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Abstract: Human pesticide exposure remains a significant issue, impacting both the environment and human health. Occupational pesticide exposure is primarily linked to improper worker practices, often due to a lack of knowledge or difficulty interpreting label information and other technical aspects of pesticide application. This systematic review aims to identify the pesticides most used by agricultural workers, the symptoms they experience due to exposure, and the GHS hazard statements on these pesticide labels. Following the PRISMA guidelines, the search identified 16 articles addressing health effects associated with the most frequently used pesticides. These studies predominantly come from Asia (68.8%), Africa (25%), and America (6.2%), with most pesticides being outside the list approved by the EC. Related symptoms were reported in 80 to 100% of the studies that included these pesticides. An evident relationship has been identified between GHS hazard statements and associated symptoms for certain pesticides. Therefore, companies and public authorities must collaborate to improve workers' training, particularly in reading and interpreting product labels. Additionally, they must thoroughly explain the risks associated with improper pesticide practices and application to safeguard workers' health.

Keywords: health effects; pesticide exposure; agricultural workers; practices



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1. Introduction

The World Health Organization (WHO) states that pesticides are a leading cause of self-poisoning deaths, especially in low- and middle-income countries [1]. This is due to varying agricultural practices, protocols, regulations, and the use of toxic chemical substances.

Oral exposure can occur by eating, drinking, or smoking while handling or by putting objects or parts of the application equipment in the mouth. Contact can also happen when using containers for handling pesticides for other secondary purposes, such as the storage of water or food, or by containers other than the original (unidentified) ones for the storage of pesticides. Protecting access to the gastrointestinal tract is essential to avoid possible contact through ingestion of contaminated water or food, including cases where ingestion is voluntary or involuntary [2].

Conversely, pesticides can reach workers' skin via the cutaneous route in situations involving spillage, splashes, use of contaminated clothing and accessories, or even airborne particles. These toxins can also enter the body through open wounds or other injuries [2]. The same authors also refer to the respiratory route, considering small particles (aerosols, droplets, dust, etc.) suspended in the atmosphere, which can allow toxic substances to reach the lungs through the air we breathe.

According to the WHO [3], pesticides are classified according to their toxicity to human health as extremely hazardous (Ia), highly hazardous (Ib), moderately hazardous (II), slightly hazardous (III), and unlikely to cause acute poisoning (U). Once in the body, active substances can cause various signs and symptoms of intoxication, whether acute (symptoms manifest in a short time) or chronic (symptoms are less visible and may only appear after prolonged exposure) in exposed individuals. Exposure can also cause allergic reactions [4–6].

On the other hand, the effects of chronic exposure may be associated with changes in the nervous system (neurotoxicity), dermatitis (skin changes), behavioral changes, and even certain cancers, in particular, prostate cancer and non-Hodgkin’s lymphoma [7–12].

However, research needs to be more consistent about this association (cancer–pesticides); the diversity of results is proposed to be based on differences in individual susceptibility [13]. Some studies suggest that pesticides may be linked to the induction of oxidative stress, leading to changes in the regular process of DNA replication and repair [8,9,12,14–16]. Some studies have also linked these toxic substances to an increase in the prevalence of asthma and restrictive lung disease in farmers, although further studies are needed to draw more accurate conclusions, as well as touch on possible immunological changes [9,15–17].

The effects of environmental and occupational exposure to pesticides are mainly associated with inappropriate worker practices. These include failure to use personal protective equipment (PPE) due to different weather conditions and levels of knowledge, ignorance of labels and technical aspects related to pesticides (such as the concentration of the product and the recommended amount to be applied), improper storage, use of pesticide mixtures, and consumption of food and drinks while using these products [2,18–24].

Therefore, this systematic review aims to identify the pesticides most used by agricultural workers and the symptoms they experience from exposure. Additionally, it will gather information on the hazard statements related to health hazards from the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) found on the labels of these pesticides. The review seeks to compare these hazard statements with the reported symptoms and to establish a qualitative relationship with agricultural workers’ pesticide use practices.

2. Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[®] guidelines were used to conduct this systematic review (Figure 1) [25].

