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LITERATURE REVIEW Open Access

MANAGEMENT OF PESTICIDE CONTAMINATION IN THE ENVIRONMENT AND AGRICULTURAL PRODUCTS: A LITERATURE REVIEW

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Abstract

Introduction: *The use of pesticides not only has benefits for product growth but also causes problems with the entry of pesticide residues in the food chain to pollution to the environment. This study aims to formulate ways to reduce pesticide contamination in the environment and agricultural products.* ***Discussion:*** *This literature review was conducted using the PRISMA method using 35 articles 14 of which were published in the ScienceDirect database, 12 in the Proquest database, and 9 in the Pubmed database. Environmental pollution due to pesticides is caused by the behavior of spraying pesticides and disposing of used pesticides by farmers. Ways to reduce it are by measuring how much pesticide is needed, training to increase knowledge about agricultural practices in preparing the required dose, and regularly monitoring environmental quality. Pesticide residues can increase due to the application of pesticides at harvest, and they can be reduced by washing, peeling, and cooking processes. In addition, another proven effective way to reduce pesticide residues is using an electrolyzed water treatment, sonolytic ozonation, and ozonated water.* ***Conclusion:*** *The use of unsafe pesticides will harm the environment and endanger health through the food chain. Training for farmers to use pesticides properly is considered effective in reducing pesticide pollution in the environment. In addition, the reduction of pesticides in agricultural products can be done by washing, peeling, cooking (boil, boil and fry), electrolyzed water treatment, sonolytic ozonation, and ozonated water.*

INTRODUCTION

Pesticides are substances that include fungicides, insecticides, herbicides, and rodenticides that are produced to control pests and vectors. Pesticides are massively used by most farmers to control pests, weeds, and plant diseases that can reduce productivity, and only a few farmers do not use chemical pest control (1). The use of unsafe pesticides is associated with the increased risks to human health such as farmers and consumers. The safe use of pesticides and proper personal hygiene practices can be considered as good safety behavior and can reduce the risk of health problems for farmers. In addition, farmers should wait some time to enter their fields after spraying. The period of time when farmers are allowed to re-enter differs, depending on the type of pesticide and the pesticide trademark. The results of study indicate that farmers reenter the land that has been sprayed for about 22-26 hours, which means that it is under the recommendation of several pesticide trademarks. For this reason, farmers should be able to read the labels and information instructions contained in the packaging so that they can practice good pesticide use to prevent contamination of the environment and agricultural products (2).

Excessive and inappropriate use of pesticides is a very common practice in both developing and developed countries (3). There are still many fruits and vegetables that contain pesticide residues, which also need to be a concern for consumers. Pesticide residues in vegetables and fruits can increase or decrease when they reach consumers. Pesticide residues may pose a risk of significant adverse health effects for consumers.

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In general, pesticides are sprayed directly on plants on the farm. Infants, children, and adults can be exposed to these pesticides by eating food contaminated with pesticides. Chemical pesticide residues have been detected in many food commodities (4).

Food is the main route for pesticide exposure to enter the human body. Until now, food safety regulations have increased globally and are continuously being developed aiming to protect people from the toxic effects of exposure to pesticides. World institutions such as the EU, FAO/WHO and EPA have set limits on pesticide residues in food. International Food Standards such as EU, EPA and CODEX (FAO/WHO) MRL have been defined and applied as an evaluation of pesticide exposure in the form of pesticide residues in agricultural products. The maximum pesticide residue number is the highest concentration of pesticide residue that is legally accepted in or on food if the pesticide is applied correctly (referred to as Good Agricultural Practices). Safety reference values for the safety of agricultural products, such as Maximum Residue Limit (MRL), Acute Reference Dose (ARfD), Estimated Daily Intake (EDI) and Acceptable Daily Intake (ADI) have been established at national and international levels to prevent problems from occurring health and overexposure of pesticides to the human body (5). Security regulations through the determination of the safety reference value, continue to be developed in various countries including developing and developed countries in the world.

In addition, the problem of pesticides is not only in the food chain but also in the environment. Pesticides can move through runoff as compounds dissolved in water or attached to soil particles. Runoff from areas that are actively using pesticides can contaminate rivers, ponds, lakes, and wells. Several studies have been carried out previously to better understand the level of pesticide application, land use, and molecular characteristics of water contamination by pesticides. The study focused on water pollution resulted from both pesticides used in agriculture. Not only that, mitigations to deal with pesticide pollution associated with runoff events such as grassy buffer strips or constructed wetlands have been undertaken. The results show that there are no efficient sustainable mitigation options for persistent water contamination due to pesticide residue dumping into rivers. For drinking water problems, the only way that can be used is to treat water with several processes so that the water can be drunk, and this activity can cost a lot of money. Consequently, the best way to reduce river pollution is to avoid continuing contamination (6).

Pesticide residues in surface water can harm plants and animals and contaminate groundwater. Many processes affect what happens to pesticides in the environment. This process includes adsorption, transfer, breakdown, and degradation. The transfer includes the process of removing pesticides from the target location. This includes evaporation, spray drift, runoff, leaching, absorption, and plant removal (7). So far, research on the contamination of pesticides and agricultural products has been carried out with different discussions. However, only a few researchers have combined these two topics into a single unit so that intervention steps for preventing pesticide contamination in the environment and agricultural products can be explained clearly. As a form of anticipation of pesticide problems, this study aims to formulate various ways that can be done to reduce the incidence of pesticide contamination in the environment and agricultural products.

DISCUSSION

This literature review was conducted using the PRISMA method in determining scientific articles to answer research questions about how to manage pesticide contamination in the environment and agricultural products. Article searches were conducted on 3 databases, namely ScienceDirect, Pubmed, and Proquest. The keywords used were the inclusion criteria for the search for scientific articles, namely 'Pesticide handling practice among farmers' AND 'environmental contamination' OR 'environmental pollution' AND 'agriculture product contamination'. Inclusion criteria for the search for scientific articles included: (i) articles originating from peer-reviewed journals which were the results of original research that discussed handling pesticide contamination in the environment and agricultural products; (ii) speak English; (iii) published in 2013-2022; and (iv) is a full-text article. After filtering and adjusting the research variables, 35 articles were analyzed consisting of 14 articles published in the ScienceDirect database, 12 articles in the Proquest database, and 9 articles in the Pubmed database. Data analysis was carried out by synthesizing and comparing research variable data with empirical/theoretical support and presenting it through tables and descriptions. The result of this review are explained in a narrative form including a comprehensive description of 2 sub-discussions, namely the contamination of pesticides on the environment and agricultural products and how to handle them.

Table 1. Research Methodology Distribution are Reviewed in a Database of 35 Articles

Research Methodology	Name of Researcher	Total Articles
Cross-sectional study	Nana AS, Falkenberg T, Rechenburg A, Adong A, Ayo A, Nbendah P, et al (1); Bagheri A, Emami N, Damalas CA (14); Bakhtawer SA (16); Jallow MF, Awadh DG, Albaho MS, Devi VY, Thomas BM (15); Berni I, Menouni A, Ghazi I, Duca R, Kestemont M, Godderis L, et al (40); Kafle S, Vaidya A, Pradhan B, Jørs E, Onta S (18); Karasmanaki E, Dimopoulou P, Vryzas Z, Karipidis P, Tsantopoulos G (22); Shentema MG, Bråtveit M, Kumie A, Deressa W, Moen BE (20); Adamu A, Abebe W (2).	9
Experimental study	Park BK, Kwon SH, Yeom MS, Joo KS, Heo MJ (28); Kumari D, John S (3); Manjarres-López DP, Andrades MS, Sánchez-González S, Rodríguez-Cruz MS, Sánchez-Martín MJ, Herrero-Hernández E (33); Park DW, Kim KG, Choi EA, Kang GR, Kim TS, Yang YS, et al (34); Jiang D, Cheng Z, Chen X, Dong F, Xu J, Liu X, et al (35); Bhandari G, Zomer P, Atreya K, Mol HGJ, Yang X, Geissen V (5); Ngabirano H, Birungi G (4); Phopin K, Wanwimolruk S, Norkaew C, Buddhaprom J, Isarankura-Na-Ayudhya C (31); Jankowska M, Łozowicka B, Kaczyński P (43); Wang S, Wang J, Li C, Xu Y, Wu Z (26); Liu Y, Wang J, Zhu X, Liu Y, Cheng M, Xing W, et al (32); Siddique Z, Malik AU, Asi MR, Inam-ur-Raheem M, Iqbal M, Abdullah M (27);	12
Mix method (laboratory and study survey)	Mottes C, Lesueur Jannoyer M, Le Bail M, Guéné M, Carles C, Malézieux E (25); Ssemugabo C, Guwatudde D, Ssempebwa JC, Bradman A (30); Nguyen Dang Giang C, Le DBC, Nguyen VH, Hoang TL, Tran TVT, Huynh TPL, et al (29); Andersson E, Isgren E (37);	4
Observational study	Sombatsawat E, Barr DB, Panuwet P, Robson MG (36); Marete GM, Lalah JO, Mputhia J, Wekesa VW (38); Istriningsih, Dewi YA, Yulianti A, Hanifah VW, Jamal E, Dadang, et al (41); Kapeleka JA, Sauli E, Sadik O, Ndakidemi PA (42); Sharafi K, Pirsaheb M, Maleki S, Arfaeinia H, Karimyan K, Moradi M, et al. (13); Shammi M, Sultana A, Hasan N, Rahman M, Islam S (44); Ali MP, Kabir MMM, Haque SS, Qin X, Nasrin S, Landis D, et al (45);	7
Case study	Bhandari G, Atreya K, Vasickova J, Yang Xiaomei, et al (39); Onwona-Kwakye M, Hogarh JN, Van den Brink PJ (12); Sosnowska EP, Sobczak WZ, Sobczak P, Doman´ski M, Szwajgier D (24);	3

