exhaled nitric oxide; GM: Geometric mean; BMRC: British medical research council; TB: Tuberculosis; PPB: Parts per billion; NO: Nitric oxide; LOQ: Limit of quantification; LOD: Level of detaction; EU/m^3: Endotoxin unit per cubic meter; RPD: Respiratory protective devices.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
AWN has contributed to the conception, planning and design of the study, data collection, analysis and interpretation, drafting and revising the manuscript. BEM contributed to the planning and design of the study, data collection, analysis and interpretation of the data and critical reviewing of the manuscript. MB contributed to the planning and design of the study, analysis and interpretation of the data and critical reviewing of the manuscript. WD contributed to the planning of the study, data collection and critical reviewing of the manuscript. All authors read and approved the final manuscript.

Authors' information
AWN: PhD Candidate, Occupational and Environmental Medicine Research Group, Bergen University, Norway. BEM: MD, PhD; Director of Center for International Health, Bergen University, Norway. MB: PhD, Occupational and Environmental Health Research Group, Bergen University, Norway. WD: PhD, Head of Public Health Faculty, Addis Ababa University, Ethiopia.

Acknowledgements
We are very grateful to the flower farm workers and the farm managements for their willingness to participate and cooperate in this study. We are grateful to Lennart Larsson and Christina Pehrson who analyzed the endotoxin samples for us. We also acknowledge the Norwegian Education Fund for the financial support to conduct the study.

Author details
[1]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway. [2]School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia.

Received: 1 November 2014 Accepted: 18 February 2015
Published online: 26 February 2015