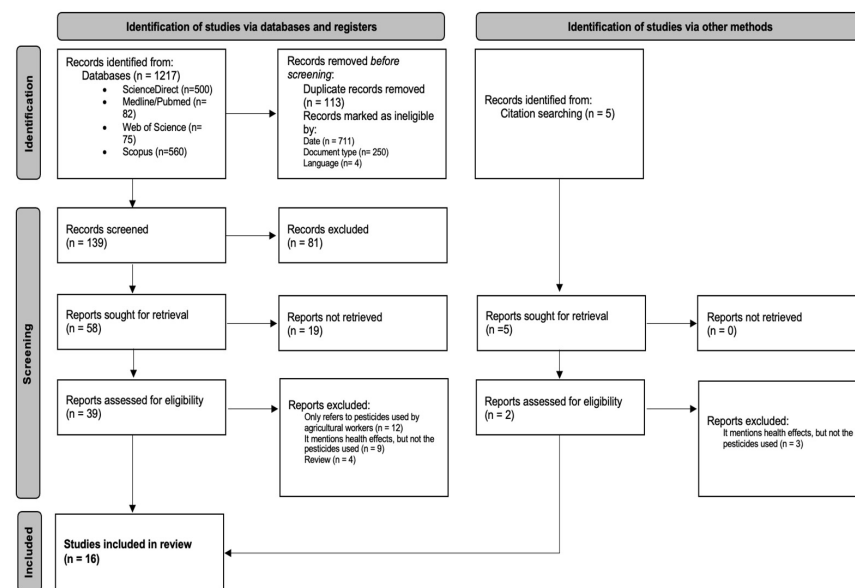


Figure 1. PRISMA 2020 flow diagram for this systematic review.

2.1. Eligibility Criteria

The following criteria were used in the search and selection process. Applying the PICOS principle (Table 1), all the articles in which the agricultural workers mentioned the pesticides used and the health effects they had already experienced were included. Articles were included if the participants were agricultural workers. Articles were excluded if they only mentioned workers' practices regarding pesticide use or included biomonitoring of exposure to the same products. In addition, articles were only included if they met the defined objective of this study.

Only articles written in English were included. Literature reviews and conference papers were considered eligible.

Table 1. PICOS principle inclusion and exclusion criteria.

PICOS	Inclusion Criteria	Exclusion Criteria
Population or Problem (P)	Agricultural workers reporting the use of pesticides at work and the health effects associated with this use (cumulatively).	<ul style="list-style-type: none"> • Studies that address pesticide exposure in other populations or environments. • Studies dealing with occupational exposure to pesticides but not specifying the pesticides used by agricultural workers. • Studies that address occupational exposure to pesticides and specify the pesticides used by agricultural workers but do not report on the health effects experienced by agricultural workers. • Studies reporting on the health effects experienced by agricultural workers during pesticide use but do not specify the pesticides used.
Intervention (I)	Occupational exposure of agricultural workers to pesticides and related health effects.	<ul style="list-style-type: none"> • Other interventions outside the study.
Comparison (C)	Not applicable	Not applicable
Outcomes (O)	Recent data reported (last 5 years) about adverse effects experienced by agricultural workers and their relationship to the health impact caused by the pesticides used.	<ul style="list-style-type: none"> • Data from literature reviews and conference papers. • Data and studies not in English. • Other outcomes outside the study.
Study Design (S)	Descriptive, observational, cross-sectional or experimental studies using inquiries or protocols, regarding the identification of pesticide groups and health effects experienced by workers	<ul style="list-style-type: none"> • Narrative literature reviews, systematic reviews with and without meta-analysis, opinion reviews and reports. • Studies where it is not possible to access all published data.

2.2. Information Sources and Search Strategy

Searches for articles were carried out in four databases: Medline/PubMed, ScienceDirect, Scopus, and Web of Science. To obtain the most recent and relevant information, articles published between the years 2018 and 2023 were searched using the following keyword expressions: ["health effect*" OR "risk*" AND pesticide AND agricultural workers OR farmworkers AND practices OR label)].

Databases were searched as follows: "article title, abstract, keywords". In addition to the database search, the references of the selected articles were analyzed to ensure that as many articles as possible that were related to the defined objective were included.

2.3. Selection Process

After entering the keywords, the databases were filtered by date (publications between 2018 and 2023), document type (articles), source type (journals), and language (English).

Articles were excluded if they referred only to data obtained through biomonitoring of pesticide exposure, referred only to workers’ practices in using these products, and did not mention the pesticides most used by workers and/or the health effects already experienced (consciously or unconsciously) because of hazardous exposure to pesticides.

All data obtained from the search and selection of articles were recorded in an Excel spreadsheet. After the search, the articles were moved to the *Mendeley Reference Manager*® 2.107.0 software to remove duplicates. Two reviewers (A.M. and M.V.S.) then independently analyzed the titles and abstracts. Any disagreements between the reviewers were the subject of discussion and resolution between the reviewers. The relevant articles were fully and independently appraised, and data were collected to select the studies for inclusion in the systematic review. Information on the selection process and the reasons for excluding an article from inclusion in the review were documented.

2.4. Data Collection Process and Data Items

The following information was collected from the included articles: authors, year of publication, the country where the study was conducted, type of study, characteristics of participants, pesticides most used by workers, classification of pesticides by group, and the WHO classification of pesticides by hazard. Finally, the most common symptoms experienced by agricultural workers were recorded. In addition, further research was carried out to complete the information on the active substances/pesticides identified, according to the *Globally Harmonized System of Classification and Labelling of Chemicals Health Hazards* (GHS).

2.5. Risk of Bias Assessment

The risk of bias was analyzed according to the *Cochrane Risk of Bias in Non-Randomized Studies of Interventions* (ROBINS) guidelines.