Articles Distribution

The results of the analysis of the 35 selected articles are described in several sub-discussions, namely the use of research methods, year of publication, and geographic distribution of the research site. Table 1 shows the research methods from 2015 to 2022 which discuss pesticide contamination in the environment and agricultural products which result in the recommendations for handling them. The results of analysis of the use of this research method indicated that so far the research method widely used in various countries regarding pesticide contamination in the environment and agricultural products is the experimental study method. This method is chosen by many researchers to determine the dose of pesticide use and pesticide residue produced so that efforts to handle pesticide contamination in agricultural products can be known. Research to determine pesticide contamination on the environment is mostly using cross sectional study or mixed method. This is done to determine the amount of pesticide pollutants that contaminate the soil to the unsafe behavior of farmers in using pesticides. Therefore, by using this method, efforts to reduce environmental contamination by pesticides can be identified.

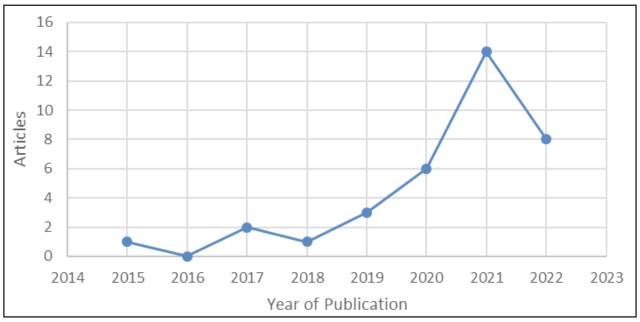

Figure 1. Year of Publication

Based on the results of analysis of the article distribution (Figure 1), during the last 8 years (2015-2022), scientific publications of research results related to the topic of pesticide contamination in the environment and agricultural products that produce recommendations for handling efforts continue to increase from year to year. Most publications were in 2021. This shows that more and more researchers are interested in collecting factors that can cause environmental contamination and agricultural products. The focus of research conducted by researchers in the last 8 years is on pesticide handling related to the use of doses, hygienic behavior of farmers when using pesticides, and the use of PPE, as well as analysis related to the presence of pesticide residues that can cause health problems for humans. Based on these results, several structured recommendations can be formulated to prevent pesticide contamination in the environment and agricultural products.

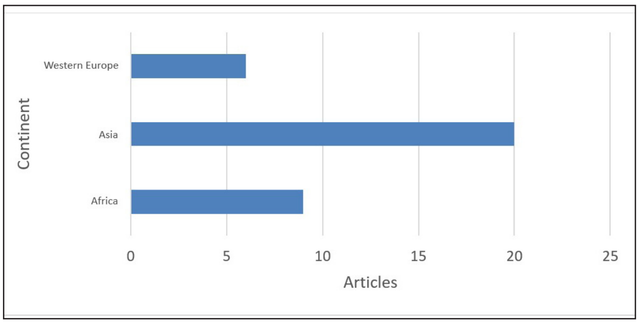

Figure 2. Geographical Area Study

Figure 2 shows the geographical distribution of the study area regarding pesticide contamination in the environment and agricultural products. There are 3 continents identified as the study sites, namely Africa, Europe, and Asia. Asia is the continent that is most widely used as a place of research. This is because Asia is the

Table 2. Journal Review

Name of The Researcher	Title of The Research	Population	Methods	Outcomes	Conclusion
Nana AS, Falkenberg T, Rechenburg A, Adong A, Ayo A, Nbendah P, et al (1)	Farming Practices and Disease Prevalence among Urban Lowland Farmers in Cameroon, Central Africa	130 farmers	Cross-sectional study	Farmers wearing masks and gloves reported fewer water-borne diseases	The number of health problems that occur is because farmers do not use the right PPE when using pesticides and farmers are exposed to polluted irrigation water
Bagheri A, Emami N, Damalas CA (14)	Farmers' Behavior towards Safe Pesticide Handling: An Analysis with The Theory of Planned Behavior	300 farmers	Cross-sectional study	Inappropriate behavior of farmers when using pesticides include disposal of residual pesticide solutions, rinsing of pesticide spray equipment, disposal of waste water washing spray equipment, and inappropriate use of PPE.	Many farmers engage in risky behavior in handling pesticides and can contaminate the environment
Bakhtawer SA (16)	A Cross Sectional Survey of Knowledge, Attitude and Practices Related to The Use of Insecticides among Farmers in Industrial Triangle of Punjab, Pakistan	300 farmers	Cross-sectional study	Farmers who do not have formal education or with basic education do not have sufficient knowledge about the practice of using insecticides, disposing of pesticide waste, and using PPE.	Farmers do not have sufficient knowledge about handling insecticides so that lack of education and awareness can endanger health and the environment.
Park BK, Kwon SH, Yeom MS, Joo KS, Heo MJ (28)	Detection of Pesticide Residues and Risk Assessment from The Local Fruits and Vegetables in Incheon, Korea	1146 vegetables and fruits from 20 different types	Experiment (Analyse the multi-residue of the pesticides from the Korean Food Code Method)	91 samples contained residues and 11 of them exceeded Korean MRL. 32 types of pesticides were found in the residue and 8 of them exceeded the MRL	Short term and long term risk assessments that have been carried out on samples containing residues do not show numbers above 100%, which means that the fruits and vegetables are still acceptable for consumption.
Mottes C, Lesueur Jannoyer M, Le Bail M, Guéné M, Carles C, Malézieux E (25)	Relationships between Past and Present Pesticide Applications and Pollution at A Watershed Outlet: The Case of A Horticultural Catchment in Martinique, French West Indies	Ravine Catchment, Martinique Island, French	Mix method (laboratory and study survey)	Several types of pesticides that pollute waters are not only caused by the content of the pesticides, but also the frequency, dosage, and hydrological function of the watershed. In addition, the past history of pesticide use also causes persistent pollution in the watershed due to soil and water that contaminated	The use of pesticides in the present and in the past shows water and soil pollution. Some types of pesticides that are legally registered and used have serious risks to water pollution in the long term.
Ssemugabo C, Guwatudde D, Ssempebwa JC, Bradman A (30)	Pesticide Residue Trends in Fruits and Vegetables from Farm to Fork in Kampala Metropolitan Area, Uganda—A Mixed Methods Study	Laboratory measurements= 160 fruits and vegetables Questionnaires= 186 stakeholders In Depth Interview= 16 stakeholders	Mix method study (laboratory, questionnaire, and in depth interview)	Several types of pesticides have increased or decreased residues due to a long supply chain process from farmer to consumer	The process of washing with water or vinegar, peeling, and cooking can reduce pesticide residues
Nguyen Dang Giang C, Le DBC, Nguyen VH, Hoang TL, Tran TVT, Huynh TPL, et al (29)	Assessment of Pesticide Use and Pesticide Residues in Vegetables from Two Provinces in Central Vietnam	233 households involved in vegetable farming 290 vegetable samples	Mix method study (survey, in depth interview, and laboratory)	20% of respondents are aware of pesticide toxicity. 81% of the vegetable samples studied contained pesticide residues with 23% exceeding the MRL. Pesticide contamination is higher in the rainy season.	Farmers have not carried out proper pesticide use practices, including storage and disposal of their waste, so that there are many fruits and vegetables that contain pesticide residues