References

1. Sutton JaNK: An Enterprise Map of Ethiopia. International Growth Centre 2010:205. http://personal.lse.ac.uk/sutton/Enterprise_Map_Ethiopia_Book.pdf
2. Zuskin E, Schachter EN, Mustajbegovic J. Respiratory function in greenhouse workers. Int Arch Occup Environ Health. 1993;64(7):521–6.
3. Hernandez AF, Casado I, Pena G, Gil F, Villanueva E, Pla A. Low level of exposure to pesticides leads to lung dysfunction in occupationally exposed subjects. Inhal Toxicol. 2008;20(9):839–49.
4. Adhikari A, Gupta J, Wilkins JR, Olds 3rd RL, Indugula R, Cho KJ, et al. Airborne microorganisms, endotoxin, and (1→3)-beta-D-glucan exposure in greenhouses and assessment of respiratory symptoms among workers. Ann Occup Hyg. 2011;55(3):272–85.
5. Sahle A, Potting J. Environmental life cycle assessment of Ethiopian rose cultivation. Sci Total Environ. 2013;443:163–72.
6. Lee SA, Adhikari A, Grinshpun SA, McKay R, Shukla R, Reponen T. Personal exposure to airborne dust and microorganisms in agricultural environments. J Occup Environ Hyg. 2006;3(3):118–30.
7. Mekonnen Y, Ejigu D. Plasma cholinesterase level of Ethiopian farm workers exposed to chemical pesticide. Occup Med. 2005;55(6):504–5.
8. Watterson A. Pesticide health and safety and the work and impact of international agencies: partial successes and major failures. Int J Occup Environ Health. 2001;7(4):339–47.
9. Madsen AM, Hansen VM, Nielsen SH, Olsen TT. Exposure to dust and endotoxin of employees in cucumber and tomato nurseries. Ann Occup Hyg. 2009;53(2):129–38.
10. Tual S, Clin B, Leveque-Morlais N, Raherison C, Baldi I, Lebailly P. Agricultural exposures and chronic bronchitis: findings from the AGRICAN (AGRIculture and CANcer) cohort. Ann Epidemiol. 2013;23(9):539–45.
11. Monso E. Occupational asthma in greenhouse workers. Curr Opin Pulm Med. 2004;10(2):147–50.
12. Mekonnen Y, Agonafir T. Effects of pesticide applications on respiratory health of Ethiopian farm workers. Int J Occup Environ Health. 2002;8(1):35–40.
13. Hanssen VM, Nigatu AW, Zeleke ZK, Moen BE, Bratveit M. High prevalence of respiratory and dermal symptoms among Ethiopian flower farm workers. Arch Environ Occup Health. 2014;15:15.
14. Madsen AM. Airborne endotoxin in different background environments and seasons. Ann Agric Environ Med. 2006;13(1):81–6.
15. Hansen VM, Winding A, Madsen AM. Exposure to bioaerosols during the growth season of tomatoes in an organic greenhouse using Supresivit (Trichoderma harzianum) and Mycostop (Streptomyces griseoviridis). Appl Environ Microbiol. 2010;76(17):5874–81.
16. Paba E, Tranfo G, Corsetti F, Marcelloni AM, Iavicoli S. Indoor exposure to airborne endotoxin: a review of the literature on sampling and analysis methods. Ind Health. 2013;51(3):237–55.
17. Dutkiewicz J, Cisak E, Sroka J, Wojcik-Fatla A, Zajac V. Biological agents as occupational hazards - selected issues. Ann Agric Environ Med. 2011;18(2):286–93.
18. Quirce S, Lemiere C, de Blay F, del Pozo V, Gerth Van Wijk R, Maestrelli P, et al. Noninvasive methods for assessment of airway inflammation in occupational settings. Allergy. 2010;65(4):445–58.
19. Khalili B, Boggs PB, Bahna SL. Reliability of a new hand-held device for the measurement of exhaled nitric oxide. Allergy. 2007;62(10):1171–4.
20. Spaan S, Wouters IM, Oosting I, Doekes G, Heederik D. Exposure to inhalable dust and endotoxins in agricultural industries. J Environ Monit. 2006;8(1):63–72.
21. Wasserfallen JB, Gold K, Schulman KA, Baraniuk JN. Development and validation of a rhinoconjunctivitis and asthma symptom score for use as an outcome measure in clinical trials. J Allergy Clin Immunol. 1997;100(1):16–22.
22. Alving K, Janson C, Nordvall L. Performance of a new hand-held device for exhaled nitric oxide measurement in adults and children. Respir Res. 2006;7:67.
23. ATS/ERS. Recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. Am J Respir Crit Care Med. 2005;171(8):912–30.
24. Rappaport SM, Kupper LL. Interpreting Levels of Exposures to Chemical Agents. In: Patty's Industrial Hygiene. edn.: John Wiley & Sons, Inc.; 2001
25. Hornung RW, Reed LD. Estimation of Average Concentration in the Presence of Nondetectable Values. Appl Occup Environ Hyg. 1990;5(1):46–51.
26. Health Council of the Netherlands. Endotoxins. Health-Based Recommended Occupational Exposure Limit. The Hague: Health Council of the Netherlands; 2010.
27. Olin AC, Bake B, Toren K. Fraction of exhaled nitric oxide at 50 mL/s: reference values for adult lifelong never-smokers. Chest. 2007;131(6):1852–6.
28. Radon K, Danuser B, Iversen M, Monso E, Weber C, Hartung J, et al. Air contaminants in different European farming environments. Ann Agric Environ Med. 2002;9(1):41–8.
29. Thilsing T, Madsen AM, Basinas I, Schlunssen V, Tendal K, Baelum J. Dust, endotoxin, fungi, and bacteria exposure as determined by work task, season, and type of plant in a flower greenhouse. Ann Occup Hyg. 2014;59:142.
30. Martin JRJ, Martin DMD. Comparison of total dust/inhalable dust sampling methods for the evaluation of airborne wood dust. Appl Occup Environ Hyg. 1998;13(3):177–82.
31. Storaas T, Steinsvåg SK, Florvaag E, Irgens A, Aasen TB. Occupational rhinitis: diagnostic critera, relation to lower airway symptoms and IgE sensitization in bakery workers. Acta Otolaryngol. 2005;125(11):1211–7.
32. Esechie JO, Ibitayo OO. Pesticide use and related health problems among greenhouse workers in Batinah Coastal Region of Oman. J Forensic Leg Med. 2011;18(5):198–203.
33. Ergonen AT, Salacin S, Ozdemir MH. Pesticide use among greenhouse workers in Turkey. J Clin Forensic Med. 2005;12(4):205–8.
34. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (FENO) for clinical applications. Am J Respir Crit Care Med. 2011;184(5):602–15.
35. Smit LA, Heederik D, Doekes G, Wouters IM. Exhaled nitric oxide in endotoxin-exposed adults: effect modification by smoking and atopy. Occup Environ Med. 2009;66(4):251–5.
36. Alving K, Weitzberg E, Lundberg JM. Increased amount of nitric oxide in exhaled air of asthmatics. Eur Respir J. 1993;6:1368–70.
37. Gratziou C, Lignos M, Dassiou M, Roussos C. Influence of atopy on exhaled nitric oxide in patients with stable asthma and rhinitis. Eur Respir J. 1999;14:897–901.

III

Nigatu *et al. BMC Public Health* (2016) 16:575
DOI 10.1186/s12889-016-3196-5

BMC Public Health

RESEARCH ARTICLE Open Access

Self-reported acute pesticide intoxications in Ethiopia

Amare W. Nigatu[1*], Magne Bråtveit[1] and Bente E. Moen[1,2]

Abstract

Background: Pesticide exposure is an important public health concern in Ethiopia, but there is limited information on pesticide intoxications. Residents may have an increased risk of pesticide exposure through proximity of their homes to farms using pesticides. Also the pesticide exposure might be related to employment at these farms. This study investigated the prevalence of acute pesticide intoxications (API) by residence proximity to a nearby flower farm and assessed if intoxications were related to working in these farms or not.

Methods: A cross-sectional survey involving 516 persons was conducted. Participants were grouped according to their residence proximity from a large flower farm; living within 5 kilometers and 5–12 kilometers away, respectively. In a structured interview, participants were asked if they had health symptoms within 48 h of pesticide exposure in the past year. Those who had experienced this, and reported two or more typical pesticide intoxication symptoms, were considered as having had API. Chi-square and independent t-tests were used to compare categorical and continuous variables, respectively. Confounding variables were adjusted by using binomial regression model.

