THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Occupational and Environmental Pesticide Exposure and Associated Health Risks in Ethiopia

Roba Argaw Tessema

UNIVERSITY OF DEBRECEN
DOCTORAL SCHOOL OF HEALTH SCIENCE

DEBRECEN, 2023

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Occupational and Environmental Pesticide Exposure and Associated Health Risks in Ethiopia

By Roba Argaw Tessema

Supervisor: Balázs Ádám, MD, PhD

UNIVERSITY OF DEBRECEN
DOCTORAL SCHOOL OF HEALTH SCIENCE

DEBRECEN, 2023

TABLE OF CONTENTS Page

LIST OF ABBREVIATIONS

Abbreviations	Explanation
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4-DCP	2,4-dichlorophenol
AChE	Acetylcholinesterase
ADI	Acceptable Daily Intake
AOR	Confounder-Adjusted Odds Ratio
APR	Unadjusted Prevalence Ratios
BLR	Binary Logistic Regression
COR	Crude (Unadjusted) Odds Ratio
COVID-19	Coronavirus Disease-2019
CPR	Crude Prevalence Ratios
CSAE	Central Statistics Agency of Ethiopia
DDT	Dichlorodiphenyltrichloroethane
DNA	Deoxyribonucleic Acid
EU	European Union
FAO-UN	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
HCSO	Hungarian Central Statistical Office
IARC	International Agency for Research on Cancer
IHRERC	Institutional Health Research Ethics Review Committee
LBR	Log-Binomial Regression
LTEUCE	Long-Term Exposure Unspecific Chronic Effect
NHL	Non-Hodgkin lymphoma
OECD	Organization for Economic Co-operation and Development
OLR	Ordinal Logistic Regression
PAN-UK	Pesticide Action Network UK
POP	Persistent Organic Pollutant
PPE	Personal Protective Equipment
PPS	Probability Proportional to Size
ROS	Reactive Oxygen Species
SSTVHLE	Single and Short-Term Very High Level of Exposure,
UAPP=	Unintentional Acute Pesticide Poisoning
UNEPA	United Nation Environmental Protection Authority
WHO	World Health Organization

1. INTRODUCTION

1.1. Definition and concept of pesticides

Primarily, pesticides are designed to kill unwanted insects, rodents, bacteria, virus, and weeds in agriculture and in domestic settings; however, incorrect use of pesticides produce a significant risk to non-targeted organisms, including humans and the environment worldwide. Pesticides are the general name that encompasses a wide range of complex mixtures of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm or otherwise interfering with the production, processing, and storage of food and agricultural commodities (FAO, 2005). Main categories of pesticides are insecticides, herbicides, fungicides, rodenticides, nematicides, molluscicides, acaricides, plant growth regulators, and others based on the target pest organism (Shah, 2020).

Based on chemical structure, pesticides can be mainly classified as organochlorines (e.g., DDT), organophosphates (e.g., Malathion), carbamates (e.g., Carbaryl), pyrethroids (e.g., Cypermethrin), phenoxy-alkonates (e.g., 2 4-D), dipyridyls (e.g., Paraquat), phenylamines (e.g., Alachlor), triazines (e.g., Atrazine), benzoic acids (e.g., Dicamba) and phthalimides (e.g. Diflotan) (Jayaraj et al, 2016). The chemical structure of the molecules of active substances influences the persistence of pesticides in the environmental compartments, toxicity potential and accumulation in living organisms. Organochlorines are a group of chlorinated organic compounds with highly toxic, and refractory characteristics. They are members of the persistent organic pollutants (POP) group due to their high persistence in the environment and storage mainly in the adipose tissues, with a process called bioaccumulation. Organophosphates (OP) are esters of phosphoric acid. OPs are much less persistent than organochlorines but much more toxic. Carbamates insecticides are N-methyl carbamates derived from carbamic acid. Carbamates pesticides break down in the environment a within short period of time, weeks or months (Coman et al, 2013; Silberman and Taylor, 2022). Pyrethroids are natural insecticides derived from chrysanthemum flowers, with comparatively slight levels of mammalian toxicity and fast biodegradation capacity. They were developed *as* a less toxic but more expensive alternative to organophosphates (Jayaraj et al, 2016). Phenoxyalkanoic acids are mostly lipophilic herbicides, readily transported to the surface and groundwater and weakly absorbed in the soil. Phenoxyalkanoic acids are degraded by soil microbes and accelerated at a higher temperature, humidity, pH, and organic matter (Muszyński et al. 2020). Triazole fungicides are systemic pesticides regarded as moderately persistent organic pollutants in soil and water system. They have high stability and moderate lipophilicity possessing long chemical and photochemical half-life. They tend to migrate and accumulate in the environmental soil and water (Roman et al, 2021).

A pesticide formulation is chemically composed of active ingredients and adjuvants. The active ingredient is the component of a formulation responsible for the direct biological activity against pests and diseases. An adjuvant is an additive intentionally incorporated in a formulation aimed to enhance solubility, absorption, penetration, and pesticidal actions of active ingredient on the target organism. These additives are typically declared as biologically inert substances and are frequently not fully disclosed by manufacturers despite substantial evidence pointing out that this is not often the case (Mesnage and Antoniou, 2018).

Due to the widespread use, persistence, bioaccumulations and transmission in the environmental partitions numerous groups of people including operators, form-workers, bystanders, and residents have diverse patterns and level of exposure and are at risk of negative effects (Remoundou et al, 2015). Work-related exposure happens among pesticide formulators, manufacturers, vendors, transporters, loaders, mixers, applicators (operators or farmers) and cleanup workers because of their direct participation in the handling of pesticides. The general population may be exposed to pesticide drift, pesticide residues in food, soil, air, drinking water, clothing and direct contact (WHO and UNEP, 1990).

1.2. Pesticide exposure

1.2.1. Occupational pesticide exposure

Pesticides are indispensable in agricultural production and food security by increasing the yields of crops productions and decreasing damage to crops due to pests. Applicators and farmworkers are routinely exposed to high levels of pesticides, usually much greater than those of consumers, through direct exposure. Occupational pesticide exposure mainly occurs during the preparation and application of the pesticide spray solutions and during the cleaning-up of spraying equipment (Damalas and Koutroubas, 2016). The main routes of exposure are dermal contact, inhalation, and oral ingestion. Dermal exposure of intact skin is the most common route in an occupational setting and occurs because of a splash, spill, or spray drift during mixing, loading, application, disposing, and cleaning of equipment in case of faulty, inadequately worn or missing personnel protective equipment. The severity of dermal exposure depends upon the dermal toxicity of the pesticide, rate of absorption through the skin, the size of the skin area contaminated, the length of time the pesticide solution is in contact with the skin, and the amount of pesticide on the skin. Dermal absorption is also influenced by concentration and temperature (MacFarlane, 2013). Respiratory exposure or inhalation of pesticides may occur during preparation but especially application of pesticides when vapors and fine droplets of spray are present in the air (Damalas and Koutroubas, 2016). Oral exposure of pesticides occurs by eating or drinking from pesticide-contaminated bottles, eating, drinking or smoking while handling pesticides, or through contaminated application equipment or pesticide residues in food and drinks.

Organochlorine pesticides recognized as a persistent organic pollutant (POP) can enter the bloodstream after absorption through the lungs or the skin; they are fat-soluble and can accumulate within the human fat-rich tissues (adipose tissue, nervous system) and excretions (breast milk) (Jackson et al, 2017). The dermal and inhalation routes of entry are typically the most common routes of applicators' exposure to pesticides. Applicators' exposure can be prevented by reducing the use of chemical pesticides, by following all required pesticide safety precautions and guidelines, and by ensuring the appropriate use of personal protective equipment in every step of pesticide handling (mixing, loading, application, cleaning spray tanks, storage, disposal) (Atlantic Working Group, 2006). Figure 1 illustrates the major routes of occupational pesticide exposure.

1.2.2. Non-occupational pesticide exposure

Experience of pesticide exposure for residents, especially for those living in agricultural areas, can occur through multiple routes other than during direct farming activities, although studies indicated that non-occupational pesticide exposure is attributable to less mortality than occupational exposures (Shiva, 2016). The characteristics of certain pesticides, like bioaccumulation, high lipophilicity, the potential of long-range transport, and long half-life, increase their possibilities of polluting the air, water, soil, and food, even after many years of application, resulting in chronic health effects (Jayaraj et al, 2016). Dietary exposure, water contamination, indoor and outdoor personal airborne exposure at the residence, dermal exposure, and dust ingestion specifically among children are the main exposure pathways (Deziel, 2015). In addition, residents may experience pesticide exposure through bring-home agricultural drift, and by domestic pesticide use. These routes include take-home exposure from the transmission of pesticides on skin, clothes, and shoes of farmworkers to the household members at home, agricultural drift exposure from the field near home where pesticides are sprayed, and domestic use of pesticides against insects, termites, fleas, and weeds in and around the house (Deziel et al, 2019).

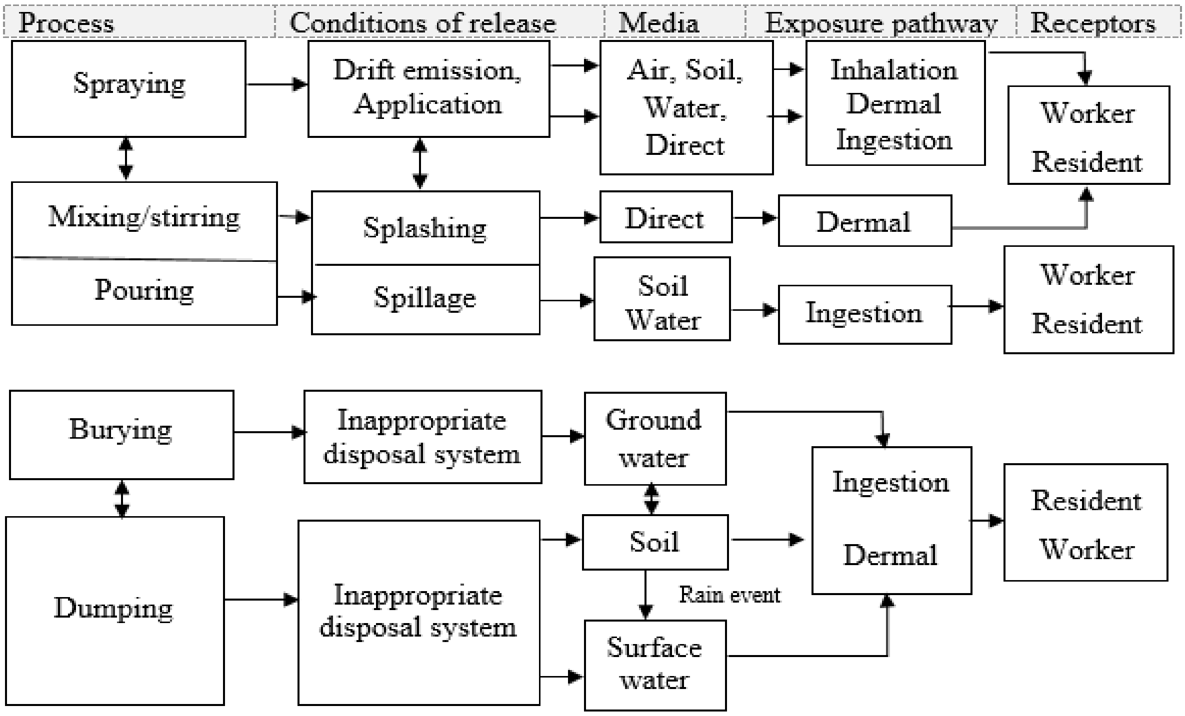

Figure 1. Conceptual model of possible pesticide exposure pathways during pesticide preparations, applications and disposal derived from the literatures (Thomas et al, 1999; Sara et al, 2006).

1.3. Mechanisms of action of pesticide toxicity

Principally pesticides are designed to kill the target organisms; however, pesticide-induced toxicity in non-target organisms may also occur. Pesticides produce various biochemical and pathophysiological alterations after entering the body; thus, having a large scale of different mode of toxicity. Pesticides can cause negative impact by affecting the nervous system, can act as endocrine disruptors by inhibiting with the manufacture, discharge, transport, or elimination of hormones (Bolognesi and Merlo, 2011), and may induce alterations in the activities of certain enzymes and enhance reactive oxygen species (ROS) levels, among others.

Major classes of insecticides include organochlorines, e.g., DDT, that alter the proper function of the central nervous system as well as endocrine disrupting chemicals by altering the molecular circuitry and function of the endocrine system. Organophosphates (e.g., Chlorpyrifos and Diazinon) assert effect through irreversible inactivation of the enzyme acetylcholinesterase, which is essential for normal nerve function in humans. Carbamates (e.g., Carbaryl) cause carbamylation of the acetylcholinesterase enzyme at neuronal synapses and neuromuscular junction. Organophosphates and carbamates possess a similar mechanism of action; however, organophosphates exert irreversible phosphorylation of acetylcholinesterase, while carbamates assert reversible inactivation of the enzyme, shorter in duration and milder in intensity (Coman et al, 2013; Silberman and Taylor, 2022). Such inactivation aggravates the accumulation of acetylthiocholine in synapses with disruption of the nerve function (Bisson and Hontela, 2002; John and Shaike, 2015; Yadav and Sehrawat, 2011; Alejo-González, 2018). Acetylcholinesterase is engaged in the deactivation of acetylcholine, hydrolysis to choline and acetate, at nerve endings and by that averting continual nerve firing. It is essential for the normal functioning of sensory and neuromuscular systems (Der et al., 2003). Deltamethrin, a pyrethroid insecticide, is known to block voltage-gated sodium channels in the plasmatic membrane of neurons (neurotoxic) and lead to paralysis of the organism (Silver et al., 2017). The herbicide 2, 4-Dichlorophenoxyacetic acid (2 4-D) and its metabolite 2, 4, Dichlorophenol (2 4-DCP) cause a reduction in the level of glutathione in erythrocytes and alter the antioxidant enzyme activities (Bukowska, 2003). Paraquat is a bipyridylium non-selective contact herbicide; intentional or unintentional ingestion of paraquat selectively accumulates in the lungs and produces oxygen-free radicals causing membrane damage and cell death (Williams et al, 2016). The central mechanism of action of triazole fungicide is the inhibition of the cytochrome P450 (CYPs) enzyme. CYPs are the human cytochrome P450 enzymes that catalyze the oxidation and metabolism of xenobiotics and endogenous compounds. They play a pivotal role in the detoxification of xenobiotics, cellular metabolism, and homeostasis (Hakkola et al, 2020; Zhao et al, 2021). Pesticides may enhance steady-state ROS levels, stimulate ROS-prompted alteration of cellular components, distress core homeostatic and regulatory processes, or reduce antioxidant defenses which jointly cause the generation of oxidative stress (Abdollahi et al., 2004; Lushchak, 2007).

Pesticides can also cause genetic and epigenetic changes by being involved in endocrine disruption and induction of inflammatory signals, which result in the production of reactive oxygen species causing oxidative stress (Cortés-Iza and Rodríguez, 2018). For instance, the herbicide glyphosate and paraquat may induce adverse effects on the development of the female reproductive tract, fertility through an endocrine-destructive mechanism (Ingaramo et al, 2020) and cause oxidative damage to pulmonary tissues (Sun and Chen, 2016), respectively. ROS disrupts the cellular functions of mitochondria and the endoplasmic reticulum. ROS reacts with genetic material and produces genotoxicity that advancing to different mutations (Franco et al., 2010). The most common type of DNA lesion includes single and double stranded-DNA breaks DNA adducts formation and oxidative DNA bases modifications (Chatterjee and Walker, 2017; Kaur, 2018).

1.4. Acute health effects of pesticides

In low- and middle-income countries like Ethiopia, acute pesticide intoxication is a substantial problem, largely because of unsafe use of pesticide and inappropriate handling practices. Occupational health and safety problems are exacerbated by illiteracy and poverty that prevails in most agricultural populations of low and middle-income countries (Chandrasekharan-Nair et al, 2009). Moreover, the use of banned pesticides, insufficient regulation, and the lack of surveillance systems were found to be the main reasons that contributed to the higher frequency of acute pesticide poisoning in these countries (Thundiyil et al, 2008). Single and short-term exposure to very high levels of pesticides through the skin or by inhalation within a relatively short period led to acute pesticide poisoning (Damalas and Koutroubas, 2016). The health risk of pesticide exposure is determined by the nature of the pesticide, route of exposure, frequency of exposure, duration, intensity of exposure, and individual susceptibility. A recent analysis of the scientific literature and WHO mortality data showed that around 385 million cases of unintentional acute pesticide poisoning (UAPP) occur globally each year, with about 11,000 fatalities (Boedeker et al, 2020). A steep increase from 25 million cases estimated in 1990 (Jeyaratnam, 1990). Based on the global agricultural community of about 860 million, 44% of agriculturalists are intoxicated by pesticides every year. The maximum estimation of UAPP cases was observed in South and South-Eastern Asia, followed by East-Africa, where Ethiopia is located (Boedeker et al, 2020). Pesticide self-poisoning is an estimated 14-20% of global suicides leading to 110,000-168,000 mortality every year (Mewa et al, 2017). The high frequency of intentional pesticide self-intoxication can partially be attributed to the ineffective pesticides management system including highly toxic ones. A comprehensive review of hospital-based surveys of poisoning admissions in sub-Saharan Africa indicates that 13% of all hospitalized poisoning cases were due to pesticide poisoning (Eddleston, 2000).

In adults and children, acute pesticide poisoning can cause a wide range of symptoms. Pesticides can cause neurotoxic effects, for example headaches, muscle twitching, confusion, dizziness, restlessness, slurred speech, unconsciousness (e.g. 2 4-D); digestive system effects, for instance burning sensation in mouth and throat, nausea, vomiting, excessive salivation, abdominal pain, diarrhea (e.g. Diazinon); respiratory system effects, such as chest pain and tightness, cough, difficulty with breathing, wheezing (e.g. Malathion); dermatological effects, including skin irritation, burning sensation, excessive sweating (e.g. Deltamethrin and Rotenone); and eye problems, including eye itching, burning sensation, watering, blurred vision (e.g. Paraquat), among others (Afshari et al, 2018; Jensen et al, 2011; García-García et al, 2016).

1.5. Chronic health effects of pesticides

Chronic exposure to pesticides can occur in occupational and non-occupational settings, as well. In addition to the repeated low to high level of workplace exposures, a high proportion of the general population can be exposed to low pesticide doses. Investigations in Ethiopia revealed that high quantity of pesticide residues is found in drinking water (Mekonen et al, 2016; Taklu et al, 2018), contaminated soil (Yohhanes et al, 2014) and food (Zelelew et al, 2018; Fesseha et al, 2020), which could pose chronic health risks to the public as well as to international consumers at large. In addition, pesticide exposure of non-targeted organisms, like soil organisms, fish, bee colonies, and wildlife are a threat to the biodiversity of ecosystems (Hussen et al, 2007; Yohannes et al, 2014; Deribe et al, 2014; Melisie et al, 2016; Mekonnen et al, 2018). Studies in Ethiopia reported that the overall prevalence of chronic diseases is 9% (8% men and 10% women), and pesticide exposure may contribute to this burden (Muluneh et al, 2012; Alemseged et al, 2012).

Evidence indicates that pesticide exposure can induce a large scale of chronic human health effects. The long-term low-dose cumulative exposure to paraquat, maneb, dieldrin, lindane, and rotenone is linked to neurodegenerative diseases such as Parkinson's disease, Alzheimer's diseases and amyotrophic lateral sclerosis (Alberto et al, 2006; Hayden et al, 2010; Baltazar et al, 2014).

Moreover, attention deficit and hyperactivity disorder (e.g., 3-phenoxy benzoic acid (3-PBA), a metabolite of pyrethroid pesticides) (Wagner-Schuman et al, 2015; Rohlman et al, 2019), autism spectrum disorder (e.g., Chlorpyrifos) (Biosca-Brull et al, 2021), and infertility and birth defects (e.g., Glyphosate) (Frazier, 2007; Milesi et al, 2021) inevitable chronic health effect of pesticide exposure.

Furthermore, asthma and bronchitis (e.g. Heptachlor) (Hoppin et al, 2007; Hernández et al, 2011), obesity (e.g. Chlorpyrifos) (Ren et al, 2020; Wang et al, 2021), diabetes (e.g. Endosulfan) (Evangelos et al, 2016; Juntarawijit and Juntarawijit, 2018), and cancers (e.g. DDT and Chlorpyrifos) (Jaga and Dharmani, 2003; Lee et al, 2004; Latifovic et al, 2020) were long-established adverse health outcomes attributed to pesticide exposure. Individuals exposed to pesticides are at a greater risk of developing various malignant diseases, including non-Hodgkin lymphoma (NHL), leukemia, brain tumors, and cancers of the breast, prostate, lung, stomach, colon, liver, and urinary bladder (Shah, 2020). WHO states that "there is no segment of the general population that is sheltered from exposure to pesticides and potentially serious health effects although a disproportionate burden is shouldered by the developing world and high-risk groups in each country" (WHO/UNEP, 1990).

As illustrated in Figure 2, a large number of people are potentially at risk from long-term low-level exposure to pesticides; however, the morbidity is small. Conversely, the number of people exposed to high levels of pesticides for a short period are small, but their morbidity and mortality are high (Jeyaratnam, 1990; Shiva, 2016). Nevertheless, people as well as the health care system may not recognize the chronic effects of pesticides due to delayed toxicity, combined exposures, insufficient knowledge, and masking by other health problems.

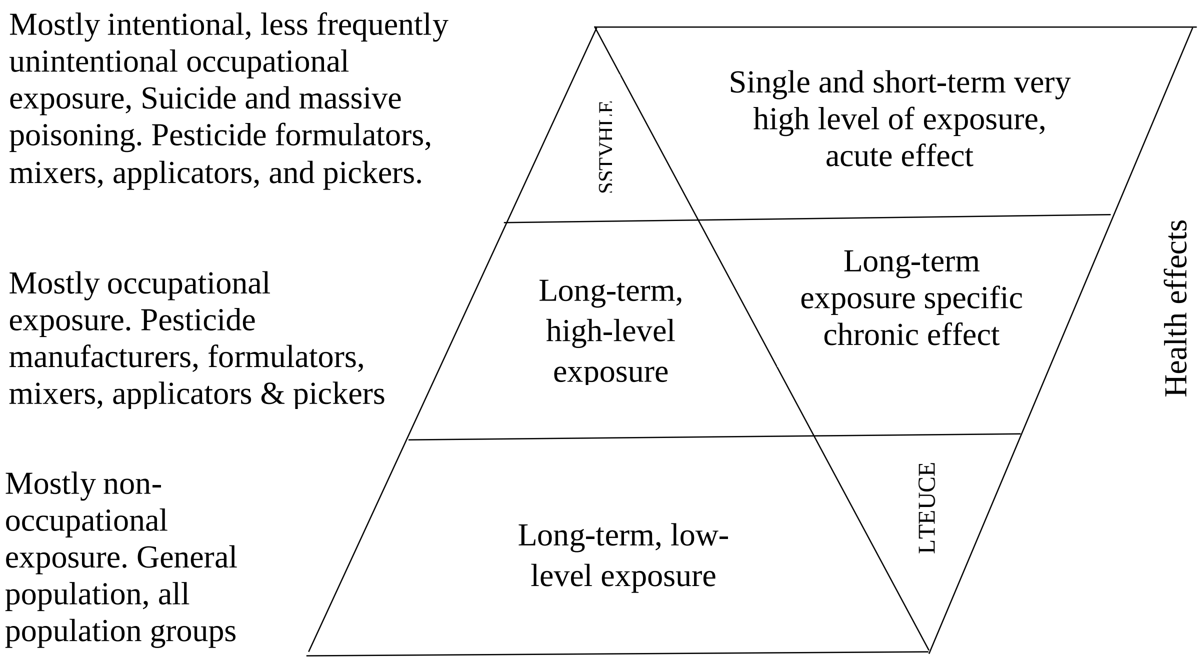

Figure 2. Hierarchy of population at risk, dose of pesticide exposure, and health effects (Jeyaratnam, 1990) SSTVHLE= Single and short-term very high level of exposure, LTEUCE= Long-term exposure unspecific chronic effect

1.6. Risk management of pesticide exposure

The health risk of pesticide exposure is a function of the toxicity of pesticide and of the potential exposure conditions. Toxicity is the inherent poisonous ability of a pesticide to produce illness or even death. Exposure is a measure of the contact and duration with a risk factor. Hence, the amount of health risk from a specific pesticide depends on the toxicity of the product used and the amount, form and time of exposure experienced. The exposure to pesticides can be minimized by less use or even elimination of chemical pesticides and by the appropriate handling practices and use of personal protective equipment in all steps of pesticide applications (Damalas and Koutroubas, 2016). Based on acute toxicity data, hazard symbols, signal words, and color on the primary display panel of a pesticide label were established to indicate the level of pesticide safety precautions required (Nesheim et al, 2014; US EPA, 2014).