Name of The Researcher	Title of The Research	Population	Methods	Outcomes	Conclusion
Kumari D, John S (3)	Health Risk Assessment of Pesticide Residues in Fruits and Vegetables from Farms and Markets of Western Indian Himalayan region	fruits and vegetables	Experimental study	Fruit and vegetable sampels from direct agriculture or markets have pesticide residues, and higher concentrations are from agriculture. Organophosphate groups (methyl parathion and triazophos) give rise to health risks for children in the study area	Fruits and vegetables from agriculture and markets contain pesticide residues that can threaten health, especially children
Jallow MFA, Awadh DG, Albaho MS, Devi VY, Thomas BM (15)	Pesticide Knowledge and Safety Practices among Farm Workers in Kuwait: Results of a Survey	250 farmers	Cross-sectional study	70% of farmers don't read pesticide labels 58% do not use PPE 82% of farmers have experienced one of the symptoms of acute pesticide poisoning 20% of farmers store pesticides in the area where they live 6% of farmers reuse empty pesticide containers for household use	Level of knowledge of farmers about the safe use of pesticides is very low, including the use of PPE and waste disposal
Manjarres-López DP, Andrades MS, Sánchez-González S, Rodríguez-Cruz MS, Sánchez-Martín MJ, Herrero-Hernández E (33)	Assessment of Pesticide Residues in Waters and Soils of A Vineyard Region and Its Temporal Evolution	Water and soil in the La Rioja Oriental vineyard region	Experimental (A multi-residue method based on solid phase extraction (for water samples) or solid-liquid extraction (for soil samples) and high-performance liquid chromatography coupled to mass spectrometry (HPLC-MS)	In the analyzed water samples, several types of pesticides such asNuarimol,azinphos-methyl,methidathion,andcarbendazim were found, whose use was prohibited. Meanwhile, the types of pesticides detected with concentrations above 0.1 g L^{-1} were metalaxyl and its degradation product CGA-62826, with the maximum concentration 9 C_{max}) was found in the parent compound 0.932 g L^{-1} in summer and 0.540 g L^{-1} in spring, and bisaconazole with C_{max} 0.917 g L^{-1} in autumn. Same as found in water samples, highest concentration in soil samples, types of pesticides found were fungicides followed by insecticides and herbicides but the highest concentrations were detected in samples taken in spring	In the waters and soil of the vineyards at DOCa Rioja, the most frequently detected type of pesticide is fungicide The highest total pesticide concentration in waters occurs in summer, while in soil it corresponds to spring.
Park DW, Kim KG, Choi EA, Kang GR, Kim TS, Yang YS, et al (34)	Pesticide Residues in Leafy Vegetables, Stalk and Stem Vegetables from South Korea: A Long-Term Study on Safety and Health Risk Assessment	leafy vegetable, stalk and stem vegetables from South Korea:	Experimental (multi-residue analysis of pesticides)	In the leafy vegetable samples, more residues were found in aster scaber, spinach, perilla leaf, pimpinella brachycarpa and butterbur than the others. The most frequently detected pesticides in leafy vegetables and stem and stem vegetables were procymidone, azoxystrobin, dimethomorph and lufenuron. There were 118 (1.4%) samples that exceeded MRL from 8,496 samples analyzed, namely 96 (1.4%) samples in 6,782 leafy vegetables samples, and 22 (1.3%) samples in 1,714 stalks and stems of vegetable samples. The type of pesticide detected that most frequently exceeds the MRL is diniconazole, especially in ssamchoo (brassica lee ssp. namai) (13 times). The type of pesticides that has the highest per cent of EDI to ADI ratio is EPN, which is 30.4%	Fungicides are used widely in the stage of the cultivation of produce in South Korea which the most common pesticides found in leafy vegetables, stalk and stem vegetables were procymidone, azoxystrobin, dimethomorph and lufenuron. There are pesticides that exceed the MRL in this study but are not harmful to human health
Jiang D, Cheng Z, Chen X, Dong F, Xu J, Liu X, et al (35)	Occurrences of Eight Common-Used Pesticide Adjuvants in Ten Vegetable Species and Implications for Dietary Intake in North China	1485 vegetable from local vegetable markets and farms; 675 vegetables from local markets and 810 vegetables from farms in Beijing city	Experimental	In the sample of vegetables from farm, the target PAs were most often found in spinach, followed by cauliflower and leeks. For total PAs levels were found in spinach and the lowest total PAs levels were in asparagus lettuce, eggplant and potato samples. The type of PAs in vegetables from farm with a higher mean concentration is methanol and the highest concentration was found in spinach. Of all types of PAs regardless of sampling origin, market or agriculture, the dominant PAs in majority of vegetable species is TPE. PAs in vegetables from farm with estimated daily intakes (EDIs) indicating little health risk were EDIs of TPE and NP	High levels of TPE were detected and predominated compared to other PAs in most vegetables, either from the market or local farms. The health risk assessment of TPE and NP exposure shows that it is still acceptable, but poses little health risk and should not be ignored.
Sombatsawat E, Barr DB, Panuwet P, Robson MG (36)	Pesticide Toxicity Assessment and Geographic Information System (GIS) Application in Small-Scale Rice Farming Operations, Thailand	75 farmers in Phimai District	Observational study	There are still many farmers (39.6%) who do not read pesticide labels before application, 48.3% who not using the the recommended dose of pesticide use, 58% of farmers do not wash their equipment after using pesticides and 65.5% of farmers kept their pesticide products at home. AChE and BuChE activities were significantly decreased during the active period of rice farming (paired simple t-test: p=0.004 and p=0.001. The practice of not using pesticides according to the recommended amount is significantly associated with AchE depression. Some of the health problems found during the active period of rice farming among farmers were 70.7% muscle fatigue, 69% blurred vision, 63.8% sweating, 62.1% shortness of breath, 58.6% dizziness, and 51.7% dyspnea and lacrimation. Based on GIS mapping results, the significant enzyme inhibition cases have spread to agriculture and nearby residential areas.	The use of OP, carbamates and pesticide handling practices which were inappropriate contributed to a significant decrease in AChE and BuChE activity, and an increase in health symptoms among farmers.