Results: The prevalence of API in the past year among the residents in the study area was 26 %, and it was higher in the population living close to the flower farm (42 %) compared to those living far away (11 %), prevalence ratio (PR) = 3.2, 95 % CI: 2.2-4.8, adjusted for age, gender & education. A subgroup living close to the farm & working there had significantly more API (56 %) than those living close & didn't work there (16 %), adjusted PR = 3.0, 95 % CI: 1.8-4.9. Flower farm workers reported more API (56 %) than those not working in the flower farm (13 %,), adjusted PR = 4.0, 95 % CI: 2.9-5.6.

Conclusion: Our study indicates a 26 % prevalence of self-reported symptoms attributable to API. The residents living closer than 5 kilometers to the flower farm reported significantly higher prevalence of self-reported API than those living 5–12 kilometers away. This increased risk of API was associated with work at the flower farm.

Keywords: Acute pesticide intoxications, Self-reported symptoms, Flower farm workers

Background

Pesticides are widely used in the agriculture sector globally to control pests, and in less developed countries the use of pesticides is increasing [1]. Spraying of pesticides to protect crops may cause human exposure during spraying, followed by adverse health effects [2–4]. This is an important public health concern in developing countries [3]. Several studies have shown that occupational exposure to pesticides is common among farm workers, resulting in high prevalence of acute pesticide intoxication (API) [4–7]. According to a survey of self-reported minor poisoning from pesticides, there could be as many as 25 million agricultural workers in the developing world suffering an episode of pesticide poisoning each year [8]. In Ethiopia over 85 % of the population depend on agriculture, and the activity is mainly characterized by small-scale farming. The use of pesticides in agriculture has increased dramatically in Ethiopia the last decades. The increased demands for productivity and the expansion of commercial farms, especially floriculture, are the prime factors. Floriculture is growing at a very fast rate involving tens of thousands of workers [9]. The cultivation of roses in these farms is highly dependent on extensive use of pesticides. The most common

* Correspondence: Amare.Nigatu@uib.no
[1]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway
Full list of author information is available at the end of the article

pesticides used in Ethiopia include organophosphates, carbamates and to some extent organo-chlorines [10]. The flower farms are usually located in close proximity to the houses of the rural community. Pesticides sprayed in the flower farms as well as on crops at small farms may increase pesticide exposure of the population. A study by Ward, et al. in USA, suggested that rural residents could be exposed to agricultural pesticides through proximity of their homes to crop fields. The study indicated that six herbicides, used almost exclusively in agriculture, were detected in 28 % of the homes [11]. In Ethiopia, most workers in the flower farm reside in nearby villages, and they might be exposed to pesticides at their workplace.

To our knowledge, there is limited information about the magnitude of API in Ethiopia. Those who use pesticides, i.e., in households, smallholder private farmers as well as flower farms workers, could all experience API. We speculated that there could be differences in API experience and related adverse health effects between different population groups according to proximity to flower farms (living close vs. far away) as well as being employed in the flower farm or not. Persons living close to the flower farms or working at these farms might have greater access to the pesticides and be more exposed to these substances. The objectives of the present study were to: i) determine the prevalence of API among residents in an area where a flower farm is located; ii) study the relationship between API and residential proximity to the flower farm and; iii) assess if the prevalence of API is related to the work in the flower farm.

Methods

Study design and study setting

A cross-sectional study involving 516 households was conducted from August to September 2014, in Ethiopia. One person from each of the selected households, usually the head of the household, was interviewed using a structured interview guide. When the household head was unavailable, the interviewer asked for consent to interview the first adult over 18 years met in the household.

Study area and study population

The study area comprised a total of 1025 villages in a district where one of the largest flower farms in Oromia region of Ethiopia, involving over ten thousand workers, is located. Lists of villages and households in this area were obtained from the local authorities as well as from a research project run by researchers from Bergen and Addis Ababa Universities [12]. For the purpose of this study, we defined two observational groups; residents living close vs. far away; /<5 & 5-12/ kilometers from the flower farm, respectively. We decided to have 5 kilometer cut-off point based on our observations of the study area. Most of the working population in the flower farm lives within a distance of 0–5 kilometer from the flower farm while those living within 5–12 kilometer are mainly involved in small-scale farming. The12 kilometer cut-off point was chosen to exclude the residents living in the villages right after the 12 kilometer mark who mostly work at a pesticide factory.

The flower farm grows roses inside plastic greenhouses. The small private farms in the area mostly grow cereal crops such as maize, wheat, and sorghum. Pesticides are widely used both for rose cultivation and for growing cereal crops, though there are differences in the types and intensity of pesticides used [10].

Sampling technique and sample size

Cluster sampling technique was used, where a village, which is the smallest administrative unit, was considered as a cluster. The number of households in a village varied considerably, ranging from 40 to 100 households (200 to 500 inhabitants) per village; and the villages closer to the flower farm were much larger than those located far away. All the villages, which were located within 0–12 kilometer from the flower farm, formed the sampling frame; a total number of 68 villages, i.e., 23 & 45 villages located < 5 & 5–12 kilometer away, respectively. Based on the prevalence of excessive sweating (25 %), a typical symptom of organophosphate intoxication reported in a previous study [13], we calculated a sample size of 520 households needed to achieve a statistical power of 80 %, at a significance level of $p < 0.05$. According to this calculation a total of 11 (4 close & 7 far) out of 68 villages were randomly selected to get the required number of households. All the households in these selected villages were invited to participate in the study.