1.7. Pesticide uses in Ethiopia.

In the Ethiopian economy, agriculture contributes over 85% of the employment, over 50% of the gross domestic product (GDP), and over 90% of the foreign exchange (Welteji, 2018). Chemical pesticide consumption increased nearly threefold between 2001 to 2013 (1440 to 4586 tons from 2001 to 2013, respectively) in Ethiopia because of the expansion of modern agricultural practices including commercial horticultural farms, small-scale irrigated farms, large-scale open farms, and cut-flower greenhouses (Negatu et al, 2021). The rate of pesticide use in Ethiopia is higher (0.33kg/ha) than in Bangladesh (0.03 kg/ha), same with India (0.3 kg/ha), but lower than in Sri Lanka (0.4 kg/ha) and Indonesia (0.8 kg/ha)

(Gordon et. al, 1995; Parveen and Nakagoshi, 2001). On average Africa has lower rate of pesticide use (1.23kg/ha) compared to Latin America (7.17kg/ha) and Asia (3.12kg/ha) (PAN-UK, 2006).

In Ethiopia, there is a significant concern about the adverse impact of pesticides on human health and the environment due to their wide distribution and potential short and long-term effects, since pesticide application had increased by almost 69% in the previous decade. Quantitative knowledge of applicators' and residents' health risks from occupational and non-occupational pesticide exposures is essential to protect human health and the environment, and to ensure the sustainability of chemical pest management. Evidence from a study conducted by Mormata et al. in the central part of Ethiopia revealed that extension officers have insufficient knowledge about pesticides. These may predispose the applicators to an elevated risk of adverse effects. Theoretically and practically, extension officers are anticipated to be experts in providing proper advice and educating appropriate and safe handling practices of pesticides to safeguard users' health (Mormeta, 2019). The main crucial obstacles among Ethiopian farmers to the adoption of self-protective behaviors from harmful effects of pesticides are the low level of education, inadequate knowledge about pesticide risks, misperception about pesticide exposure, improper handling, storage, and disposal practices, and lack/imperfect use of personal protective equipment (Negatu et al, 2016; Negatu et al, 2021). These may be aggravated by insufficient extension service and inadequate knowledge of extension officers about pesticides (Mormeta, 2019).

1.8. Pesticide uses in Hungary.

In Hungary, agriculture has an important historical role in the economy of the country and 60% of the total land areas are covered by arable land, where agrochemicals, including pesticides, are massively applied. Although Hungary had developed several measures to limit pesticides used in the last decade, the intensity of pesticide application, measured in quantity of the active ingredient per hectare of agricultural land, is still higher than in many other OECD member countries (OECD, 2018). In 2019, the Hungarian central statistical office data indicate that the rate of pesticide use in Hungary (1.5 kg per hectare) was higher than in the Czech Republic (1.4 kg/hectare), Slovakia (1.2 kg/hectare), and Romania (0.7 kg/per hectare), but lower than in Poland (1.7 kg/hectare) and in the Netherlands (5.1 kg/hectare) (BBJ, 2019). Hungary became a net importer of pesticides by the 21st century. The high price of mainly imported pesticides contributed to the decreasing level of their use and the high rate of illegal sources (Laczó, 2004). An investigation carried out on agricultural workers in southeastern Hungary in 1998 indicated that 22.6% of agricultural workers exposed to several complex mixtures of pesticides and experienced pesticide poisoning where 12% of farmworkers had been hospitalized (Pastor, 2002).

1.9. Pesticide-related regulations in Ethiopia and in Hungary

In Ethiopia, pesticide regulation called "Pesticide regulation and control proclamation No. 674/2010" was indorsed in 2010. The proclamation gives the mandate to the Ministry of Agriculture to control and regulate all types of pesticides. The regulation was ratified in 2010 by the government in cooperation with the Food and Agriculture Organization of the United Nations (FAO). Pesticide registration, safety measures, analysis of the product formulations and license certificates for competence were included (Federal Negarite Gazzeeta, 2010). Despite the country proclaiming the regulation and related policies, there is an immense gap between the proclamation and its implementation. The main policy actors have very little information and lack the motivation to enforce it, the laboratory facilities and infrastructure, which help to check the efficacy and safety of registered pesticides before they are permitted to enter the country and are distributed, are insufficient (Haylamicheal and Dalvie, 2009; Mengistie et al, 2015).
During the accession of Hungary into the European Union (EU) in 2004, the country complied with the regulations related to pesticide use of the EU (EU, 2009). However, an increased rate of illegal pesticide use, and a considerable proportion of inappropriate disposal were reported in 2000 (Laczó, 2004).

1.10. Rational of the study

The sustainable use of pesticides should rely on evidence-based management of occupational and non-occupational pesticide exposures aimed at extension officers and plant doctors, applicators and residents to adopt self-protective behavior and by that to reduce the health risks of pesticides. The primary role of extension workers in Ethiopia and plant doctors in Hungary (together called officers hereafter) is to ensure the safe use of pesticides and novel knowledge and upgraded technologies are continuously disseminated to the end-users. The principal duties of officers range from counseling individual farmworkers to adopt self-protective behavior to assisting farming companies in appropriate handling, sufficient and safe use of agrochemicals, including pesticides, in their control area (Rivera, 2001; Mossie and Meseret, 2015). The efficiency of extension service provision is critically dependent on the knowledge of the officers about the different agricultural regulations and innovations, which they are responsible to disseminate to the pesticide applicators. Primarily, officers are the principal source of life-saving information about the acute and chronic health effects of pesticides on humans and the environment. However, on many occasions, they may not have sufficient training and skills, and may have misperceptions about pesticides. So they have an inadequate ability to provide satisfactory services to pesticide users (Ngowi et al, 2002; Lekei et al, 2014; Saleh et al, 2016; Mormeta, 2019). There are scanty studies on extension officers, who are supposed to be both theoretically and practically experts in providing proper advice to farmers and promoting appropriate and safe handling practices of pesticides to applicators and non-applicator residents. Therefore, an investigation of the overall knowledge and perceptions of officers, their experience with the health risks of pesticides, and pesticide management systems are crucial. The officers' knowledge and attitude toward pesticides directly affect the farmer's practice in the field, therefore their insufficient knowledge may negatively affect farmers' decisions about pesticide use and may lead farmers to take more risks than required. In addition, investigation of the actual health risk of occupational pesticide exposure and related health effects among applicators and residents is crucially important. To our knowledge, there are scanty studies evaluating the health risk of occupational and non-occupational pesticide exposure and related health effects among key stockholders in Ethiopia. Therefore, we planned to investigate the overall knowledge about pesticides, perceived health risk, experienced health effects and pesticide management practices among officers in Ethiopia, in Hungary, and among pesticide applicators and residents in Ethiopia. The acquired information is vital to ensure sustainable use of pesticides and forward concrete and actionable recommendations for interventions.

2. AIM AND OBJECTIVES

The main aim of this study was to investigate the health risks of pesticide exposure and their management practices among officers, pesticide applicators and residents in a developing country. To address the aim, the following objectives were set:

- To explore the level of knowledge, health risk perceptions and experiences on the practice of pesticide use and management among extension officers in Ethiopia and plant doctors in Hungary.
- To investigate the health risks of occupational and environmental pesticide exposure, experienced health effects, risk behaviors and preventive measures among pesticide applicators and residents in Ethiopia.

3. MATERIALS AND METHODS

3.1. Study design, study area and source population

A community-based cross-sectional field survey was completed between 2019 and 2021 in Ethiopia and Hungary. In Ethiopia, out of 27 districts in the East Hararge zone (FDRE-CSA, 2013) and the Harari region (Tessema, 2017), six districts were selected, namely Kombolcha, Karsa, Haramaya, Babile, Diretiyara, and Sofi districts. The last two districts are contained in the Harari region. A total of 754 extension workers in the six selected districts served as the source population. The survey was conducted between 17 July and 24 August 2019 in Ethiopia (Figure 3). Thirteen counties, namely Baranya, Borsod-Abaúj-Zemplén, Fejér, Győr-Moson-Sopron, Hajdú-Bihar, Heves, Nógrád, Pest, Somogy, Szabolcs-Szatmár-Bereg, Vas, Veszprém, Zala, and the capital Budapest (HCSO, 2020) were included in the Hungarian survey. In Hungary, a total of 2,462 plant doctors were identified in the 14 included study areas used as geographically representative source populations. An interactive online survey platform was used to collect data between 16 September and 10 December 2020. This survey generated information that helped us to make an international comparison between the officers of the two countries who are mainly responsible for equipping adequate knowledge and skill to pesticides users. Based on the recommendations of our first study, especially for Ethiopia, a further community-based investigative study was conducted about pesticide exposure through directly assessing the actual occupational and non-occupational health risks of pesticide applicators and residents in Ethiopia from 26 April to 31 August 2021. For this study, three districts, namely Haramaya, Karsa, and Kombolcha, were determined where the agricultural activities were intensively practiced with an immense application of pesticides (Figure 3). Ten selected kebeles of the three districts comprised a total of 15,908 households that served as the reference population for the study areas. People who applied pesticides on their farm in the selected household were regarded as pesticide applicators. They could be farmworkers who participated in handling, mixing, loading, spraying and disposing obsolete pesticides, as well as repairing and cleaning application machinery, including spray tanks. People in the selected households who did not participate in the application of pesticides and were not a farmer by occupation; however, lived, worked, attended a school, or any other institution neighboring to a farm-field that has been treated with pesticides were taken as residents. From the same house, only an applicator or a resident was involved in the study.

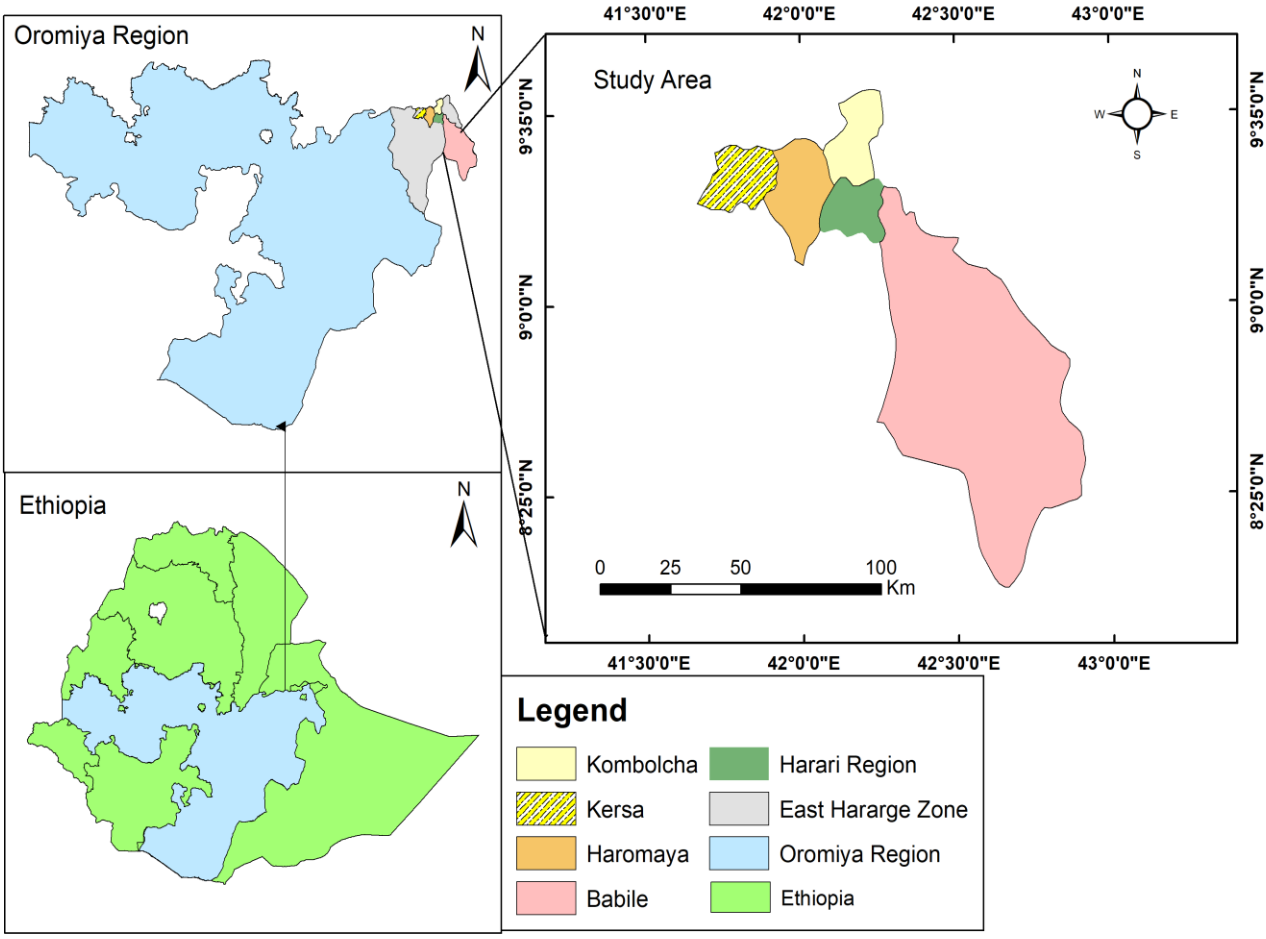

Figure 3. Map of the study area, Kombolcha, Kersa, Haramaya, Babile districts, and Harari region East Hararge zone, Oromiya region, Ethiopia

3.2. Sample size determinations and sampling

A single population proportion formula was used to determine the minimum sample size required for this study (Daniel, 2013):

$$n=\frac{[NZ^2(1-p)]}{[d^2(N-1)+Z^2p(1-p)]};$$

by considering N is the source population in the survey areas; n is the minimum required sample size; z is the standard normal variate value equivalent to 95% confidence level ($Z_{1-\alpha/2}=1.96$); p is the expected proportion of outcome of interest in population based on previous studies; and the design precision (d^2) is 5%.

3.3. Pesticide management survey

In a previous study conducted in Ethiopia, the proportion of extension officers (PE) who perceived good pesticide-related knowledge was 33% (Mormeta, 2019); this provided a sample size of 234 study subjects. In Hungary, the proportion of officers who have a good pesticide-related competency was accepted as

93%, taken from a previously conducted similar study in Georgia, USA (Cole, 2010); this provided a sample size of 96 study subjects. Out of 27 districts in the East Hararge zone and Harari region in Ethiopia, six districts were prioritized where extensive agricultural activities were performed, and immense amounts of pesticides applied. After the total number of extension officers in six designated districts was identified, the probability proportional to size sampling technique was used to calculate the exact sample size for each district. Finally, to select the study population, the systematic random sampling technique was applied.

As a result of the COVID-19 pandemic, we had to use an interactive online survey platform in Hungary. Each plant doctor in the selected counties was reached by email, inviting them to participate in the study (Figure 4, Survey 1).

3.4. Pesticide exposure survey

Sample size was separately calculated for pesticide applicators and residents for the pesticide exposure survey. In a previous study conducted in Ethiopia, the proportion of pesticide applicators (p_a) who encountered acute pesticide poisoning because of pesticide exposure in their farmland was 0.56 (Nigatu et al, 2016). The proportion of residents (p_r) who encountered health effects by living in the proximity (<5km) of pesticide treated farmland was determined as 0.23 from the same study (Nigatu et al, 2016). These gave the sample size of 740 for applicators and 268 for residents, with a design effect of 2 and 1, respectively. Hence, the smallest sample size to achieve statistical importance was 1008 participants. To achieve the sample size required by the multistage sampling design, a design effect of 2 was applied, which was used to determine the districts, kebeles, households, pesticide applicators and non-applicator residents. The sample selection procedure encompassed four stages. In the first stage, out of 18 districts in the East Hararge zone, Oromiya region Ethiopia, considering extensive agricultural practice and intensive application of pesticides, three districts were chosen for this study. In the second stage, the total number of kebeles in the three selected districts was identified. Then, the probability proportional to size (PPS) sampling technique was applied to determine the required number of kebeles in each district. In the third stage, the total number of households in the selected kebeles was determined. Then, the number of households was selected using the PPS technique from each randomly selected kebele. Finally, systematic random sampling was used, every 14th household was interviewed from the involved kebeles in the study sites. The lottery technique was applied to choose the starter household to administer the questionnaire. One eligible applicator aged greater than 18 years who could communicate appropriately was interviewed. In case there was no applicator in the selected household, a randomly eligible inhabitant was interviewed as a non-applicator resident. When there were two applicators in one household, the one that was latest involved in pesticide application was interviewed. Only one applicator or resident was interviewed in each selected household. The procedure was resumed when the calculated minimum sample size was achieved. The detailed illustration of the sampling procedure is depicted on Figure 4, Survey 2.

3.5. Data collection procedure

3.5.1. Officers survey on pesticide management

In Ethiopia, two data collectors, who had previous experience with field studies, were recruited and trained on how to conduct the interviews. Data collectors administered questionnaires-based, face-to-face interviews to obtain data associated with pesticide use and management in Ethiopia. On a daily basis, the principal investigator made field supervision and required rectifications were provided during the process. In Hungary, the face-to-face field study could not be applied because of the onset of the COVID-19 pandemic. Therefore, a web-based survey was employed using the Google platform. Every officer was invited to participate in the study through an email that contained the survey link. The online survey was presumed appropriate for officers in Hungary because of their skills in web technologies and access to the Internet. With the help of the Hajdú-Bihar County Office of the Hungarian Plant Protection Engineers and Plant Doctors' Chamber, every officer was contacted via the corresponding county offices of their professional organization. Since all the officers are members of the chamber, the invitation letter was forwarded to every officer. The objective of the survey was explained at the beginning of both questionnaires, and the detailed contact address of the investigator was disclosed in case of any queries from the study participants.

3.5.2. Applicators and residents survey on pesticide exposure

For the pesticide exposure survey three people, who had previous experience in data collection, were recruited. Training was provided on the content of the data collection tool and how to administer the questionnaire. Data collection was conducted using questionnaire-based face-to-face interviews. On a daily basis, the principal investigator accomplished field supervision during the process and required amendments as deemed necessary. Data collection for both pesticide applicators and residents was conducted simultaneously. After the purpose of the study was explained, each participant signed a written consent form, then the required information was collected from them.

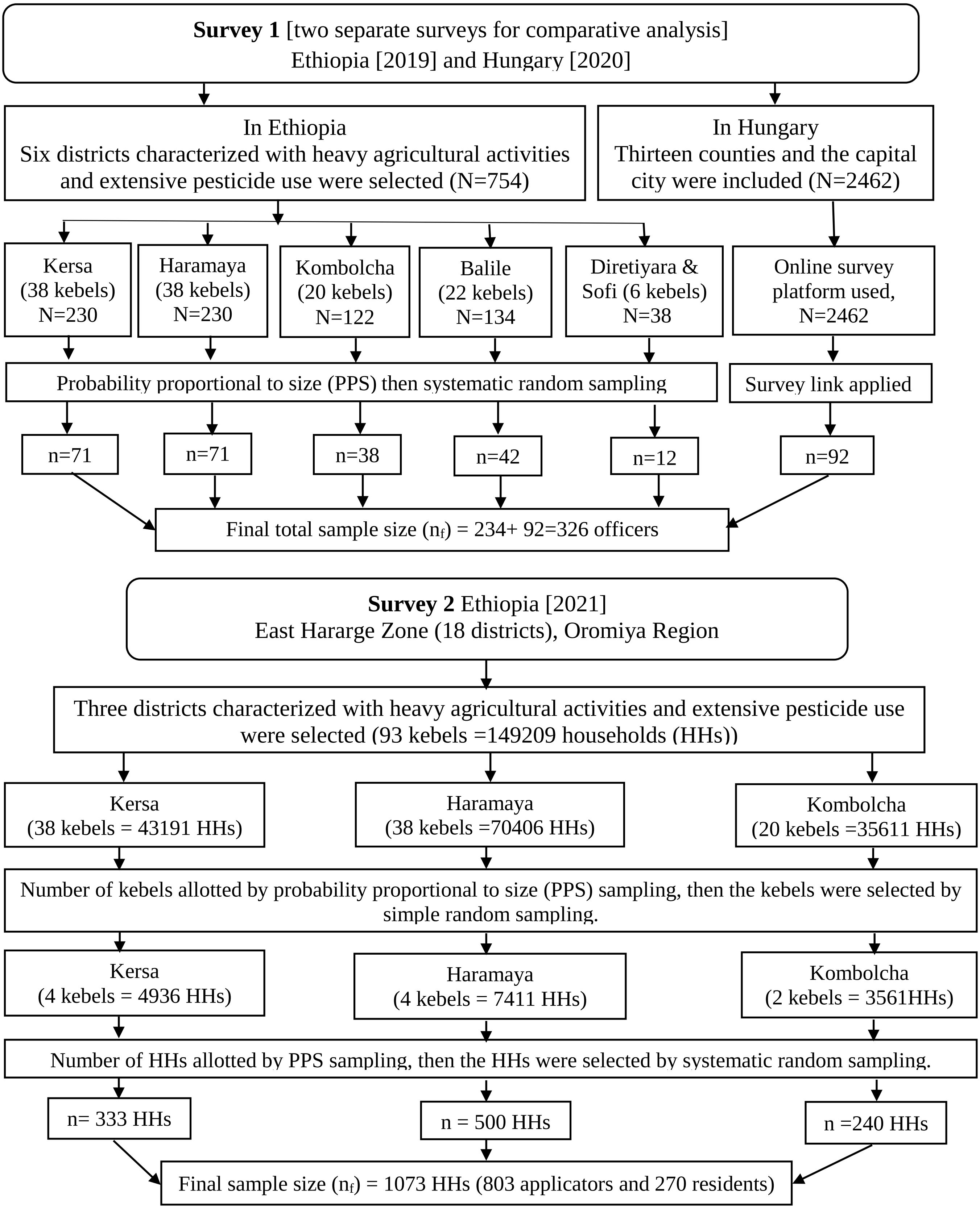

Figure 4. Flowchart showing sampling procedures and stratification among officers (Survey 1) and applicators & residents (Survey 2) in Ethiopia and Hungary.

3.6. Data collection instrument

3.6.1. Officers survey on pesticide managment

The field survey questionnaire was designed in English and translated into the local languages, Hungarian and Oromo. The questionnaire was then translated back to English to compare with the original version and secure its consistency. A structured and pre-tested questionnaire was used that encompassed sixteen closed-ended questions, some of them with open-ended sections. The questionnaire collected data in three main parts: socio-demographics, knowledge and attitude associated with pesticide use and management, and experienced practice related to pesticides (Appendix 1). To calculate officers' knowledge about pesticide products and routes of pesticide exposure, the investigation aimed to assess whether officers could specify utilized pesticide products by their name and mention the routes of exposure. The knowledge questions and scores comprised the following: (1) do you know pesticides by name? (scored 1 for yes; 0 for no response), (2) mention as many pesticide products as you can (score 1 for less than three; 2 for three and above responses), (3) do you know the routes of pesticide exposure? (scored 1 for yes; 0 for no response), and (4) list all the routes of entry (scored 1 for less than three; 2 for three correct responses). The overall knowledge score was computed by the combination of the responses the officers could deliver to those questions. The mean value was calculated for both the knowledge related to pesticide products and knowledge related to routes of pesticide exposure. This value was used to separate good knowledge (scored higher than 1.5) from poor knowledge (scored less than or equal to 1.5) category. To measure the specific dimensions of attitude and experienced practice related to pesticide use, management, and preventive measures, questions constructed with multiple choice responses and five-item psychometric Likert scales were applied. The five-item Likert scale questions ranged from the lowest-ordered extreme (1) to the highest-ordered extreme (5). The scales of the inquiries anchored from strongly disagree to strongly agree; very cheap to extremely expensive; ineffective to very effective; never/not at all to always (Table 1).

Table 1. Overview of the questions included in the questionnaire used in pesticide use survey among officers in Ethiopia and Hungary.

