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Occupational and Environmental Pesticide Exposure and Associated Health Risks in Ethiopia

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INTRODUCTION

Occupational and non-occupational pesticide exposure

Pesticides are indispensable in agriculture and food security by increasing the yields of crops production 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. The main routes of exposure are dermal contact, inhalation, and oral ingestion. Dermal exposure of intact skin in an occupational setting 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. 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. 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. 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 or even eliminating 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, and disposal). In Ethiopia, chemical pesticide consumption experienced an almost threefold increase over the previous decade from 1440 in 2001 to 4586 in 2013, and the rate of pesticide use in Ethiopia is 0.33kg/ha. Hungary became a net importer of pesticides by the 21st century, and the rate of pesticide use is 1.5 kg/ha.

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. The characteristics of certain pesticides, such as 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. Dietary exposure, water contamination, indoor and outdoor airborne exposure at the residence, dermal exposure, and dust ingestion specifically among children are the main exposure pathways. In addition, residents may experience pesticide exposure

through take-home agricultural drift, and by residential pesticide use. These routes include take-home exposure from the transfer of pesticides on skin, clothes, and shoes of farmworkers to the family home, agricultural drift exposure from living near fields where pesticides are applied, and residential use of pesticides against insects, termites, fleas, and weeds in and around the home.

Acute and chronic health effects of pesticides

Acute pesticide poisoning is a substantial problem in low and middle-income countries, mainly because of unsafe pesticide application and poor 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. 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. 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. The health effects of pesticide exposure depend on the nature of the pesticide, route of exposure, frequency, duration, intensity of exposure, and individual susceptibility. A recent review of scientific literature and WHO mortality data indicated that about 385 million cases of unintentional acute pesticide poisoning (UAPP) occur globally each year, with around 11,000 fatalities. A steep increase from 25 million cases estimated in 1990. Based on the worldwide farming population of about 860 million, 44% of farmers are poisoned by pesticides every year. References to non-fatal UAPP, the highest estimate of UAPP cases was observed in southern and south-eastern Asia, followed by east Africa, where Ethiopia is situated. Pesticide self-poisoning accounted for 14-20% of global suicides leading to 110,000-168,000 deaths annually. The high frequency of intentional pesticide self-poisoning can partly be attributed to the poor management system of pesticides 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.

Acute pesticide poisoning can cause a wide range of symptoms in adults and children. Pesticides can induce neurotoxic effects, such as headaches, dizziness, confusion, restlessness, muscle twitching, slurred speech, unconsciousness; digestive system effects, such as burning sensation in mouth and throat, excessive salivation, nausea, vomiting, abdominal pain, diarrhea; respiratory effects, such as cough, chest pain and tightness, difficulty with breathing, wheezing; dermatological effects, such as irritation, burning sensation, excessive sweating; and eye effects, such as itching, burning sensation, watering, blurred vision, among others.

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. Studies in Ethiopia indicated that high quantity of pesticide residues are found in drinking water, contaminated soil and food, 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. 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. Evidence indicate that pesticide exposures can induce a large scale of chronic human health effects, such as Alzheimer's disease, Parkinson's disease, attention deficit and hyperactivity disorder, autism, asthma, bronchitis, obesity, diabetes, infertility and birth defects, and cancers. Individuals exposed to pesticides are at a greater risk to develop various malignant diseases, including non-Hodgkin lymphoma (NHL), leukemia, brain tumors, and cancers of the breast, prostate, lung, stomach, colon, liver, and urinary bladder. 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". Generally, 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. 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.

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.