Name of The Researcher	Title of The Research	Population	Methods	Outcomes	Conclusion
Andersson E, Isgren E (37)	Gambling in The Garden: Pesticide Use and Risk Exposure in Ugandan Smallholder Farming	20 smallholder farmers, 8 focus group discussions, 5 agro-input dealers, 3 agricultural staff at district and sub-county levels	Mixed Methods (survey and qualitative research)	Based on the results of household surveys, the plants that are most often given pesticides are peanuts, beans, cassava, corn and soybeans where the cultivated plants are mainly used for daily household consumption. The type of pesticide that is mostly used by farmers is insecticide and only a small number of households use herbicide. Very few farmers (12%) who understand and are able to identify pesticide toxicity based on the colo coding system. Farmers who use adequate protective equipment when pesticide use is still very few. Pesticide handling practices among farmers still use inadequate personal protective equipment and the number of farmers who use inadequate personal protective equipment is also very small. Most households did not have adequate equipment for pesticide application and rely on borrowed spray pumps from their neighbors and friends or use only plastic basins. and brooms made of grass to manually apply pesticides to plants. Based on the results of a household survey, some of the symptoms of health problems due to exposure to pesticides were skin irritation, cough/ throat irritation, headache, dizziness, difficulty breathing and nausea.	Pesticide use and handling practices among Ugandan farmers pose a major risk to human health and environmental health due to lack of access to technical support and protection.
Marete GM, Lalah JO, Mputhia J, Wekesa VW (38)	Pesticide Usage Practices as Sources of Occupational Exposure and Health Impacts on Horticultural Farmers in Meru County, Kenya	173 farmers' households, 70 health care workers (HCW) and 73 agricultural extension workers (AEW).	Observational Study	Some level of pesticide poisoning was experienced by 26% of households in the last 3 years. Higher health effects were found with the use of dimethoate, malathione, heptachlor, endrin, dursban (chlorpyrifos), parathion and dieldrin. Most of the farmers in Meru Regency understand the label on the pesticide package, but most of them did not apply the instructions for using the pesticide listed on the label	The level of compliance with the use and safe handling of pesticides in the three sub county of Meru was still very low. Cases of poisoning due to pesticides were still found in the three sub-districts, both based on reports from farmers and health workers
Bhandari G, Zomer P, Atreya K, Mol HGJ, Yang X, Geissen V (5)	Pesticide Residues in Nepalese Vegetables and Potential Health Risks.	Vegetable crops grown in Southern Nepal: 27 eggplants, 27 chilies and 32 tomatoes, adolescents 10-19 years old and adults >19 years old.	Experimental	97% percent of vegetables tested contain at least one type of pesticide. The mean concentration of carbendazim was higher than the concentration of other pesticides that was detected in tomato samples. The mean total pesticide concentration in vegetables from conventional farming is higher than that found in vegetables grown using the Integrated Pest Management (IPM) method. Consumption of tomatoes in adolescents and adults has the greatest risk for human health compared to consumption of other vegetables because of the high concentrations of triazophos and chloropyrifos. Some pesticides whose use exceeds EU MRL were chloropyrifos, omethoate, carbendazim in tomato samples and omethoate in tomato and eggplant samples.	The use of pesticides on vegetables in Nepal exceeds the EU MRL and poses a great risk to human health problems
Bhandari G, Atreya K, Vašíčková J, Yang X, Geissen V (39)	Ecological Risk Assessment of Pesticide Residues in Soils from Vegetable Production Areas: A Case Study in S-Nepal	Soils (3 depths) from 11 integrated and 38 conventional vegetable farms	Case Study	$RQ_{maximum}$ of chlorpyrifos, midacloprid and profenofos were indicated a high risk for soil organisms in all soil. The mean TER and maximum TER of chlorpyrifos ranged from 0.37 to 3.22 which indicated chronic toxicity to F. candida.	Chlorpyrifos is a main soil pollutant that contributes to ecological risks, especially for soil organisms, at various levels of depth.
Ngabirano H, Birungi G (4)	Pesticide Residues in Vegetables Produced in Rural South-Western Uganda	Vegetable samples sprayed (28) and unsprayed or control (4)	Experimental	Pesticide residue levels in this study were determined by LC–MS/MS, QuEChERS, UV–Vi, and GC–MS/MS methods. The concentrations of cypermethrin, dimethoate, metalaxyl, profenofos, malathion, dichlorvos and mancozeb in the sprayed samples were 0.00403 and 0.05350, 0.17478–62.60874, 0.12890–3.55681, 0.0107– 0 .59722, 0.03144–0.63328, 0.00240–0.34102 and 0.00001–0.00244. Pesticide residue levels in 59.52% of sprayed vegetable samples, 18% of unsprayed vegetable samples, and 8% of samples from the market. The quality index of vegetables traded in the market is mostly known as much as 75%. The remaining optimal quality is 14.29%, 3.57% is sufficient, and 14.29% is less.	In this study, it was found that in all the samples of vegetables, both sprayed and unsprayed, as well as vegetables sold in the market, all contained pesticide residues. Overall, pesticide concentrations in unsprayed vegetables were lower than in sprayed vegetables. This study concludes that a mixture of pesticides can produce synergistic or antagonistic effects that can affect the efficiency of pesticide use. In addition, certain types of pesticide residues can affect the quality of food.

Name of The Researcher	Title of The Research	Population	Methods	Outcomes	Conclusion
Berni I, Menouni A, Ghazi I, Duca R, Kestemont M, Godderis L, et al (40)	Understanding Farmers' Safety Behavior Regarding Pesticide Use in Morocco	232 arboricultural farmers	Cross-sectional survey	The incidence of health problems related to pesticide exposure to farmers who are respondents in this study is high. Health problems such as skin irritation and headaches. Low level of education and inadequate training are variables that affect unsafe pesticide handling practices. As a result, to increase agricultural yields, farmers apply large amounts of pesticides to agricultural land (an average of 12.02 kg/ha per growing season). It was also reported that farmers in this country still use prohibited types of pesticides, such as endosulfan (organochlorine group) and ethyl chlorpyrifos (organophosphate group). Adherence to safe pesticide handling practices increased significantly with a high level I (standardized path coefficient, SPC = 0.31) and perceived health risk severity (SPC = 0.27). Uncertainty about the risks of pesticide use was significantly related to the low adoption of safety measures in the use of pesticides (SPC = 0.24).	Farmers in the research location still use several types of pesticides that are prohibited, use high amounts of pesticides, and are not disciplined in using PPE during pesticide handling. Therefore, arboriculture farmers are at high risk of exposure to pesticides. It was also noted that the most reported consequences felt by farmers were irritation and headaches. The main variable that can affect the safety practices in pesticide use among farmers in the Sass Plain is the level of knowledge.
Istriningsih, Dewi YA, Yulianti A, Hanifah VW, Jamal E, Dadang, et al (41)	Farmers' Knowledge and Practice Regarding Good Agricultural Practices (GAP) on Safe Pesticide Usage in Indonesia	298 farmers managing the commodities in the wet season	Observasional study	In this study, it was found that good agricultural practices (GAP) were not in line with the level of knowledge in the use of pesticides, for example: (1) reading pesticide labels before using them, (2) not mixing pesticides with bare hands, (3) wearing PPE (masks and gloves) when applying pesticides, (4) using a tool to remove clogs, (5) not even blowing the nozzle with your mouth to clear it of blockages, (6) discarding empty pesticide containers according to the instructions on the label. All of these practices require further intervention, especially in the 4th and 5th practices because the respondents' knowledge of these two things is high but the practice is low. Contrary to these findings, in other cases it was found that a high level of knowledge was in line with good practices, namely: (1) storing pesticides not in the house or in a separate place, (2) bathing after handling pesticides, (3) washing hands with soap before eating and drinking.	A high level of knowledge is not necessarily in line with practice: for example on the behavior of using masks and gloves, using tools to remove clogs, not blowing nozzles to remove clogs, and properly disposing of empty pesticide containers. In other cases, however, a high level of knowledge goes hand in hand with good practice.
Kapeleka JA, Sauli E, Sadik O, Ndakidemi PA (42)	Co-exposure Risks of Pesticides Residues and Bacterial Contamination in Fresh Fruits and Vegetables under Smallholder Horticultural Production Systems in Tanzania	613 samples vegetables were analyzed for pesticide residues,and which 250 were also analyzed for bacterial contamination.	Observasional using Association of Official Analytical Chemists (AOAC) Official Method (QuEChERS Protocol),	This study found that there were pesticide residues in 47.5% of fresh fruits and vegetables, 74.2% even exceeding the Maximum Residual Limit (MRL). The findings of pesticide residues were dominated by organophosphates (95.2%), organochlorines (24.0%), pyrethroids (17.3%), and carbamates (9.2%). The findings of pesticide residues with values exceeding the MRL in fresh fruits and vegetables were found in shallots, tomatoes, cucumbers, watermelons, chicory, and sweet chilies. carbaryl (0.0215–1.5068 mg/kg), Tetramethrin (0.0329–1.3733 mg/kg), permethrin (0.0009–2.4537 mg/kg), pyrimifos-methyl (0.0003– 1.4093 mg/kg), profenofos (0.0176-2.1377 mg/kg), endosulfan (beta) (0.0008–2.3416 mg/kg), dieldrin (0.0011-0.5271 mg/kg) kg), and chlorpyrifos (0.0004-1.2549 mg/kg) exceeded the MRL. The prevalence of bacterial contamination was 63.2%. Others were Enterobacter (55.6%) Pseudomonas aeruginosa (32.4%), E. coli (28.2%), Citrobacter (26.8%), Klebsiella oxytoca (14.8%), and Salmonella (7.8%). 7% isolated. In addition, 46.4% of the samples were found to be contaminated with bacteria and pesticide residues. When compared to vegetables obtained from the market, vegetables from agricultural land were found to contain more multiple contaminants. This is thought to be caused by excessive use of pesticides. In addition, fruit and vegetable production is estimated to be unhygienic. Based on the results of the binary logistic regression test, it is known that fruits and vegetables containing pesticide residues are 2,231 times more at risk of being contaminated with bacteria (OR: 2.231, 95% CI: 0.501, 8.802).	Oxyfluorfen, profenofos, cyhalothrine (lambda and gamma), chlorpyrifos, triadimenol, triadimefon, carbofuran, endosulfan (beta), and dieldrin were the active pesticide active ingredients that were mostly found in the samples. Meanwhile, Enterobacter E. coli, Pseudomonas aeruginosa, Salmonella, Citrobacter, Salmonella oxytoca and Klebsiella oxytoca, were isolated. There is a significant correlation in the findings of pesticide residues and bacterial contamination in the samples.
Phopin K, Wanwimolruk S, Norkaew C, Buddhaprom J, Chartchalerm INA (31)	Boiling, Blanching, and Stir-Frying Markedly Reduce Pesticide Residues in Vegetables	Eight pesticides	Experimental using the pesticide QuEChERS (Quick Easy Cheap Effective Rugged and Safe) method	Experiments in this study, two vegetables are cooked by three processes: grabbing, blanching, and sauteing. The result in Chinese kale, boiling reduces pesticides 18-71%, blanching reduces pesticides 36-100%, and sauteing pesticides reduces 25-60%. For long beans, boiling reduces pesticides 38-100%, blanching reduces pesticides 27-28%, and roasting reduces pesticides 35-63%. Cooking vegetables is proven to be one way to protect consumers from consuming pesticide residues.	The results showed that cooking vegetables before consumption (boiling, blanching, and frying) can help reduce pesticide residue levels in two types of vegetables commonly consumed (long beans and Chinese kale).