Domains	Descriptions	Measured with
Socio-demographic questions	Sex; age; occupational status, educational status, and nationality	Multiple choice questions
Knowledge and attitude	Knowledge regarding pesticide products; knowledge about routes of pesticide exposure; attitude related to pesticide toxicity; perceived cost of pesticides; attitude concerning environmental pesticide pollution; and perceived health risks of pesticides	Binary, Likert scale, and open-ended questions
Experienced practices related questions	Kind of pesticides utilized; ways of pesticide product importation; pesticide administration; pesticide disposal method; training regarding health risks of pesticides; personal protective equipment utilization; and experience of pesticide intoxication	Multiple choice questions, binary, Likert scale and open-ended questions

3.6.2. Applicators and residents survey on pesticide exposure

The field survey questionnaire was prepared from tools applied earlier in studies published in the literature (Muñoz-Quezada et al, 2018; Gesesew et al, 2016; Lekei et al, 2014), with minor adjustments to meet the present study aims. Originally, the questionnaire was designed in English and translated into Afan Oromo. To ensure its consistency, it was translated back to English and compared to the original version. The structured and pre-tested questionnaire contained 66 closed and open-ended questions. The questionnaire gathered data on seven domains: (1) socio-demographic and lifestyle factors; (2) knowledge related to pesticide products, routes of pesticide exposure and health effects; (3) attitude about pesticide usage and health risks of pesticide exposure; (4) general health problems that may be related to pesticide exposure; (5) experienced health effects and symptoms potentially associated to pesticide exposure; (6) pesticide usage at work, exposure history and experienced risky practice; and (7) any preventive measures applied (Appendix 2). The first five domains of the questionnaire were completed by applicators and residents. The last two parts were only completed by applicators. To estimate applicators and residents' knowledge about pesticide products, modes of pesticide exposure, pesticide-related environmental problems and health effects, the study sought to evaluate how applicators and residents were able to answer the following questions: (1) do you know pesticide products used by their name? (scored 0 for no response; 1 for yes), and (2) list at least one pesticide product (score 0 for no response; 1 for ≥1 responses); (3) do you know routes of pesticide exposure into human body? (scored 0 for no response; 1 for yes), and (4) list at least one route of pesticide exposure (score 0 for no response; 1 for ≥1 responses); (5) do you know environmental problems related to pesticide use? (scored 0 for no response; 1 for yes), and (6) list at least one pesticide-related environmental problem (score 0 for no response; 1 for ≥1 responses); (7) do you know health effects pesticide exposure can induce? (scored 0 for no response; 1 for yes), and (8) list at least one health effect pesticide can induce (score 0 for no response; 1 for $\geq$1 response). The overall knowledge score was computed by the combination of the answers the applicators and residents could provide to these questions. The mean value was applied as the cut-off value to differentiate poor knowledge (scored less than or equal to 0.6) from good knowledge (scored higher than 0.6) groups.

For collecting data about the types of applied pesticides, the applicators were asked by the interviewers about the type of pesticides they use and about the pesticide products they know by name, of which they listed as many as they could. The residents were also asked to list as many pesticide products by name as they could. Additionally, all participants were asked about any harmful chemicals they could be exposed to at work or at home, and to specify these harmful chemicals (including pesticides, organic solvent, and others).

Regarding medical conditions and experienced symptoms, both applicators and non-applicator residents were asked whether they have ever had any of the following medical conditions: cardiovascular disease (e.g., high blood pressure, heart attack, stroke, etc.), kidney disease, liver disease, cancer, and other chronic conditions. When they responded yes, they were asked to specify the year of diagnosis. In addition, the participants, both applicators and non-applicator residents, were requested to specify how often they have experienced the following symptoms in recent months: skin irritation, skin rushes, eye irritation, blurred vision, chest pain, shortness of breath, cough, abdominal pain, nausea and vomiting, diarrhea, poor appetite, fatigue, difficulty to concentrate, forgetfulness, dizziness, headache, muscle cramps, and numbness in the arms or legs. For this, they used a five-item psychometric Likert scale anchored from never to always happen (i.e., always, often, sometimes, seldom, and never) (Table 2).

Table 2. Overview of the questions included in the questionnaire used in the pesticide exposure survey among applicators and residents in Ethiopia.

Domains	**Descriptions**	**Measured with**
Socio-demographic and lifestyle factors	Sex, age, marital status, family size, education status, income level, smoking status, alcohol drinking status, khat consumption status	Multiple-choice and open-ended questions
Knowledge about pesticide products, mode of exposure and health risks	Knowledge about pesticide products, knowledge about mode of pesticide exposure, knowledge of pesticide-related environmental problems, knowledge of health problems pesticide exposure can induce,	Binary followed by open-ended questions
Attitude about pesticide use and health risks of pesticide exposure	Perception about pesticide management system efficiency, health risks related to pesticide use, pesticide-related environmental pollution, utilization of personal protective equipment, training about health effects of pesticides to reduce health risks; attitude about past pesticides application practices, pesticide toxicity, and appropriateness of the present application practices	Five-items psychometric Likert scale ranged from the lowest ordered extreme (1: strongly disagree) to the highest ordered extreme (5: strongly agree)
General health problems may be related to pesticide exposure	A prescription drug utilized in the past year, experienced health effects probably associated with pesticide exposure, encountered health effects from pesticide exposure among family members, asthma, diabetes, high blood pressure (hypertension), kidney and liver disease, cancer	Dichotomy response and open-ended questions
Experienced symptoms potentially related to pesticide exposure	Skin irritation, skin rashes, eye irritation, blurred vision, cough, chest pain, shortness of breath, abdominal pain, nausea and vomiting, diarrhea, poor appetite, fatigue, difficulty to concentrate, forgetfulness, dizziness, headache, muscle cramps, numbness in the arms or legs	Five-items psychometric Likert scale ranged from the lowest ordered extreme (1: never experienced) to the highest ordered extreme (5: always experienced):
Occupational pesticide use, exposure history and experienced practice	Type of pesticides used, toxicity of pesticide products presently used, years of pesticide application, time of single application (minute), number of pesticides spraying in a month, trend of pesticide use, method of mixing pesticides, washing the sprayer tank after spraying, pesticide splash during mixing, application, and tank wash, regular maintenance of the sprayer tank, place of pesticides storage	Multiple-choice questions
Applied preventive measures	Training about pesticide use, reading and following label instructions, using face mask, using respirator, using gloves, using rubber boots (safety shoes), using coveralls, reasons for not using or rarely using preventive measures, changing clothes after application, taking shower after application	Multiple-choice questions, binary, Likert scale and open-ended questions

3.7. Statistical analysis

Comparison of the overall knowledge, attitude, and experienced practice of pesticide usage and the level of effectiveness of the pesticide management system was made between Ethiopia and Hungary by conducting survey among officers accountable for the safe management of agrochemicals. In addition, the level of knowledge, attitude, and practice related to pesticide use and exposure, health effects, and preventive measures applied among pesticide applicators compared to non-applicator residents in Ethiopia was performed.

The analysis of data was performed using the SPSS version 25 statistical package. Mean, standard deviation, proportion, and frequency were determined in descriptive statistics. The overall mean score of knowledge of and attitude related to pesticides was calculated. Chi-square test was applied to compare the relationship between socio-demographic and lifestyle factors, knowledge of and attitude related to pesticides, pesticide use and exposure, health effects and experienced symptoms, and preventive measures applied among applicators and residents. Using generalized leaner models, binary logistic regression (BLR), ordinal logistic regression (OLR), and log-binomial regression (LBR) were computed, and possible adjustments were made to control for potential confounding factors and confirm the independent predictors of the outcome variables accordingly. Unadjusted (crude) odds ratio (COR)/prevalence ratios (CPR) and confounder-adjusted odds ratio (AOR)/prevalence ratios (APR) were computed to examine the strength of association between outcome and explanatory variables. The BLR and OLR models were used because some outcome variables had two and more than two ordered categories, respectively. In cross-sectional studies, the log-binomial regression model generates the unbiased prevalence ratio (PR) estimate when the outcome variable of interest is common. PR avoids the overestimation produced by odds ratios (Behrens et al, 2004; Spiegelman and Hertzmark, 2005).

The predictive variables of knowledge and attitude were identified by controlling for gender, age, marital status, family size, income, and educational status using multivariate analysis (Survey 1 & 2). For outcome variables such as medical conditions, experienced symptoms and health effects, further adjustment was applied for past and present smoking status, frequency of alcohol drinking, and khat consumption (Survey 2). The significance of statistical associations was secured using odds and prevalence ratios with 95% confidence intervals (CI) and p-values. Statistical significance was accepted at 5% level.

3.8. Ethical clearance

Both studies were performed based on the declaration of Helsinki guidelines. The studies were approved by the College of Health and Medical Science (CHMS) Institutional Health Research Ethics Review Committee (IHRERC) of the Haramaya University, Ethiopia (Ref. No. CHMS/10.0/2458/11, 2019 and Ref No. IHRERC/237/2020, 2020). In Ethiopia, an official letter of assistance was written to the local district administration. Data were collected from each study interviewee after obtaining the informed consent voluntarily in writing. In Hungary, a formal request letter including the survey link to the online questionnaire was distributed to each officer via the county offices of the Hungarian Plant Protection Engineers and Plant Doctors' Chamber with the assistance of the Hajdú-Bihar County Office. No reference was made to a survey link or questionnaire that could identify participants in the research. The participants' names and identification numbers were not documented in the questionnaire. Information was recorded anonymously, and confidentiality was assured throughout the study.

4. RESULTS

4.1. Pesticide management reported by officers in Ethiopia and Hungary

4.1.1. Socio-demographic characteristics of officers in Hungary and Ethiopia

In this interview survey, a total of 326 people (234 from Ethiopia and 92 from Hungary) have participated. Seventy-eight percent of the respondents were male and forty-three percent of them were within the age range of 30 to 39 years old with a mean age of 38.4 (±9.5 SD) years (Table 3). A substantial percentage of the Hungarian participants were found age between 50 to 59 years compared to Ethiopian (30% vs. 8%). Related to education, 87% of the Hungarian and 66% of the Ethiopian participants held a university degree (BSc and above) (Table 3).

Table 3. Socio-demographic characteristics of officers in Ethiopia and Hungary

Characteristics (n=326)	Options	Overall %	Officers		**p value*
			Hungary [n=92]	Ethiopia [n=234]	
Sex	Male	78	72%	81%	0.038
	Female	22	29%	19%	
Age (years)	20–29	16	12%	17%	<0.001
	30–39	43	30%	48%	
	40–49	27	28%	27%	
	50–59	14	30%	8%	
Educational level	College diploma	28	13%	34%	<0.001
	University BSc	52	32%	60%	
	University MSc and above	20	55%	6%	

*Note: *p value <0.05 taken as statistically significant*

4.1.2. Types of pesticides applied as reported by officers in Hungary and Ethiopia

The most frequently stated types of pesticides utilized in the study areas were insecticides, herbicides, and fungicides (Table 4). Malathion (85%), 2, 4-D (78%), and Diazinon (59%) were the most frequently reported pesticides by Ethiopian officers, while the Hungarian officers frequently most frequently mentioned Glyphosate (97%), Deltamethrin (74%) and Pendimethalin (66%). Based on the WHO classification, 70% of pesticides reported from Ethiopia and 60% from Hungary were moderately hazardous (WHO class II). According to the International Agency for Research on Cancer (IARC) classification, 20% and 40% of pesticide reported from Hungary and 40% and 20% of pesticide reported from Ethiopia were probably (2A) and possibly (2B) carcinogenic to human, respectively (Table 4).

Table 4. Types of pesticides reported by extension officers; applicators and residents in the study areas, in Ethiopia and Hungary (survey 1 and 2 combined)

Pesticide type per chemical group	Active ingredient	WHO Toxicity Class	IARC (EPA) classification	ADI[a] (Mg kg^{-1} BW Day^{-1})	Officers		Applicators (*n =803)	Residents (*n =270)
					Hungary (*n =92)	Ethiopia (*n =234)		
Herbicide								
Glycine derivative	Glyphosate	III	2A	0.1	96.7%	48.7%	39.5%	15.2%
Phenoxy-carboxylic acid	2-4 D	II	2B	0.05	20.7%	77.8%	24.9%	13.3%
Triazine	Atrazine	III	G3	0.02	-	-	0.5%	1.1%
Chloroacetamide	Alachlor	III	GIII(EPA)	0.01	-	-	0.2%	1.1%
Dinitroaniline	Pendimethalin	III	2B	0.125	66.3%	-	-	-
Insecticide								
Organophosphate	Malathion	III	2A	0.03	-	85.0%	35.1%	19.3%
Organophosphate	Diazinon	II	2A	0.0002	7.6%	59.0%	31.5%	15.9%
Organophosphate	Dimethoate	II	G3	0.001	26.1%	28.6%	29.5%	0.4%
Pyrethroids	Deltamethrin	II	G3	0.01	73.9%	29.5%	16.8%	15.9%
Organochlorine	Endosulfan	II	G3	0.006	4.3%	26.1%	10.7%	16.3%
Organochlorine	DDT	II	2A	0.01	-	5.6%	10.3%	4.1%
Carbamate	Carbaryl	II	G3	0.0075	-	19.7%	8.2%	0.4%
Pyrethroids	Cypermethrin	II	2B	0.05	-	-	0.9%	1.1%
Organophosphate	Fenitrothion	II	G3	0.005	-	-	0.6%	1.1%
Fungicide								
Dithiocarbamate	Mancozeb	IV	G3	0.05	-	-	2.5%	0.4%
Chloronitrile	Chlorothalonil	III	2B	0.015	30.4%	14.1%	1.7%	1.1%
Triazole	Epoxiconazole	II	G3	0.008	57.6%	-	0.5%	1.1%
Carbamic acid	Thiram	III	G3	0.01	-	-	0.4%	0.7%
Triazole	Tetraconazole	IV	2B	0.004	47.8%	-	-	-

NB: WHO classification of pesticide by hazardousness (LD_{50}): Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = Slightly hazardous; IV = Unlikely to present acute hazard in normal use; Based on International Agency for Research on Cancer (IARC) classification: Group 1 = carcinogenic to human; 2A = probably carcinogenic to human; 2B = possibly carcinogenic to human; G3 = not classifiable as to its carcinogenicity to human; GIII = likely to be a human carcinogen at high doses (based on USEPA classification); *Multiple choices were possible. [a]According to Pesticide Properties Database (PPDB); ADI=acceptable daily intake.

4.1.3. Knowledge of and attitude to pesticide products among officers in Hungary and in Ethiopia

This study revealed that the Hungarian officers had better knowledge related to pesticide products (92%) and mode of pesticide exposure (92%) than Ethiopian officers (66% and 58%, respectively). whereas the Hungarian officers were less likely to agree that pesticides are toxic (51%), induce environmental pollution (61%) and perceived less health risk for applicators (49%) than the Ethiopian counterparts (74%, 82%, and 77%, respectively). A substantial proportion of the officers from both countries reported that the price of pesticide is extremely high (Table 5).

Table 5. Knowledge of and attitude to pesticides among officers in Hungary and Ethiopia

Characteristics (n=326)	**Categories**	**Overall %**	**Hungary (*n* = 92)**	**Ethiopia (*n* = 234)**	***p value**
Knowledge about pesticide products	Good	73	92%	66%	<0.001
	Poor	27	8%	32%	
Knowledge related to mode of pesticide exposure	Good	68	92%	58%	<0.001
	Poor	32	8%	42%	
Attitude toward pesticide toxicity	Disagree	10	12%	9%	<0.001
	Undecided	23	37%	18%	
	Agree	43	27%	49%	
	Strongly agree	24	24%	24%	
Opinion about the cost of pesticide products	Moderately expensive	10	14%	9%	0.309
	Very expensive	37	37%	38%	
	Extremely expensive	53	49%	54%	
Attitude toward environmental pesticide pollution (water, food, air, and soil)	Disagree	17	26%	13%	0.001
	Undecided	8	13%	6%	
	Agree	33	27%	36%	
	Strongly agree	42	34%	46%	
Perceived health risk of pesticide use	Disagree	20	32%	15%	<0.001
	Undecided	11	20%	8%	
	Agree	45	27%	53%	
	Strongly agree	24	22%	24%	

*Note: *p value <0.05 taken as stastically significant*

4.1.4. Practice of pesticide use, preventive measures and pesticide disposal reported by officers in Hungary and in Ethiopia

Fourteen percent of Ethiopia and 57% of Hungarian officers presumed that the pesticide management system was effective in their control area; nevertheless, 46% of Ethiopia and 83% of Hungarian colleagues declared illegal import of pesticides from adjacent countries. A substantial proportion (81%) of Ethiopian extension officers presumed that farmworkers were rarely trained regarding the health risks of pesticides, rarely utilized personal protective equipment (76%), and more often experienced pesticide intoxication in their service area (41%) than the Hungarian participants (14%, 16%, and 7%, respectively) (Table 6).

Table 6. Experienced practice of pesticide uses and preventive measures among officers in Hungary and Ethiopia

Characteristics (n=326)	**Categories**	**Overall %**	**Hungary (*n* = 92)**	**Ethiopia (*n* = 234)**	***p value***
Effectiveness of the pesticide management system	Ineffective	44	12%	56%	<0.001
	Somewhat effective	21	14%	24%	
	Moderately effective	9	17%	6%	
	Effective	26	57%	14%	
Illegal import of pesticides	Yes	56	83%	46%	<0.001
	No	44	17%	54%	
Training of farmers about the health risk of pesticides	Rarely	62	14%	81%	<0.001
	Sometime	20	39%	12%	
	Fully trained	18	47%	7%	
Use of personal protective equipment (PPE) by farmers	Rarely	59	16%	76%	<0.001
	Sometimes	19	43%	9%	
	Very often	22	41%	15%	
Experience of pesticide poisoning among farmers	No	68	93%	59%	<0.001
	Yes	32	7%	41%	

*Note: *p value <0.05 taken as stastically significant*

4.1.5. Source of information, risk behaviors and pesticide disposal reported by officers in Hungary and in Ethiopia

Concerning the management of leftover pesticides, eighty percent of the Hungarian participants agreed that farmers returned the pesticide residues to a waste management site. Conversely, forty-four percent of the Ethiopian participants revealed that farmers stored pesticide residues in dwellings for next usage. A substantial proportion of the participants testified that farmworkers disposed of leftover pesticide residues improperly in both study areas, though the condition was more deficient in Ethiopia (Table 7).

Table 7. Pesticide residues disposal as reported by officers of the two study areas

Type of pesticide disposal system used	**Hungary (*n=92)**	**Ethiopia (*n=234)**
Return to waste management site	80%	0%
Incinerate	26%	0%
Offer to other farmers	24%	33%
Dump on open field	7%	25%
Flush into sewer	4%	0%
Bury in the ground	3%	22%
Store at home for next use	1%	44%

*Multiple choices were possible

4.1.6. Predictors of knowledge of and attitude to pesticides, practice of pesticide use and preventive measures reported by officers in Hungary and Ethiopia

Sex, age, education, and nationality of participants were tested as potential factors (explanatory variables) determining knowledge, attitude, and practice about pesticides (outcome variables). Officers' nationality was discovered as the most powerful factor significantly associated with all aspects of knowledge, attitude, and practice except the perceived cost of pesticides (Tables 8 & 9). The knowledge related to the mode of pesticide exposure was statistically significantly positively associated with the participants' level of education (β=0.49, SE=0.22, p<0.026), revealing that more educated officers are more likely to have good knowledge regarding the modes of pesticide exposure. Female officer's, attitude related to pesticide toxicity (β=1.29, SE=0.29, p<0.001) and their perception on the effectiveness of the pesticide management system (β=0.83, SE=0.27, p<0.002) were significantly positively associated; however, their perception related to the cost of pesticide products (β=−0.58, SE=0.27, p<0.033) were significantly negatively associated compared to the reference (male), showing that female officers were more likely to perceive that pesticides are toxic and the pesticide management system is effective but less likely to presume that the pesticide products overpriced. There was no statistically significant relationship found between age and any aspects of knowledge, attitude, and practice related to pesticides.

Table 8. Factors determining knowledge of and attitude to pesticides reported by officers in Hungary and Ethiopia

Explanatory Variables		**Outcome Variables**					
		Knowledge about pesticides products	**Knowledge about routes of pesticide exposure**	**Attitude towards pesticide toxicity**	**Opinion about the cost of pesticide products**	**Attitude towards environmental pesticide pollution**	**Perceived health risk of pesticide use**
Country (1 = Hungary, 2= Ethiopia)	β	−1.78	−1.75	0.60	0.15	0.75	0.77
	SE	0.46	0.45	0.27	0.29	0.28	0.28
	p value	0.000***	0.000***	0.028*	0.614	0.007**	0.006**
Sex (1 = Male, 2 = Female)	β	0.214	0.10	1.29	−0.58	0.07	0.08
	SE	0.35	0.34	0.29	0.27	0.27	0.27
	p value	0.543	0.773	0.000***	0.033*	0.800	0.761
Age (1=18–29, 2 = 30–39, 3 = 40–49, 4 = 50–60)	β	−0.031	0.21	0.01	0.15	0.03	0.12
	SE	0.16	0.16	0.14	0.13	0.12	0.12
	p value	0.850	0.195	0.912	0.249	0.803	0.353
Education (1=diploma, 2 = BSc, 3 = MSc+	β	0.085	0.49	−0.25	−0.22	−0.01	−0.19
	SE	0.22	0.22	0.17	0.18	0.17	0.17
	p value	0.703	0.026*	0.143	0.216	0.941	0.257

NB: β = Regression coefficient, Beta; SE = Standard Error, the first category was used as reference for all explanatory variables. * *P < 0.05, ** P < 0.01, *** P < 0.001*

Table 9. Factors determining practice of using pesticides reported by officers in Hungary and Ethiopia

Explanatory Variables		**Outcome Variables**				
		Effectiveness of pesticide management system	**Illegal import of pesticides**	**Training of farmers about the health risk of pesticides**	**Use of PPE by farmers**	**Experience of pesticide poisoning among farmers**
Country (1 = Hungary, 2 = Ethiopia)	β	−2.33	−1.44	−3.03	−2.19	2.04
	SE	0.30	0.34	0.34	0.30	0.47
	p value	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Sex (1 = Male, 2 = Female)	β	0.83	0.14	0.58	0.19	−0.55
	SE	0.27	0.31	0.30	0.29	0.36
	p value	0.002**	0.656	0.055	0.500	0.120
Age (1 = 18–29, 2 = 30–39, 3 = 40–49, 4 = 50–60)	β	−0.10	0.02	−0.27	0.06	0.01
	SE	0.13	0.15	0.15	0.14	0.16
	p value	0.444	0.885	0.071	0.642	0.936
Education (1 = diploma, 2 = BSc, 3 = MSc+)	β	−0.13	0.39	−0.01	−0.17	−0.42
	SE	0.18	0.20	0.20	0.19	0.22
	p value	0.474	0.053	0.967	0.371	0.057

NB: β = Regression coefficient, Beta; SE = Standard Error, the first category was used as reference for all explanatory variables. ** $P < 0.01$, *** $P < 0.001$

Nationality remained a significant independent predictor of all the ten aspects of knowledge, attitude, and practice about pesticides after controlling for sex, age, and education status of the respondents, revealing that the explanatory power of nationality is very strong. The current study indicated that the Hungarian officers were less likely to presume that pesticides are poisonous (AOR=0.55 (0.32–0.94), $p<0.05$), pesticides induce environmental pollution (AOR=0.47 (0.27–0.82), $p<0.01$), and perceived that pesticide-use induces less health risk among farmworkers (AOR=0.46 (0.27–0.80), $p<0.01$). Conversely, Hungarian participants were over five times more likely to have good knowledge related to pesticide products (AOR=5.93 (2.42–14.55), $p<0.001$) and modes of pesticide exposure (AOR=5.78 (2.41–13.85), $p<0.001$) compared to their Ethiopians counterparts. Contrarily, the opinions of the officers in the two study areas were not significantly different regarding the cost of pesticide products (Table 10). Concerning practice, Hungarian officers were over ten times more likely to presume the pesticide managing system effective (AOR=10.23 (5.68–18.46), $p<0.001$), whereas over four times more likely to report illegal importation of pesticide products from bordering countries compared to their Ethiopian counterparts (AOR=4.23 (2.16–8.31), $p<0.001$). Hungarian officers were over twenty times more likely to perceive that farmworkers are adequately trained concerning the health risks of pesticides (AOR=20.74 (10.61–40.57), $p<0.001$), and nine times more likely to declare that they often utilize personal protective equipment (AOR=8.95(4.94–16.28), $p<0.001$). Hungarian officers were 87% less likely to experience pesticide-related poisoning in the past in their service area than Ethiopian colleagues (AOR=0.13 (0.05–0.33), $p<0.001$) (Table 11).

Table 10. Effect of nationality on the knowledge of and attitude to pesticides in Hungary and Ethiopia

Country	Outcome variables (Hungary *n* = 92; Ethiopia n=234)				Odds ratio (95%CI)	
					Crude odds ratio (COR)	Adjusted odds ratio (AOR) †
	Knowledge about pesticide products					
	Poor		Good			
Hungary	8%		92%		6.31 (2.79–14.28) ***	5.93 (2.42–14.55) ***
Ethiopia	34%		66%		1.00	1.00
	Knowledge about routes of pesticide exposure					
	Poor		Good			
Hungary	8%		92%		8.75 (3.88–19.73) ***	5.78 (2.41–13.85) ***
Ethiopia	42%		58%		1.00	1.00
	Attitude toward pesticide toxicity					
	Disagree	Undecided	Agree	Strongly agree		
Hungary	12%	37%	27%	24%	0.56 (0.36–0.88) *	0.55 (0.32–0.94) *
Ethiopia	8%	18%	49%	25%	1.00	1.00
	Opinion about the cost of pesticides products					
	Moderately expensive	Very expensive	Extremely expensive			
Hungary	14%	37%	49%		0.77 (0.48–1.22)	0.86 (0.49–1.53)
Ethiopia	8%	38%	54%		1.00	1.00
	Attitude towards environmental pesticide pollution					
	Disagree	Undecided	Agree	Strongly agree		
Hungary	26%	13%	27%	34%	0.48 (0.31–0.76) ***	0.47 (0.27–0.82) **
Ethiopia	13%	5%	36%	46%	1.00	1.00
	Perceived health risk of pesticide use					
	Disagree	Undecided	Agree	Strongly agree		
Hungary	32%	20%	27%	22%	0.44 (0.28–0.69) ***	0.46 (0.27–0.80) **
Ethiopia	15%	8%	53%	24%	1.00	1.00

NB: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$; † adjusted for sex, age and education; % indicate the percentage of the respondents to each category of the outcome variables.