MATERIALS AND METHODS

Study design, study area and source population

A community-based cross-sectional field study was conducted between 2019 and 2021 in Ethiopia and Hungary. In Ethiopia, six districts, namely, Karsa, Haramaya, Kombolcha, Babile, Diretiyara and Sofi districts, were selected out of 27 districts in the east Hararge zone and in the Harari region for extension officer's study to investigate pesticide use, perceived health risks and management by a questionnaire survey conducted from 17 July to 24 August 2019. In Hungary, 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 were involved in the study. Data were collected through an interactive online survey platform from 16 September to 10 December 2020 in Hungary. A total of 2462 plant doctors in the fourteen included areas geographically representative for Hungary and 754 agricultural extension workers in the six selected districts in Ethiopia served as the source population. Based on our previous study recommendations, especially for Ethiopia, a further community-based investigative questionnaire survey was conducted in Ethiopia from 26 April to 31 August 2021. For this study, three districts, namely Haramaya, Karsa, and Kombolcha, were selected based on the extent of pesticide use and agricultural activities. A total of 15,908 households in ten selected kebeles of three districts served as the source population.

Sampling

In Ethiopia, the probability proportional to size (PPS) sampling and systematic random sampling techniques were used to select extension officers in the study population. In Hungary, a web-based survey using the Google Forms platform was distributed to all eligible plant doctors due to the onset of the COVID-19 pandemic. A total of 326 study participants were involved in the study (234 from Ethiopia and 92 from Hungary). For pesticide exposure survey in Ethiopia, a total of 1073 individuals were involved (740 applicators and 268 residents). For the pesticide exposure survey in Ethiopia, a multistage sampling technique was used to select districts, kebeles, households, applicators and residents. Finally, a total of 1073 individuals were involved (740 applicators and 268 residents).

Statistical analysis

In addition to descriptive statistics, generalized leaner models, binary logistic regression (BLR), ordinal logistic regression (OLR), and log-binomial regression (LBR) were used and adjusted to control for confounding factors and ascertain the independent predictors of the outcome variables accordingly. Unadjusted (crude) odds ratios (COR)/prevalence ratios (CPR) and confounder-adjusted odds ratios

(AOR)/prevalence ratios (APR) were calculated to investigate the strength of association between outcome and explanatory variables. The significance of statistical associations was assured using odds and prevalence ratios with 95% confidence interval (CI) and p-values. Statistical significance was accepted at 5% level.

RESULTS

Pesticide management reported by officers in Ethiopia and Hungary

A total of 326 respondents (234 from Ethiopia and 92 from Hungary) have participated in the study. The majority (78%) of the respondents were male and most (43%) of them were 30 to 39 years old with a mean age of 38.4 (±9.5 SD) years. A considerably higher proportion of the Hungarian participants belonged to the older 50-59 years age group (30% vs. 8%). On education, 87% of the Hungarian and 66% of the Ethiopian respondents had university degrees (BSc and above).

Insecticides, herbicides, and fungicides were the most frequently reported types of pesticides used by agricultural workers in the study areas. The pesticides most frequently reported by Ethiopian officers were Malathion (85%), 2, 4-D (78%) and Diazinon (59%), while Glyphosate (97%), Deltamethrin (74%) and Pendimethalin (66%) were mainly reported by Hungarian officers. According to the WHO classification, 70% of pesticides reported from Ethiopia and 60% reported from Hungary were moderately hazardous (WHO class II). Based on 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

The study indicated that the Hungarian officers had better knowledge about pesticide products (92%) and routes of exposure (92%) than Ethiopian officers (66% and 58%, respectively), but less likely agreed that pesticides are toxic (51%), cause environmental pollution (61%) and use of pesticides carries risk for applicators (49%) than Ethiopian colleagues (74%, 82%, and 77%, respectively). In both countries, the majority of officers agreed that pesticides are extremely expensive.