Interview

Interviews were performed from 9:00–17:00 using a structured interview guide developed from similar previous studies done elsewhere in English language [3, 14–16]. The interview guide was translated from English to the local language (Afan Oromo) and vice-versa. A pretest was conducted among ten households in the area, which were excluded from the final analysis. Some minor changes, such as redefining the job categories to accommodate all job types, were made before the interview guide was finalized.

Exposure to pesticides may occur among agricultural workers in open fields and in greenhouses through occupational exposure, and among persons using pesticides to control house pests. Moreover, although a particular occupation does not actually use pesticides themselves, the presence of pesticides in the working environment constitutes potential occupational exposure for them [17].

As shown in Table 1, the questions were on socio-demographic information, current job, work experience, pesticide use, experienced health problems within 48 h of exposure to pesticides in the last year, and whether the exposure to pesticides occurred through occupational exposure in the case of flower farm workers and small-scale farmers or pesticide application for household pest control. The respondents, who explained a plausible description of exposure to pesticides; and reported to have experienced health problems within 48 h of the exposure once or several times the past year, were asked to state the health symptoms they had. The interviewers then ticked off the symptoms they mentioned from the list in the interview guide (Table 1). In the present study, we used WHOs standard definition for possible API [15]; The respondents, who presented a plausible description of exposure and reported to have experienced two or more of these symptoms within 48 h of the exposure to pesticides once or several times the past year, were considered to have suffered API.

Table 1 Interview guide used on the study of API in Ethiopia

Section	Items in the interview guide	
Socio-demographic information	Identification: House Number: ________; Village: ____________	
	Gender: 1. Male 2. Female	
	Age in years: ___________	
	Are you head of the household? (yes/no)	
	How many people live in the family? 1. Male: ______ 2. Female: _____3. Total: _______	
	What is the level of your education in school years? _________________	
Current job	What is your current job?	
	1. Farmer-own land	
	2. Flower farm worker (greenhouse, pack-house, sprayer, other)	
	3. Other (Office worker, small private business, housewife)	
Work experience	How long have you been working in this job?	
Pesticide use	Do you use pesticide at home for pest control? (yes/no)	
	Do you use pesticides on your own farm? (if a farmer) (yes/no)	
	Do they use/spray pesticides in the flower farm? (if you are working in the flower farm) (yes/no)	
Pesticide-related health problems experienced	Have you ever felt health problems within 48 h of exposure to pesticides in the last 12 months?	
	1. Never 2. Once 3. Several times 4. Not exposed to pesticides	
	If you ever had health problem within 48 h of exposure to pesticides, which health symptoms did you experienced? (Tick off all the symptom (s) mentioned by the respondents from the below list)	
	1. Headache	12. Abdominal cramp
	2. Dizziness	13. Chest tightness
	3. Excessive sweeting	14. Dyspnea
	4. Salivation	15. Morning cough
	5. Confusion	16. Day/night time cough
	6. Weakness	17. Shortness of breath
	7. Anxiety	18. Wheezing
	8. Loss of consciousness	19. Miosis
	9. Bradycardia	20. Eye tear
	10. Vomiting	21. Rash on hand
	11. Diarrhea	22. Skin rash
Exposure to pesticides	If you ever had health problem within 48 h of exposure to pesticides, the exposure to pesticides occurred through:	
	1. Pesticide application for household pest control	
	2. Pesticide application at own farm or working at sprayed farm	
	3. While pesticide application or working at sprayed flower farm	
Smoking	Do you currently smoke cigarette (tobacco) daily? (yes/no)	

Five health workers (nurses and public health officers), who were familiar with the area and spoke the local language, did the interview. A half-day orientation/training about the interview guide was given for the interviewers. The interviewers went door-to-door and informed the households about the purpose of the research; and a written consent was obtained. To ensure confidentiality, the interview was done face-to-face with only the interviewer and the respondent present. All participating houses were given numbers for identification instead of participants' names in order to keep the anonymity of the respondents.

Statistical analysis

The data were entered into SPSS version 21. Descriptive statistics were used to describe demographic data and the prevalence of API. Chi-square and independent t-tests were used to compare the groups, i.e., living close (<5 kilometers) to the flower farm vs. far away (5–12 kilometers); living close & work in the flower farm vs. living close & don't work in flower farm as well as flower farm workers vs. all others, for categorical and continuous variables, respectively. Potential confounding variables were all checked for statistical significance between the comparison groups using chi-square and independent t-tests. Those variables with $p < 0.05$, i.e., age, gender, education and being small-scale farmer were all included in the binomial regression model analysis to adjust for these differences, while comparing the API prevalence between the different groups.