Table 11. Differences in practice of using pesticides in Hungary and Ethiopia

Country	Outcome Variables (Hungary *n* = 92; Ethiopia n=234)				Odds Ratio (95%CI) Crude Odds Ratio (COR])	Adjusted Odds Ratio (AOR) †
	Effectiveness of the pesticide management system					
	Ineffective	Somewhat effective	Moderately effective	Effective		
Hungary	12%	14%	17%	57%	9.15 (5.57–15.04) ***	10.23 (5.68–18.46) ***
Ethiopia	56%	24%	6%	14%	1.00	1.00
	Illegal import of pesticides					
	No		Yes			
Hungary	17%		83%		5.54 (3.05–10.07) ***	4.23 (2.16–8.31) ***
Ethiopia	54%		46%		1.00	1.00
	Training of farmers about the health risk of pesticide					
	Rarely	Sometimes	Fully trained			
Hungary	14%	39%	47%		17.86 (10.32–30.91) ***	20.74 (10.61–40.57) ***
Ethiopia	81%	12%	7%		1.00	1.00
	Use of personal protective equipment by farmers					
	Rarely	Sometimes	Very often			
Hungary	16%	43%	41%		8.27 (5.08–13.48) ***	8.95 (4.94–16.28) ***
Ethiopia	76%	9%	15%		1.00	1.00
	Experience of pesticide poisoning among farmers					
	No		Yes			
Hungary	93%		7%		0.10 (0.04–0.24) ***	0.13 (0.05–0.33)] ***
Ethiopia	59%		41%		1.00	1.00

NB: *** $P < 0.001$; †adjusted for sex, age and education; % indicate the percentage of the respondents to each category of the outcome variables.

4.2. Pesticide exposure among applicators and residents in Ethiopia

4.2.1. Socio-demographic characteristics and lifestyle of applicators and residents in Ethiopia

A total of 1073 participants of which 803 applicators and 270 residents were interviewed in this study, and all the contacted eligible individuals agreed to participate and responded, which provides a 100% participation and response rate. Ninety-three percent of the applicators and eighty-three percent of the residents were male respondents. Thirty percent and 34% of the participants were between 40-49 years of age, with the mean age of 42 (±10.12 SD) and 41 (±10.18 SD) years for applicators and residents, respectively. Ninety-one percent and 85% of the applicators and residents were married, respectively, and 46% of the applicators and 37% of the residents attended tertiary education. Forty three percent of applicators and 44% of residents, 11% of applicators and 24% of residents, and 87% of applicators and 92% of residents were active cigarette smokers, consumed alcohol 2-4 times a month and chewed khat daily, respectively (Table 12).

Table 12. Socio-demographic characteristics and lifestyle of pesticide applicators and residents in East Hararge zone, Oromiya region, Ethiopia

Characteristics (n=1073)	**Categories**	**Overall %**	**Applicators (*n* = 803)**	**Residents (*n* = 270)**	***p value***
Sex	Male	90.0	92.5%	82.6%	<0.001
	Female	10.0	7.5%	17.4%	
Age (years)	20–29	13.0	12.1%	15.9%	0.111
	30–39	29.7	30.4%	27.8%	
	40–49	31.4	30.4%	34.4%	
	50–59	25.8	27.1%	21.9%	
Marital status	Married	89.4	90.8%	85.2%	0.010
	Single	10.6	9.2%	14.8%	
Family size	Less than or equal to 3	11.6	13.6%	5.9%	0.001
	Greater than 3	88.4	86.4%	94.1%	
Under-five child	None	87.8	87.7%	88.1%	0.808
	1-2 children	10.3	10.2%	10.4%	
	≥3 children	2.0	2.1%	1.5%	
Monthly income (average =9000ETB)	Below average	10.9	9.7%	14.4%	0.031
	Above average	89.1	90.3%	85.6%	
Educational level	Primary (grade 1-8)	19.4	17.1%	26.3%	0.002
	Secondary (grade 9-12)	36.9	37.1%	36.3%	
	Tertiary (≥ 12 grade)	43.7	45.8%	37.4%	
Current smoking status	Daily	43.2	42.8%	44.1%	0.014
	Less than daily	35.4	37.5%	29.3%	
	Not at all	21.4	19.7%	26.7%	
Past smoking status	Daily	49.8	53.7%	38.1%	<0.001
	Less than daily	38.7	39.7%	35.6%	
	Not at all	11.6	6.6%	26.3%	
Frequency of alcohol consumption	2-4 times a month	14.1	10.7%	24.1%	<0.001
	Monthly or less	17.1	16.1%	20.0%	
	Don't drink	68.9	73.2%	55.9%	
Alcohol consumption on a typical day when drinking	5-6 drinks	7.7	6.6%	11.1%	<0.001
	3-4 drinks	11.7	9.0%	20.0%	
	1-2 drinks	11.6	11.2%	13.0%	
Consume six or more alcohol drink on one occasion	Monthly	10.7	6.5%	23.3%	<0.001
	Less than monthly	10.1	6.8%	19.6%	
	Not at all	79.2	86.7%	57.0%	
Khat (Catha Edulis) consumption	Daily	88.1	86.9%	91.5%	0.046
	Less than daily	11.9	13.1%	8.5%	

*Note: ETB = Ethiopian birr; *p value <0.05 taken as statistically significant, n_t= total number of respondents; n_a=number of applicators responded, n_r=number of residents responded*

4.2.2. Types of pesticides reported by applicators and residents in Ethiopia

Insecticides (53%), herbicides (23.5%), and fungicides (23.5%) were the most frequently mentioned types of pesticides exposing applicators and residents in the study area. Based on the WHO classification of pesticides by hazardousness (LD_{50}), 59%, 35%, and 6% of declared pesticides were moderately hazardous (WHO class II), slightly hazardous (WHO class III), and unlikely to present acute hazard in normal use (WHO class IV), respectively. Glyphosate (40%), Malathion (35%), and Mancozeb (2.5%) were the most frequently reported active ingredients exposing applicators. Twenty-five percent of reported pesticide products were probably carcinogenic to humans (2A), 19% are possibly carcinogenic (2B), and 56% of them weren't classified as to their carcinogenicity to humans (3), based on the IARC classification (Table 4). The pesticides with the lowest acceptable daily intake (ADI) value have the highest toxic effects.

In addition to pesticides, benzene (31.8% and 48.4%), kerosene (40.9% and 22.6%), diesel fuel (18.2% and 16.1%), and gasoline (9.1% and 12.9%) were organic chemicals that exposed the study participants (n=53) (applicators (n=22) and residents (n=31), respectively) during use of cleaning agents, domestic heaters or furnaces, transportations, and engine fuel in vehicles at work or at home settings.

4.2.3. Hazardous pesticide handling and disposalpractices among applicators in Ethiopia

None of the applicators had application licenses to spray pesticide in this study, and every applicator used manual backpack sprayers. Sixty-nine percent and 80% of the participants declared that leftover pesticide residues were sold or offered to other fellow farmers or the empty pesticide containers disposed on an open field, respectively. A significant percentage of the participants practiced risky behaviors during application, either khat chewing, cigarette smoking, drinking water or eating food in the course of pesticides administration (Table 13).

Table 13. Hazardous practices of applicators during spraying and disposal of pesticides in East Hararge zone, Oromiya region, Ethiopia

Characteristics	**Options**	**Applicators (*n=803)**
Pesticide residue disposal system	Sell or offer to other farmworkers	69.0%
	Buy only the quantity applied	43.3%
	Disposed of on an open field	31.9%
	Burry	31.8%
Disposal of empty pesticide containers	Disposed of on an open field	80.2%
	Used for storing of other pesticides	59.3%
	Burry	44.2%
	Burn	35.2%
Practices made during spraying pesticides	Chew Khat	55.7%
	Smoke cigarette	45.0%
	Drink water, eat food	35.0%
	Do nothing	34.9%

*Multiple choices were possible

4.2.4. Predictors of knowledge of and attitude to pesticides, practice of pesticide use and preventive measures among applicators and residents in Ethiopia

The present study showed that applicators had better knowledge related to pesticide products (75% had good overall knowledge, of whom 93.5% mentioned at least one pesticide product) and modes of pesticide exposure (79%) than residents (23% and 30%, respectively). A considerably higher proportion of applicators were knowledgeable about the health effects caused by pesticide exposure (79%) than residents (34%). In multivariate analysis, knowledge about pesticide products (APR=1.43(1.26-1.62), $p<0.001$), modes of pesticide exposure (APR=1.37(1.22-1.55), $p<0.001$), pesticide-related environmental problems (APR=1.33(1.19-1.51), $p<0.001$), health effects caused by pesticide exposure (APR=1.33(1.18-1.50), $p<0.001$) and overall knowledge about pesticides (APR=1.54(1.36-1.75), $p<0.001$) was significantly higher among applicators (Table 14). Perceived health risk of pesticides (APR=1.08(1.01-1.16), p<0.05), positive attitude towards making use of personal protective equipment in decreasing the health risk of pesticide exposure (APR=1.08(1.01-1.16), $p<0.05$); however, also being comfortable with the present pesticide application practice and perceiving no personal risk of pesticide poisoning (APR=1.11(1.01-1.22), $p<0.05$) were significantly more frequently declared by applicators (Table 15).

Table 14. Knowledge of pesticides among pesticide applicators and residents in East Hararge zone, Oromiya region, Ethiopia

Respondents' knowledge of pesticides	Applicators (N=803)	Residents[R] (N=270)	Unadjusted PR (95%Cl)	Adjusted PR† (95%Cl)
	Good% (95%Cl)	Good% (95%Cl)		
Knowledge of pesticide products	75.0(71.8-77.9)	22.6(17.7-28.1)	1.43(1.27-1.61) ***	1.43(1.26-1.62) ***
Knowledge of routes of pesticide exposure	79.0(76.0-81.7)	30.4(24.9-36.2)	1.37(1.22-1.54) ***	1.37(1.22-1.55) ***
Knowledge of environmental problems related to pesticide use	78.1(75.1-80.9)	34.1(28.4-40.1)	1.33(1.18-1.49) ***	1.33(1.19-1.51) ***
Knowledge of health effects pesticide exposure can induce	78.8(75.8-81.6)	34.1(28.4-40.1)	1.33(1.19-1.50) ***	1.33(1.18-1.50) ***
Overall knowledge level about pesticide hazards	75.1(72.0-78.1)	13.7(9.8-18.4)	1.54(1.36-1.74) ***	1.54(1.36-1.75) ***

Note: †adjusted for sex, age, marital status, family size, income level, and education level; [R]Reference category; ***$P < 0.001$; PR = Prevalence Ratio; "Good" knowledge proportion of applicators and residents

Table 15. Attitude to pesticides among pesticide applicators and residents in East Hararge zone, Oromiya region, Ethiopia

Respondents' attitude to pesticide exposure	Mean[1](95%Cl)		Unadjusted PR (95%Cl)	Adjusted PR† (95%Cl)
	Applicators (n=803)	Residents[R] (n=270)		
Effectiveness of the pesticide management system	2.7(2.58-2.73)	2.7(2.55-2.79)	0.99(0.91-1.08)	0.99(0.91-1.09)
Perceived health risk of pesticide use	4.2(4.14-4.28)	3.9(3.79-4.01)	1.08(1.01-1.16) *	1.08(1.01-1.16) *
Pesticide residues are likely to be present in the food we eat, air we breathe, water we drink and soil in the environment	4.5(4.47-4.58)	4.5(4.38-4.57)	1.01(0.95-1.08)	1.01(0.95-1.08)
Use of PPEs, such as gloves, foot, and eye protection, respirators and full body suits, reduces health risk of pesticide exposure	4.1(4.04-4.17)	3.8(3.67-3.89)	1.09(1.01-1.17) *	1.08(1.01-1.16) *
Attitude about the training of health effects of pesticides in reducing the health risk	4.5(4.46-4.55)	4.5(4.40-4.56)	1.01(0.94-1.07)	1.01(0.94-1.08)
Spraying pesticides is an ancestral practice passed down through generations and does not bring any health problems	1.4(1.38-1.48)	1.4(1.35-1.53)	0.99(0.88-1.11)	0.99(0.88-1.12)
Exposure to pesticides can induce life-threatening conditions	4.1(4.07-4.14)	4.0(3.99-4.02)	1.03(0.96-1.10)	1.02(0.95-1.10)
Satisfied with the current pesticide spraying practice and has no risk of pesticide poisoning	2.3(2.22-2.38)	2.1(1.93-2.20)	1.11(1.01-1.23) *	1.11(1.01-1.22) *

Note: [1]Mean score of the attitude to pesticide exposure on a 5-item Likert scale (from 1 = strongly disagree to 5 = strongly agree); †adjusted for sex, age, marital status, family size, income level, and education level; [R]Reference category; *P < 0.05; PR= Prevalence Ratio

Inhalation and dermal exposure were the most likely mentioned modes of pesticide exposure by applicators (70% vs 61%) and residents (28% vs 30%), respectively; and applicators' knowledge related to all modes was also significantly higher (inhalation: ARP=1.33 (1.10-1.51), *p <0.001*; oral ingestion: ARP=1.29 (1.141.46), *p<0.001*; and dermal contact: ARP=1.24 (1.10-1.40), *p<0.001*). The most frequently mentioned pesticide-related environmental health problem stated by applicators and residents was water pollution. The applicators had considerably better knowledge about all pertinent environmental health problems. Asthma and cancer were the most frequently mentioned health effects related to pesticides by applicators and residents, respectively. Applicators were more knowledgeable regarding four health effects, including the most important ones (asthma, cancer, diarrhea, and allergy) (Table 16).

Table 16. Knowledge of routes of exposure, problems that pesticides pose on the environment, and health effects of pesticide exposure among pesticide applicators and residents in East Hararge zone, Oromiya region, Ethiopia.

Characteristics		Applicators (n=803)	Residents[R] (n=270)	Unadjusted PR (95%Cl)	Adjusted PR† (95%Cl)
		Yes% (95%Cl)	Yes% (95%Cl)		
The routes through which pesticides can enter the human body	Inhalation	70.0 (66.7-73.1)	27.8 (22.5-33.5)	1.33 (1.11-1.60) **	1.33 (1.10-1.51) ***
	Oral ingestion	64.9 (61.5-68.2)	27.4 (22.2-33.1)	1.29 (1.08-1.55) **	1.29 (1.14-1.46) ***
	Dermal contact	61.3 (57.8-64.7)	30.0 (24.6-35.8)	1.24 (1.04-1.49) *	1.24 (1.10-1.40) ***
The major problems of the environment associated with pesticide use	Water pollution	78.7 (75.7-81.5)	31.1 (25.6-37.0)	1.36 (1.140-1.63) ***	1.37 (1.22-1.55) ***
	Soil contamination	77.5 (74.4-80.3)	29.6 (24.2-35.5)	1.37 (1.14-1.64) ***	1.38 (1.22-1.56) ***
	Food contamination	72.7 (69.5-75.8)	24.8 (19.8-30.4)	1.38 (1.15-1.66) ***	1.39 (1.23-1.57) ***
	Air pollution	73.1 (69.9-76.1)	23.7 (18.8-29.2)	1.40 (1.17-1.68) ***	1.41 (1.24-1.59) ***
	Harm to non-target animals	43.3 (39.9-46.8)	18.1 (13.7-23.3)	1.21 (1.01-1.46) *	1.22 (1.07-1.38) **
Health effects pesticide exposure can induce	Asthma	55.3 (51.8-58.8)	17.8 (13.4-22.9)	1.32 (1.10-1.59) **	1.31 (1.15-1.49) ***
	Cancer	52.6 (49.0-56.1)	18.1 (13.7-23.3)	1.29 (1.14-1.46) **	1.29 (1.14-1.47) ***
	Diarrhea	38.4 (35.0-41.8)	15.6 (11.4-20.4)	1.20 (1.06-1.36) **	1.18 (1.04-1.35) **
	Allergy	34.6 (31.3-38.0)	14.8 (10.8-19.6)	1.17 (1.03-1.33) **	1.18 (1.03-1.34) **
	Headache	26.5 (23.5-29.7)	13.0 (9.2-17.6)	1.14 (1.00-1.29) *	1.12 (0.98-1.28)
	Diabetes	14.1 (11.7-16.7)	13.0 (9.2-17.6)	1.01 (0.89-1.15)	1.02 (0.89-1.16)
	Nerve Disorders	6.8 (5.2-8.8)	0.7 (0.1-2.7)	1.06 (0.93-1.22)	1.06 (0.92-1.22)
	Stomach Pain	6.7 (5.1-8.7)	3.0 (1.3-5.8)	1.04 (0.91-1.19)	1.03 (0.90-1.19)
	Liver Dysfunction	5.7 (4.2-7.6)	0.7 (0.1-2.7)	1.05 (0.92-1.20)	1.05 (0.91-1.21)
	Infertility	5.4 (3.9-7.1)	4.4(2.3-7.6)	1.01 (0.88-1.15)	1.01 (0.88-1.16)
	Stroke	5.2 (3.8-7.0)	2.2 (0.8-4.8)	1.03 (0. 90-1.18)	1.03 (0.89-1.19)
	Kidney Disease	3.2 (2.1-4.7)	1.5 (0.4-3.7)	1.02 (0.89-1.17)	1.02 (0.88-1.17)
	Depression	3.0 (1.9-4.4)	1.1 (0.2-3.2)	1.02 (0.89-1.17)	1.02 (0.89-1.18)
	Blindness	2.4 (1.4-3.7)	1.5 (0.4-3.7)	1.01 (0.88-1.16)	1.01 (0.88-1.16)
	Heart Attack	1.6 (0.9-2.8)	1.9 (0.6-4.3)	1.00 (0.87-1.14)	1.00 (0.87-1.15)
	Chronic Bronchitis	1.5 (0.8-2.6)	0.7 (0.1-2.7)	1.01 (0.88-1.16)	1.01 (0.87-1.16)
	Birth Defects	1.4 (0.7-2.4)	3.0 (1.3-5.8)	0.99 (0.86-1.13)	0.98 (0.86-1.13)
	High blood pressure	0.2 (0.0-0.09)	1.9 (0.6-4.3)	0.98 (0.86-1.13)	0.98 (0.85-1.13)

Note: *Multiple choices were possible and the percentages (%) indicate proportions of spontaneous quotations by the subjects; †adjusted for sex, age, marital status, family size, income level, and education level; [R]Reference category; *P < 0.05, **P < 0.01; ***P < 0.001; PR = Prevalence Ratio; "yes" proportion of applicator and residents

4.2.5. Predictors of medical conditions and experienced symptoms among applicators and residents in Ethiopia

The diagnosed medical conditions among applicators and residents included asthma (12.3%, 11.5%), diabetes (4.6%, 10.4%) and high blood pressure (10.3, 15.2%), respectively. Prescribed drug use in the previous year was significantly more frequent among applicators (APR=1.14 (1.00-1.30), $p<0.05$). The applicators experienced statistically significantly more health effects presumably associated with pesticide exposure than residents (15%) (APR=1.15(1.01-1.32), $p<0.05$). Moreover, the applicators also more frequently declared family members affected by pesticide exposure than residents (31% vs 26%, respectively), even though the association was statistically not significant (Table 17). The symptoms significantly more likely declared by applicators than their counterpart, included skin irritation (APR=1.11(1.01-1.23), $p<0.05$), shortness of breath (APR=1.09(1.00-1.19), $p<0.05$), cough (APR=1.09(1.01-1.19), $p<0.05$), and dizziness (APR=1.09(1.003-1.19), $p<0.05$). Conversely, the symptoms like chest pain (APR=0.91(0.84-0.99), $p<0.05$), nausea and vomiting (APR=0.90(0.83-0.98), $p<0.05$), and muscle cramps (APR=0.90(0.83-0.96), $p<0.05$) were more frequently notified by residents (Table 18).

Table 17. Existing medical conditions and experienced health effects presumably caused by pesticide exposure among applicators and residents in East Hararge zone, Oromiya region, Ethiopia.

Medical conditions	**Applicators (N=803)**	**Residents[R] (N=270)**	**Unadjusted PR (95%Cl)**	**Adjusted PR† (95%Cl)**
	Yes% (95%Cl)	**Yes% (95%Cl)**		
Asthma	12.3(10.1-14.8)	11.5(7.9-15.9)	1.01(0.88-1.15)	1.00(0.87-1.15)
Diabetes	4.6(3.3-6.3)	10.4(7.0-14.6)	0.95(0.83-1.08)	0.96(0.83-1.11)
High blood pressure	10.3(8.3-12.7)	15.2(11.1-20.0)	0.96(0.84-1.09)	0.96(0.84-1.11)
Kidney and liver disease	0.0	0.0	NA	NA
Cancer	0.0	0.0	NA	NA
A prescription drug used in the past 12 months	51.1(47.5-54.6)	31.9(26.3-37.8)	1.15(1.02-1.29) *	1.14(1.00-1.30) *
Experienced health effects presumably related to pesticide exposure	36.0(32.7-39.4)	15.9(11.8-20.8)	1.17(1.04-1.33) *	1.15(1.01-1.32) *
Experienced health effects presumably related to pesticide exposure among family members	31.1(27.9-34.5)	25.9(20.8-31.6)	1.04(0.92-1.18)	1.028(0.90-1.17)

Note: †adjusted for sex, age, marital status, family size, income level, education level, past and present smoking status, frequency of alcohol consumption, and Khat consumption; [R]Reference category; *$P < 0.05$; PR = Prevalence Ratio; “Yes” proportion of the applicators and residents; NA = Not applicable

Table 18. Experienced symptoms among applicators and residents in East Hararge zone, Oromiya region, Ethiopia

Experienced symptoms	**Mean[1] (95%Cl)**		**Unadjusted PR (95%Cl)**	**Adjusted PR† (95%Cl)**
	Applicators (n=803)	**Residents[R] (n=270)**		
Skin irritation	2.5 (2.41-2.53)	2.2 (2.12-2.31)	1.12 (1.02-1.22) **	1.11 (1.01-1.23) *
Skin rashes	3.0 (2.92-3.02)	2.9 (2.81-3.01)	1.02 (0.94-1.11)	1.04 (0.95-1.14)
Eye irritation	2.6 (2.53-2.65)	2.6 (2.44-2.66)	1.02 (0.93-1.11)	1.01 (0.92-1.11)
Blurred vision	3.0 (2.94-3.05)	3.1 (2.98-3.17)	0.98 (0.90-1.06)	0.98 (0.90-1.07)
Chest pain	3.1 (3.07-3.19)	3.4 (3.30-3.50)	0.92 (0.85-0.99) *	0.91 (0.84-0.99) *
Shortness of breath	3.2 (3.09-3.22)	3.0 (2.84-3.07)	1.07 (0.99-1.16)	1.09 (1.00-1.19) *
Cough	3.3 (3.24-3.36)	3.1 (2.95-3.15)	1.08 (1.00-1.17) *	1.09 (1.01-1.19) *
Abdominal pain	3.1 (2.99-3.14)	3.0 (2.86-3.10)	1.03 (0.95-1.12)	1.04 (0.96-1.14)
Nausea and vomiting	3.1 (3.07-3.20)	3.6 (3.44-3.68)	0.88 (0.82-0.95)	0.90 (0.83-0.98) *
Diarrhea	3.1 (3.02-3.17)	3.2 (3.08-3.33)	0.97 (0.89-1.04)	0.96 (0.89-1.05)
Poor appetite	2.4 (2.29- 2.45)	2.3 (2.18-2.44)	1.03 (0.94-1.13)	1.03 (0.93-1.13)
Fatigue	1.8 (1.75-1.89)	1.8 (1.67-1.92)	1.01 (0.91-1.12)	1.01 (0.91-1.13)
Difficulty to concentrate	3.0 (2.92-3.03)	2.9 (2.74-2.96)	1.04 (0.96-1.13)	1.04 (0.95-1.13)
Forgetfulness	2.9 (2.85-2.99)	2.9 (2.80-3.05)	1.00 (0.92-1.08)	1.01 (0.92-1.10)
Dizziness	3.2 (3.10-3.25)	2.9 (2.81-3.05)	1.08 (1.00-1.17) *	1.09 (1.00-1.19) *
Headache	3.1 (3.04-3.18)	3.0 (2.90-3.09)	1.04 (0.96-1.12)	1.05 (0.97-1.15)
Muscle cramps	3.5 (3.43-3.57)	3.9 (3.73-3.96)	0.91 (0.85-0.98) **	0.90 (0.83-0.97) *
Numbness in the arms or legs	3.3 (3.27-3.41)	3.5 (3.37-3.60)	0.96 (0.89-1.03)	0.96 (0.88-1.04)

Note: [1]Mean score of the frequency of experienced symptoms measured by 5-item Likert scale (from 1= always to 5= never); †adjusted for sex, age, marital status, family size, income level, education level, past and present smoking status, frequency of alcohol consumption, and Khat consumptions; [R]Reference category; $*P < 0.05$, $**P < 0.01$; PR = Prevalence Ratio

In multivariate analysis, perceived toxicity of presently used pesticide products (APR=1.40(1.23-1.60), $p<0.001$), mixing pesticides with a stick without wearing gloves (APR=1.13(1.00-1.27), $p<0.05$), washing spray tank after work (APR=1.29(1.13-1.46), $p<0.001$), event of an incidental splash (APR=1.14(1.01-1.29), $p<0.05$), and regular maintenance of sprayer tank (APR=1.30(1.14-1.48), $p<0.001$) were significantly associated with health effects among applicators (Table 19). Health effects were 17% more frequently experienced among those who experienced exposure to harmful chemicals, including pesticides at work or at home (CPR=1.17(1.02-1.33), $p<0.05$) in the total study population; however, the association disappeared after controlling for potential confounders. On the other hand, we analyzed the lifestyle variables, including smoking cigarettes, khat consumption and alcohol drinking, to see the extent of their association with experienced health effects among applicators and non-applicator residents; but found no statistical significance were observed (Table 20). Hence, in this study, the contribution of these lifestyle factors to the development of health effects may be minimal.