Fifty-seven percent of Hungarian and 14% of Ethiopian officers thought that the pesticide management system was effective in their service areas; however, 83% of Hungarian and 46% of Ethiopian respondents reported illegal importation of pesticides from neighboring countries. Considerably more Ethiopian officers thought that farmers were rarely trained about the health risks of pesticides (81%), rarely used personal protective equipment (76%), and more often experienced pesticide poisoning in their service area (41%) than the Hungarian responders (14%, 16%, and 7%, respectively). Regarding the pesticide residues disposal system, the majority (80%) of the Hungarian respondents reported that agricultural workers returned the pesticide residues to a waste management site while most (44%) of the Ethiopian respondents reported that applicators stored pesticide residues at home for later use. In both study areas, a high proportion of the

respondents testified that agricultural workers disposed pesticide residues improperly, though the situation was worse in Ethiopia.

Nationality, sex, age, and education of respondents were used as potential factors (explanatory variables) determining knowledge, attitude, and practice related to pesticides (outcome variables). Nationality was found to be the strongest factor that significantly correlated with all aspects of knowledge, attitude and practice except the opinion on the cost of pesticides. The knowledge about routes of pesticide exposure was found to be statistically significantly positively associated with the respondents' educational status (β=0.49, SE=0.22, $p<0.026$), indicating that more educated officers are more likely to have good knowledge about the routes of pesticide exposure. The officers' attitude toward pesticide toxicity, opinion on the effectiveness of the pesticide management system were significantly positively, and their opinion on the cost of pesticide products were significantly negatively associated with the respondents' gender (β=1.29, SE=0.29, $p<0.001$; β=0.83, SE=0.27, $p<0.002$; and β=−0.58, SE=0.27, $p<0.033$, respectively), indicating that female officers are more likely to perceive that pesticides are toxic and the pesticide management system is effective but less likely to think that the cost of pesticide products is too high. Age had not shown a statistically significant association with any aspects of knowledge, attitude and practice related to pesticides. After controlling for sex, age, and education, nationality remained a significant independent predictor of all the ten aspects of knowledge, attitude, and practice related to pesticides, indicating that the explanatory power of nationality is very strong. We found that Hungarian officers were less likely to think that pesticides are toxic (AOR=0.55 (0.32–0.94), *p<0.05*), cause environmental pollution (AOR=0.47 (0.27–0.82), *p<0.01*), and perceived less health risk of pesticide use among farmers (AOR=0.46 (0.27–0.80), *p<0.01*). Contrary, Hungarian respondents were over five times more likely to have good knowledge about pesticide products (AOR=5.93 (2.42–14.55), *p<0.001*) and routes of pesticide exposure (AOR=5.78 (2.41–13.85), *p<0.001*) compared to their counterparts. Conversely, the opinions of the officers in the two study areas were not significantly different about the cost of pesticide products. Regarding practice, Hungarian officers were over 10 times more likely to deem the pesticide management system effective (AOR=10.23 (5.68–18.46), *p<0.001*), but over four times more likely to report illegal import of pesticide products from neighboring countries compared to their Ethiopian counterparts (AOR=4.23 (2.16–8.31), *p<0.001*). Hungarian officers were over 20 times more likely to think that farmers are well trained about the health risks of pesticides (AOR=20.74 (10.61–40.57), *p<0.001*), and 9 times more likely to report that farmers often use personal protective equipment (AOR=8.95(4.94–16.28), *p<0.001*). Hungarian officers were 87% less likely to experience pesticide poisoning in the past in their service areas than Ethiopian colleagues (AOR=0.13 (0.05–0.33), *p<0.001*).

Pesticide exposure among applicators and residents in Ethiopia

In this study, a total of 1073 participants (803 applicators and 270 residents) were contacted, and all the contacted eligible persons responded, which gives a 100% response and participation rate. The majority (93% for applicators; 83% for residents) of the respondents were male. Thirty- and thirty-four percent of the respondent's ages ranged between 40-49 years, with the mean age of 42 (±10.12 SD) and 41 (±10.18 SD) years for applicators and residents, respectively. Ninety-one and 85 percent 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 currently cigarette smokers, consumed alcohol 2-4 times a month and chewed khat daily, respectively.