Results

Characteristics of the population

A total of 516 persons (257 and 259 close and far, respectively) out of the planned 520 participated in the survey (99 % response rate); and out of this, 85 % of the respondents were household heads. The remaining four households did not participate in the survey because they were not available during the interview. The mean age of the surveyed population was 30 years (Table 2). There were significant age differences between the subgroups living close vs. living far away as well as between the subgroups "living close & work" vs. "living close & don't work" in the flower farm. In terms of current job, 53 % were small-scale farmers, 32 % were flower farm workers and the remaining 15 % were categorized as others such as office work, small business holders and housewives (Table 2). Many of those living close to the flower farms were working at the flower farm (64 %), while the majority of those living far away were small-scale farmers working on their own farms (92 %). The majority of the population (76 %) had a low level of education (primary school level) and those who lived far away from the flower farm had lower education than the others. Only 1 % of the surveyed population smoked cigarettes (tobacco).

The participants used pesticides for pest control in households (mosquito, fleas and bed bug control), crop farming and in the flower farm (33, 41 and 34 % respectively).

Acute pesticide intoxication (API)

During the last year 29 % ($n = 141$) had experienced health problems within 48 h of exposure to pesticides at least once; 23 % and 6 %, once and several times, respectively (Fig. 1). A total of 136 respondents (26 %) had experienced two or more symptoms, and were thus considered to have had API the last year (Table 3). Among those with API the most frequent self-reported symptoms were nervous system symptoms (79 %) followed by respiratory and gastrointestinal symptoms (58 %), (Table 4).

Of those living close to the flower farm, 42 % reported to have had API, compared to 11 % among those living far away (PR = 3.7, 95 % CI: 2.6-5.4) (Table 3). The subgroup, who was living close to & worked in the flower farm had a significantly higher proportion of API (56 %) than the subgroup living close to & didn't work in the flower farm (16 %), (PR = 3.5, 95 % CI: 2.1-5.6). Flower farm workers reported significantly higher API in the last 12 months than "all others", 56 % & 13 %, respectively (PR = 4.4, 95 % CI: 3.3-6.1). These differences in the prevalence of API between the groups remained significant after adjusting for age, gender and education using binomial regression analyses (Table 3). We found no significant difference in the prevalence of API between the residents living far away and those living close to, but were not working in the flower farm, after adjusting for being small-scale farmer, gender, age and education (Table 3). Pesticide exposure at the flower farm was related to 68 % of the API cases, followed by 16 % and 15 % pesticide exposure related to household pest control and small-scale farmers, respectively. There were significant differences in API prevalence among the different job groups in the flower farm. Greenhouse workers had the highest API prevalence (57 %) followed by sprayers (22 %) and pack-house workers (15 %/) ($p < 0.01$). The prevalence of API among small-scale farmers in the study area was 12 %.

Discussion

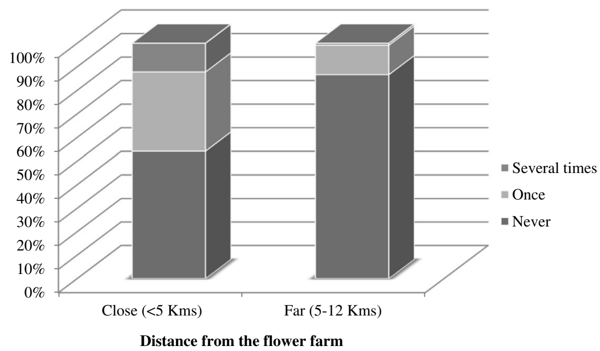
The overall prevalence of symptoms attributable to API in the last 12 months among the households was 26 %, and it was highest in the population, who lived close to and worked at the flower farm.

According to a pilot study done among Ethiopian flower farm workers, the pesticides mostly used in the flower farms were organophosphate, carbamate,

Table 2 Characteristics of the surveyed population

Variable	Total $N = 516$	Living proximity from FF and work in FF			
		Close to FF $N = 257$	Close & work in FF $N = 164$	Close & don't work in FF $N = 93$	Far from FF $N = 259$
Gender N (%)					
Men	298 (58)	132 (51)	86 (52 %)	46 (49)	166 (64) [a**]
Women	218 (42)	125 (49)	78 (48)	47 (51)	93 (36)
Family size					
Mean (SD)	4.9 (2.9)	3.6 (2.0)	3.1 (1.9)	4.4 (2.1) [bb**]	6.4 (2.9)
Age in years					
Mean (SD)	30 (10.6)	26 (6.9)	25 (5.5)	29 (7.9) [bb**]	34 (12.1) [b*]
Education in school years					
Mean (SD)	5.5 (3.7)	6.6 (3.5)	6.7 (3.4)	6.4 (3.6)	4.4 (3.6) [b**]
Type of job N (%)					
Farmer own farm	275 (53)	36 (14)	0	36 (39)	239 (92)
Flower farm	165 (32)	164 (64)	164 (100)	0	1 (0.003)
Green house	87 (17)	86 (34)	86 (52)	0	1 (0.003)
Pack-house	29 (6)	29 (6)	29 (18)	0	0
Sprayer	29 (6)	29 (6)	29 (18)	0	0
Other	20 (4)	20 (4)	20 (12)	0	0
Other	76 (15)	57 (22)	0	57 (61)	19 (7)
Work experience (months)					
Mean (SD)	46 (43)	35 (27)	31 (24.5)	52 (31.3) [bb**]	71 (61)
Family members working in FF N {%}	109 (21)	104 (20)	82 (50)	22 (22)	5 (1)
Pesticide use N (%) [c]					
Household use	172 (33)	58 (23)	38 (23)	20 (22)	114 (44) [d]
Own farm	214 (41)	47 (18)	10 (6)	37 (40) [dd**]	167 (65) [d]
Flower farm	173 (34)	172 (67)	157 (96)	15 (16) [dd**]	1 (0.003) [d]
Cigarette smoking (tobacco) N (%)	7 (1)	0	0	0	7 (3)