3. Results

3.1. Study Selection

The systematic review included 16 articles. The article selection process is described in Figure 1.

3.2. Included Study Characteristics

The selected studies for the systematic review show a decreasing trend in publication over time, with 2021 being the year with the highest number of articles. Table 2 summarizes the other key characteristics of the studies included in the review.

Table 2. Summary of the general characteristics of the studies in the review.

Study	Country	Number of Participants (Gender)	Pesticide Safety Education/Training	Representative PPE Use ¹
[26]	Nigeria	524 (Male = 79.3% Female = 19.1%)	There is no mention of their training in the study, but the workers do have high scores on the knowledge questions	Yes
[27]	India	217 (Male = 92% Female = 18%)	The study did not mention training, and the workers revealed poor knowledge	No
[28]	Iran	380 (Male = 100%)	Participation in a training course (92.1%), and the workers revealed moderate knowledge	No
[29]	Pakistan	307	Training is mentioned but not quantified	No

Table 2. Cont.

Study	Country	Number of Participants (Gender)	Pesticide Safety Education/Training	Representative PPE Use ¹
[30]	Thailand	70 (Male = 100%)	The study did not mention training	No
[21]	India	96	There is no mention of their training in the study, but they do have high scores on the knowledge questions	Yes
[19]	Iran	200	Participation in a training course (27%)	Yes
[31]	Morocco	526 (Male = 100%)	Participation in a training course (19.4%)	No
[32]	Cameroon	104 (Male = 86.5% Female = 13.5%)	Participation in a training course (35.6%)	No
[33]	Bangladesh	150 (Male = 87.3% Female = 12.7%)	There is no mention of their training in the study, but the workers do have moderate scores on the knowledge questions	Yes
[34]	Pakistan	260 (Female = 100%)	The study did not mention training, and the workers revealed poor knowledge and practices	No
[35]	Kenya	173	Participation in a training course (31%)	No
[36]	Thailand	117 (Male = 66.7% Female = 33.3%)	There is no mention of their training in the study, but the workers do have high scores on the knowledge questions	Yes
[37]	Thailand	4035 (Male = 45.6% Female = 54.4%)	There is no mention of their training in the study, but they do have high scores on the knowledge questions	Yes
[38]	Kelantan	144 (Male = 85.4% Female = 14.6%)	Participation in a training course (52.8%)	Mentioned but not detailed use
[39]	Costa Rica	48 (Male = 96% Female = 4%)	The study did not mention training	Unmentioned

¹ Representative PPE use—more than 50% of workers report using at least one type of personal protective equipment (not specified).

Regarding study type, this systematic review includes four observational studies and twelve cross-sectional studies. Regarding the location of the studies, 68.8% were conducted in Asia and 25% in Africa. Only one study was conducted in America.

The studies involved agricultural workers who reported their pesticide use practices and associated symptoms through interviews and questionnaires. The number of participants ranged from 70 to 526.

3.3. Most Used Pesticides and Mainly Reported Health Effects

Analysis of the included articles showed that 94 different pesticides/active substances commonly used by agricultural workers were mentioned. This analysis also identified four types of active substances, listed in the WHO classification of pesticides by hazard (2019) as obsolete or no longer used as pesticides (dieldrin, endrin, aldrin and diclorofenthion). In addition, seven pesticides were mentioned that were not identified by the same classification, and 4% of the identified pesticides are classified as extremely hazardous, 9% as highly hazardous, and 57% as moderately hazardous. In turn, 21% and 7% are slightly hazardous and unlikely to present an acute hazard in normal use.

Most pesticides identified are insecticides (52%) and fungicides (26%), as shown in Figure 2. It should be noted that some studies did not report the most used pesticides, only the pesticide group. However, the values reported are consistent with those presented.

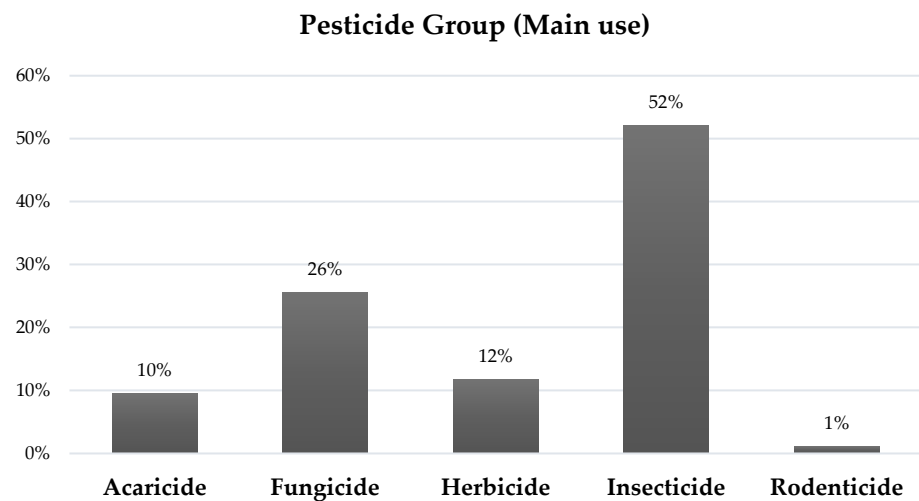


Figure 2. Pesticide group/main use of mentioned pesticides.