Based on the WHO classification of pesticides by hazardousness (LD_{50}), 59%, 35%, and 6% of reported 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. Insecticides (53%), herbicides (23.5%), and fungicides (23.5%) were the most frequently reported pesticides exposing applicators and residents in the study area. Glyphosate (40%), Malathion (35%), and Mancozeb (2.5%) were the most frequently reported active ingredients exposing applicators. Based on the IARC classification, 25%, 19% and 56% of reported pesticide products are probably carcinogen to human (2A), possibly carcinogen to human (2B) and not classifiable as to its carcinogenicity to human (3), respectively. 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 6.1%), and gasoline (9.1% and 12.9%) were organic chemical that exposed 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.

In this study, all applicators used manual backpack sprayers, and none of them had application licenses. Sixty-nine percent and 80% of the respondents reported that leftover pesticide residues were sold/offered to other fellow farmers or disposed on an open field, respectively. A significant proportion of the respondents practice risky behaviors, either chewing khat (56%), smoking cigarette (45%), drinking water or eating food (35%) during spraying pesticides.

This study indicates that applicators have better knowledge about pesticide products (75% had good overall knowledge, of whom 93.5% cited at least one pesticide product) and routes of exposure (79%) than residents (23% and 30%, respectively). A significantly higher proportion of applicators were knowledgeable about health effects induced by pesticide exposure (79%) than residents (34%). In multivariate analysis, knowledge of pesticide products (APR=1.43(1.26-1.62), $p<0.001$), routes of pesticide exposure (APR=1.37(1.22-1.55), $p<0.001$), environmental problems induced by pesticide use (APR=1.33(1.19-1.51),

p<0.001), health effects induced by pesticide exposure (APR=1.33(1.18-1.50), *p<0.001*) and overall knowledge (APR=1.54(1.36-1.75), *p<0.001*) was significantly more advanced among applicators. Perceived health risk of pesticides (APR=1.08(1.01-1.16), p<0.05), positive attitude to PPE use in reducing the health risk of pesticide exposure (APR=1.08(1.01-1.16), *p<0.05*), but also being comfortable with current pesticide spraying practice and perceiving no own risk of pesticide poisoning (APR=1.11(1.01-1.22), *p<0.05*) were significantly more frequently reported by applicators.

Inhalation and dermal contact were the most frequently reported routes of pesticide exposure by applicators (70% vs 61%) and residents (28% vs 30%), respectively; and applicators' knowledge about all routes was 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*). Water pollution was the most often reported major pesticide-related environmental health problem by both applicators and residents, and all relevant environmental problems were significantly better known among applicators. Asthma and cancer were the most frequently named pesticide-related health effects by applicators and residents, respectively. Applicators were more knowledgeable about four health effects including the most important ones (asthma, cancer, diarrhea and allergy).

Asthma (12.3%, 11.5%), diabetes (4.6%, 10.4%) and high blood pressure (10.3, 15.2%) were the diagnosed medical conditions among applicators and residents in the study areas, respectively. Prescribed drug use in the past 12 months was significantly more frequent among applicators (APR=1.14(1.00-1.30), *p<0.05*). Significantly more applicators (36%) experienced health effects presumably related to pesticide exposure than residents (15%) (APR=1.15(1.01-1.32), *p<0.05*), and they also reported pesticide exposure-affected family members more frequently (31% vs 26%, respectively), although without statistical significance. 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*) were significantly more likely reported by applicators than by their counterparts. On the contrary, 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 reported by residents.

In multivariate analysis, perceived toxicity of currently applied 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 application (APR=1.29(1.13-1.46), *p<0.001*), occurrence 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. In the total study population, health effects were 17% more frequently experienced among those who reported exposure to harmful chemicals at work or at home (CPR=1.17(1.02-1.33), *p<0.05*), but the association disappeared after adjustment for potential confounders. On the other hand, we analyzed the lifestyle variables, including

smoking cigarettes, drinking alcohol, and khat consumption, to see the extent of their association with experienced health effects among applicators and non-applicator residents. But neither showed a statistically significant association with experienced health effects. Hence, in this study, the contribution of these lifestyle factors to the development of health effects may be minimal. Moreover, experiencing health effects was not significantly associated with any preventive practices, except that it was positively correlated with using home-based care when experiencing a symptom presumably due to pesticide exposure (APR=1.13 (1.00-1.28), $p<0.05$).