FF: flower farm; [a]: Chi-square test comparing the subgroups close vs. far; [b]: independent *t*-test comparing the subgroups close vs. far; [bb]: independent *t*-test comparing the subgroups "close & work" vs. "close & don't work" in FF; [c]: percentage may not add to 100 %; [d]: comparing the subgroups close vs. far by logistic regression; [dd]: comparing the subgroups "close & work" vs. "close & don't work" in FF by logistic regression; *:$p < 0.05$; **:$p < 0.01$



*: Those reported as not exposed to pesticides (n = 38) were excluded in the analysis of health problems experience.

Fig. 1 Health problems experienced in the last year by living proximity from the flower farm*

Table 3 Prevalence of API by living proximity from the flower farm and working there or not

	Total	API n (%)	CPR (95 % CI) [a]	APR (95 % CI) [b]
Total	516	136 (26)		
Living proximity				
Close	257	107 (42)	3.7 (2.6, 5.4)	3.2 (2.2, 4.8) [b]
Far (reference)	259	29 (11)	1.0	
Close & don't work in flower farm	93	15 (16)	1.5 (0.8, 2.9)	1.6 (0.8, 3.2) [c]
Living close & work in the flower farm or not				
Close & work	164	92 (56)	3.5 (2.1, 5.6)	3.0 (1.8, 4.9) [b]
Close & don't work (reference)	93	15 (16)	1.0	
Flower farm worker	165	92 (56)	4.4 (3.3, 6.1)	4.0 (2.9, 5.6) [b]
Others (reference)	351	44 (13)	1.0	

[a]: Crude Prevalence Ratio; [b]: Adjusted Prevalence Ratio for age, gender and education; [c]: Adjusted Prevalence Ratio for age, gender, education and being small-scale farmer; CI: Confidence Interval

pyrethroid +, azole and neonicotinoid [18]. We did not collect information on the type of pesticides involved in our present study as most of the participants had low levels of education, and was expected not to be able to specify the pesticides used. However, the most frequent symptoms reported in the present study are typical symptoms of exposure to the aforementioned pesticides [15].

The prevalence of API among the residents in the present study was similar to the findings in a national survey of male farmers in South Korea on self-reported cases of API (24.7 %; $n = 1958$) [16]. Population-based surveys in Central America ($n = 32{,}245$) and Nicaragua ($n = 3169$) reported that 2 % and 2.3 % of the population, respectively suffered from API yearly [4, 19]. These low figures compared to our results, is probably explained by the differences in type of studies. The present study should not be considered as a general population study since the majority of the population was selected from an area with a flower farm, and included a high fraction of flower farm workers as well as small- scale farmers. Furthermore, in the studies from Central America and Nicaragua, they asked for self-reported cases of API within the first 24 h of pesticide exposure, while we asked for symptoms within the first 48 h. Also, the differences between these two studies and ours might be attributed to underreporting of cases [20, 21].

The prevalence of API among small-scale farmers (12 %) in our study is slightly higher than reported by Zhang et al. among Chinese farmers (8.8 %; $n = 910$) [14]. This might be due to differences in the definition of API since the Chinese study reported on API cases occurring within 24 h of exposure to pesticides, and not within 48 h as in our study. A survey of agricultural workers in Asian countries also reported lower prevalence of API than our results among small-scale farmers (0.08 % in Indonesia, 2.7 % in Sri Lanka, and 6.7 % in Malaysia; $n = 8982$) [5]. These differences might also be related to the types of pesticides used for the crop they grow in these regions. Since we did not collect specific information on pesticides, it is not possible to verify if this factor accounted for the higher prevalence of API in our study. However, a study among Tanzanian small-scale farmers reported much higher proportion of API (93 %; $n = 121$) than did farmers in our study [22]. The higher prevalence of API in the Tanzanian study might be explained by the difference in methods, as they asked for "past lifetime APP (Acute Pesticide Poisoning) experienced", while we only asked for their experiences in the past year.