Name of The Researcher	Title of The Research	Population	Methods	Outcomes	Conclusion
Sharafi K, Pirsaheb M, Maleki S, Arfaeinia H, Karimyan K, Moradi M, et al (13)	Knowledge, Attitude and Practices of Farmers about Pesticide Use, Risks, and Wastes; A Cross-Sectional Study (Kermanshah, Iran)	311 farmers	Observational study with questionnaire	In this study, only a small proportion of respondents had been formally trained before (the majority had never). About 10% of pesticides contain very harmful compounds, 45% are moderately harmful, and 17% are slightly harmful. Farmers are primarily knowledgeable about pesticide risks. Farmers use inappropriate and high-risk methods in handling pesticides and their waste. The groups that are more at risk of experiencing health problems due to exposure to pesticides are those aged 65 years, uneducated, earning below 482 USD, not trained in using pesticides, and applying very dangerous pesticides. Efforts that can be made to reduce the release of pesticides into the environment are comprehensive training and implementation of a waste management system.	Most of the farmers in this study had never been trained to use pesticides, so many of them had incorrect knowledge about pesticides and the risks of using them. This also causes them to use wrong and high-risk methods in the practice and management of pesticide waste. Symptoms of health problems are related to socioeconomic factors, age, and training in using pesticides. In general, this lack of training implies low knowledge and poor behavior in the use and disposal of pesticide waste.
Jankowska M, Łozowicka B, Kaczyński P (43)	Comprehensive Toxicological Study Over 160 Processing Factors of Pesticides in Selected Fruit and Vegetables After Water, Mechanical and Thermal Processing Treatments and their Application to Human Health Risk Assessment	280 samples of blackcurrants (127), broccolis (41), strawberries (54) and tomatoes (58)	Experimental study	Water, mechanical, and thermal technologies are known to significantly reduce pesticide levels in several types of fruit and vegetables (strawberries, tomatoes, broccoli, and black currants) with Processing Factor (PF) values of 0.09-0.94, respectively; 0.13-0.32; and 0.02-0.57. High temperature affects the PF of pyrethroid insecticides (deltamethrin, alpha cypermethrin and lambda cyhalothrin) in one of the berries. Processing factor database technology/pesticide/matrix (more than 160 PFs) has been made for 24 pesticides on selected fruits and vegetables after going through different treatment processes. It is estimated that the hazard quotients (HQs) of acute and chronic intake exposure (Model I) exceed 20% and after correction of intake (Model II) the HDs values fall to 11.5% for water, 9.5% for thermal, and 3% for mechanics.	Processing using selected technologies (water, mechanics, and temperature) can significantly reduce the levels of twenty-one active substances in fruits and vegetables (strawberries, tomatoes, broccoli, and black currants). At high temperatures, the processing factor of pyrethroid insecticides in berries resulted in a processing factor above one.
Shammi M, Sultana A, Hasan N, Rahman M, Islam S (44)	Pesticide Exposures towards Health and Environmental Hazard in Bangladesh: A Case Study on Farmers' Perception	150 respondents	Observasional study using questionnaire	Information about pesticides on farmers was significantly different (v2 = 19,679 at $p<0.05$). The main sources of information for SU farmers are mass communication tools (35%) while for MU farmers are other farmers and pesticide sellers (28%). There was no storage and use of PPE, but there was a significant difference in the use of cloth to cover the face (v2 – 22.019 at $p<0.05$). This cover was partially used by farmers in SU (69%) while in MU it was not used (48%). In both regions (SU and MU), the following data were obtained: only 14% and 5% used complete PPE, 39% and 42% disposed of empty pesticide containers to the nearest water body, 31% and 24% took empty containers home for reuse. , 88% and 82% consumed betel nut/smoking during spraying, 87% and 66% believed that the use of pesticides could reduce soil fertility (v2 = 12,265 at $p<0.05$), 83% and 24% of farmers reported that pesticides pollute water surfaces, and killing beneficial insects, 67% and 26% said that there was a decrease in environmental quality. It is proven that there is no significant difference between background (variables of age, population, farming experience, and land ownership) and understanding of the dangers of pesticide health and environmental impacts according to canonical correspondence analysis (CCA) in both regions (both rural and urban).	Problems of safety, health and environmental pollution by pesticides include: (a) lack of economic development, (b) lack of/unable to read labels and preparation procedures (because of illiteracy or semi-illiteracy), (c) limited number of extension workers, (d)) knowledge about the dangers of pesticides and low use of PPE, (e) Often older farmers are not interested in new methods of personal safety, (f) low use of PPE in locations with humid weather.

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Ali P, Moniruzzaman M, Shamiul S, Qin X, Nasrin S, Landis D, et al (45)	Farmer's Behavior in Pesticide Use: Insights Study from Smallholder and Intensive Agricultural Farms in Bangladesh	917 agricultural households	Observational study	Farmer's crop type and location greatly affect PBs. Farmers' PBS in the use of pesticides has not been adequate due to lack of knowledge and ineffective actions of the government and pesticide retailers. Vegetable farmers show higher knowledge and income compared to other farmers, but also higher probability of using pesticides (to ensure their large yields and income). Training on sustainable pesticide safety, and on PBs namely the use of PPE, personal hygiene and sanitation practices during pesticide use is deemed necessary. The results showed that the predictor to significantly reduce pesticide risk was risk knowledge. Thus the promotion of the safe use of pesticides is considered very important to improve the health of farmers. The lack of PB is also caused by the confidence gap between farmers, pesticide retailers, and the government. It is necessary to strengthen the mechanism of environmental supervision and monitoring in a systematic manner. There is also a need for national-scale studies on the safety of pesticide use and the risks to human health and the environment. To overcome the risk of using unsafe pesticides, cooperation between farmers, pesticide producers and retailers, and government agencies is needed.	Farmers' perceptions and knowledge about the impact of pesticides positively affect PB, while government actions and retailers' beliefs negatively affect PB. Differences between farmers and crop locations are important to be further recognized and studied.
Onwona-Kwakye M, Hogarh JN, Van den Brink PJ (12)	Environmental Risk Assessment of Pesticides Currently Applied in Ghana	131 farmers	Case study	The risk assessment in this study was divided into two stages. The first stage, the assessment is carried out using the PRIMET model. As a result, there are many pesticides that are harmful to aquatic ecosystems close to land that is treated with pesticides. In addition, pesticides are also known to pose an acute risk to terrestrial soil ecosystems and there are many insecticides and some fungicides that pose an acute risk to bees and non-target terrestrial arthropods. The second stage of risk assessment is acute aquatic risk using the SSD concept. The results show that most of the aquatic risks from pesticides do exist. The current practice of using pesticides is 1.3-13 times higher than the instructions/recommendations for use listed on the pesticide label. This indicates a general practice of overdosage.	It is concluded that the combination of the PRIMET model and the SSD concept can provide recommendations to the Ghanaian authorities (in charge of pesticide registration) to assess environmental risks due to pesticide exposure so that environmentally friendly and cost-effective pesticides can be used.
Wang S, Wang J, Li C, Xu Y, Wu Z (26)	Ozone Treatment Pak Choi for The Removal of Malathion and Carbosulfan Pesticide Residues	4 groups treatments (@50 g) of pak choi leaves, 30 volunteer	Experimental study	Based on the experimental results, it is known that the residual levels of malathion and carbosulfan pesticides in both the treatment group (using ozonated water with concentrations of 0.5, 1.0, and 2.0 mg/L) and the control group, generally showed a continuous downward trend, then there is a deceleration, then the curve flattens over time. The effect of reducing pesticide residue levels by ozonated water treatment reached its maximum condition at 15 minutes. There was a significant difference ($p<0.05$) in pesticide residue levels after treatment with treatment durations of 0, 5, 10, and 15 minutes. Under optimal conditions, treatment with ozonated water with a concentration of 2.0 ml/L and a treatment duration of 15 minutes, pesticide residues (malathion and carbosulfan) can decrease to 53.0% and 33.0%, respectively. However, it should be noted that after treatment, there was a slight decrease in Vitamin C levels in pak coi leaves, namely ~7.9 mg/100g. In addition, it was also found that there was a significant decrease in microbial colonies on the leaves of Pak coi vegetables after treatment.	The use of ozonated water can be considered as an effective strategy to degrade pesticide residues on vegetables, especially Pak Coi. Giving ozonated water to the sample with a concentration of 2.0 mg/L for only 15 minutes has been able to reduce the levels of pesticide residues of malathion and carbosulfan by ~40-60% without any change in the sensory quality of the vegetable samples.
Kafle S, Vaidya A, Pradhan B, Jørs E, Onta S (18)	Factors Associated with Practice of Chemical Pesticide Use and Acute Poisoning Experienced by Farmers in Chitwan District, Nepal	790 farmers	cross-sectional study	From all research respondents, it was found that 84% of farmers exclusively use pesticides. Farmers who have better knowledge of pesticide handling, 8.3 times more likely to practice safe pesticide buying, 4 times more likely to practice safe pesticide mixing and spraying, and 2 times more likely to practice pesticide storage and disposal with safe. Farmers with positive perceptions/attitudes towards pesticide policies and market management, have a significant relationship with the practice of purchasing, mixing, and spraying and disposing of pesticides. Among farmers who use chemical pesticides, there are farmers who feel one or more acute symptoms due to pesticide exposure during the last 12 months, which is 18.7%. Farmers who practice unsafe methods of handling pesticides are 2 times more likely to experience symptoms of acute pesticide poisoning. From the results of the study, it can be concluded that knowledge of pesticide handling and positive perceptions/attitudes towards policies on pesticides and market management are predictors of safe use of pesticides.	There are findings of high use of chemical pesticides among farmers in Chitwan District, Nepal. It can also be concluded that knowledge about pesticide handling and positive perceptions/attitudes towards pesticide policy and market management are predictors of safe pesticide use practices. Furthermore, safe pesticide handling practices were significantly associated with a reduction in acute pesticide poisoning in Nepal. The last finding is that there is no significant relationship between gender, age, and farmer's education with symptoms of health problems they feel.