Ninety-five percent (764) and 76% (610) of the responding applicators acquired information about the health risks of pesticides from agricultural health extension workers, respectively. Fifty-eight percent of the applicators attended training on the health risks and use of pesticides, and 50% of them reported that they followed the label instructions found on pesticide containers. Fifty-four percent and 53% of the respondents reported changing their clothes after the application and taking a shower immediately after spraying, respectively. Being very expensive (53%) or unavailability in the local market (47%) were the main reasons for not or rarely using preventive measures in this study population. All the applicators reported that they sometimes use safety glasses (goggles). Use of face mask (APR=1.12(1.00-1.25), $p<0.05$) and visiting health facility when experiencing a symptom presumably due to pesticide exposure (APR=1.19(1.06-1.35), $p<0.01$) were significantly positively correlated with attending training on the health risks and use of pesticides. Use of respirators (APR=0.71(0.62-0.81), $p<0.001$), gloves (APR=0.89(0.80-0.99), $p<0.05$), safety shoes (APR=0.76(0.67-0.87), $p<0.001$) and use of home-based care after experiencing a symptom presumably due to pesticide exposure (APR=0.90(0.79-0.99), $p<0.05$) showed a significant negative correlation with training.

DISCUSSIONS

Pesticide management reported by officers in Ethiopia and Hungary

Based on the study findings, a clear difference was observed in all aspect of knowledge, attitude, and experienced practice of using pesticides between Ethiopian and Hungarian officers responsible for safe handling of these agrochemicals. A good level of knowledge of and risk attitude towards pesticide products among officers responsible for occupational safety and environmental health are vital for providing appropriate advice to reduce human health risks from inappropriate pesticide application among farmers.

Insecticide products were more frequently reported by officers to be used than herbicides and fungicides at a ratio of 7:2:1 and 4:3:3 in Ethiopia and in Hungary, respectively. According to the WHO hazard classification of pesticides, many reported pesticides pose 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). Seventy percent of pesticide products reported from Ethiopia and 60% reported from Hungary were moderately hazardous (WHO class II). Pendimethalin, Epoxiconazole, and Tetraconazole were reported only by Hungarian, while Malathion, Sevin, and DDT only by Ethiopian officers. Besides acute risks, some reported pesticides have a tendency to bioaccumulate in the food chain (e.g., Deltamethrin, DDT, and Endosulfan) posing chronic health risks from long-term low-dose exposure. The toxic and persistent organic pollutant organochlorine pesticide products, like DDT and Endosulfan, were reported from Ethiopia, Endosulfan even from Hungary, which had already been banned in most countries worldwide. In Ethiopia,

Compared to Hungarian officers, the lower levels of knowledge about pesticide products and routes of pesticide exposure among Ethiopian extension workers impairs the safe use of pesticides by farmers in Ethiopia and negatively influences the adoption of self-protective behaviors. However, compared to the study done by Mormeta in the central part of Ethiopia, where only 33% of the extension workers perceived a good pesticide hazard related knowledge, our result (66%) shows a promising improvement. Nevertheless, more effort should be in place to address the knowledge deficit of extension workers and in that way minimize the greater risk and vulnerability to the negative effects of pesticide exposure among Ethiopian applicators.