Flower farm workers in the present study also had higher API prevalence (56 %) than in a study of 102 cut-flower workers (23.5 %) in the Philippines [23]. The

Table 4 List of self-reported symptoms among the population with API the last year ($N = 136$)

	List of symptoms	Responses *N* (%)
Nervous system	Headache, dizziness, excessive sweeting, salivation, confusion, weakness, anxiety and loss of consciousness	107 (79)
Cardiovascular	Bradycardia	55 (40)
Gastrointestinal	Vomiting, diarrhea, abdominal cramp	79 (58)
Respiratory system	Chest tightness, dyspnea, morning cough, day/night time cough, shortness of breath and wheezing	79 (58)
Ocular	Miosis and eye tear	73 (54)
Dermatologic	Rash on hand and skin rash	69 (51)

Philippine study reported on respondents' illness experiences due to pesticide in the last year, which might explain some of the observed difference.

Our study indicated that residence close to the flower farm as such was not associated with an increased prevalence of API. Thus, it seems unlikely that the pesticides are more accessible among the closest residents. This is in contrast with previous studies that reported increased exposure to pesticides with increased living proximity to farms [24, 25]. In the present study, the increased risk of API among residents living close to the flower farm is associated with being employed at the flower farm since the subgroup living close to the flower farm and working there had significantly more API than those living close but did not work there. This is also supported by the lack of difference in API prevalence between the residents living close to the flower farm but did not work there and those living far away after adjusting for being small-scale farmer. Most of the APIs in the present study were reported to occur after exposure to pesticides at the flower farm. Previous studies have shown that several factors can contribute to increased pesticide exposure for flower-farm workers [17, 22, 25, 26]. Such factors are for instance poor working conditions, inappropriate handling and storage of pesticides, lack of safety training as well as individual's behavioral factors.

This study demonstrated that the prevalence of API among the residents in the study area is very high. There is very limited information in Ethiopia on the magnitude of API. Our study is located in one region of Ethiopia, but there might be similar problems in other parts of the country. The high prevalence of API seems to be related to pesticide exposure at the flower farm, and decision makers should be informed about the finding and take action to examine this topic further to address this problem in Ethiopia. The handling of pesticides at the flower farms must be improved to avoid API in the future.

Strength and limitation

Strengths of the present study are that the response rate was high, and we used the WHO's standard definition of API. However, it is a weakness that there are no objective examinations done of the population, and the severity of the symptoms was not addressed. This may have caused a bias in reporting of API. The information was collected using a population-based survey through interview grouped by proximity to flower farm, in order to include both workers and other persons in the area. This made it possible to obtain information about flower farm workers without entering any workplace. Workplace studies may have the weakness of lack of confidence from the participants, and by the chosen method we presumably increased the likelihood of obtaining correct information also from the workers. There may be re-call bias during the interview, since we asked for symptoms the past year, however, we used interview instruction to minimize the re-call bias. Also, the respondents themselves described symptoms, and they might not have known the name of all symptoms they had. Therefore, the symptom description must be evaluated with caution. Another limitation was that we did not collect detailed information about how intoxication took place and the type of pesticides involved. Thus we suggest further studies to investigate the risk factors of API among the population in the study area.

The use of many interviewers might also be a problem on the consistency of how the interview was done. However, in order to minimize this problem, orientation on the interview guide and interviewing procedures was given to the interviewers by the principal investigator before the actual data collection.

Conclusion

Our study indicates a 26 % prevalence of self-reported symptoms attributable to API among the population in the study area. The residents living closer than 5 kilometers to the flower farm reported significantly higher prevalence of self-reported API than those living 5–12 kilometers away. This increased risk of API was associated with work at the flower farm.

Abbreviations

API, acute pesticide intoxication; APP, acute pesticide poisoning; CI, confidence interval; PR, prevalence ratio; SPSS, Statistical Package for the Social Sciences; WHO, World Health Organization

Acknowledgements

We are very grateful to the population in the study area for their willingness to participate and cooperation in order to conduct this study. We would like to thank Professor Bernt Lindtjørn and Eskindir Loha for sharing us the list of households and villages. We also extend our appreciation to the Norwegian Education Fund for the financial support to conduct the study.

Funding

This research is supported by the Norwegian education fund.

Availability of data and materials

The dataset supporting the conclusion of this article is available upon request.

Authors' contributions

AWN has contributed to the conception, planning and design of the study, data collection, analysis and interpretation, drafting and revising of the manuscript. BEM contributed to the planning and design of the study, analysis and interpretation of the data and critical reviewing of the manuscript. MB contributed to the planning and design of the study, analysis and interpretation of the data and critical reviewing of the manuscript. All authors read and approved the final manuscript.

Authors' information

AWN: PhD Candidate, Occupational and Environmental Medicine Research Group, University of Bergen, Norway. BEM: MD, PhD; Director of Center for International Health, University of Bergen, Norway. MB: PhD, Occupational and Environmental Health Research Group, University of Bergen, Norway.

Competing interests
The authors declare that there are no competing interests.

Ethics approval and consent to participate
The study was approved by, the Regional Committee for Medical and Health Research Ethics, Norway and Research Ethics Committee of Oromia Regional State Health Bureau, Ethiopia. All the participants were informed about the purpose of the study and written consent was obtained.

Author details
[1]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway. [2]Centre for International Health, University of Bergen, Bergen, Norway.