Table 19. Association between pesticide use and exposure, and health effects among pesticide applicators in East Hararge zone, Oromiya region, Ethiopia.

Pesticide use and exposure (n=803)	**Options**	**Overall %**	**Experienced health effects**			
			No% (n=514)	**Yes% (n=289)**	**Unadjusted PR (95%Cl)**	**Adjusted PR† (95%Cl)**
Toxicity of pesticide products currently applied	Highly toxic	26.5	12.3	51.9	1.38(1.22-1.56) ***	1.40(1.23-1.60) ***
	Slightly toxic	73.5	87.7	48.1	1.00	1.00
Years of pesticide application	1-5 years	20.8	19.3	23.5	1.10(0.91-1.33)	1.10(0.91-1.33)
	5-9 years	59.4	58.4	61.2	1.07(0.92-1.26)	1.07(0.92-1.26)
	over 10 years	19.8	22.4	15.2	1.00	1.00
Length of a single application (minutes)	46-65	54.2	49.6	62.3	1.09(0.97-1.23)	1.09(0.97-1.23)
	25-45	45.8	50.4	37.7	1.00	1.00
Frequency of pesticide application in a month	Two sessions	52.4	49.0	58.5	1.07(0.95-1.20)	1.07(0.95-1.21)
	One session	47.6	51.0	41.5	1.00	1.00
Trend of pesticide use	Increasing	45.5	42.8	50.2	1.05(0.93-1.18)	1.06(0.94-1.19)
	Decreasing	54.5	57.2	49.8	1.00	1.00
Place of storing pesticides before application	In the house	17.8	17.7	18.0	1.09(0.90-1.33)	1.10(0.91-1.34)
	In house yard	60.0	56.2	66.8	1.12(0.97-1.31)	1.13(0.97-1.31)
	In secured warehouse	22.2	26.1	15.2	1.00	1.00
Method of mixing pesticides	With a stick without gloves	48.8	42.6	59.9	1.12(1.00-1.27)	1.13(1.00-1.27) *
	With a stick wearing gloves	51.2	57.4	40.1	1.00	1.00
Washing the sprayer tank after application	Yes	61.1	49.0	82.7	1.28(1.13-1.45) ***	1.29(1.13-1.46) ***
	No	38.9	51.0	17.3	1.00	1.00
Regular maintenance of the sprayer tank	Yes	59.4	47.1	81.3	1.28(1.13-1.45) ***	1.30(1.14-1.48) ***
	No	40.6	52.9	18.7	1.00	1.00
Incident of pesticide splash during mixing, application, and tank wash	Yes	55.7	48.8	67.8	1.14(1.01-1.29) *	1.14(1.01-1.29) *
	No	44.3	51.2	32.2	1.00	1.00

Note: †adjusted for sex, age, marital status, family size, income level, and education level, past and present smoking status, frequency of alcohol consumption, and Khat consumptions; *$P < 0.05$, ***$P < 0.001$, PR = Prevalence Ratio

Table 20. Lifestyle factors among pesticide applicators and non-applicator residents in East Hararge zone, Oromiya region, Ethiopia

Lifestyle variables	**Options**	**Experience health effect**					
		Applicators (*n* = 803)			**Residents (*n* = 270)**		
		No%	**Yes%**	**Adjusted PR† (95%Cl)**	**No%**	**Yes%**	**Adjusted PR† (95%Cl)**
Current smoking status	Daily	65.7	34.3	0.97 (0.83-1.14)	74.8	25.2	1.01(0.78- 1.31)
	Less than daily	63.5	36.5	0.99 (0.84-1.16)	75.9	24.1	0.99(0.74-1.32)
	Not at all	61.4	38.6	1.00	75.0	25.0	1.00
Past smoking status	Daily	65.4	34.6	0.95(0.75-1.22)	74.8	25.2	0.99(0.75-1.30)
	Less than daily	63.0	37.0	0.97(0.76-1.24)	76.0	24.0	0.97(0.74-1.28)
	Not at all	58.5	41.5	1.00	74.6	25.4	1.00
Frequency of alcohol consumption	2-4 times a month	70.9	29.1	0.95(0.77-1.17)	70.8	29.2	1.02(0.79-1.32)
	Monthly or less	58.9	41.1	1.04(0.88-1.22)	83.3	16.7	0.92(0.69-1.22)
	Don't drink	64.1	35.9	1.00	74.2	25.8	1.00
Alcohol consumption on a typical day when drinking	5-6 drinks	67.9	32.1	0.98(0.77-1.26)	83.3	16.7	0.92(0.64-1.32)
	3-4 drinks	68.1	31.9	0.97(0.78-1.21)	68.5	31.5	1.04(0.79-1.37)
	1-2 drinks	55.6	44.4	1.07(0.89-1.28)	82.9	17.1	0.92(0.66-1.20)
	Not at all	64.5	35.5	1.00	74.2	25.8	1.00
Consume six or more alcohol drink on one occasion	Monthly	63.5	36.5	1.02(0.80-1.30)	71.4	28.6	1.02(0.79-1.33)
	Less than monthly	52.7	47.3	1.09(0.87-1.37)	81.1	18.9	0.94(0.70-1.25)
	Not at all	64.9	35.1	1.00	74.7	25.3	1.00
Khat (Catha Edulis) consumption	Daily	64.5	35.5	0.98(0.82-1.17)	74.5	25.5	1.07(0.72-1.59)
	Less than daily	61.0	39.0	1.00	82.6	17.4	1.00

Note: †adjusted for sex, age, marital status, family size, income level, and education level; PR = Prevalence Ratio

4.2.6. Predictors of preventive measures use among pesticide applicators in Ethiopia

The agricultural extension workers and health extension workers were the principal source of information regarding the health risks of pesticides for 95% and 76% of the pesticide applicators, respectively. Fifty-eight percent and 50% of the applicators attended training on the health risks associated with pesticide exposure and followed the label instructions on pesticide containers. In this study population, 54% and 53% of the participants reported changing their clothes after spraying and taking shower immediately after application, respectively. Moreover, 53% and 47% of the respondents stated that being very expensive and unavailability in the local market were the major reasons for not or rarely using preventive measures, respectively. Visit of a health facility when experiencing a symptom presumably related to pesticide exposure (APR=1.19(1.06-1.35), $p<0.01$) and use of a face mask (APR=1.12(1.00-1.25), $p<0.05$) were significantly positively associated with attending training on the pesticide-use-related health risks. All the pesticide applicators declared that they occasionally utilize safety glasses (goggles) during pesticide application. Wearing of gloves (APR=0.89(0.80-0.99), $p<0.05$), respirators (APR=0.71(0.62-0.81), $p<0.001$), safety shoes (APR=0.76(0.67-0.87), $p<0.001$) and practice of home-based care after experiencing a symptom presumably related to pesticide exposure (APR=0.90(0.79-0.99), $p<0.05$) indicated a significant negative association with attending training on pesticide-use-related health risks (Table 21).

Table 21. Association between completing training on the health risks and use of pesticides and applying preventive measures among pesticide applicators in East Hararge zone, Oromiya region, Ethiopia.

Preventive measures (n=803)	**Options**	**Overall %**	**Receiving training on pesticides-use related health risks**			
			No (n=338)	**Yes (n=465)**	**Unadjusted PR (95%Cl)**	**Adjusted PR† (95%Cl)**
Read and follow the label instructions on pesticide containers	Yes	50.1	43.2%	55.1%	1.08(0.90-1.28)	1.08(0.96-1.21)
	No	49.9	56.8%	44.9%	1.00	1.00
Using face mask	Always	46.7	38.8%	52.5%	1.12(1.00-1.25)	1.12(1.00-1.25) *
	Sometimes	53.3	61.2%	47.5%	1.00	1.00
Using respirator	Always	28.0	52.4%	10.3%	0.71(0.58-0.86) ***	0.71(0.62-0.81) ***
	Sometimes	72.0	47.6%	89.7%	1.00	1.00
Using gloves	Always	48.4	58.6%	41.1%	0.90(0.75-1.07)	0.89(0.80-0.99) *
	Sometimes	51.6	41.4%	58.9%	1.00	1.00
Using rubber boots	Always	32.0	52.7%	17.0%	0.77(0.63-0.93) **	0.76(0.67-0.87) ***
	Sometimes	68.0	47.3%	83.0%	1.00	1.00
Using coveralls	Always	47.7	50.9%	45.4%	0.97(0.81-1.15)	0.96(0.86-1.08)
	Sometimes	52.3	49.1%	54.6%	1.00	1.00
Reasons for not using or rarely using preventive measures	Very expensive	47.9	42.3%	52.0%	1.06(0.89-1.27)	1.06(0.95-1.18)
	Unavailable in local marker	52.1	57.7%	48.0%	1.00	1.00
Changing clothes after application	Yes	53.8	59.2%	49.9%	0.95(0.79-1.13)	0.95(0.85-1.06)
	No	46.2	40.8%	50.1%	1.00	1.00
Taking shower immediately after spraying	Always	52.7	57.4%	49.2%	0.95(0.80-1.14)	0.95(0.85-1.07)
	Sometimes	47.3	42.6%	50.8%	1.00	1.00
Visited health facility when experienced a symptom presumably due to pesticide exposure	Yes	63.8	48.2%	75.1%	1.20(1.07-1.35) **	1.19(1.06-1.35) **
	No	36.2	51.8%	24.9%	1.00	1.00
Used home-based care when experienced a symptom presumably due to pesticide exposure	Yes	42.1	53.3%	34.0%	0.92(0.77-1.10)	0.89(0.79-0.99) *
	No	57.9	46.7%	66.0%	1.00	1.00

Note: †adjusted for sex, age, marital status, family size, income level, and education level, past and present smoking status, frequency of alcohol consumption, and Khat consumptions; **P* < *0.05*, ***P* < *0.01*, ****P* < *0.001*; PR = Prevalence Ratio

Experienced health effects were not significantly associated with any preventive practices, except that it was positively associated with the practice of home-based care when experiencing a symptom presumably related to pesticide exposure (APR=1.13 (1.00-1.28), $p<0.05$) (Table 22).

Table 22. Association between experienced health effects and applying preventive measures among pesticide applicators in East Hararge zone, Oromiya region, Ethiopia.

Preventive measures (n=803)	**Options**	**Overall %**	**Experienced health effects**			
			No (n=514)	**Yes (n=289)**	**Unadjusted PR (95%Cl)**	**Adjusted PR† (95%Cl)**
Read and follow the label instructions on pesticide containers	Yes	50.1	50.4%	49.5%	0.99(0.88-1.12)	0.99(0.88-1.12)
	No	49.9	49.6%	50.5%	1.00	1.00
Using face mask	Always	46.7	44.7%	50.2%	1.04(0.92-1.17)	1.03(0.92-1.16)
	Sometimes	53.3	55.3%	49.8%	1.00	1.00
Using respirator	Always	28.0	30.0%	24.6%	0.96(0.84-1.09)	0.95(0.83-1.09)
	Sometimes	72.0	70.0%	75.4%	1.00	1.00
Using gloves	Always	48.4	50.4%	45.0%	0.96(0.86-1.09)	0.96(0.86-1.09)
	Sometimes	51.6	49.6%	55.0%	1.00	1.00
Using rubber boots	Always	32.0	34.4%	27.7%	0.95(0.83-1.08)	0.95(0.83-1.08)
	Sometimes	68.0	65.6%	72.3%	1.00	1.00
Using coveralls	Always	47.7	50.2%	43.3%	0.95(0.85-1.07)	0.96(0.85-1.08)
	Sometimes	52.3	49.8%	56.7%	1.00	1.00
Reasons for not using or rarely using preventive measures	Very expensive	47.9	46.7%	50.2%	1.02(0.91-1.15)	1.02(0.91-1.16)
	Unavailable in marker	52.1	53.3%	49.8%	1.00	1.00
Changing clothes after application	Yes	53.9	57.0%	48.4%	0.94(0.84-1.06)	0.94(0.84-1.06)
	No	46.1	43.0%	51.6%	1.00	1.00
Taking shower immediately after spraying	Always	52.7	54.3%	49.8%	0.97(0.86-1.09)	0.97(0.86-1.09)
	Sometimes	47.3	45.7%	50.2%	1.00	1.00
Visited health facility when experienced a symptom presumably due to pesticide exposure	Yes	63.8	61.3%	68.2%	1.05(0.93-1.19)	1.05(0.93-1.19)
	No	36.2	38.7%	31.8%	1.00	1.00
Used home-based care when experienced a symptom presumably due to pesticide exposure	Yes	42.1	35.6%	53.6%	1.13(1.01-1.28) *	1.13(1.00-1.28) *
	No	57.9	64.4%	46.4%	1.00	1.00

Note: †adjusted for sex, age, marital status, family size, income level, and education level, past and present smoking status, frequency of alcohol consumption, and Khat consumptions; *$P < 0.05$, PR = Prevalence Ratio

5. DISCUSSIONS

5.1. Pesticide management reported by officers in Ethiopia and Hungary

This study investigated pesticide use and handling practice, exposure status, and the potential pesticide-related health effects in Ethiopia and in Hungary. In the two countries, agriculture has a similarly significant historical role in the economy, although they have different levels of development. In the current study findings, an evident discrepancy was identified in all aspects of knowledge, attitude, and experienced practice of using pesticides between Ethiopian and Hungarian officers accountable for the safe management of these agrochemicals. A good knowledge level and risk attitude regarding pesticide products among officers accountable for occupational safety and environmental health are essential for delivering proper guidance to decrease human health risks from improper pesticide application among farm workers (Sharafiet al, 2018). The primary responsibility of extension workers is to deliver sufficient knowledge, skills, and attitude to the farm agricultural workers so that they develop self-protective behaviors and adopt new and improved technologies, including the safe-use practice of pesticides, to improve productivity while reducing risk from pesticide exposure (Rivera, 2001; FAO and INTERPAKS, 1997; Fetene et al, 2016).

In study, the Hungarian plant doctors were older and had a higher education than the Ethiopian extension workers. This difference manifested in their knowledge of pesticide products and modes of pesticide exposure. This may be related to the disparity in socioeconomic and demographic factors of study populations and better access to higher education for the Hungarian plant doctors. In the present study, the Hungarian plant doctors were older and had higher education than the Ethiopian extension workers, which is also reflected in their level of knowledge related to pesticide products and routes of exposure. This pronounced discrepancy may be attributed to the difference in socio-economic and demographic characteristics of study populations and more access to higher education in the case of Hungarian officers. Based on the WHO hazard classification of pesticides, several declared pesticides induce a risk of moderate (e.g., 2, 4-D, Diazinon, Deltamethrin, Dimethoate, Endosulfan, Sevin, DDT, Epoxiconazole) and slight acute toxicity (e.g., Malathion, Glyphosate, Chloronitrile, Pendimethalin).

In the present study, the officers reported that insecticides, herbicides, and fungicides were used in their respective control areas in the ratio of 7:2:1 and 4:3:3 in Ethiopia and Hungary, respectively Based on the WHO hazard classification of pesticides (WHO and IPCS, 2009), 60% of pesticide products declared from Hungary and 70% from Ethiopia were moderately hazardous (WHO class II). The use of Epoxiconazole, Tetraconazole, and Pendimethalin were reported merely by Hungarian, while Malathion, Sevin, and DDT were only by Ethiopian officers. In addition to acute health risks, some pesticides apprised in this study have a tendency to bioaccumulate in the food chain (e.g., Deltamethrin, DDT, and Endosulfan), causing chronic health risks from long-term low-dose exposure (Singh et al, 2014; Corcellas et al, 2015; Gerber et al, 2016). The use of the persistent and toxic organic pollutant organochlorine pesticide products, which had already been banned in most countries in the world, were reported from Ethiopia (including Endosulfan and DDT) and Hungary (such as Endosulfan) (Lallas, 2001; Tesfahunegny and Mulualem, 2016). In Ethiopia, DDT is still actively applied for malaria vector control by the Ministry of Health, however, farmworkers also spray it on food crops and khat (Catha edulis) in illegally (Mekonen et al, 2015; 2017). In addition to DDT, the toxic and persistent organochlorine Endosulfan had also been banned from the member states of the European Union, (in 2012), including Hungary (Singh et al, 2014).

The comparatively insufficient poorer levels of knowledge regarding pesticide products and modes of pesticide exposure among Ethiopian extension workers compromises the safe use of pesticides by farmworkers in Ethiopia and negatively impacts the development of self-protective behaviors. Nonetheless, compared to the study done by Mormeta in the central part of Ethiopia, where merely 33% of the extension workers perceived good level of pesticide hazard related knowledge, our findings (66%) indicate an encouraging advancement (Mormeta, 2019). However, more effort should be given to address the knowledge deficiency of extension workers and thereby minimize the significant risk and susceptibility to the negative effects of pesticide exposure among Ethiopian applicators particularly and residents generally. Improving their level of education is essential as a considerable proportion of them have only college diplomas, i.e., attended two years of college education. The higher level of knowledge and education among Hungarian officers is consistent with the findings of Cole in Georgia (Cole 2010), and Remoundou et al. in Greece, Italy, and the UK (Remoundou et al, 2015). These studies confirmed that education equips the officers with the capability to capture the very nature of pesticide products and give accurate and uncensored information to the applicators in their working areas. It emphasizes the need to provide continuous training on various aspects of pesticide products and their management among Ethiopian officers and evaluate its effectiveness.

Misperceptions regarding pesticide products can severely damage the capability of agricultural workers to develop self-protective behaviors against the pesticide-induces short-and long-term health effects. Based on the current study findings, a considerable proportion of officers perceived a reduced the risk of pesticides; only half (51%) of the Hungarian and almost three-fourths (74%) of the Ethiopian officers perceived that pesticides are poisonous. These results are similar to the study findings in Mexico, where 75% of extension workers showed the correct risk perception regarding the inherent toxic capacity of pesticide products (Rios-Gonzalez, 2013). In another study in Tanzania, merely a quarter of the extension workers perceived pesticides as a principal health problem in the community they were serving (Ngowi et al, 2002). It seems that Hungarian plant doctors deem pesticides less dangerous probably because they experience pesticide health effects less frequently due to the more adequate pesticide management system, nevertheless, the inherent poisonous nature of pesticides should not be forgotten. This initiates the necessity of in-service training This misperception regarding the intrinsic toxicity of a pesticides affects the extent of decisions making to control pesticide-related health risks, design applicable interventions, as well as the quantity and the quality of safety training they provide to the farmworkers (Rao et al, 2004; Frank and Ottoboni, 2011; Damalas and Koutroubas, 2016; Msuya et al, 2017).

Concerning pesticide management in Hungary, the policy coverage and law enforcement on occupational health and environmental health are strict, and the measures taken to control the process seems to be well organized; the pesticide transportation, storage, and distribution system appear fully effective. Regardless, a significant proportion (83%) of officers declared that there is a practice of illegal trade of pesticide products from bordering countries. This indicates a warning sign that the existing pesticide management system needs to be evaluated and further strengthened. Conversely, although the policy coverage is sufficient, the pesticide transportation, storage, and distribution system appeared inefficient (56%), and the law enforcement on occupational health and safety and environmental health insufficient in Ethiopia. Moreover, the measures designed to control the procedure are reported to be not well coordinated. In Ethiopia, the Ministry of Agriculture is the largest pesticide distributor to agriculturalists; however, a substantial proportion of the study participants (46%) declared the practice of illegal importation of pesticide products from bordering countries. The results from both study areas show that pesticide applicators can purchase unapproved pesticide products from unauthorized sources, presumably at a lower price. A substantial proportion of Hungarian officers perceived that the ways how pesticides are presently handled by applicators are less likely to cause health risks to them, and the pesticide residues are less likely to contaminate environmental compartments compared to their Ethiopian counterparts. This outcome is coherent with a study completed in North Carolina, where a significant proportion of extension workers deemed that applicators were at a minimum health risk of pesticide exposure since, they received adequate training and utilized preventive measures sufficiently (Rao et al, 2004). A study done in Saudi Arabia supports our results from Ethiopia where extension workers thought that pesticide residues are a considerable health risk to our food and environment (AL-Subaiee et al, 2005). This disparity between the perception of the Hungarian and Ethiopian officers may be attributed to the different level of effectiveness of the preventive measures applied and the different socio-economic development status. A substantial proportion of Hungarian officers presumed that farmers are fully trained regarding the health risks of pesticides and employed the full set of required personal protective equipment during pesticide spraying. This may be the cause why Hungarian officers deemed lower pesticide use-related health risks among farmworkers since they perceived that the preventive measures were sound and the pesticide management system effective in their control area, and the health risk of pesticides is influenced by the combination of the intrinsic toxicity and the exposure situation. A substantial proportion of Ethiopian officers declared that they experienced pesticide-related illnesses and poisoning among farmers at some point previously in their service area. This result was underpinned by the unsafe use of pesticide products including inadequate utilization of PPE, and insufficient training of farmers and extension workers. Although the risk awareness towards pesticides is high, preventive practices are unsatisfactory. Therefore, the knowledge and skill disseminated to the farmworkers should be determined based on the real-life working environment in Ethiopia. Otherwise, the quality of advisory service remains low, maintaining a high level of risk, particularly to applicators and the environment at large. Pesticide risk communication and education approaches, which focus only on providing information, are inadequate. Instead, sustainable pesticide safety approaches, and risk reduction strategies should be guaranteed based on behavioral change (Msuya et al, 2017). The counseling services provided by the extension officers about pesticide application should be regularly monitored and evaluated during field spraying. Since farmworkers typically have a low education level, they usually well-recognize and adopt protective behaviors through learning by doing (Rios-Gonzalez, 2013).

In Hungary, 80% of officers apprised that farmworkers returned leftover pesticide products to waste management places as the dominant disposal method. This finding is encouraging and recognizes the measure taken by the agricultural sector and stockholders. Dissimilarly, a considerable proportion of extension officers (44%) from Ethiopia disclosed that farmworkers stored leftover pesticide products in their dwellings for next use or offered them to other farmers (33%). These observations presumably could be attributed to their lower economic capability. This practice may not merely subject the applicators to elevated risk of pesticide exposure. Take-home pathways also allow for non-occupational pesticide exposure among family members, bystanders, neighbors, as well as for the pollution of environmental compartments, including water, food, soil, and air. These exposures routes can extend not only to family members, including children and pregnant women, but also to residents, and consumers at large through direct (including dermal contact, inhalation, and ingestion) and indirect (through contamination of food, water, soil, and air) pathways (Remoundou et al, 2015). Extension officers may tend to give more focus to higher crop product yields for farmworkers by extended use of pesticide products, but its adverse consequences on human health and the environment may hold less attention (Rios-Gonzalez, 2013; Kriesemer et al, 2009). Therefore, a comprehensive study on the health risk of occupational and environmental pesticide exposure to identify the actual risk to farmworkers and residents is crucial to protect not only the applicators but also the entire community.

5.2. Pesticide exposure among applicators and residents in Ethiopia

Based on our previous study findings, the investigation was completed in Ethiopia on the health risk of occupational and environmental pesticide exposure and associated factors among pesticide applicators in comparison to non-applicator residents. Based on the findings, several unsafe behaviors leading to increased pesticide exposure were pinpointed and prominent deviations were detected in all aspects of knowledge of and attitude related to pesticide exposure and experienced health effects among pesticide applicators and non-applicator residents.