According to our findings, a substantial proportion of officers lessened the danger of pesticides; only almost half (51%) of the Hungarian and nearly three-fourths (74%) of the Ethiopian officers agreed that pesticides are toxic. 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, the inherent poisonous nature of pesticides should not be forgotten. This triggers the necessity of intensive in-depth education and regular in-service training and capacity building, because this misperception about

the inherent toxicity of a pesticide influences the extent of decisions making to control risks and design appropriate interventions, and the amount and the quality of safety training and information they offer to the farmers.

In Hungary, the pesticide distribution, transportation, and storage system were deemed quite effective (74%), the policy coverage and the law enforcement on occupational and environmental health is much stricter, and the efforts made to govern the process seem well organized; however, a substantial proportion (83%) of officers reported that there is a practice of unregistered import of pesticide products from neighboring countries. Hence, this gives a signal that the current pesticide management system needs to be evaluated and strengthened. On the other hand, in Ethiopia, the pesticide management system appeared to be ineffective (56%). Although the policy coverage is sufficient, the law enforcement on occupational and environmental health is poor, and the efforts made to govern the process are not well organized. The Ministry of Agriculture was found to be the largest pesticide distributor to farmers in Ethiopia; however, a considerable proportion of the respondents (46%) reported the practice of import of unregistered and illegal pesticide products from neighboring countries. The findings from both study areas indicate that there is a possibility for users to buy uncontrolled pesticide products directly from illegal sources, probably at a lower cost.

A greater proportion of Hungarian officers thought that the way how currently pesticides are applied by users' poses less risk to their health, and pesticide residues are less likely to be present in food, air, water, and soil in the environment than their Ethiopian counterparts. A high proportion of Hungarian officers thought that farmers are fully trained about the health risks of pesticides and used the full set of necessary personal protective equipment during pesticide application. This may be the reason why Hungarian officers claimed lower health risk of pesticide use among farmers, as they thought that the preventive measures were good and the pesticide management system effective in their control area, since the health risk of pesticides is determined by the combination of toxicity and exposure conditions.

A significant proportion of Ethiopian officers reported that they experienced pesticide-related poisoning and illnesses among farmers at some point in the past in their service area. This finding is clearly supported by the unsafe use of pesticides, poor utilization of PPE, inadequate training of farmers and officers, and signifies that the risk-awareness towards pesticides is high but preventive practices are still insufficient.

Eighty percent of officers in Hungary reported that farmers returned leftover pesticide products to waste management sites as the dominant method of disposal. This finding is promising and acknowledges the effort made by the sector, while a significant proportion of Ethiopian officers (44%) reported that farmers stored leftover pesticide residues at home for future use and/or offered to other farmers (33%), probably because their limited financial capacity. This practice may not only subject the farmers to high risk of pesticide exposure, but, by take-home pathways, also increase the risk of non-occupational exposure among

family members, neighbors, and bystanders, as well as of the contamination of environmental compartments (air, water, soil, and food).

Pesticide exposure among applicators and residents in Ethiopia

Insecticide, herbicide, and fungicide products were reported to be used frequently by applicators at a ratio of 9:4:4. Based on the WHO hazard classification of pesticides, 59% and 35% of reportedly used pesticide products are moderately and slightly hazardous, respectively. Based on the IARC classification, 25% and 19% of reported pesticide products are probably (Group 2A, e.g., Glyphosate, Malathion, Diazinon, and DDT) and possibly (Group 2B, e.g., 2, 4-D, Cypermethrine, and Chlorothalonil) carcinogenic to humans, respectively. In addition to acute health risks, some reported pesticides might tend to be persistent in the environment and bioaccumulate in the food chain (e.g., Deltamethrin, DDT, Endosulfan, and Cypermethrine) and pose chronic health risks. Use of the toxic and persistent organochlorine pesticides, that had already been banned in most countries worldwide, were reported from the study area.