Due to the large number of active substances identified in the articles, only those active substances used by agricultural workers that were mentioned in three or more of the included articles were selected. These substances were then analyzed according to the GHS to establish a relationship with the symptoms already experienced by agricultural workers in relation to this use. However, an overview was made of all active substances mentioned by the workers, the number of articles in which they were mentioned, their classification according to the most common group/use, and the WHO classification. This information is presented in Appendix A (Table A1). Table 3 summarizes the active substances/pesticides most used by agricultural workers in the different articles and the corresponding WHO classification of pesticides by health hazard. Most of the 22 selected active substances are insecticides (63.6%). Within the European legal framework, only 31.8% of these pesticides are approved by the European Commission.

Of the pesticides used, 68.1% are classified as moderately hazardous according to the WHO classification of pesticides by hazard (2019). Altogether, 18% are classified as highly hazardous (Figure 3).

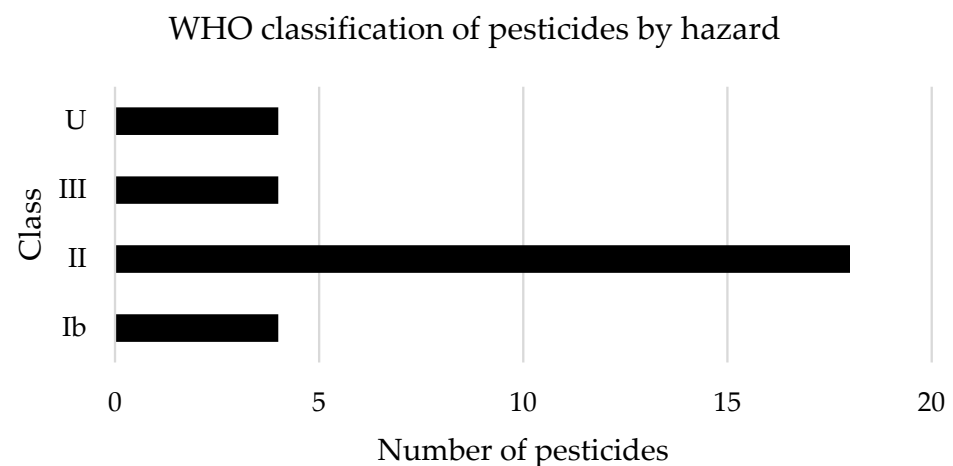


Figure 3. WHO classification of pesticides by hazard for the 22 most used pesticides. Note: Ib = highly hazardous, II = moderately hazardous, III = slightly hazardous, U = unlikely to present acute hazard in normal use [3].

To qualitatively analyze the relationship between the symptoms most frequently reported by agricultural workers about different pesticides/active substances and the GHS hazard statements for the same substances, the respective active substances/pesticides were organized, and the GHS hazard statements were assigned only to health hazards (classified with $\geq 50\%$) [40]. The articles mentioning each pesticide were then referenced.

Table 3. Summarized information about the most used pesticides mentioned (≥ 3 articles) in the included articles.

Pesticide Group (Main Mentioned)	Most Used Pesticides	Approved/Not Approved by EC ⁽¹⁾	WHO Classification ⁽²⁾	Number of Articles
Acaricide	Dicofol	Not approved	II	3
Fungicide	Mancozeb	Not approved (2021) *	U	8
	Carbenzadim	No information	U	6
	Captan	Approved	U	3
	Dodine	Approved	II	3
Herbicide	Paraquat	Not approved	II	6
	Glyphosate	Approved	III	5
	2,4 Dichlorophenoxyacetic acid	No information	II	3
Insecticide	Cypermethrin	Approved	II	10
	Imidacloprid	Not approved (2020) *	II	6
	Chlorpyrifos	Not approved	II	8
	Lambda Cyhalothrin	No information	II	6
	Malathion	Not approved	III	5
	Acetamiprid	Approved	II	4
	Deltamethrin	Approved	II	4
	Methomyl	Not approved (2019) *	Ib	3
	Diazinon	Not approved	II	4
	Dimethoate	Not approved (2019) *	II	3
	Endosulfan	Not approved	II	3
	Carbofuran	Not approved	Ib	3
	Triazophos	Not approved	Ib	3
	Emamectin Benzoate	Approved	II	3

⁽¹⁾ <https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/start/screen/active-substances> (accessed on 7 August 2024); ⁽²⁾ Ib = highly hazardous, II = moderately hazardous, III = slightly hazardous, U = unlikely to present acute hazard in normal use [3]; * year of application to 'not approved'.