Based on the WHO hazard classification of pesticides, 59% and 35% of pesticide products declared by the study participants were moderately and slightly hazardous, respectively (WHO, 2020). Insecticide, herbicide, and fungicide products were reported to be used frequently by applicators at a ratio of 9:4:4 in the study area. In addition to acute health effects, some declared pesticides such as Deltamethrin, DDT, Endosulfan, and Cypermethrine, tend to be persistent in the environment and bioaccumulate in the food chain and pausing chronic health risks over long-term exposure. Based on the IARC classification, 25% and 19% of declared pesticide products were probably (Group 2A) (for example, Glyphosate, Malathion, Diazinon, and DDT) and possibly (Group 2B) (for instance, 2, 4-D, Cypermethrin, and Chlorothalonil) carcinogenic to humans, respectively (Singh et al, 2014; Corcellas et al, 2015; Gerber et al, 2016). The use of persistent and toxic organochlorine pesticides, which had previously been banned in several countries in the world, was documented in the study area (Lallas et al, 2001; Tesfahunegny and Mulualem, 2016). Dichloro diphenyl trichloroethane (DDT) is still vigorously applied by the Ministry of Health to control malaria vectors in Ethiopia. Nevertheless, pesticide users also spray it on food crops and Khat (Catha edulis) illegally (Mekonen et al, 2015; 2017). Several banned pesticide products are still extensively utilized in Ethiopia because the pesticide management system is weak. Insufficient provision of extension services provision was regarded as a critical factor leading to the misuse of pesticide products in our earlier investigation among extension officers. A sufficient level of knowledge regarding pesticides is essential for farmers to employ effective strategies to decrease pesticide-related health risks. In our study, inhalation, contamination of water, and asthma were the most frequently reported mode of pesticide exposure, pesticide-use-related environmental problem, and presumably pesticide-related health effect, respectively. Effective training to raise awareness of applicators regarding routes of pesticide exposure is crucial since absorption via dermal exposure can be high in occupational settings (MacFarlane et al, 2013). In this study, the overall knowledge about pesticide risks was remarkably higher among applicators than non-applicator residents. This may be because applicators have a higher opportunity to get training on pesticide risks from different sources than residents. Our study indicated a higher level of knowledge than earlier studies done by Mequanint (Mequanint et al, 2019), Mergia (Mergia et al, 2021) and Endalew (Endalew et al, 2020), but similar observations were made by Mengistie et al. and Gesesew et al. in Ethiopia (Mengistie et al, 2017; Gesesew et al, 2016), and Lekei et al. in Tanzania (Lekei et al, 2014). Nevertheless, merely owning sufficient knowledge about pesticide-related health risks does not inevitably translate into best practices of pesticide, handling and consistent application of appropriate preventive measures. Therefore, regular monitoring and evaluation of application practice during field spraying are essential because a substantial proportion of the current study population had low education level. Such farmers usually well-materialize their knowledge into practice and develop self-protective behaviors through learning by doing on the farm. Incomprehension of pesticides risks can negatively influence the capacity of applicators to adopt self-protective behaviors and prevent pesticide-related acute and chronic health effects. The present study indicated that applicators had a statistically significantly higher mean score on several aspects of attitude than residents, such as perceived health risks from pesticide use and the consequences and usage of personal protective equipment in reducing pesticide exposure. A similar observation was made in Brazil by Pasiani and Recena (Pasiani et al, 2012; Recena et al, 2006) and by Hamid in Malaysia (Hamid et al, 2021). A substantial proportion of applicators presumed that pesticide exposure might cause life-threatening illnesses; however, a significant proportion of them declared that they were satisfied with the current application practice. This discrepancy in perception indicated that the applicators didn't show a readiness to modify their current pesticide-handling practices. Evidence-based interactive training, practice-oriented, target-specific behavioral change, risk communication strategies concerning pesticide use, and preventive measures are crucial. The gap between the knowledge, attitude, and fundamental safety practices needs to be associated with a better multifaceted and participatory training model and behavioral interventions. A substantial proportion of applicators declared that they experienced health effects potentially attributable to previous pesticide exposure, a consistent finding with what was reported among Bolivian (Cuenca et al, 2020) and Thai farmers (Kangkhetkron and Juntarawijit, 2021). Furthermore, nearly one-third of the applicators declared that they encountered health effects among their family members, probably due to exposure to pesticides. Para-occupational exposure routes are possible sources of exposure families of agricultural workers, as well as the general population. Agrochemicals used in farming, including pesticides, can transfer from the workplace to residential settings and, depending on the chemical properties, ultimately lead to the accumulation of pesticide residues over time, specifically in vehicle and home dust. In addition, applicators may bring pesticide products home for domestic use, and the improper handling and storage of these products could be a potential source of health risks for those dwelling in the house, particularly for children, elderly people, and pregnant women (Lu et al, 2000; Curl et al, 2002). In this study, a significant proportion of applicators used prescription drugs in the past 12 months before data collection. However, diagnosed medical conditions, such as diabetes and high blood pressure, were less frequently reported by applicators compared to residents. These may be typically attributed to the "healthy worker effect" as occupational observational studies, including cross-sectional ones, are particularly prone to this type of bias (Pearce et al, 2007). Several adverse symptoms observed by other studies to be presumably associated with pesticide exposures (Mwabulambo et al, 2018), such as cough, shortness of breath, dizziness and skin irritation, have been more frequently reported by applicators than residents in this study, too. Conversely, symptoms including chest pain, muscle cramps, nausea and vomiting were significantly less likely declared by applicators. This can also be due to the "healthy worker effect" (Pearce et al, 2007), or to other confounding factors that have not been measured in study.

The extension officers are the primary channels for transferring knowledge regarding pesticide use and management to pesticide applicators, though the extent of assistance may be insufficient (Midega et al, 2012; Togbe et al, 2012). To improve the safety of applicators and residents from adverse pesticide exposure before, during, and after the transportation, distribution, storage, application and disposal of leftover pesticide residues and empty containers are critical points of intervention. In the present study, a significant proportion (69%) of applicators sold or offered leftover pesticide products to other farmers. On the other hand, a substantial proportion (43%) of applicators reported that they buy merely the quantity of pesticide that is needed for the application, which is the best practice that should be acknowledged. An alarmingly high proportion (80%) of applicators disposed of empty pesticide containers on open fields, whereas 59% of applicators also used empty containers to store other pesticide products. Similar conclusions were documented in other studies (Damalas et al, 2008; Yassin et al, 2002). This practice may not merely subject the applicators to increased health risk of pesticide exposure but also threaten the health of household members, residents, and bystanders through environmental pesticide exposure routes. Therefore, to decrease human health risks and environmental pollution associated with pesticide use, proper collection, recycling, and disposal of empty containers and pesticide residues should be enforced. A considerable proportion of the applicators practiced unsafe behaviors during pesticide handling. Applicators either smoke cigarettes, drink water, eat food or consume Khat while applying pesticides. Consistent results were declared from Gaza (Yassin et al, 2002). A substantial proportion of applicators utilized home-based care treatment when encountering symptoms likely related to pesticide exposure. This is presumably associated with their economic limitations, lower education levels and inadequate health literacy. This practice could exacerbate the health consequences and lead to severe outcomes as due to the missed opportunity of early detection and sufficient treatment (Pérès et al, 2012), which also result in higher burden of healthcare costs on the applicators (Memon et al, 2019).

The current study findings indicated that the use of highly toxic pesticide products, mixing and loading pesticides without gloves, incidents of a splash during mixing and application, regular maintenance and washing spray tank after spraying were significantly positively associated with experienced health effects probably associated with pesticide exposure among applicators. Comparable findings were reported from Rwanda (Ndayambaje et al, 2019). A substantial proportion of applicators rated the toxicity of currently applied pesticide products as slightly toxic; however, these pesticides may exert higher toxicity than expected. This misperception may diminish the sufficient use of preventive measures. Identical findings were also documented by Memon et al. (2019) and Jallow et al. (2017).

The benefit of preventive measures is a key aspect of lowering the health risks of work-related pesticide exposure. The cost of preventive measures is much less than that of medical treatment. (Memon et al, 2019); therefore, the use of preventive measures is not a merely ethical issue but also a cost-effective and achievable strategy to combat health effects from occupational pesticide exposure, particularly in low- and middle-income countries like Ethiopia. Our study indicates that about 50% of the applicators did not read and follow the label instructions posted on the pesticide containers. Although significantly more applicators received tailored training, only less than half of them used always face masks, gloves, and coveralls during pesticide handling. Interestingly, self-reported use of gloves, respirators, safety shoes, and coveralls were more frequent among non-trained applicators. Generally, the use of preventive measures among applicators was mainly intermittent. Similar findings were reported by Ndayambaje et al, (2019) in Rwanda and by Orozco et al, (2011) in Ecuador. Training regarding the appropriate use of PPE and ensuring the availability of good quality protective equipment in the local market at an affordable cost is a key factor in their utilization (Maddah et al, 2019). Personal hygiene among applicators, including taking a shower and changing cloth immediately after spraying, is critical in lowering the pesticide-related health risk in work-related settings (Gaber and Abdel-Latif, 2012, Maddah et al, 2019). It further decreases health risks to family members that may otherwise face para-occupational exposure. The current study also revealed that applicators who experienced health effects significantly more frequently utilized home-based care than health facilities. Hence, comprehensive training focusing on basic safety precautions, appropriate selection and use of PPE, and visiting health facilities at the onset of potentially pesticide-related symptoms are essential for lowering the disease burden associated with pesticides.

5.3. Strength and limitations

A temporal causal relationship between exposure and outcome could not be identified in our studies using a cross-sectional design, because both aspects were investigated at the same point of time. The data collected were self-reported by respondents; hence, it may be exposed to social desirability and recall bias. Moreover, pesticide exposure levels were not verified by biological or environmental monitoring; however, we can assume that pesticide exposure levels are higher in the occupational than in the residential settings. Although the occurrence of confounders cannot be excluded, probable absence of strong confounding was verified by the absence of significant variations (<10%) between crude and adjusted ORs and PRs in most cases. In the effort made to address these limitations, a questionnaire-based survey by face-to-face interviewer-administered interviews was performed on a large random sample of pesticide applicators and residents in Ethiopia, assuring a high degree of reliability and representativeness for the target working population as well as for the general public.

6. CONCLUSIONS

Apparent discrepancies were observed in knowledge, attitude, and experienced practice of pesticide use between officers in Ethiopia and Hungary. Based on our findings, it can be deduced that there is a significant disparity in the effectiveness of pesticide control systems between the two study areas. Improving extension service provisions and optimization of the pesticide control system through strict law enforcement related to occupational safety and environmental health are critical interventions. The provision of adequate pesticide safety training, including process and content dimensions of pesticide use, is necessary. Securing satisfactory knowledge and skills for identifying and managing unsafe pesticide exposures of farmworkers and the environment without compromising product yield are recommended, especially in Ethiopia. In the survey of occupation and non-occupational pesticide exposure and associated health risks, the main determinants of health risks related to pesticide exposure were identified in Ethiopia. Improving formal education of the applicators and training programs for strict utilization of personal protective measures are essential to further risk reduction. Raising the overall knowledge of pesticide hazards, correcting erroneous perceptions, and avoiding risky behaviors during pesticide application are of paramount importance. Pursuing a safe practice of pesticide preparation, application, storage, and disposal and ensuring access to appropriate PPE and other preventive measures on the local market at affordable costs are principal factors for risk reduction. The consistent monitoring and evaluation of the whole process of pesticide management are crucial for the better protection of pesticide users and the general public.

7. SUMMARY

7.1. Background

Pesticides have a great role in guaranteeing food security and economic development; however, their intensive use has raised concern regarding the possible short-and long-term health effects of pesticides among applicators in particular and the public at large.

7.2. Aim

Our study aimed to investigate occupational and non-occupational pesticide exposures, associated health risks, and pesticide management practices among extension officers, pesticide applicators and non-applicator residents in rural Ethiopia, and to compare it to the situation in Hungary, as reported by plant doctors.

7.3. Methods

A community-based cross-sectional study was completed involving 326 officers (234 extension officers from Ethiopia and 92 plant doctors from Hungary) between 2019 and 2020. Thereafter, a survey involving 1073 study participants (803 pesticide applicators and 270 non-applicators residents) was conducted in Ethiopia in 2021. In both questionnaire surveys, information on pesticide handling, knowledge and attitude to risks of pesticides, experienced health effects and applied preventive measures were collected. Uni- and multivariate statistical analysis was used to identify predictors of knowledge and attitude, health effects and applied preventive measures by estimating crude and adjusted odds ratios and prevalence ratios.

7.4. Results

The Ethiopian officers had significantly lower knowledge of pesticide products (66%) and more frequently experienced pesticide poisoning among applicators (41%) than the Hungarian colleagues (92% and 7%, respectively). The Hungarian officers deemed less health risk of pesticide use (AOR=0.46 (0.27-0.80), $p<0.01$), were ten times more likely to perceive the pesticide control system effective (AOR=10.23 (5.68-18.46), $p<0.001$) and were nine times more likely to declare that applicators used personal protective equipment (AOR=8.95 (4.94-16.28), $p<0.001$). A substantial proportion of respondents from both countries reported unacceptable methods of pesticide residue disposal and illegal importation of pesticides from bordering countries. In Ethiopia, applicators had a significantly higher proportion of good knowledge of pesticides (75% vs 14%; APR=1.54 (1.368-1.75), $p<0.001$) and had a higher mean score of perceived health risk of pesticide use (4.21 vs 3.90; APR=1.08 (1.01-1.16), $p<0.05$) than the residents. A considerably higher proportion of applicators experienced health effects probably related to pesticide exposure (36%) than the residents (16%) (APR=1.15 (1.01-1.32), $p<0.05$). Certain symptoms presumably associated with pesticide exposure, such as cough, shortness of breath, dizziness and skin irritation, were significantly more frequently declared by them. Perceptions related to the toxicity of presently used pesticide products, mixing pesticides without gloves, the occurrence of splash during mixing and application, regular maintenance and washing of the sprayer tank after spraying, and using home-based care after experiencing a symptom presumably related to pesticide exposure were significantly associated with experiencing health effects among applicators. A considerably high proportion of applicators declared insufficient use of preventive measures and inappropriate leftover pesticide residue disposal methods. Nevertheless, consistent use of a face mask and visiting a health facility when experiencing a symptom presumably related to pesticide exposure were significantly positively associated with receiving training on health risks and pesticide use. A considerably higher proportion of applicators declared insufficient use of preventive measures and inappropriate leftover pesticide residue disposal methods.

7.5. Conclusions and recommendations

From the findings of the two studies, we deduced that the situations of pesticide use and exposure are worse in Ethiopia. Pesticide management systems are ineffective, deficiency of knowledge and misperception about pesticides, hazardous practices of pesticide use and handling, and poor use of preventive measures are observed. Consequently, the applicators in Ethiopia are exposed to elevated health risks of occupational pesticide exposure and are working in risky conditions. Even trained applicators pursue poor preventive practices. Therefore, comprehensive interventions are required, practical-oriented field-based in-depth training for extension officers and applicators focusing on safety precautions and proper use of personal protective equipment is of paramount importance. It is inevitable to establish effective pesticide management, monitoring, and evaluation system and to ensure restrictive law enforcement. Providing accessibility of PPE at affordable prices and provision of adequate pesticide waste disposal means are crucial interventions to safeguard the health of pesticide applicators and the public at large.

8. KEY WORDS

Pesticide; exposure; knowledge; risk perception; risk management; extension officer; plant doctor; health risk; applicators; residents; occupational health; preventive measures.

9. FUNDING

This study was funded by the Stipendium Hungaricum Scholarship scheme under Tempus Public Foundation (TPF) with the reference number SHE-25885-005/2018 to Roba Argaw Tessema.
Address: H-1077 Budapest, Kéthly Anna Tér 1. E-Mail: stipendiumhungaricum@tpf.hu

10. ACKNOWLEDGEMENT

First of all, I would like to express my deepest gratitude to my supervisor Dr. Balázs Ádám for his trust and grant for me to pursue this higher education opportunity at the University of Debrecen, Hungary, for his willingness to accept me as his student and his indispensable continuous support, insight comments, encouragement, and all rounded guidance throughout my research work. My special thanks also go to Dr. Károly Nagy for his magnificent help to me with all technical assistance and facilitation during my experimental work in the genotoxicology laboratory work.

Furthermore, my deepest appreciation goes to Tempus Public Foundation for awarding me the Stipendium Hungaricum Scholarship throughout my study periods that made my learning desire realistic, and this PhD work possible. My deep gratitude also goes to the whole staff of the Department of Public Health and Epidemiology and to the leadership of the Doctoral School of Health Sciences, University of Debrecen, who provided me opportunity and help in all aspects of this PhD accomplishment.

My thanks go to the Haramaya University College of Health and Medical Science for supporting me to endorse my PhD study.

Last but not least, I would like to thank my family for their love and continuous support.

All thanks to Almighty God, who supported and protected me throughout my study and life.

11.REFERENCE

1. Afshari, M.; Poorolajal, J.; Assari, M.J.; Shahkolai, F.R.; Karimi-Shahanjarini, A. Acute pesticide poisoning and related factors among farmers in rural Western Iran. Toxicology and Industrial Health 2018, 34(11):764–777. DOI: 10.1177/0748233718795732
2. Alberto, A.; Honglei, Ch.; Marc, G.W.; Eilis, O.; Marjorie, L.McC.; Eugenia, E.C. et al. Pesticide exposure and risk for Parkinson's disease. Ann Neurol 2006, 60(2):197-203. DOI: 10.1002/ana.20904
3. Alejo-González, K.; Hanson-Viana, E.; Vazquez-Duhalt, R. Enzymatic detoxification of organophosphorus pesticides and related toxicants. J. Pestic. Sci.; 2018, 43(1):1-9. DOI: 10.1584/jpestics. D17-078
4. Alemseged, F.; Haileamlak, A.; Tegegn, A.; Tessema, F.; Woldemichael, K.; Asefa, M. et al. Risk Factors for Chronic Non-Communicable Diseases at Gilgel Gibe Field Research Center, Southwest Ethiopia: Population Based Study. Ethiop J Health Sci. 2012 Aug; 22(S):19-28.
5. AL-Subaiee, S.S.F.; Yoder, E.P.; Thomson, J.S. Extension Agents' Perceptions of Sustainable Agriculture in the Riyadh Region of Saudi Arabia. *J. Int. Agric. Ext. Educ.* 2005, *12*, 5–14, doi:10.5191/jiaee.2005.12101.
6. Atlantic Working Group for Pest Management Education and Training Standards (AWGPMETS). Atlantic Canada Pesticide Applicator Training Manual Series: Applicator Core Training Manual, volume 1: Chapter 5: Pesticide Safety, page 93-137, Government of New Brunswick, Canada, 2006
7. Baltazar, M.T., Dinis-Oliveira, R.J, Bastos, M.L., Tsatsakis, A.M., Duarte, J.A., Carvalho, F. Pesticides exposure as etiological factors of Parkinson's disease and other neurodegenerative diseases: A mechanistic approach. Toxicology Letters, 2014 230(2): 85-103. https://doi.org/10.1016/j.toxlet.2014.01.039
8. BBJ. Budapest business journal [Accessed April 19, 2021). https://bbj.hu/economy/agriculture/crops/pesticide-use-in-hungary-averages-1-5-kg-per-hectare
9. Behrens, T.; Taeger, D.; Wellmann, J.; Keil, U. Different methods to calculate effect estimates in cross-sectional studies. A comparison between prevalence odds ratio and prevalence ratio. Methods Inf Med.**2004**; 43(5):505-9.
10. Biosca-Brull, J.; Pérez-Fernández, C.; Mora, S.; Carrillo, B.; Pinos, H.; Conejo, N.M.; et al. Relationship between Autism Spectrum Disorder and Pesticides: A Systematic Review of Human and Preclinical Models. Int. J. Environ. Res. Public Health 2021, 18, 5190. https://doi.org/10.3390/ ijerph18105190
11. Boedeker W, Watts M, Clausing P, Marquez E. The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. BMC Public Health. 2020 20:1875. Doi: 10.1186/s12889-020-09939-0
12. Bukowska, B. Effects of 2,4-D and its metabolite 2,4-dichlorophenol on antioxidant enzymes and level of glutathione in human erythrocytes. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 2003, 135(Issue 4): 435-441. https://doi.org/10.1016/S1532-0456(03)00151-0
13. Chandrasekharan-Nair, K.; Mohammad, F.; Manoj Kumar, P.; Vipin, B.; Neeraj, M.; Anup Kumar, S. Adverse Health Effects of Pesticides in Agrarian Populations of Developing Countries. Reviews of Environmental Contamination and Toxicology Vol 200, 2009, pp 33-52, publisher: Springer US, Boston
14. Chatterjee, N., Walker, G.C. Mechanisms of DNA damage, repair and mutagenesis. Environ Mol Mutagen. June 2017, 58(5): 235-263. doi:10.1002/em.22087
15. Coman, G., Farcas, A., Matei, A.V., Florian, C. Pesticides Mechanisms of Action in Living Organisms. In: Simeonov, L., Macaev, F., Simeonova, B. (eds) Environmental Security Assessment and Management of Obsolete Pesticides in Southeast Europe. NATO Science for Peace and Security Series C: Environmental Security. Springer, 2013, Dordrecht. https://doi.org/10.1007/978-94-007-6461-3_16
16. Cole, S.E. Identifying Pesticide Competencies and Perceived Competence among Pesticide Safety Educators. Doctoral Dissertation,University of Georgia, Athens, GA, USA, 2010.
17. Cole, S.E. Identifying Pesticide Competencies and Perceived Competence among Pesticide Safety Educators. Doctoral Dissertation, University of Georgia, Athens, GA, USA, 2010
18. Corcellas, C.; Eljarrat, E.; Barceló, D. First report of Pyrethroid bioaccumulation in wild river fish: A case study in Iberian river basins (Spain). *Environ. Int*. **2015**, *75*, 110–116, doi: 10.1016/j.envint.2014.11.007.
19. Cortés-Iza, S.C.; Rodríguez, A.I. Oxidative stress and pesticide disease: a challenge for toxicology. Rev. Fac. Med. 2018, 66(2): 261-267. DOI: http://dx.doi.org/10.15446/revfacmed.v66n2.60783
20. Damalas, C.A.; Koutroubas, S.D. Farmers' Exposure to Pesticides: Toxicity Types and Ways of Prevention, Toxics. March 2016; 4(1): 1. doi: 10.3390/toxics4010001
21. Damalas, C.A.; Koutroubas, S.D. Farmers' exposure to pesticides: Toxicity types and ways of prevention. *Toxics* **2016**, *4*, 1,doi:10.3390/toxics4010001
22. Daniel, W.W.; Cross, C.L. *Biostatistics: A Foundation for Analysis in the Health Sciences*, 10th ed.; Wiley: New York, NY, USA, 2013.
23. Deribe, E.; Rosseland, B.O.; Borgstrøm, R.; Salbu, B.; Gebremariam, Z.; Dadebo, E.; Skipperud, L.; Eklo, O.M. Organochlorine pesticides and polychlorinated biphenyls in fish from Lake Awassa in the Ethiopian Rift Valley: human health risks. Bull Environ Contam Toxicol, 2014; 93(2):238-244. https://doi.org/10.1007/s00128- 014-1314-6