Applicators in this study most frequently indicated that inhalation, water contamination, and asthma were the most important route of exposure, the major problem of the environment associated with pesticide use, and the most frequently reported health effect pesticide exposure can induce, respectively. Regular training and raising awareness of applicators about pesticide routes of exposure are essential since uptake through dermal exposure can also be high in occupational settings. The overall knowledge about pesticide hazards was significantly higher among applicators than residents, which may be attributed to the fact that applicators more regularly deal with pesticides and have a higher opportunity to get training from different sources than residents. Our study revealed a higher level of knowledge than previous studies done by Mequanint, Mergia and Endalew but similar findings investigated by Mengistie et al, and Gesesew et al in Ethiopia, and Lekei et al, in Tanzania. However, having good knowledge of pesticide hazards doesn't necessarily translate into best practices of pesticide handling and adequate use of preventive measures. Hence, continuous monitoring and evaluation of application practice during field spraying are crucial, because a significant proportion of study participants had a low level of education but usually well materialize their knowledge into practice and adopt protective behaviors through learning by doing in the field.

In this study, applicators reported a statistically significantly higher mean score on many attributes of attitude than residents. For instance, attitude related to the perceived health risks of pesticide use and their consequences, and use of PPEs in reducing the health risk of pesticide exposure showed a significantly higher mean score among applicators. In addition, a significant proportion of applicators thought that exposure to pesticides might induce life-threatening conditions. However, a substantial percentage of them reported that they are comfortable with the existing spraying practice. This inconsistency in perception

gave an indication that the applicators did not show a readiness or willingness to change their present pesticide handling practices. Evidence-based interactive education, practice-oriented, target-specific behavioral change, risk communication strategies regarding pesticide use and preventive measures are necessary. The gap between the knowledge, attitude and actual safety practices needs to be linked with a more multifaceted and participatory training model and behavioral interventions.

A significant proportion of applicators reported that they experienced health effects presumably related to pesticide exposure at some point in the past. Moreover, almost one-third of them also reported that they encountered health effects among their family members probably related to pesticide poisoning. Para-occupational or take-home exposure pathways are potential sources of exposure for this population. Chemicals used in agriculture, including pesticides, can move from the workplace to residential environments and eventually lead to elevated concentration of pesticide residues over time, particularly in house dust and vehicle dust. It is also possible that applicators brought pesticides home for residential use, and the inappropriate handling and storage of these products constitute potential health risk for those living in the household, especially for children. Although significantly more applicators used prescription drugs in the past 12 months, diabetes and high blood pressure were less reported by applicators compared to residents, which may typically be a result of "healthy worker effect" as observational studies are particularly prone to this type of bias. A range of adverse symptoms that were related to pesticide exposure reported by other studies, such as skin irritation, shortness of breath, cough, and dizziness have also been more frequently reported by applicators than residents in this study. On the other hand, chest pain, nausea and vomiting, and muscle cramps were significantly less likely reported by applicators. This may also be due to the "healthy worker effect", or to other confounding factors that have not been assessed in this study.

Storage and disposal of leftover pesticide residues and empty containers are critical points of intervention to enhance safety awareness before, during, and after the application of pesticides. In the present study, a high proportion (69%) of applicators sold or offered leftover pesticide residue to other farmers; however, a considerable proportion (43%) of applicators purchase only the amount of pesticide that is needed for the application, which is the best practice that should be encouraged. On the other hand, the majority (80%) of applicators disposed empty pesticide containers on open fields, whereas 59% of them also used empty containers to store other pesticides. Similar figures were reported in other studies. This practice may not only subject the applicators to a high risk of pesticide exposure, but also endanger the health of family members, residents, and bystanders through non-occupational exposure pathways. Hence, the appropriate collection, recycling and disposal of residues and empty pesticide containers should be implemented to reduce human health risk and environmental pollution.

A significant proportion of the applicators practiced risky behaviors during pesticides application. They either chew khat, smoke cigarettes, drink or eat food while spraying pesticides. Similar findings were

reported from Gaza. A substantial proportion of them used home-based care treatment when experiencing symptoms presumably due to pesticide exposure. This is probably because of financial constraints, low level of education and low health literacy. This practice could worsen the illness and lead to severe consequences due to the missed opportunity of early detection and adequate treatment, which also result in higher healthcare costs.