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Karasmanaki E, Dimopoulou P, Vryzas Z, Karipidis P, Tsantopoulos G (22)	Is The Environmental Behavior of Farmers Affecting Their Pesticide Practices? A Case Study from Greece	199 farmers	cross-sectional study	The results of the ANOVA analysis in the study showed that only environmental behavior variables had a relationship with the practice of disposing of used pesticide containers (r=0.296, p<0.01), while with other pesticide handling practices there was no significant relationship. It was also found that the practice of rinsing used pesticide containers before the containers were disposed of was related to farmers' practices before and during pesticide use (r=0.271, p<0.01). In addition, the practice of disposing of used pesticide containers by farmers was related to the practice of rinsing empty pesticide containers before disposing of them (r=0.296, p<0.01). Another finding from this study is that farmers have followed correct practices in the use of masks and appropriate clothing when spraying as well as rinsing 3 times on empty pesticide containers. However, farmers do not wear gloves when applying pesticides and are often found dumping the rest of the pesticide concentrate on unproductive land.	There is no relationship between farmers' environmental behavior and pesticide handling practices. Therefore, strategies aimed at increasing public awareness will not necessarily affect the practice of using pesticides among farmers. It is predicted that the agricultural sector will not stop relying on the use of pesticides to produce food at affordable prices, but the safety in the practice of using pesticides can still be improved. Farmers are important partners of agricultural stakeholders, because farmers can be empowered in the pesticide pollution reduction scheme.
Liu Y, Wang J, Zhu X, Liu Y, Cheng M, Xing W, et al (32)	Effects of Electrolyzed Water Treatment on Pesticide Removal and Texture Quality in Fresh-Cut Cabbage, Broccoli, and Color Pepper	54 groups treatment (@10 g) of cabbage, broccoli, and color pepper	Experimental study	Alkaline electrolyzed (AlEW) is proven to efficiently remove pesticide residues found in colored chilies, while Acid Electrolyzed (AcEW) is proven to be optimal for removing pesticide residues in broccoli and cabbage. AcEW can remove pyrethroids and organophosphates more than fungicides, while AlEW is more effective in removing fungicides. The most optimal removal of pesticide residues in cabbage is achieved through continuous oscillations (effective up to 72.28%-91.04%), while intermittent oscillations with a duration of 20 minutes can achieve optimal results for removing pesticide residues in broccoli and colored chilies (effective up to 20 minutes). with 72.28%-90.11% for broccoli and 72.24%-88.12% for colored chili). Overall, there was no significant negative change in the texture of the samples treated with electrolyzed water for 5 – 25 minutes. Alkaline electrolyzed (AlEW) is proven to efficiently remove pesticide residues found in colored chilies, while Acid Electrolyzed (AcEW) is proven to be optimal for removing pesticide residues in broccoli and cabbage. AcEW can remove pyrethroids and organophosphates more than fungicides, while AlEW is more effective in removing fungicides. The most optimal removal of pesticide residues in cabbage is achieved through continuous oscillations (effective up to 72.28%-91.04%), while intermittent oscillations with a duration of 20 minutes can achieve optimal results for removing pesticide residues in broccoli and colored chilies (effective up to 20 minutes). with 72.28%-90.11% for broccoli and 72.24%-88.12% for colored chili). Overall, there was no significant negative change in the texture of the samples treated with electrolyzed water for 5 – 25 minutes.	The results of this study found that organophosphate, pyrethroid, and fungicide pesticide residues contained in fresh vegetable pieces can be removed by electrolyzing water treatment. This treatment does not reduce the quality of the texture of the vegetables.
Siddique Z, Malik AU, Asi MR, Inam-ur-Raheem M, Iqbal M, Abdullah M (27)	Impact of Sonolytic Ozonation (O3/US) on Degradation of Pesticide Residues in Fresh Vegetables and Fruits: Case Study of Faisalabad, Pakistan	18 groups treatment (@50 g) of vegetables (okra, spinach, tomato, cucumber, cauliflower and chillies) and fruits (peach, grapes and guava)	Experimental study	In this study, various types of vegetables (such as tomatoes, okra, cucumber, spinach, cauliflower, and chilies) and fruits (such as peaches, guavas, and grapes) that were contaminated with pesticides, were collected from Faisalabad Market. Most of the MRL of these vegetables and fruits exceeds the CODEX standard, where the residual content of vegetables is relatively higher than that of fruits (mean residue of vegetables is 9.006 g/g and fruit is 1.921 g/g). The solonic ozonation technique (O3/US) for 6 and 10 minutes was found to significantly reduce the levels of pesticide residues in vegetables and fruits. The effectiveness of reducing pesticide residues varies between 24-100% depending on the type of fruit/vegetable and chemical/pesticide. Treatment using O3/US on vegetables on average can reduce pesticide residues by 44.61%, and 60.85% on fruit when compared to ordinary washing using tap water.	Based on the experiments in this study, it is known that solonic ozonation (O3/US) is included in food safety interventions at the household level because it is proven to significantly reduce pesticide contamination in fresh agricultural products (vegetables and fruit) and reduce health risks for consumers.