Concerning the symptoms reported, we created a set of the most frequently mentioned symptoms in the included articles to see how many articles mentioned a particular symptom for an episode of pesticide exposure. This information is presented in Table 4. The first column of the table lists the most frequently mentioned pesticides in the included studies, focusing on active substances cited in three or more studies. The second column identifies the studies that reference these frequently mentioned active substances. From this, the number of studies in which agricultural workers reported experiencing symptoms after handling pesticides (without specifying the substance) was used to calculate percentages. The third column presents an analysis of the safety data for these substances, based on the Globally Harmonized System of Classification and Labelling of Chemicals Health Hazards (GHS). The most reported symptoms of acute pesticide poisoning, as documented in the studies, were analyzed in relation to the specific pesticides used. A cross-reference was then made to determine whether studies mentioning a particular pesticide also reported associated symptoms of acute poisoning. This process enabled us to calculate the percentage of studies that contained self-reported symptoms for each pesticide. For example, when examining deltamethrin, we found it was mentioned in four studies. We then determined what proportion of these studies included self-reported data on the symptom "skin injury". All four studies (100%) reported this symptom in relation to pesticide exposure.

Table 4. The most used pesticides and their common symptoms reported by agricultural workers in the articles included most related to the GHS health hazard statements of the active substances mentioned.

Pesticide ¹	Studies with Reference to Pesticide	No. of Participants *	GHS ²	Reported Health Effects Related to GHS Hazards for Health (%) ³						
				Skin Injury	Eye Injury	Headache and Dizziness	Nausea and Vomiting	Fever	Respiratory Problems and Allergy	Diarrhea
2,4 Dichlorophenoxyacetic acid	[26,31,39]	620	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal]) H317 (May cause an allergic skin reaction [Warning Sensitization, Skin]) H318 (Causes serious eye damage [Danger Serious eye damage/eye irritation]) H334 (May cause allergy or asthma symptoms or breathing difficulties if inhaled [Danger Sensitization, respiratory]) H335 (May cause respiratory irritation [Warning Specific target organ toxicity, single exposure; Respiratory tract irritation])	66.7	66.7	66.7	66.7	66.7	66.7	33.3
Acetamiprid	[19,29,31,34]	859	H301 (Toxic if swallowed [Danger Acute toxicity, oral])	75	100	100	100	25	75	25
Captan	[19,21,31]	576	H317 (May cause an allergic skin reaction [Warning Sensitization, Skin]) H318 (Causes serious eye damage [Danger Serious eye damage/eye irritation]) H331 (Toxic if inhaled [Danger Acute toxicity, inhalation]) H351 (Suspected of causing cancer [Warning Carcinogenicity])	100	100	100	66.7	0	100	33.3
Carbenzadim	[21,27,31–33]	802	H317 (May cause an allergic skin reaction [Warning Sensitization, Skin]) H340 (May cause genetic defects [Danger Germ cell mutagenicity])	60	60	80	40	20	60	40
Carbofuran	[29,33,35]	442	H300 (Fatal if swallowed [Danger Acute toxicity, oral]) H330 (Fatal if inhaled [Danger Acute toxicity, inhalation])	100	66.7	100	100	0	33.3	66.7
Chlorpyrifos	[21,27,29,30,32–35,39]	1179	H301 (Toxic if swallowed [Danger Acute toxicity, oral])	77.8	77.8	66.7	55.6	11.1	44.4	33.3

Table 4. Cont.

Pesticide ¹	Studies with Reference to Pesticide	No. of Participants *	GHS ²	Reported Health Effects Related to GHS Hazards for Health (%) ³						
				Skin Injury	Eye Injury	Headache and Dizziness	Nausea and Vomiting	Fever	Respiratory Problems and Allergy	Diarrhea
Cypermethrin	[21,26–29,31–35]	1518	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H332 (Harmful if inhaled [Warning Acute toxicity, inhalation]) H335 (May cause respiratory irritation [Warning Specific target organ toxicity, single exposure; Respiratory tract irritation])	80	80	70	70	10	80	10
Deltamethrin	[27,31,34,35]	811	H331 (Toxic if inhaled [Danger Acute toxicity, inhalation]) H301 (Toxic if swallowed [Danger Acute toxicity, oral])	100	100	100	75	25	75	25
Diazinon	[19,28,33,35]	687	H302 (Harmful if swallowed [Warning Acute toxicity, oral])	100	100	75	100	0	25	50
Dicofol	[21,31,34]	636	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal]) H315 (Causes skin irritation [Warning Skin corrosion/irritation]) H317 (May cause an allergic skin reaction [Warning Sensitization, Skin])	66.7	66.7	100	66.7	33.3	33.3	33.3
Dimethoate	[31,34,35]	521	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal])	100	33.3	33.3	33.3	0	100	33.3
Dodine	[19,21,31]	576	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H315 (Causes skin irritation [Warning Skin corrosion/irritation]) H319 (Causes serious eye irritation [Warning Serious eye damage/eye irritation])	66.7	66.7	100	100	0	33.3	66.7

Table 4. Cont.