Our findings showed that using highly toxic pesticides, mixing pesticides without gloves, regular maintenance and washing spray tank after application, and incidents of splash during mixing and application were significantly positively associated with experienced health effects presumably related to pesticide exposure among applicators. A considerable proportion of applicators rated the toxicity of applied pesticide products as slightly toxic, although several of them can express high toxicity together with their bioaccumulation tendency and synergistic effects, which may undermine the adequate use of preventive measures.

The use of protective measures among applicators is an indispensable factor for the reduction of health risks of occupational pesticide exposure. The cost of preventive measures is considerably lower than the cost of medical treatment of health effects from exposure to pesticides; hence, preventive measures are not only more ethical but also more cost-effective and feasible strategies to combat these issues, especially in low- and middle-income countries, including Ethiopia. In the present study, about half of the applicators did not read and follow the label instructions on the pesticide containers, and only less than half of them used always face mask during spraying, although significantly more among those who received tailored training. About the same proportion used gloves and coveralls, although, interestingly, self-reported use of gloves was more frequent among non-trained applicators. The use of respirators and safety shoes was mainly intermittent. Training related to effective and consistent utilization of adequately selected and maintained PPE is crucial. Availability of PPEs at an affordable cost in the local market is also a key factor of their utilization. Changing cloth after application and taking a shower immediately after application is also important in reducing the health risk of occupational pesticide exposure among applicators. It additionally reduces risk to family members that may otherwise face take-home exposure. This study also showed that applicators, who experienced health effects, significantly more frequently used home-based care, but not health facilities. Therefore, comprehensive training focusing on basic safety precautions, proper choice and use of PPE and visiting health facilities at onset of potentially pesticide-related symptoms are crucial interventions for reducing the risk of health effects due to pesticides in the occupational setting.

This study has its potential limitations. As both surveys used cross-sectional design, a temporal causal relationship between exposure and outcome could not be determined because both were examined at the same time. The collected information was self-reported; therefore, it may be subject to recall and social

desirability bias. In addition to self-reported exposure status, exposure levels were not confirmed by environmental or biological monitoring,

CONCLUSIONS AND RECOMMENDATIONS

Our studies investigated the knowledge, attitude, and experienced practice of pesticide use, pattern related to pesticide exposure, health effects and symptoms, pesticide handling and management system, and applied preventive measures among the most critical actors (extension officers, applicators, and residents). There were evident differences in officers' knowledge, attitude, and experienced practice of pesticide use in Ethiopia and Hungary. From the findings of the two studies, we deduced that the situation 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 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 pursued 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 an 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.

SUMMARY

Globally, intensive pesticide use has raised concern regarding the possible short-and long-term health effects of pesticides among pesticide users. This 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. 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. Based on previous survey recommendations, a study involving 1073 participants (803 pesticide applicators and 270 non-applicators residents) was conducted in Ethiopia in 2021. In both studies, questionnaires were applied. The multivariate statistical analysis was used to identify predictors of knowledge and attitude, health effects, and applied preventive measures by estimating adjusted odds ratios and prevalence ratios.

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). 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), $p<0.05$). 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. A considerably higher proportion of applicators declared insufficient use of preventive measures and inappropriate leftover pesticide residue disposal methods. Hence, improving extension services, overall optimization of the pesticide management system through strict law enforcement of occupational and environmental health regulations, and training for extension officers and applicators focusing on safety precautions and proper use of personal protective equipment and provision of adequate pesticide waste disposal means are crucial interventions.

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LIST OF PUBLICATIONS

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List of publications related to the dissertation

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   Front. Public Health. 10, 1-18, 2022.
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   Ethiop. J. Health. Dev. 26 (1), 3-8, 2012.

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