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Shentema MG, Bråtveit M, Kumie A, Deressa W, Moen BE (20)	Respiratory Health among Pesticide Sprayers at Flower Farms in Ethiopia	285 male farms	cross-sectional study	This study involved 285 male workers as respondents, the figure consisted of 152 sprayers and 133 non-pesticide sprayers. The average age of respondents in this study was 25 years for sprayers and 24 years for non-sprayers. The results showed that symptoms such as coughing, coughing up phlegm, shortness of breath, and wheezing were not significantly different in the two groups. Meanwhile, chest tightness was significantly higher in the non-spray group. The sprayer group had significantly higher FVC and FEV1 measurements than the non-spray group.	There was no significant difference in symptoms of respiratory distress in the spraying and non-spraying worker groups. However, non-spray workers experienced increased chest tightness. The results of the FVC and FEV1 measurements in the sprayer group were significantly higher than the non-spray group. The findings in this study must be interpreted with caution considering that there is a possibility that this might occur because the spraying group used respiratory protection equipment that could reduce pesticide exposure. In addition, young and healthy age factors can also influence and are present in the spray group.
Sosnowska EP, Sobczak WZ, Sobczak P, Domański M, Szwajgier D (24)	Determination of The Content of Selected Pesticides in Surface Waters as A Marker of Environmental Pollution	25 of water sample	Case study	Research on water quality testing to determine the presence or absence of neonicotinoid pesticide contamination in the Lublin rural area, showed that there was no pesticide residue contamination from the cultivated land and gardens examined. Therefore, monitoring water quality in rural areas can be used as a good factor in increasing sustainable village development.	The results of this study revealed that there was no evidence of neonocotinoid contamination in the studied water. Water quality in the studied area can be a good factor in promoting sustainable development. These results, have complemented previous knowledge about the impact of neonicotinoids on the environment and the food chain in the long term. It can be concluded that in the studied villages there is no use of neonicotinoids.
Adamu A, Abebe W (2)	Practices and Challenges of Wheat Producer Farmers on Safe Pesticide Use in Basoliben District, East Gojjam Zone, Ethiopia	302 smallholder wheat producer farmers	Cross sectional study	Some farmers practice good practices in pesticide use such as calibrating the sprayer machine and paying attention to the wind direction when spraying. However, there are still many farmers who practice bad practices in the use of pesticides such as poor personal hygiene, disposal of pesticide waste, and not using PPE.	Poor pesticide use practices are caused by the lack of knowledge of farmers. This is due to the lack of access to training for farmers and the lack of information they get from agricultural extension workers.

largest continent on the earth's surface with a land area of one quarter of the earth's surface area. This condition certainly shows that the area for agriculture in the Asian continent is wider than that in the other two continents, so that there will be more agricultural products from the Asian continent. However, this will also create a potential risk of contamination of the environment and agricultural products that is greater if no preventive procedures are carried out when using pesticides.

Pesticide Contamination in the Environment and its Handling

Although the initial purpose of using pesticides was for the benefit of humans through increasing agricultural yields, nowadays the negative impact of pesticide use on human health and various environmental components is widely recognized. This happens because most pesticides do not specifically kill the target animal but can kill other organisms that are useful for the survival of the ecosystem (8). In addition, pesticides can contaminate the environment so that they can reduce soil health, water quality, and air quality (9–11). This statement is supported by the results of a review, where pesticide residues in water can pose an acute risk to aquatic ecosystems, terrestrial soil ecosystems, bees, and non-target terrestrial arthropods (12).

Research on small-scale wheat farmers in Ethiopia states that there are many farmers who practice bad pesticide use. These practices include the use of unlabeled pesticides. This is because the pesticide circulating in the market has a dosage for -1 hectare of land and small-scale farmers do not have that area of land. As a result, farmers buy unlabeled pesticides that are repackaged so that there is no clear information on how to use them. Farmers do not know the actual dose when mixing leading them to spray below or above the dose. Moreover, farmers re-spray the remaining pesticide in the tank because there is still a lot of liquid left, even though this harms other microorganisms in the soil or insects that are not harmful. Mixing 2-3 types of pesticides in one spray is also a common thing done by farmers because they think it is more effective. However, this is actually very dangerous as some pesticides are not used in open areas or actually increase pest resistance and reduce their effectiveness (2). Based on the results of previous studies, farmers with a high level of education or training for pesticide application can use fewer pesticides, thereby reducing pesticide contamination in the environment. This is because farmers are unlikely to be influenced by retailers' suggestions (13).

Improper handling of pesticides can pose risks to human health and the environment such as disposal of residual pesticide solutions in any place, and washing spray equipment in rivers or water sources for irrigation (14). In addition, personal hygiene is a serious concern because farmers do not apply good personal hygiene, including not taking a shower immediately after spraying, not changing clothes immediately or not washing clothes separately from other clothes that are not used for handling pesticides (2). Most farmers practice unsafe practices against empty pesticide containers such as burning and burying them on agricultural land (15). Disposal of empty pesticide containers in any place is also something that is commonly done in developing countries, even being reused for domestic purposes (16). The way that can be done for zero residual solution is by measuring how much pesticide is needed and not storing the residual pesticide for use in the next spraying because it can reduce its effectiveness (14). Improper solution preparation also allows for overuse which can pollute the environment and can lead to pest resistance (16).

A study in Uganda stated that based on data from the Food and Agriculture Organization, the use of pesticides in the country in 2020 reached 18,928.16 tons per year, which is about 0.1% of global pesticide use. Farmers in Uganda use several classes of pesticides at once in their fruit and vegetable production process. These pesticides include organophosphates, pyrethroids, carbamates, neonicotinoids, and dithiocarbamates (30). The same thing was also found in Nepal and Bangladesh, where it was found that the level of pesticide use in Nepal was 396 g/ha and 47% of farmers in Bangladesh have used pesticides excessively (17−18). Environmental contamination by pesticide residues is also exacerbated by the inappropriate behavior of farmers in the use of pesticides. These pesticide use behaviors include purchasing, mixing, spraying, storage, and disposal. The overall behavior is based on the results of the review, influenced by knowledge of pesticide handling and perceptions/attitudes towards pesticide policy and market management (18).

Among the behavior of pesticide use, behaviors that can significantly contaminate the environment based on the results of the review are spraying pesticides and disposing of used pesticide containers. When farmers spray pesticides on crops, pesticides are not only released into the air in the form of aerosols but also enter the soil and water (19). In the air, pesticide aerosols sprayed on agricultural land can last several hours even though they cannot be detected visually. If workers enter the fields without wearing respiratory protective equipment, pesticides can expose workers and cause health problems both acutely and chronically. In the results of the review, some studies state that there is no significant difference between respiratory symptoms in spray workers and other workers in agriculture. The measurement results of FVC and FEV1 in the non-pesticide sprayer group were higher than in the non-sprayer group. An important note of this study is that these results should be interpreted with caution considering that spray workers generally use respiratory protection equipment when spraying pesticides so that this can reduce pesticide exposure (20). As previously explained, the disposal of used pesticide containers also needs attention to the issue of environmental pollution. In China, for example, more than 3.2 billion packages of pesticide waste weighing an estimated 100,000 tons are improperly disposed of. The pesticide residue contained in the waste package is estimated at 2-5% or around 2,000-5,000 tons (21). According to a literature study, it is known that the behavior of farmers in handling used pesticide containers is positively correlated with the behavior of farmers towards the environment. Farmers with good behavior towards the environment are more likely to practice rinsing the pesticide container before disposing of the pesticide container (22).

The presence of pesticide residues such as neonicotinoids in the environment can accumulate and mix with other pesticide residues to form new compound combinations that are more toxic than the single compound. As a form of preventing this accumulation, it is necessary to monitor environmental quality as a form of early detection. This is done to prevent a greater detrimental effect due to repeated pesticide pollution from human activities (23−24).

The history of pesticides used in horticulture 10-20 years ago resulted in continuous pollution in catch outlets due to contamination of soil and aquifers. This type of pollution raises questions about the management of contaminated compartments (such as soil and aquifers) and the potential implications of these long-term local conditions on larger-scale pollution. River flow is also one of the environmental media that is potentially polluted by pesticides. Pollution of rivers due to pesticides can be reduced only by avoiding the emergence of continuous contamination. Based on a combination of water quality monitoring and farmer surveys, several studies present and analyze farmer practices and water contamination at catchment outlets. Pesticide contamination depends not only on the intrinsic characteristics of the pesticide but also on the combination of application intensity in terms of frequency and quantity and on the hydrological function of the catchment.

The types of pesticides that are still used in tropical conditions can present a serious risk of aquifer contamination. Metholachlor is still permitted even though it chronically contaminates sewers. The use of glyphosate, phosphatase, and propiconazole can result in persistent contamination in the medium to long term, as can some historical pesticides. To reduce the risk of polluting these water resources in the long term, the only way to protect them is to reduce or prohibit the use of these pesticides in the horticultural system. Research in India's watersheds shows the design of cropping systems that are less dependent on pesticides and their appropriation by farmers. In addition, there are some pesticides that are not detected in the river despite the intensive application pattern. This undetected pollution raises questions about the processes underlying the fate of these pesticides. First, understanding their fate will allow them to better anticipate and avoid future pollution. Second, it will make it possible to assess the potential impact of the increased pesticide use in the case of farmers shifting pesticides (changes to cropping systems or evolution of regulations) (6). Therefore, the incorporation of modeling and monitoring research to assess the current and future effects of pesticides in tropical horticultural cropping systems on water resources is still necessary to co-design and adapt cropping systems with farmers.