Received: 10 November 2015 Accepted: 8 June 2016
Published online: 15 July 2016

References
1. Atreya K. Pesticide use knowledge and practices: a gender differences in Nepal. Environ Res. 2007;104(2):305–11.
2. Cole D, Carpio F, Julian J, Leon N. Health impacts of pesticide use in Carchi farm population. 1998.
3. Litchfield M. Estimates of Acute Pesticide Poisoning in Agricultural Workers in Less Developed Countries. Toxicol Rev. 2005;24(4):271–8.
4. Corriols M, Marín J, Berroteran J, Lozano LM, Lundberg I. Incidence of Acute Pesticide Poisonings in Nicaragua: A Public Health Concern. Occup Environ Med. 2009;66(3):205–10.
5. Jeyaratnam J, Lun KC, Phoon WO. Survey of acute pesticide poisoning among agricultural workers in four Asian countries. Bull World Health Organ. 1987;65(4):521–7.
6. Soares W, Almeida RM, Moro S. Rural work and risk factors associated with pesticide use in Minas Gerais, Brazil. Cadernos de saude publica. 2003;19(4):1117–27.
7. Jørs E, Morant RC, Aguilar GC, Huici O, Lander F, Bælum J, Konradsen F. Occupational pesticide intoxications among farmers in Bolivia: a cross-sectional study. Environ Health. 2006;5:10.
8. London L, Bailie R. Challenges for improving surveillance for pesticide poisoning: policy implications for developing countries. Int J Epidemiol. 2001;30:564–70.
9. Sutton J, Kellow N. An Enterprise Map of Ethiopia, vol. 205. London: International Growth Centre; 2010.
10. Karunamoorthi K, Mohammed M, Wassie F. Knowledge and practices of farmers with reference to pesticide management: implications on human health. Arch Environ Occup Health. 2012;67(2):109–16.
11. Ward M, Lubin J, Giglierano J, Colt J, Wolter C, Bekiroglu N, Camann D, Hartge P, Nuckols J. Proximity to crops and residential exposure to agricultural pesticides in Iowa. Environ Health Perspect. 2006;114:893–7.
12. Deressa W, Loha E, Balkew M, Hailu A, Gari T, Kenea O, Overgaard HJ, Gebremichael T, Robberstad B, Lindtjørn B. Combining long-lasting insecticidal nets and indoor residual spraying for malaria prevention in Ethiopia: study protocol for a cluster randomized controlled trial. Trials. 2016;17:20.
13. Zyoud SH, Sawalha AF, Sweileh WM, Awang R, Al-Khalil SI, Al-Jabi SW, Bsharat NM. Knowledge and practices of pesticide use among farm workers in the
West Bank, Palestine: safety implications. Environ Health Prev Med. 2010;15(4):252–61.
14. Zhang X, Zhao W, Jing R, Wheeler K, Smith GA, Stallones L, Xiang H. Work-related pesticide poisoning among farmers in two villages of Southern China: a cross-sectional survey. BMC Public Health. 2011;11:429.
15. Thundiyil JG, Stober J, Besbelli N, Pronczuk J. Acute pesticide poisoning: a proposed classification tool. Bull World Health Organ. 2008;86(3):205–9.
16. Lee WJ, Cha ES, Park J, Ko Y, Kim HJ, Kim J. Incidence of acute occupational pesticide poisoning among male farmers in South Korea. Am J Ind Med. 2012;55(9):799–807.
17. Damalas CA, Eleftherohorinos IG. Pesticide exposure, safety issues, and risk assessment indicators. Int J Environ Res Public Health. 2011;8(5):1402–19.
18. Hanssen VM, Nigatu AW, Zeleke ZK, Moen BE, Bratveit M. High Prevalence of Respiratory and Dermal Symptoms Among Ethiopian Flower Farm Workers. Arch Environ Occup Health. 2015;70(4):204–13.
19. Murray D, Wesseling C, Keifer M, Corriols M, Henao S. Surveillance of pesticide-related illness in the developing world: putting the data to work. Int J Occup Environ Health. 2002;8(3):243–8.
20. Wesseling C, Corriols M, Bravo V. Acute pesticide poisoning and pesticide registration in Central America. Toxicol Appl Pharmacol. 2005;207(2):697–705.
21. Henao S, Arbelaez M. Epidemiologic situation of acute pesticide poisoning in Central America, 1992–2000. Epidemiol Bull. 2002;23(3):5–9.
22. Lekei EE, Ngowi AV, London L. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health. 2014;14:389.
23. Del Prado-Lu JL. Pesticide exposure, risk factors and health problems among cutflower farmers: a cross sectional study. J Occup Med Toxicol. 2007;2:9.
24. Simcox NJ, Fenske RA, Wolz SA, Lee IC, Kalman DA. Pesticides in household dust and soil: exposure pathways for children of agricultural families. Environ Health Perspect. 1995;103(12):1126–34.
25. Loewenherz C, Fenske RA, Simcox NJ, Bellamy G, Kalman D. Biological monitoring of organophosphorus pesticide exposure among children of agricultural workers in central Washington State. Environ Health Perspect. 1997;105(12):1344–53.
26. Gun S, Kan M. Pesticide use in Turkish greenhouses: health and environmental consciousness. Pol J Environ Stud. 2009;18(4):607–15.