Pesticide ¹	Studies with Reference to Pesticide	No. of Participants *	GHS ²	Reported Health Effects Related to GHS Hazards for Health (%) ³						
				Skin Injury	Eye Injury	Headache and Dizziness	Nausea and Vomiting	Fever	Respiratory Problems and Allergy	Diarrhea
Emamectin Benzoate	[27,29,34]	587	H301 (Toxic if swallowed [Danger Acute toxicity, oral]) H311 (Toxic in contact with skin [Danger Acute toxicity, dermal]) H318 (Causes serious eye damage [Danger Serious eye damage/eye irritation]) H331 (Toxic if inhaled [Danger Acute toxicity, inhalation]) H370 (Causes damage to organs [Danger Specific target organ toxicity, single exposure]) H372 (Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure])	100	100	100	66.7	33.3	66.7	33.3
Endosulfan	[31,32,35]	521	H300 (Fatal if swallowed [Danger Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal]) H330 (Fatal if inhaled [Danger Acute toxicity, inhalation])	100	66.7	66.7	66.7	0	100	33.3
Glyphosate	[19,26,31,32,35,39]	1061	H318 (Causes serious eye damage [Danger Serious eye damage/eye irritation])	83.3	66.7	66.7	66.7	0	66.7	50
Imidacloprid	[19,27,29,31,32,34]	1135	H302 (Harmful if swallowed [Warning Acute toxicity, oral])	83.3	100	66.7	66.7	16.7	50	33.3
Lambda Cyhalothrin	[26,31–35]	1203	H301 (Toxic if swallowed [Danger Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal]) H330 (Fatal if inhaled [Danger Acute toxicity, inhalation])	100	83.3	83.3	66.7	16.7	66.7	33.3
Malathion	[26,31,33–35]	1135	H302 (Harmful if swallowed [Warning Acute toxicity, oral]) H317 (May cause an allergic skin reaction [Warning Sensitization, Skin])	100	80	100	80	20	60	40
Mancozeb	[19,21,26,27,31–33,35,39]	1515	H317 (May cause an allergic skin reaction [Warning Sensitization, Skin])	88.9	88.9	66.7	77.8	0	55.6	55.6

Table 4. Cont.

Pesticide ¹	Studies with Reference to Pesticide	No. of Participants *	GHS ²	Reported Health Effects Related to GHS Hazards for Health (%) ³						
				Skin Injury	Eye Injury	Headache and Dizziness	Nausea and Vomiting	Fever	Respiratory Problems and Allergy	Diarrhea
Methomyl	[30,31,35]	513	H300 (Fatal if swallowed [Danger Acute toxicity, oral])	100	100	66.7	66.7	0	66.7	33.3
Paraquat	[19,26,28,31,32,35]	1225	H301 (Toxic if swallowed [Danger Acute toxicity, oral]) H311 (Toxic in contact with skin [Danger Acute toxicity, dermal]) H315 (Causes skin irritation [Warning Skin corrosion/irritation]) H319 (Causes serious eye irritation [Warning Serious eye damage/eye irritation]) H330 (Fatal if inhaled [Danger Acute toxicity, inhalation]) H335 (May cause respiratory irritation [Warning Specific target organ toxicity, single exposure, respiratory tract irritation]) H372 (Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure]);	100	100	66.7	66.7	0	66.7	50
Triazophos	[27,29,34]	587	H301 (Toxic if swallowed [Danger Acute toxicity, oral]) H312 (Harmful in contact with skin [Warning Acute toxicity, dermal]) H331 (Toxic if inhaled [Danger Acute toxicity, inhalation])	100	100	66.7	66.7	33.3	66.7	33.3

¹ Most used pesticides mentioned in included articles (≥ 3). ² Globally Harmonized System of Classification and Labelling of Chemicals Health Hazards (GHS) by National Institutes of Health (NIH) only for health hazards ($\geq 50\%$) (2023). ³ Percentage of studies in which the agricultural workers surveyed reported having experienced this symptom after handling pesticides (not specified). N * = Total number of agricultural workers surveyed who reported they experiencing at least one of the listed symptoms related to the use of the pesticides mentioned in the studies.

From Table 4, the most frequently mentioned GHS hazard statements are H300, H301, H302, H317, H318, and H319: “fatal if swallowed”, “toxic if swallowed”, “harmful if swallowed”, “may cause an allergic skin reaction”, “causes serious eye damage”, and “causes serious eye irritation”, respectively (NIH, 2023). The most reported symptoms were skin and irritation, eye lesions, headache and dizziness, nausea, and vomiting. Fever, on the other hand, was the least frequently reported symptom.

Considering the above results, it is possible to see a potential connection between the GHS hazard statements mentioned on the labels of the respective pesticides and the symptoms most frequently reported by agricultural workers as having already been experienced. A possible relationship was found between the GHS hazard statements for certain pesticides and their associated symptoms. This was particularly evident for the following active substances: acetamiprid, captan, carbofuran, cypermethrin, diazinon, dimethoate, dodine, emamectin benzoate, endosulfan, lambda-cyhalothrin, malathion, mancozeb, paraquat, and triazophos. Related symptoms were reported in 75 to 100% of the studies that included these pesticides.