24. Deziel, N.C.; Freeman, L.E.B.; Hoppin, J.A.; Thomas, K.; Lerro, C.C.; Jones, R.R.; et al. An algorithm for quantitatively estimating non-occupational pesticide exposure intensity for spouses in the Agricultural Health Study. Journal of Exposure Science & Environmental Epidemiology, 2019, 29:344-357 https://doi.org/10.1038/s41370-018-0088-z
25. Deziel, N.C.; Friesen, M.C.; Hoppin, J.A.; Hines, C.J.; Thomas, K.; Beane Freeman, L.E. A review of non-occupational pathways for pesticide exposure in women living in agricultural areas. Environ Health Perspect, 2015, 123:515-524. http://dx.doi.org/10.1289/ehp.1408273
26. Eddleston M. (2000). Patterns and problems of deliberate self-poisoning in the developing world. Q J Med; 93: 715-731
27. Endalew, M.; Gebrehiwot, M.; Dessie, A. Pesticide Use Knowledge, Attitude, Practices and Practices Associated Factors Among Floriculture Workers in Bahirdar City, Northwest, Ethiopia. Environmental Health Insights (2020) 16: 1-10. https://doi.org/10.1177/11786302221076
28. EU. Regulation (EC) No. 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC.
29. Evangelos, E.; Georgios, N.; Maria, Ch.; Fotini, K.K.; Antonio, F.H.; Evangelia, E.N.; Ioanna,T. Exposure to pesticides and diabetes: A systematic review and meta-analysis. Environment International, 2016, 19: 60-68. https://doi.org/10.1016/j.envint.2016.02.013
30. FAO. International Code of Conduct on the Distribution and Use of Pesticides. Adopted by the Hundred and Twenty-third Session of the FAO Council in November 2002. Food and Agriculture Organization of the United Nations, Rome, 2005
31. FDRE-CSA. Population Projection at Wereda Level from 2014–2017. Federal Democratic Republic of Ethiopia Central Statistical Agency,August 2013, Addis Ababa, PDF. Available online: https://www.statsethiopia.gov.et (accessed on 24 December 2021).
32. Federal negarit gazeta of the Federal Democratic Republic of Ethiopia. Pesticide Registration and Control Proclamation No 674/2010, 16th year No 52. 25th August, Addis Ababa
33. Fesseha, H.; Aliye, S.; Kifle, T.; Mathewos, M. Chemical and drug use in dairy farms of Hawassa Town, Southern Ethiopia. Public Health Open Journal, 2020; 5(1):1-7. https://doi.org/10.17140/PHOJ-5-137
34. Fetene, N.; Linnander, E.; Fekadu, B.; Alemu, H.; Omer, H.; Canavan, M. The Ethiopian Health Extension Program and Variation in Health Systems Performance: What Matters? *PLoS ONE* **2016**, *11*, e0156438, doi: 10.1371/journal.pone.0156438
35. Frank, P.; Ottoboni, M.A. *The Dose Makes the Poison*, 3rd ed.; Wiley and Sons Inc.: Hoboken, NJ, USA, 2011; p. 213. 35. Damalas, C.A.; Koutroubas, S.D. Farmers' exposure to pesticides: Toxicity types and ways of prevention. *Toxics* **2016**, *4*, 1, doi:10.3390/toxics4010001.
36. Frazier, L.M. Reproductive disorders associated with pesticide exposure. J Agromedicine, 2007, 12(1):27-37. DOI: 10.1300/J096v12n01_04
37. Gaber, S.; Abdel-Latif, S.H. 2012. Effect of education and health locus of control on safe use of pesticides: a cross sectional random study. Journal of Occupational Medicine and Toxicology, (2015) 7:3. https://doi.org/10.1186/1745-6673-7-3
38. García-García, C.R., Parrón, T.; Requena, M.; Alarcón, R.; Tsatsakis, A.M.; Hernández, A.F. Occupational pesticide exposure and adverse health effects at the clinical, hematological and biochemical level. Life, January 2016, 145: 274-283. https://doi.org/10.1016/j.lfs.2015.10.013
39. Gerber, R.; Smit, N.J.; Vuren, J.V.; Nakayama, S.M.M.; Yohannes, Y.B.; Ishizuka, M.; Wepener, V. Bioaccumulation and human health risk assessment of DDT and other organochlorine pesticides in an apex aquatic predator from a premier conservation area. *Sci. Total Environ.* **2016**, *550*, 522–533, doi: 10.1016/j.scitotenv.2016.01.129.
40. Gesesew, H.A.; Woldemichael, K.; Massa, D.; Mwanri, L. Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, Southwest Ethiopia. PLoS One. 2016, 11: e0162527
41. Gordon, H.; Chiri, A.; Abate, Ts. Environmental and economic review of crop protection and pesticide use in Ethiopia. Environmental and Natural Resources Policy and Training Project. United States. Agency for International Development. Bureau for Africa. Office of Sustainable Development. Publisher: Arlington, VA : Winrock International Environmental Alliance, 1995.
42. Hayden, K.M.; Norton, M.C.; Darcey, D.; Ostbye, T.; Zandi, P.P.; Breitner, J.C.S.; Welsh-Bohmer, K.A. Occupational exposure to pesticides increases the risk of incident AD: the Cache County study. Neurology, 2010, 74, 1524–1530
43. Haylamicheal, I.D., Dalvie, M.A. Disposal of obsolete pesticides, the case of Ethiopia. Environ. Int. 2009, 35: 667-673. https://doi.org/10.1016/j.envint.2008.11.004.
44. Hakkola, J.; Hukkanen, J.; Turpeinen, M.; Pelkonen, O. Inhibition and induction of CYP enzymes in humans: an update. Archives of Toxicology 2020, 94:3671-3722. https://doi.org/10.1007/s00204-020-02936-7
45. HCSO. Hungarian Central Statistical Office. The Counties of Hungary. 4 June 2020. Available online: https://www.ksh.hu/regionalatlas_counties (accessed on 24 December 2021).
46. Hernández, A.F.; Parrón, T.; Alarcón, R. Pesticides and asthma. Curr Opin Allergy Clin Immunol, 2011, 11(2):90-96. DOI: 10.1097/ACI.0b013e3283445939
47. Hussen, A.; Westbom, R.; Megersa, N.; Björklund, E. Selective pressurized liquid extraction for multi- residue analysis of organochlorine pesticides in soil. Journal of Chromatography A, June 2007, 1152(1–2):247-253, https://doi.org/10.1016/j.chroma.2007.02.076

48. Hoppin, J.A., Valcin, M., Henneberger, P.K., Kullman, G.J., Umbach, D.M., London, S.J., et al. Pesticide Use And Chronic Bronchitis Among Farmers in The Agricultural Health Study. Am J Ind Med. 2007 50(12): 969-979. doi:10.1002/ajim.20523
49. Ingaramo, P., Alarcón, R., Muñoz-de-Toro, M., Luque, E.H. Are glyphosate and glyphosate-based herbicides endocrine disruptors that alter female fertility? Molecular and Cellular Endocrinology 2020, 518:110934, https://doi.org/10.1016/j.mce.2020.110934
50. Improving Agricultural Extension: A Reference Manual. FAO and the International Program for Agricultural Knowledge System (INTERPAKS), College of Agricultural, Consumer, and Environmental Sciences, University of Illinois at Urbana-Champaign, 1997, United States. Available online: https://www.oerafrica.org (accessed on 25 August 2021)
51. Jackson, E.; Shoemaker, R.; Larian, N.; Cassis, L. Adipose Tissue as a Site of Toxin Accumulation. Compr Physiol. 2017, 7(4): 1085-1135. doi: 10.1002/cphy.c160038
52. Jaga, K.; Dharmani, Ch. Global surveillance of DDT and DDE levels in human tissues. International Journal of Occupational Medicine and Environmental Health, 2003; 16(1): 7-20
53. Jayaraj, R.; Megha, P.; Sreedev, P. Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. Interdiscip Toxicol. 2016; 9(3–4): 90-100. doi: 10.1515/intox-2016-0012
54. Jensen, H.K.; Konradsen, F.; Jørs, E.; Petersen, J.H.; Dalsgaard, A. Pesticide Use and Self-Reported Symptoms of Acute Pesticide Poisoning among Aquatic Farmers in Phnom Penh, Cambodia. Journal of toxicology, 2011, 8, doi:10.1155/2011/639814
55. Jeyaratnam, J. Acute pesticide poisoning: A major global health problem. World health statistics quarterly; 1990, 43(3) : 139-144 .https://apps.who.int/iris/handle/10665/51746
56. Juntarawijit, Ch., Juntarawijit, Y. Association between diabetes and pesticides: a case-control study among Thai farmers. Environ Health Prev Med. 2018, 23(1):3. DOI: 10.1186/s12199-018-0692-5
57. Kamanyire, R.; Karalliedde, L. Organophosphate toxicity and occupational exposure. Occup Med (Lond) 2004; 54:69 75.
58. Kangkhetkron, T.; Juntarawijit, C. Factors Influencing Practice of Pesticide Use and Acute Health Symptoms among Farmers in Nakhon Sawan, Thailand. Int. J. Environ. Res. Public Health 2021, 18, 8803. https://doi.org/10.3390/ijerph18168803
59. Kaur, K.; Kaur, R. Occupational pesticide exposure, impaired DNA repair, and diseases. Indian J Occup Environ Med 2018; 22:74-81
60. Kriesemer, S.K.; Chadha, M.L.; Weinberger, K. Extension Messages on Pesticide Use: A Precondition for Safe Vegetable Production in Jharkhand, India. Biophysical and Socio-Economic Frame Conditions for the Sustainable Management of Natural Resources. Tropentag, 6–8 October **2009**, Hamburg (accessed on 24 August 2021).
61. Laczó, F. Pesticide Use in Hungary. Published by Pesticide Action Network Germany (PAN Germany) in co-operation with Center for Environmental Studies Foundation, CES, 2004
62. Lallas, P.L. The Stockholm Convention on Persistent Organic Pollutants. *Am. J. Int. Law* **2001**, *95*, 692–708.https://doi.org/10.2307/2668517.
63. Latifovic, L.; Beane Freeman, L.E.; Spinelli, J.J.; Pahwa, M.; Kachuri, L.; Blair, A.; et al. Pesticide use and risk of Hodgkin lymphoma: results from the North American Pooled Project (NAPP). Cancer Causes & Control, 2020, 31:583-599. https://doi.org/10.1007/s10552-020-01301-4
64. Lekei, E.E.; Ngowi, A.V.; London, L. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health, 2014, 14:389. http://www.biomedcentral.com/1471-2458/14/389
65. Lee, W.J. , Blair, A., Hoppin, J.A., Lubin, J.H , Rusiecki, J.A., Sandler, D.P. et al. Cancer incidence among pesticide applicators exposed to chlorpyrifos in the Agricultural Health Study. J Natl Cancer Inst 2004 96(23):1781-1789. DOI: 10.1093/jnci/djh324
66. Liu, J.; Schelar, E. Pesticide Exposure and Child Neurodevelopment. Workplace Health Saf. 2012, 60(5): 235-243. doi: 10.3928/21650799-20120426-73
67. MacFarlane, E.; Carey, R.; Keegel, T.; El-Zaemay, S.; Fritschi, L. Dermal Exposure Associated with Occupational End Use of Pesticides and the Role of Protective Measures. Safety and Health at Work September 2013, 4 (3):136-141
68. Maddah, D.; Ghach, W.; Farraj, N.A.; Yehya, M.; Al Khatib, J.,; Alami, N.H. The first community-based intervention to promote safe pesticide use by developing knowledge, attitudes, and practices among Lebanese farmers, Human and Ecological Risk Assessment: An International Journal (2019), DOI: 10.1080/10807039.2019.1688639
69. Mekonen, S.; Ambelu, A.; Negassa, B.; Spanoghe, P. Exposure to DDT and its metabolites from khat (Catha edulis) chewing: Consumers risk assessment from southwestern Ethiopia. *Regul. Toxicol. Pharmacol.* **2017**, *87*, 64–70
70. Mekonen, S.; Argaw, R.; Simanesew, A.; Houbraken, M.; Senaeve, D.; Ambelu, A.; Spanoghe, P. Pesticide residues in drinking water and associated risk to consumers in Ethiopia. Chemosphere, 2016, 162: 252-260
71. Mekonen, S.; Lachat, C.; Ambelub, A.; Steurbaut, W.; Kolsteren, P.; Jacxsens, L.; Wondafrash, M.; Houbraken, M.; Spanogh, P.Risk of DDT residue in maize consumed by infants as complementary diet in southwest Ethiopia. *Sci. Total Environ*. **2015**, *511*,454–460, doi: 10.1016/j.scitotenv.2014.12.087.
72. Mekonnen, S.; Gebremichael, B.; Gela, A. Assessment of Honeybee Colonies and production status linked with the application of Agrochemicals in Ejere District, West Shoa, Oromia, Ethiopia. J Vet Med Res, 2018, 5(8): 1152.

73. Melisie, D.; Damte, T.; Thakur, A.K. Farmers' insecticide use practice and its effect on honeybees foraging on onion flower in Adami Tullu district of Ethiopia. Global Journal of Pests, Diseases and Crop Protection, 2016; 4 (1):139-145.
74. Mengistie, B.T.; Mol, A.P.J.; Oosterveer, P.; Simane, B. Information, motivation and resources: the missing elements in agricultural pesticide policy implementation in Ethiopia. Int. J. Agric. Sustain, 2015, 13, 240–256. https://doi.org/10.1080/14735903. 2014.959330.
75. Mergia, M.T.; Weldemariam, E.D.; Eklo, O.M.; Yimer, G.T. Small-scale Farmer Pesticide Knowledge and Practice and Impacts on the Environment and Human Health in Ethiopia J Health Pollution 2021, 11(30)
76. Mesnage, R.; Antoniou, M.N. Ignoring Adjuvant Toxicity Falsifies the Safety Profile of Commercial Pesticides. Front. Public Health 2018, 5:361. doi: 10.3389/fpubh.2017.00361
77. Mewa EJ, Padmanathanb P, Konradsenc F, Eddlestond M, Change SS, Phillips MR, et al. The global burden of fatal self-poisoning with pesticides 2006-15: systematic review. J Affect Disord. 2017, 219:93–104. Doi: 10.1016/j.jad.2017.05.002
78. Milesi MM, Lorenz V, Durando M, Rossetti MF and Varayoud J. Glyphosate Herbicide: Reproductive Outcomes and Multigenerational Effects. Front. Endocrinol. 2021 12:672532. doi: 10.3389/fendo.2021.672532
79. Mormeta, B.N. Assessment of pesticide hazard related knowledge and practices of agricultural extension workers in selected small-scale horticulture production areas in Ethiopia. J. Agric. Environ. Int. Dev.-JAEID 2019, 113, 5–15, doi:10.12895/jaeid.20191.739.
80. Mormeta, B.N. Assessment of pesticide hazard related knowledge and practices of agricultural extension workers in selected small-scale horticulture production areas in Ethiopia. *J. Agric. Environ. Int. Dev.-JAEID* **2019**, *113*, 5–15, doi:10.12895/jaeid.20191.739
81. Mossie, M.; Meseret, B. A review on the role of extension service for agricultural transformation with particular emphasis on Ethiopia. J. Agric. Econ. Ext. Rural. Dev. 2015, 2, 224–228. ISSN-2360-798X.
82. Msuya, C.P.; Annor-Frempong, F.K.; Magheni, M.N.; Agunga, R.; Igodan, C.; Ladele, A.A.; Huhela, K.; Tselaesele, N.M.; Msatilomo, H.; Chowa, C.; et al. Role of agricultural extension in Africa's development, the importance of extension workers and the need for change. *Int. J. Agric. Ext*. **2017**, *5*, 59–70.
83. Muluneh, A.T; Haileamlak, A.; Tessema, F.; Alemseged, F.; Woldemichael, K.; Asefa, M.; et al. Population based survey of chronic non-communicable diseases at gilgel gibe field research center, southwest Ethiopia. Ethiop J Health Sci. 2012 Aug; 22(S):7-18.
84. Muñoz-Quezada, M.T.; Lucero, B.; Bradman, A.; Baumert, B.; Iglesias, V.; Muñoz, M.P.; Concha, C. Reliability and factorial validity of a questionnaire to assess organophosphate pesticide exposure to agricultural workers in Maule, Chile, International Journal of Environmental Health Research, 2019, 29(1):45-59. DOI: 10.1080/09603123.2018.1508647.
85. Muszyński, P.; Brodowska, M.S.; Paszko, T. Occurrence and transformation of phenoxy acids in aquaticenvironment and photochemical methods of their removal: a review. Environmental Science and Pollution Research 2020, 27:1276–1293. DOI: 10.1007/s11356-019-06510-2
86. Negatu, B.; Dugassa, S.; Mekonnen, Y. Environmental and Health Risks of Pesticide Use in Ethiopia. Journal of Health & Pollution, June 2021, 11(30)
87. Negatu, B.; Dugassa, S.; Mekonnen, Y. Environmental and Health Risks of Pesticide Use in Ethiopia. Journal of Health & Pollution, June 2021, 11(30)
88. 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., February 2016, 60(5): 551–566. doi:10.1093/annhyg/mew004
89. Nesheim, O.N.; Fishel, F.M.; Mossler, M. Toxicity of Pesticides. PI-13; University of Florida (UF), Institute of Food and Agricultural Sciences, Extension: Gainesville, FL, USA, 2014; p. 6
90. Ngowi, A.V.F.; Maeda, D.N.; Partanen, T.J. Knowledge, attitudes and practices (KAP) among agricultural extension workers concerning the reduction of the adverse impact of pesticides in agricultural areas in Tanzania. Med. Lav. 2002, 93, 338–346.
91. Ngowi, A.V.F.; Maeda, D.N.; Partanen, T.J. Knowledge, attitudes and practices (KAP) among agricultural extension workers concerning the reduction of the adverse impact of pesticides in agricultural areas in Tanzania. *Med. Lav.* **2002**, *93*, 338–346.
92. Nigatu, A.W.; Bråtveit, M.; Moen, B.E. Self-reported acute pesticide intoxications in Ethiopia, BMC Public Health, 2016, 16:575, DOI 10.1186/s12889-016-3196-5
93. OECD. OECD Environmental Performance Reviews: Hungary 2018. OECD Publishing, Paris. https://doi.org/10.1787/9789264298613-en
94. Orozco, F.A.; Cole, D.C.; Ibrahim, S.; Wanigaratne, S. Health promotion outcomes associated with a community-based program to reduce pesticide-related risks among small farm households. Health Promotion International (2011) 26 (4). doi:10.1093/heapro/dar006
95. PAN-UK. Hazardous pesticides and health impacts in Africa. Food & Fairness brifing number 6. 2006. Food & Fairness project partners: PAN Africa in Senegal, PAN Germany, Netherlands Society for Nature & Environment
96. Parveen, S.; Nakagoshi, N. An Analysis of Pesticide Use for Rice Pest Management in Bangladesh. Journal of International Development and Cooperation, 2001, 8(1):107-126

97. Pastor, S.; Creus, A.; Xamena, N.; Siffel, C.; Marcos, R. Occupational Exposure to Pesticides and Cytogenetic Damage: Results of a Hungarian Population Study Using the Micronucleus Assay in Lymphocytes and Buccal Cells. Environ. Mol. Mutagen. 2002, 40, 101–109. doi.org/10.1002/em.10100.
98. Rao, P.; Arcury, T.A.; Quandt, S.A.; Doran, A. North Carolina Growers' and Extension Agents' Perceptions of Latino Farmworker Pesticide Exposure. *Hum. Organ. Summer* **2004**, *63*, 151–161, doi:10.17730/humo.63.2. qdyhan8n1ngkf2rk.
99. Remoundou, K.; Brennan, M.; Sacchettini, G.; Panzone, L.; Butler-Ellis, M.C.; Capri, E.; Charistou, A.; Chaideftou, E.; Gerritsen-Ebben, M.G.; Machera, K.; et al. Perceptions of pesticides exposure risks by operators, workers, residents and bystanders in Greece, Italy and the UK. Sci. Total. Environ. 2015, 505, 1082–1092, doi: 10.1016/j.scitotenv.2014.10.099.
100. Remoundou, K.; Brennan, M.; Sacchettini, G.; Panzone, L.; Butler-Ellis, M.C.; Capri, E.; Charistou, A.; Chaideftou, E.; GerritsenEbben, M.G.; Machera, K.; et al. Perceptions of pesticides exposure risks by operators, workers, residents and bystanders in Greece, Italy and the UK. *Sci. Total. Environ.* **2015**, *505*, 1082–1092, doi: 10.1016/j.scitotenv.2014.10.099
101. Ren, X.M.; Kuo, Y.; Blumberg, B. Agrochemicals and obesity. Molecular and Cellular Endocrinology, 2020, 515: 110926. https://doi.org/10.1016/j.mce.2020.110926
102. Rios-Gonzalez, A.; Jansen, K.; Sanchez-Perez, H.J. Pesticide risk perceptions and the differences between farmers and extensionists: Towards a knowledge-in-context model. *Environ. Res*. **2013**, *124*, 43–53, doi: 10.1016/j.envres.2013.03.006
103. Rivera, W.M. Agricultural and Rural Extension Worldwide: Options for Institutional Reform in the Developing Countries; FAO-UN: Rome, Italy, 2001.
104. Rivera, W.M. *Agricultural and Rural Extension Worldwide: Options for Institutional Reform in the Developing Countries*; FAO-UN:Rome, Italy, 2001
105. Rohlman, D.S.; Ismail, A.; Bonner, M.R.; Rasoul, G.A.; Hendy, O.; Dickey, L.O.; et al. Occupational pesticide exposure and symptoms of attention deficit hyperactivity disorder in adolescent pesticide applicators in Egypt. Neurotoxicology, 2019, 74:1-6. DOI: 10.1016/j.neuro.2019.05.002
106. Saleh, J.M.; Man, N.; Lafta, A.H.; Saleh, M.H.; Hassan, S.; Nawi, N.M.; Kshash, B.H. A Review: Training Requirement of Agriculture Extension Officers in Iraq. Asian J. Appl. Sci. 2016, 9, 34–40, doi:10.3923/ajaps.2016.34.40.
107. Sara, A.; Quandt, M.A.; Hernández-Valero, J.G.; Grzywacz,, J.D.; Hovey, M.G.; Thomas A.A. Workplace, Household, and Personal Predictors of Pesticide Exposure for Farmworkers. Environ Health Perspective 2006, 114:943-952.
108. Shah, R. Pesticides and human health in Emerging Contaminants by Aurel Nuro (4th ed). InTechOpen. 2020, Chapter. (ISBN 978-1-83962-419-3). DOI: 10.5772/intechopen.93806
109. Sharafi, K.; Pirsaheb, M.; Maleki, S.; Arfaeinia, H.; Karimyan, K.; Moradi, M.; Safari, Y. Knowledge, attitude and practices of farmers about pesticide use, risks, and wastes; a cross-sectional study (Kermanshah, Iran). *Sci. Total Environ.* **2018**, *15*, 509–517, doi: 10.1016/j.scitotenv.2018.07.132
110. Shiva, V. Who really feeds the world? The failures of agribusiness and the promise of agroecology. Agriculture & Food. Political Science. Publisher, North Atlantic Books, page 55, Berkeley California, 2016
111. Singh, P.; Volger, B.; Gordon, E. *Endosulfan. Encyclopedia of Toxicology*, 3rd ed.; Publisher: Academic Press, London, UK; 2014; pp. 341–343. https://doi.org/10.1016/B978-0-12-386454-3.00141-X.
112. Silberman J, Taylor A. Carbamate Toxicity. [Updated 2022 May 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan
113. Spanoghe, P.; Houbraken, M. Faculty of Bioscience Engineering Department Crop Protection Laboratory of Crop Protection Chemistry. Environmental Impact of Pesticides Practicums, Gent University, 2013-2014, page 15
114. Spiegelman, D.; and Hertzmark, E. Easy SAS calculations for risk or prevalence ratios and differences. Am J Epidemiol. **2005** Aug 1; 162(3):199-200. doi: 10.1093/aje/kwi188.
115. SUN, B., CHEN, Y.G. Advances in the mechanism of paraquat-induced pulmonary injury. European Review for Medical and Pharmacological Sciences. 2016; 20: 1597-1602
116. Stenersen J. Chemical Pesticides: Mode of Action and Toxicology. Boca Raton, Florida: CRC Press; 2004
117. Teklu, B.M.; Hailu, A.; Wiegant, D.A.; Scholten, B.S.; Van den Brink, P.J. Impacts of nutrients and pesticides from small- and large-scale agriculture on the water quality of Lake Ziway, Ethiopia. Environ. Environ Sci Pollut Res, 2018, 25:13207–13216, DOI 10.1007/s11356-016-6714-1
118. Tesfahunegny, W.; Mulualem, G. Impact of pesticides on birds from DDT to current fatality: A Literature Review. *J. Zool. Stud.* **2016**, *3*, 45–56
119. Tessema, R.A. Assessment of the implementation of community-led total sanitation, hygiene, and associated factors in Diretiyara district, Eastern Ethiopia. *PLoS ONE* **2017**, *12*, e0175233.
120. Thomas, S.; Roel, V.; Derk, H.B.; John, W.C.; Hans, Kr.; Christian, L.F. Conceptual model for assessment of dermal exposure. Occup Environ Med; 1999, 56:765–773
121. Thundiyil, J.G.; Stober, J.; Besbelli, N.; Pronczuk, J. Acute pesticide poisoning: a proposed classification tool. Policy and practice. Bulletin of the World Health Organization 2008; 86:205-209.
122. Ungváry, G. Chemical Safety in Hungary-New National Profile: Summary, Budapest, 2006; 12(2):77-131
123. US EPA. Label Review Manual- Chapter 7: Precautionary Statements, Revised July 2014