Most of the farmers in Cameroon, Iran, Pakistan, and Kuwait only have primary education or no formal education and are even illiterate, and only a small proportion of farmers receive training on safe agricultural practices (1,14–16). Low levels of education can affect the capacity of farmers to understand safe agricultural practices such as the use of pesticides (1). Farmers with low education or illiteracy find it difficult to understand the danger warnings on pesticide labels and how to avoid exposure to pesticides, as well as safe practices for their use. This is in line with research which states that farmers who have knowledge of agricultural practices can understand the product information used and can prepare the required dosage. The training is considered to be able to improve the attitudes and behavior of farmers in handling pesticides and using the correct PPE (10, 12). However, studies in Pakistan and Kuwait show that farmers have never received training from related parties, which results in farmers practicing unsafe agricultural practices (15−16).

The use of PPE on farmers such as long clothes, hats and boots is only intended to protect farmers from cold temperatures and prevent droplets during pesticide spraying, not to protect themselves from exposure to hazards due to the use of pesticides from mixing, spraying, to disposal of waste. This is due to the lack of knowledge that farmers have regarding this matter. Another factor is the limited availability of PPE in the market because the price is quite expensive for farmers. Traders do not provide PPE because they feel that farmers will not be able to afford it. Some farmers who do spraying sometimes cover their mouths and noses with towels to avoid the smell of pesticides, but this cannot prevent exposure to pesticides that enter through inhalation (2).

The problem in this study which became the main problem of poor pesticide handling was the lack of knowledge about safe pesticide handling due to lack of training or limited information from health educators. If farmers are provided with knowledge of how to read labels and instructions correctly, at least this can reduce the risk of exposure to pesticides that harm farmers and other microorganisms. Other training needed is also related to how farmers can apply good personal hygiene and the use of PPE aimed at reducing the danger of exposure to hazard due to the use of pesticides (2).

Health risks from pesticide residues in drinking water have been widely reported in many countries (1). Pollution of water used for agricultural purposes due to poor handling of pesticides does not only occur in developing countries but also in developed countries (14). Research conducted in Ravine Catchment, France, which is 20% of the drinking water sources for local residents, shows that the waters are contaminated with pesticides. Some types of pesticides that are proven to have a risk of polluting waters should be banned and not allowed to be used again (25).

Lack of training in agricultural practices affects farmers in the use of PPE such as incomplete PPE used by farmers when using pesticides such as trousers, long sleeves, boots, gloves, masks, hats, and glasses. Farmers only wear one or two types of PPE such as long sleeves and long pants when using pesticides even though they know the health risks of using pesticides

(1,14). Farmers feel uncomfortable and do not need to use several types of PPE in handling pesticides (14). In line with research from Kuwait, farmers are reluctant to use PPE because they are uncomfortable with the hot and humid environment; besides, PPE is considered as something that can slow down the work of farmers (11).

Whereas in doing their work, farmers are accustomed to walking in irrigation flows and wetting their clothes which cause them to experience complaints such as itching and skin burning due to pesticide contamination in the waters. The use of PPE such as gloves and boots can reduce contact with polluted irrigation water which can reduce the risk of waterborne disease (1). Most farmers also experience complaints of acute pesticide poisoning due to poor handling of pesticides such as headaches, nausea, eye and skin irritation, which can be reduced by using proper PPE (15). In addition, the training should also be delivered on safe and appropriate methods for storing and applying pesticides, use of personal protective equipment and personal hygiene during and after contact with pesticides, introducing the risk of adverse pesticide exposure to health and the environment, introducing strategies as other alternatives in controlling pests, and introducing safe methods for managing used pesticide stocks and containers, such as rinsing used pesticide containers before disposal.

Pesticide Contamination in the Agriculture Product and its Handling

An experimental study conducted in rural south-western Uganda found that pesticide residues exceeded the MRL in 59.52% of sprayed samples, 18% not sprayed, and 8% in marketed vegetable samples. The study revealed that the use of mixed pesticides can cause antagonistic or synergistic effects that can affect the efficiency of pesticides and some pesticide residues that can affect food quality. Therefore, farmers should avoid the use of mixed pesticides on food crops and look for plant-specific pesticides that are properly tested against the specific pests of those crop (4).

Based on the results of the review, many experimental studies have been conducted to investigate effective ways to reduce pesticide residues in agricultural products. This is motivated by the finding of pesticide residue levels that exceed the MRL in agricultural products and to reduce these levels is not enough to use only tap water (26−27). Research conducted in Korea of 1,055 samples (92%) were residue free and 91 samples contained residues and 11 of them exceeded the Korean MRL. A risk assessment was carried out to calculate the food safety value of fruits and vegetables containing pesticide residues and the result was that the fruits and vegetables were still safe for consumption because they had values below the provisions. In contrast to other studies conducted in Vietnam, 81% of the 290 samples contained pesticide residues and 23% exceeded MRL and one of the pesticide residues, namely friponil, was proven to be a potential risk to human health. In line with research conducted in India, organophosphorus pesticide residues (methyl parathion and triazophos) pose a health risk to children. This needs to be a concern to improve food safety so that fruits and vegetables circulating in the community should not contain pesticide residues that exceed the MRL (2, 24−25). Several previous studies have found pesticide residues in vegetables, but this study did not assess the health risks associated with pesticide food intake. Pesticide intake in food (especially the amount consumed) differed between groups (2).

Pesticide residues can increase because pesticide applications are carried out at harvest time and residues can be reduced by washing, peeling, and cooking processes (30). Thus, consumers are recommended to wash fruits and vegetables and cook vegetables properly as a way to reduce the impact of health risks from pesticide residues (29). Many previous studies have shown that washing vegetables under running water can effectively remove pesticide residues left on fruits and vegetables. However, it is important to note that running water alone is not enough to completely remove pesticide residues. This is confirmed by the results of a study which found that washing under running water only reduced 41-44% chlorpyrifos residue on the tomato surface, 93% dimethoate residue and 65% carbofuran residue on the cabbage surface, and 24% chlorpyrifos residue on the asparagus surface. Washing under running water can also only remove 55% of profenofos residue on the surface of Chinese kale. The results of these measurements prove that pesticide residues on the surface of vegetables cannot be removed 100% by washing under running water. Residual levels of pesticide residues can still be found in vegetables that have been washed because these pesticides have been absorbed into plant components and cannot be washed away by washing water (31).

Another study in Thailand also confirmed that the process of cooking vegetables by blanching, boiling, and frying can help reduce pesticide residues left on the 2 types of vegetables that are most often consumed (Chinese kale and long beans). Therefore, consumers need not only motivation to wash vegetables but also information about proper and effective cooking methods in reducing pesticide residues on vegetables before consuming them. Knowledge and awareness of consumers about the effects of an effective cooking/processing of vegetables to reduce the possibility of pesticides entering the body has the potential to encourage consumers to consume more vegetables (31).

Other proven effective ways to reduce pesticide residues are using electrolyzed water treatment (for pyrethroid, organophosphate and fungicide residues on fresh-cut vegetables), sonolytic ozonation (for pesticide residues Thiamethoxam, Imidacloprid, Acetamiprid, Thiacloprid, and Carbendazim in fruits and vegetables), and ozonated water (for pesticide residues malathion and carbosulfan on green vegetables) (26−27, 32). From these findings, it has also been noted how to remove pesticide residues on vegetables and fruits without reducing the quality of the product and its application at the household scale (26−27).

CONCLUSION

Environmental pollution due to pesticides is caused by the behavior of spraying pesticides and the disposal of used pesticide containers by farmers. Ways to reduce it are by measuring how much pesticide is needed, training to increase knowledge about agricultural practices in preparing the required dose, and monitoring environmental quality regularly. Pesticide residues can increase because pesticide applications are carried out at harvest time and residues can be reduced by washing, peeling, and cooking processes. In addition, other proven effective ways to reduce pesticide residues are using electrolyzed water treatment, sonolytic ozonation, and ozonated water. The use of unsafe pesticides will pollute the environment and endanger health through the food chain. Training for farmers to use pesticides properly is considered effective in reducing pesticide contamination in the environment. Training should be able to provide appropriate skills on methods of storing and applying pesticides, use of personal protective equipment and the application of personal hygiene (during and after pesticide management), introduction of pesticide risks to health and the environment, introduction of other strategies to control pests (besides pesticides), and introduction of safe methods in the management of used pesticide waste. In addition, the reduction of pesticide residues in agricultural products can be done by carrying out treatment processes for washing, peeling, cooking (boil, boil and fry), electrolyzed water treatment, sonolytic ozonation, and ozonated water.

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