For instance, the hazard warnings for cypermethrin (the pesticide most mentioned), an active ingredient, refer to acute toxicity by inhalation and ingestion, which can cause respiratory tract irritation. In total, 80% of studies that mention the use of cypermethrin report that agricultural workers have experienced respiratory problems and allergic reactions after using pesticides, displaying H332- and H335-related symptoms. Additionally, regarding H302, 70% of the studies reported nausea, vomiting, headaches, and dizziness episodes. For the remaining cases, the possible relationship could have been stronger. This may be because the symptoms indicate a general use of pesticides. It should be noted that the symptoms reported by workers are general symptoms already experienced when using pesticides and are not directly related to a single pesticide.

Therefore, as in biomonitoring studies, a study of specific symptoms for each active substance is necessary. So, only a possible qualitative relationship can be established between the hazard statements on product labels and the symptoms most reported by workers.

3.4. Risk of Bias in Studies

Regarding the risk of bias in the studies, it was possible to verify that six have a low risk [26,29,30,32,37,39] and ten have a moderate risk of bias [19,21,27,28,31,33–36,38]. Therefore, this needs to be considered when analyzing the results.

4. Discussion

The analysis of the included studies suggests an association between the GHS hazard statements for a certain pesticide and the symptoms commonly reported by agricultural workers, particularly in cases of inappropriate agricultural practices. For instance, workers have reported skin and eye lesions after using captan, which aligns with the GHS warning of its acute toxicity and potential to cause such damage. By cross-referencing these data, we can establish clearer links between the pesticides used and the associated adverse health effects, while also gaining insights into the agricultural practices of workers in the region and their understanding of health protection measures. Moreover, the studies indicate that these practices are influenced by factors such as age, education level, and lack of training or knowledge, leading to unsafe pesticide handling. These unsafe practices, which are frequently reported, pose significant risks to workers' health [2,19,26,28,29,34,41].

The lack of knowledge and training is reflected in practices such as not using personal protective equipment when preparing and applying pesticides, using unsuitable pesticides for the presented problem, not reading product labels, failing to appreciate associated dangers, not following recommended doses for the treated area, and using empty packaging for domestic purposes [21,28,29,31,35]. Such practices have short- and long-term effects on workers' health. In the included studies, a high incidence of acute symptoms was observed in agricultural workers, which were consciously associated with the (inappropriate) use of pesticides—such as using the pesticide without first reading the label and considering the

warnings it contains—resulting in higher exposure levels. This practice is evidenced by workers' self-reports that they do not read or know how to interpret the information on the label of the product they are using. These are the same workers who report episodes of acute poisoning because of unprotected and uncontrolled exposure. In addition, other studies show that many of the workers who say they know how to interpret the labelling of this type of product or are aware of the health risks of exposure, are unable to interpret the safety pictograms on the product when asked [19,21,30,37,41].

The most reported symptoms are related to neurological and neuromuscular symptoms [42], breathing difficulties [26,27,29,31,35], eye and skin irritation and other symptoms of acute intoxication, such as nausea, vomiting, headache, and dizziness [21,23,26–29,31,33,35,37,41]. The reporting and analysis of these symptoms are consistent with the WHO classification of pesticides, considering the associated hazards and the GHS hazard statements for the same products. Given that most pesticides used pose a high or moderate risk to workers' health and that label warnings and precautions are not followed, workers can be expected to contribute to increased exposure to these substances if they do not use personal protective equipment when handling pesticides or if they do not read product labels before use [18,19,21,28,38,43,44].

Training workers to understand the pictograms and color codes on pesticide labels is essential to prevent symptoms of pesticide poisoning. Many workers do not read labels and lack knowledge of hazard classifications [19,21,35,37]. Therefore, providing clear and concise information is crucial to ensure their safety. The number of workers who reported experiencing symptoms resulting from hazardous exposure to pesticides validates these data. Biomonitoring studies of pesticides in urine also indicate the presence of biomarkers associated with these substances, further confirming the need to reduce exposure [45–47].

Biomonitoring directly measures the body's internal dose of pesticides, reflecting actual exposure and potential health risks to individuals [32,48,49]. It provides insight into the adverse effects of pesticide exposure at a biochemical level by allowing the assessment of biomarkers that may indicate early biological effects and potential toxicity [32]. It can be used to target interventions to minimize health risks by identifying periods of high pesticide exposure and assessing the adoption and effectiveness of protective measures [32,48].

Knowledge of standard agricultural practices in handling hazardous pesticides reinforces the need for effective measures to improve workers' understanding of associated health risks. Training in reading and interpreting pesticide labels and GHS hazard statements can be helpful. It is essential to encourage the use of personal protective equipment based on hazard statements and precautions [26,33,36,37]. This approach can reduce workers' exposure to hazardous substances, preventing acute symptoms and irreversible health damage.