124.Wagner-Schuman, M., Richardson, J.R., Auinger, P., Braun, JM., Lanphear, B.P., Epstein, J.N., Yolton, K., Froehlich, T.E. Association of pyrethroid pesticide exposure with attention-deficit/hyperactivity disorder in a nationally representative sample of U.S. children. Environmental Health, 2015 14:44. DOI 10.1186/s12940-015-0030-y
125.Wang, B., Tsakiridis, E.E., Zhang, Sh., Llanos, A., Desjardins, E.M. et al. The pesticide chlorpyrifos promotes obesity by inhibiting diet-induced thermogenesis in brown adipose tissue. Nature Communications, 2021; 12 (1) DOI: 10.1038/s41467-021-25384-y
126.Welteji, D. A critical review of rural development policy of Ethiopia: access, utilization and coverage, Agriculture & Food Security, 2018, 7:55. https://doi.org/10.1186/s40066-018-0208-y
127.Wesseling, C.; McConnell, R.; Partanen, T.; Hogstedt, C. Agricultural pesticide use in developing countries: health effects and research needs. International Journal of Health Services, 1997, 27(2):273-308.
WHO and UNEP. (1990) .Public health impact of pesticides used in agriculture .World Health Organization. https://apps.who.int/iris/handle/10665/39772
128.Williams, J.H., Whitehead, Z., Van-Wilpe, E. Paraquat intoxication and associated pathological findings in three dogs in South Africa. Journal of the South African Veterinary Association 2016, 87(1): a1352. http://dx.doi.org/10.4102/ jsava. v87i1.1352
129.World Health Organization & International Programme on Chemical Safety. The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009; World Health Organization: Geneva, Switzerland, 2010; https://apps.who.int/iris/handle/10665/44271 (accessed on 3 April 2021)
130. Yadav AS, Sehrawat G. Evaluation of genetic damage in farmers exposed to pesticide mixtures. Int J Hum Genet 2011; 11:105 9
131. Yohannes, Y.B.; Ikenaka, Y.; Nakayama, S.M.; Ishizuka, M. Organochlorine pesticides in bird species and their prey (fish) from the Ethiopian Rift Valley region, Ethiopia. Environmental Pollution 2014; 192:121-128. https://doi.org/10.1016/j.envpol.2014.05.007
132. Zelelew, D.; Gebrehiwot, H, Bezuyehu, D. Multi residue analysis of pesticides in pre and postharvest wheat grains in Misha Woreda, Hadiya Zone, Ethiopia. Afric J Pure Appl Chem 2018; 12(3):14-24. https://doi.org/10.5897/AJPAC2018.0751
133.Zhao, M.; Ma, J.; Li, M.; Zhang, Y.; Jiang, B.; Zhao, X.; et al. Cytochrome P450 Enzymes and Drug Metabolism in Humans. Int. J. Mol. Sci. 2021, 22:12808. https://doi.org/ 10.3390/ijms222312808

12. APPENDIX

12.1. Appendix 1. Pesticide management survey questionnaire used in Ethiopia and Hungary

Appendix 1.1. Questionnaire on pesticide use, storage, handling, transportation and disposal in Ethiopia

Name of the District: …..................... Sex: M/F Date: ………Questionnaire ID: ……

1. What is your age?

   a. 18-29 ☐ d. 50-59 ☐
   b. 30-39 ☐ e. 60 and above ☐
   c. 40-49 ☐

2. What is your educational status?

   a. Primary (grade 1-8) ☐ d. University BSc ☐
   b. Secondary (grade 9-12) ☐ e. University MSc and above ☐
   c. Diploma (two years college training) ☐

3. What is your current position?

   a. Zonal / district agricultural coordinator ☐ d. Health extension worker ☐
   b. Agricultural extension worker (DAs) ☐ e. Other ☐ Specify: ____________
   c. Agricultural extension worker supervisor ☐

4. Do you know pesticides by name?
   1. Yes ☐ List as many as you can: __________________________________
   0. No ☐

5. Do you know the routes through which pesticides can enter the human body?
   1. Yes ☐ List all the routes of entry: ______________________________
   0. No ☐

6. Do you agree that pesticides are poisonous?
   0= Strongly disagree 4= Strongly agree
   0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

7. Which of the following pesticides are used in your control area? (You can tick more than one option)

Sn	Type of pesticide	Yes	No
1.	Glyphosate (Glyfos, roundup, etc.)	☐	☐
2.	2,4-D	☐	☐
3.	Pendimethalin	☐	☐
4.	Dimethoate	☐	☐
5.	Malathion	☐	☐
6.	Deltamethrin	☐	☐
7.	Diazinon	☐	☐
8.	Endosulfan	☐	☐
9.	Chlorothalonil	☐	☐
10.	Carbaryl	☐	☐
11.	Other ☐ Specify: ________________________________		

8. Do you think that current pesticide distribution, transportation, and storage to the end users is effective?

0 = Not effective at all ... 4 = Very effective

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

9. Do you think that the cost of pesticides used by farmers is high?

0= Very low ... 4 = Very high

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

10. Do you think there is illegal importation of pesticide products from neighboring countries?

1. Yes ☐ Specify where/how: ________________________________

0. No ☐

11. According to your experience, are farmers trained about the health risks of pesticides, proper handling and safe application of pesticide products in your control area?

0= Not at all ... 4 = Very much

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

12. According to your experience, how frequently do farmers use personal protective equipment's such as gloves, foot and eye protection, respirators and full body suits etc during pesticide application in your control area?

0= Never ... 4 = Always

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

13. According to your experience, how do users dispose pesticide residues? (You can tick more than one option)

a. Burning ☐
b. Dumping on open field ☐
c. Throwing it in the toilet/sewage ☐
d. Sell/lend/offer to other farmers ☐
e. Burying ☐
f. Return to waste management site ☐
g. Other ☐ Specify: ________________

14. Do you agree that pesticide residues are likely to be present in food we eat, air we breathe, water we drink and soil in the environment?

0= Strongly disagree 4 = Strongly agree

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

15. Do you agree that the way currently pesticides are applied by users poses risk to their health in your control area?

0= Strongly disagree 4 = Strongly agree

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

16. Have you ever experienced any pesticide poising among farmers in your control area?

1. Yes ☐ Specify where/how: ___________________________________
0. No ☐

Thank you very much for your cooperation!

Appendix 1.2. Kérdőív a növényvédőszerek Magyarországon történő használatáról, tárolásáról, kezeléséről, szállításáról és ártalmatlanításáról

Megye: ….......................... Neme: férfi / nő Dátum: ………………......

Kérdőív azonosító: ………

1. Az Ön életkora:

a. 18-29 ☐
b. 30-39 ☐
c. 40-49 ☐
d. 50-59 ☐
e. 60, vagy afölött ☐

2. Mi az Ön legmagasabb iskolai végzettsége?

a. Általános iskola (1-8. évfolyam) ☐
b. Középiskola (9–12. évfolyam) ☐
c. Felsőfokú szakképzés (egy, vagy kétéves) ☐
d. Egyetemi diploma (BSc) ☐
e. Egyetemi diploma (MSc) vagy doktori (PhD) fokozat ☐

3. Mi az Ön jelenlegi foglalkozása?

a. Megyei mezőgazdasági koordinátor ☐
b. Mezőgazdasági munkavállaló ☐
c. Mezőgazdasági munkát felügyelő ☐
d. Egészségügyi alkalmazott ☐
e. Egyéb (nevezze meg):________

4. Ismer Ön növényvédőszereket név szerint?

1. Igen ☐ Nevezzen meg annyit, amennyit csak tud: ________
0. Nem ☐

5. Ismeri Ön a növényvédőszerek emberi szervezetbe történő bejutásának lehetséges módjait?

1. Igen ☐ Nevezze meg azokat a módokat, amelyek során a növényvédőszerek az emberi szervezetbe juthatnak: __________
0. Nem ☐

6. Egyetért-e Ön azzal, hogy a növényvédőszerek mérgezők?

0= Egyáltalán nem értek egyet 4= Teljes mértékben egyetértek

0. ☐ 1 ☐ 2. ☐ 3. ☐ 4. ☐

7. Az alábbi növényvédőszerek közül melyiket használják az Ön által ellenőrzött területen? (Egynél több választ is megjelölhet!)

Szám	Peszticid típusa	Igen	Nem
1.	Glifozát (Glyfos, Roundup, stb.)	☐	☐
2.	Diklórfenoxi-ecetsav (2,4-D)	☐	☐
3.	Pendimetalin	☐	☐
4.	Dimetoát	☐	☐
5.	Malathion	☐	☐
6.	Deltamethrin	☐	☐
7.	Diazinon	☐	☐
8.	Endoszulfán	☐	☐
9.	Klórthalonil	☐	☐
10.	Karbaril	☐	☐
11.	Egyéb ☐ Nevezzemeg:____________________		

8. Ön szerint a növényvédőszerek forgalmazásának, szállításának és tárolásának jelenlegi módjai hatékonyak a végfelhasználók szempontjából?

0 = Egyáltalán nem hatékony — 4 = Nagyon hatékony

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

9. Ön szerint a mezőgazdasági munkát végzők által használt növényvédőszerek költségesek?

0= Egyáltalán nem költségesek — 4 = Nagyon költségesek

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

10. Az Ön véleménye szerint történik illegális növényvédőszer behozatal a szomszédos országokból?

1. Igen ☐ Amennyiben igen, Ön szerint honnan és milyen módon?

____

0. Nem ☐

11. Az Ön tapasztalatai szerint a mezőgazdasági munkát végzők képzettek a növényvédőszerek egészségi kockázatainak, a szerek megfelelő kezelésének és azok biztonságos felhasználásának szempontjából?

0 = Egyáltalán nem képzettek — 4 = Teljes mértékben képzettek

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

12. Az Ön tapasztalatai szerint milyen gyakran használnak a mezőgazdasági munkát végzők személyi védőfelszereléseket, például kesztyűt, láb- és szemvédő eszközt, maszkot és teljes testet védő felszerelést?

0= Soha — 4 = Mindig

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

13. Az Ön tapasztalatai szerint hogyan ártalmatlanítják a mezőgazdasági munkát végzők a növényvédőszer-maradványokat? (Egynél több választ is megjelölhet!)

a. Égetéssel ☐
b. A szabadba történő kiürítéssel ☐
c. A szennyvízbe történő kiürítéssel ☐
d. Eladással/kölcsönadással/más gazdálkodóknak való felajánlással ☐
e. Föld alá való elásással ☐
f. A hulladékgazdálkodással foglalkozó szervezethez történő eljuttatással ☐
g. Egyéb ☐ Nevezze meg: ____________

14. Egyetért-e Ön azzal, hogy a növényvédőszer-maradványok jelen lehetnek az általunk elfogyasztott élelmiszerekben, a levegőben, az ivóvízben és a talajban, a közvetlen környezetünkben?

0= Egyáltalán nem értek egyet 4 = Teljes mértékben egyetértek

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

15. Egyetért-e Ön azzal, hogy a növényvédőszerek felhasználási módjai a felhasználók által veszélyt jelenthet az egészségükre az Ön által ellenőrzött területen?

0= Egyáltalán nem értek egyet 4 = Teljes mértékben egyetértek

0. ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐

16. Előfordult-e valaha növényvédőszer okozta mérgezés az Ön által ellenőrzött területen dolgozó mezőgazdasági munkát végzők körében?

1. Igen ☐ Amennyiben igen, hol és hogyan: ______________________________

0. Nem ☐

Nagyon köszönjük a kérdőív kitöltésében való részvételét!

12.2. Appendix 2. Pesticide exposure survey questionnaire used in Ethiopia.

This study investigates health risk of occupational pesticide exposure among pesticide applicators and non-applicators residents in rural Ethiopia using a structured survey questionnaire. The questionnaire collects data on socio-economic and demographic factors, knowledge on pesticides, pesticide handling and application practice, risk perception, health effects and confounding factors.

Survey questionnaire for study participants

Name of the district	**Questionnaire ID_____HH ID__**
Name of kebele _______________	Supervisor name and signature _____
Day /Month /Year ______/_____/______	Completed ☐ Not completed ☐

Part I: Socio-demographic characteristics and lifestyle

No	Question	Options	Tick
1	Sex	Male Female	☐ ☐
2	Age in years	Specify: ___________________	
3	Marital status	Married Single Divorced/Separated Widowed	☐ ☐ ☐ ☐
4	How many family members live in your household?	≤3 >3	☐ ☐
5	How many children less than 5 years old live in your household?	No under 5 children ≤ 2 ≥3	☐ ☐ ☐
6	What is the approximate monthly income per person in your family?	Below average: <9000 ETB Above average: ≥9000 ETB	☐ ☐
7	What is your educational status?	Illiterate Primary (gr. 1-8) Secondary (gr. 9-12) Tertiary (gr. 12+)	☐ ☐ ☐ ☐
8	Do you currently smoke tobacco on daily basis, less than daily or not at all? *If the respondent says Not at all, go to Q10.*	Daily Less than daily Not at all	☐ ☐ ☐
9	On average, how many of the following products do you currently smoke each week? *Write # of items/sessions per week for each product.*	Manufactured cigarette: ___________________ Hand-rolled cigarette: ____________________ Waterpipe sessions: ______________________ Others, specify: ___________________	
10	In the past, have you smoked tobacco on daily basis, less than daily, or not at all?	Daily Less than daily Not at all	☐ ☐ ☐
11	How often do you have a drink containing alcohol?	Never	☐ ☐ ☐ ☐ ☐ ☐

	If the respondent says Never, go to Q14.	Monthly or less 2-4 times a month 2- 3 times a week ≥ 4 times a week	
12	How many drinks containing alcohol do you have on a typical day when you are drinking?	1-2 drinks 3-4 drinks 5- 6 drinks 7-9 drinks ≥ 10 drinks	☐ ☐ ☐ ☐ ☐
13	How often do you have six or more drinks on one occasion?	Never Less than monthly Monthly Weekly Almost daily	☐ ☐ ☐ ☐ ☐
14	Do you chew khat (*Catha edulis*) on a daily basis, less than daily, or not at all?	Daily Less than daily Not at all	☐ ☐ ☐
	Part II: Knowledge about pesticides		
15	Do you know any pesticide product by name? *If the respondent says No, go to Q17.*	Yes No	☐ ☐
16	List as many pesticide products as you can: ____		
17	Do you know the routes through which pesticides can enter the human body? *If the respondent says No, go to Q 19.*	Yes No	☐ ☐
18	Specify as many routes as you can: ____		
19	Do you know the major problems of the environment associated with pesticide use? *If the respondent says No, go to Q 21.*	Yes No	☐ ☐
20	Specify as many problems as you can: ____		
21	Do you know any health effects pesticide exposure can induce? *If the respondent says No, go to Q23.*	Yes No	☐ ☐
22	Specify as many health effects as you can: ____		
23	What are your sources of information related to the health risks of pesticides? *Respondent can tick more than one option.*	Health extension workers Agricult. extension workers Model farmers Mass media Pesticide retailers Other, specify: _____________	☐ ☐ ☐ ☐ ☐
	Part III: Risk perception related to pesticide exposure		

		I don't know	1	2	3	4	5
	Respondent should rate the following statements from 1 to 5 as how much they agree with them (1= strongly disagree to 5= strongly agree).						
24	The current pesticide distribution, storage, handling, and utilization system is effective.	☐	☐	☐	☐	☐	☐
25	The way you currently apply pesticides poses risk to your health.	☐	☐	☐	☐	☐	☐
26	Pesticide residues are likely to be present in the food we eat, air we breathe, water we drink and soil in the environment.	☐	☐	☐	☐	☐	☐

27	Use of PPEs, such as gloves, foot, and eye protection, respirators and full body suits, reduces health risk of pesticide exposure.	☐	☐	☐	☐	☐	☐
28	Training about the health effects of pesticides, their proper handling and safe application can reduce health risk of pesticide exposure.	☐	☐	☐	☐	☐	☐
29	Spraying pesticide is an ancestral practice passed down through generations, it does not bring any health problem.	☐	☐	☐	☐	☐	☐
30	Exposure to pesticides can induce life threatening conditions and shorten the life span.	☐	☐	☐	☐	☐	☐
31	I am comfortable with the current spraying practice; I have no risk of pesticide poising.	☐	☐	☐	☐	☐	☐

Part IV: General health

32	Have you taken prescription drugs in the past 12 months? *If the respondent says No, go to Q34.*	Yes No	☐ ☐
33	Name of drug(s): ______________________ Specify drug(s) used for: _______________		
34	Have you ever had any of the following medical conditions? *If respondent says Yes, please ask to indicate the year of diagnosis.*		

Medical conditions	No	Yes	Specify year of diagnosis
Asthma	☐	☐	____________
Diabetes	☐	☐	____________
Cardiovascular disease (e.g. high blood pressure, heart attack, stroke, etc.) → Specify type of disease: ________________	☐	☐	____________
Kidney disease → Specify type of disease: ______________	☐	☐	____________
Liver disease → Specify type of disease: _______________	☐	☐	____________
Cancer → Specify type of disease: ___________________	☐	☐	____________
Other chronic condition → Specify disease: _______________			____________

Part V: Experienced symptoms

35 How often have you experienced the following symptoms in recent months?

Respondent should indicate how often in recent months they have experienced a particular symptom.	Always	Often	Sometimes	Seldom	Never
Skin irritation	☐	☐	☐	☐	☐
Skin rushes	☐	☐	☐	☐	☐
Eye irritation	☐	☐	☐	☐	☐
Blurred vision	☐	☐	☐	☐	☐
Chest pain	☐	☐	☐	☐	☐
Shortness of breath	☐	☐	☐	☐	☐
Cough	☐	☐	☐	☐	☐

	Abdominal pain	☐	☐	☐	☐	☐
	Nausea and vomiting	☐	☐	☐	☐	☐
	Diarrhea	☐	☐	☐	☐	☐
	Poor appetite	☐	☐	☐	☐	☐
	Fatigue	☐	☐	☐	☐	☐
	Difficulty to concentrate	☐	☐	☐	☐	☐
	Forgetfulness	☐	☐	☐	☐	☐
	Dizziness	☐	☐	☐	☐	☐
	Headache	☐	☐	☐	☐	☐
	Muscle cramps	☐	☐	☐	☐	☐
	Numbness in the arms or legs	☐	☐	☐	☐	☐

36	Have you ever experienced any health effect presumably related to pesticide exposure/poisoning?	Yes No	☐ ☐
37	Have you ever encountered any health consequences of pesticide exposure/poising among your family members?	Yes No	☐ ☐
	Part VI: Pesticide use and exposure		
38	Have you been exposed to harmful chemicals in your work or at home? *If the respondent says No, go to Q 40.*	Yes No	☐ ☐
39	Please specify the chemical(s) and exposure period		
	Specify the chemical	For how many years exposed	
	Pesticide → Specify: ___________________________________	____________ ____________	
	Organic solvent → Specify: ______________________________	____________ ____________	
	Others → Specify: _____________________________________	____________	
40	Do you currently use pesticides in your farmland? *If the respondent says No, the questionnaire ends here.* ***Thank you very much for your cooperation!***	Yes No	☐ ☐
41	Specify type of pesticides typically used: _________________________________		
42	How would you rate the toxicity of the pesticide product(s) currently applied?	Highly toxic Slightly toxic Not toxic	☐ ☐ ☐
43	Do you have a pesticide applicator license?	Yes No	☐ ☐
44	For how many years have you used pesticides in your farmland?	≤1years 1-5 years 5-9 years Over 10 years	☐ ☐ ☐ ☐
45	On average, how long time does a pesticide application take?	Minutes: _________	
46	How many times do you apply pesticides in a month?	Number: _________	
47	In the past 5 years, have you used a decreasing, increasing or unchanged amount of pesticide products in your farmland?	Decreasing Increasing Constant	☐ ☐ ☐

48	Which application mode do you use to apply pesticides? *Respondent can select more than one option.*	Pressurized hand sprayer Manual backpack sprayer Tractor operated sprayer	☐ ☐ ☐
49	How do you mix pesticides?	With bare hands With a stick With hands wearing gloves With a stick wearing gloves	☐ ☐ ☐ ☐
50	Do you wash the sprayer tank after the application?	Yes No	☐ ☐
51	Have you faced any incidents of splash or spill of pesticide droplets during mixing, application and tank wash?	Yes No	☐ ☐
52	Is the sprayer tank maintained regularly?	Yes No	☐ ☐
53	Where do you store the pesticides before application?	In secured warehouse In the house yard In the house	☐ ☐ ☐
54	How do you dispose off the leftover pesticide? *Respondent can select more than one option.*	Burn Burry Dump on open field Sell/offer to other farmers Return to waste management site. Other, specify: ___________________	☐ ☐ ☐ ☐ ☐
55	Where do you put the used empty containers? *Respondents can select more than one option.*	Burn Burry Dump on open field Use for storage of food items. Use for storage of water. Use for storage of other pesticides. Other, specify: __________________	☐ ☐ ☐ ☐ ☐ ☐
56	Which of the following practices do you do during spraying pesticides? *Respondent can select more than one option.*	Chew khat Drink water, eat food. Smoke cigarette None	☐ ☐ ☐ ☐
	Part VII: Preventive measures		
57	Are you trained on the health risks of pesticides, pesticide use, management & application?	Yes No	☐ ☐
58	During mixing, loading & application, do you read and/or follow the label instructions on pesticide containers?	Yes No	☐ ☐
59	What measure have you taken when you experienced a symptom presumably due to pesticide exposure/poisoning? *Respondent can select more than one option.*	Visited health facility. Used home-based care (drink milk, etc.) Did nothing Other, specify: ____________________	☐ ☐ ☐
60	Do you use any preventive measures during pesticide handling and application? *If the respondent says No, go to Q 62.*	Yes No	☐ ☐
61	How often do you use the following personal protective equipment during handling and applying a pesticide product?		

	Respondent should indicate how often they use personal protective equipment.	Always	Sometimes	Never	
	Face mask	☐	☐	☐	
	Respirator	☐	☐	☐	
	Goggles or safety glasses	☐	☐	☐	
	Gloves	☐	☐	☐	
	Rubber boots	☐	☐	☐	
	Coveralls	☐	☐	☐	
62	Do you use any preventive measure other than personal protective equipment during handling and applying a pesticide product? *If no, go to Q64*			Yes No	☐ ☐
63	Specify preventive measure: ____				
64	What are the main reasons for not using or rarely using preventive measures?	Not important Very expensive Not available to buy. Not comfortable I do not care. Other, specify: ______________			☐ ☐ ☐ ☐ ☐
65	Do you change your clothes after the application?	Yes No			☐ ☐
66	Do you take a shower immediately after finishing spraying?	Always Sometimes Not at all			☐ ☐ ☐

Thank you very much for your cooperation!

13.LIST OF PUBLICATIONS

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Registry number: DEENK/490/2022.PL
Subject: PhD Publication List

Candidate: Roba Argaw Tessema
Doctoral School: Doctoral School of Health Sciences

List of publications related to the dissertation

1. **Tessema, R. A.**, Nagy, K., Ádám, B.: Occupational and environmental pesticide exposure and associated health risks among pesticide applicators and non-applicator residents in rural Ethiopia.
   Front. Public Health. 10, 1-18, 2022.
   DOI: http://dx.doi.org/10.3389/fpubh.2022.1017189
   IF: 6.461 (2021)
2. **Tessema, R. A.**, Nagy, K., Ádám, B.: Pesticide Use, Perceived Health Risks and Management in Ethiopia and in Hungary: a Comparative Analysis.
   Int. J. Environ. Res. Public Health. 18 (19), 1-15, 2021.
   DOI: http://dx.doi.org/10.3390/ijerph181910431
   IF: 4.614

List of other publications

3. **Tessema, R. A.**, Alemu, B. M.: Adequacy of Improved Sources of Drinking Water, Sanitation, and Hygiene Practice for the Reduction of Diarrheal Disease Among People Living with HIV/AIDS, Harar Region, Ethiopia.
   HIV/AIDS. 13, 1-11, 2021.
   DOI: https://doi.org/10.2147/HIV.S286976
4. Nagy, K., **Tessema, R. A.**, Szász, I., Smeirat, T., Al Rajo, A., Ádám, B.: Micronucleus Formation Induced by Glyphosate and Glyphosate-Based Herbicides in Human Peripheral White Blood Cells.
   Front. Public Health. 9, 1-12, 2021.
   DOI: http://dx.doi.org/10.3389/fpubh.2021.639143
   IF: 6.461

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

5. Nagy, K., **Tessema, R. A.**, Budnik, L. T., Ádám, B.: Comparative cyto- and genotoxicity assessment of glyphosate and glyphosate-based herbicides in human peripheral white blood cells.
Environ. Res. 179, 1-7, 2019.
DOI: http://dx.doi.org/10.1016/j.envres.2019.108851
IF: 5.715

6. Getachew, B., Mengistie, B., Mesfin, F., **Tessema, R. A.**: Factors associated with acute diarrhea among children aged 0-59 months in Harar town, eastern Ethiopia.
EAJHBS. 2 (1), 26-35, 2018.

7. **Tessema, R. A.**: Assessment of the implementation of community-led total sanitation, hygiene, and associated factors in Diretiyara district, Eastern Ethiopia.
PLoS One. 12 (4), 1-11, 2017.
DOI: http://dx.doi.org/10.1371/journal. pone.0175233
IF: 2.766

8. Mekonen, S., **Tessema, R. A.**, Simanesew, A., Houbraken, M., Senaeve, D., Ambelu, A., Spanoghe, P.: Pesticide residues in drinking water and associated risk to consumers in Ethiopia.
Chemosphere. 162, 252-260, 2016.
DOI: http://dx.doi.org/10.1016/j.chemosphere.2016.07.096
IF: 4.208

9. **Tessema, R. A.**, Seyoum, B., Egata, G.: Influencing preventive behavior with regard to HIV/AIDS among the Police Force of Harari Region, Eastern Ethiopia, 2011.
Ethiop. J. Health. Dev. 26 (1), 3-8, 2012.

Total IF of journals (all publications): 30,225
Total IF of journals (publications related to the dissertation): 11,075

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

07 December, 2022