Several studies suggest that targeted educational interventions are needed to improve farmworkers' safety, health, and wellbeing. Additionally, local authorities and employers must provide education, motivation, and support to improve farmers' quality of life. These findings are essential for informing policymakers and future research on agricultural health and safety [28,29,34,35].

Although government regulations exist for the use and handling of pesticides, some studies suggest that there needs to be a significant gap in their implementation among dealers, farmers, and agricultural workers. In some cases, the use of prohibited pesticides has been observed, indicating non-compliance with safety standards in this area. Regular inspections of farms are essential to verify working conditions that contribute to the safety and health of workers. A significant association has been found between the availability of personal protective equipment and the incidence of toxicity. Training farm workers to safely use pesticides is essential, but it is equally important to train companies to ensure safe use—a balance between the two is essential [26,27,35,38].

The studies suggest implementing alternative agricultural practices, including biological control, organic farming, and the use of reduced-risk pesticides, to ensure long-term sustainability and mitigate the adverse health effects of pesticide use. It is important to note

that these practices are not only environmentally friendly but also beneficial for human health [28,29,31,36,37].

5. Conclusions

Reducing workers' exposure to pesticides is crucial for protecting their health. This can be achieved by addressing misinformation and promoting the adoption of safer practices that prevent health problems related to both acute and chronic exposure to these substances. It is essential to encourage the reading of product labels and the consideration of the warnings contained therein. In this sense, the adoption of the safe practices mentioned in these documents should be encouraged as a decisive factor in reducing the risk of exposure to pesticides. Therefore, companies and public authorities must collaborate to enhance workers' training, particularly in reading and interpreting product labels, and to clearly explain the risks associated with improper pesticide use. Personal protective equipment (PPE) should also be provided and promoted as a critical tool for reducing exposure, especially given the data on its underuse. By taking these steps, we can protect workers' health and promote the quality and preservation of public health and the environment.

The studies focused on agricultural practices, pesticide use, and exposure-related symptoms among workers associated with selected studies from Asia, Africa, and the Americas. However, similar studies in other regions, including non-EU countries with comparable agricultural practices and EU countries, are equally relevant. Furthermore, more quantitative data is needed to strengthen the conclusions.

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Appendix A

Table A1. Pesticide/active substances mentioned in 1 or 2 included articles, respective pesticide group, and WHO classification.

Pesticide Referenced	Pesticide Group ¹	WHO Classification ²	Pesticide Referenced	Pesticide Group ¹	WHO Classification ²
3-Phenoxybenzoic acid	I	-	Hexythiazox	A	U
Abamectin	A	Ib	Indoxacarb	I	II
Acephate	I	II	Iprodione	F	III
Amitraz	A	II	Maneb	F	U
Atrazine	H	III	Metalaxyl	F	II
Azoxystrobin	F	U	Methyl parathion	I	Ia
Bentazone	H	II	Monocrotophos	I	Ib
Bifenthrin	I	II	Nitenpyram	I	II
Bordeaux mixture	F	II	Nitenpyram	I	II
Boscalid	F	U	Oxycarboxin	I	Ib
Brodifacoum	R	Ia	Oxyfluorfen	H	U
Bromopropylate	A	U	Parathion	I	Ia
Butachlor	H	III	Pendimethalin	H	II
Carbaryl	I	II	Phenothrin	I	II
Carbosulfan	I	II	Phorate	I	Ia
Cartap	I	II	Phosalone	I	II
Chlorantraniliprole	I	U	Profenofos	I	II
Chlorfenapyr	I	II	Propanil	H	II
Copper hydroxide	F	II	Propargite	A	III

Table A1. Cont.

Pesticide Referenced	Pesticide Group ¹	WHO Classification ²	Pesticide Referenced	Pesticide Group ¹	WHO Classification ²
Copper oxychloride	F	II	Propiconazole	F	II
DDT	I	II	Propineb	F	U
Diafenthiuron	I	III	Propoxur	I	II
Dicamba	H	III	Pyridaben	A	II
Dichlorovos	I	Ib	Pyriproxyfen	I	U
Difenoconazole	F	II	Quinalphos	I	II
Edifenphos	F	Ib	Sulphur	F	III
Esfenvalerate	I	II	Tau-fluvinat	I	III
Ethion	I	II	Tebuconazole	F	II
Fenitrothion	I	II	Tetraconazole	F	II
Fenprothrin	A	III	Thiabendazole	F	III
Fenpyroximate	A	II	Thiacloprid	I	II
Fenthion	I	II	Thiophanate-methyl	F	U
Fenvalerate	I	II	Thiram	F	II
Fluazifop-P-butyl	H	III	Ziram	F	II
Hexaconazole	F	III			

¹ A = Acaricide, F = Fungicide, H = Herbicide, I = Insecticide; ² Ia = extremely hazardous, Ib = highly hazardous, II = moderately hazardous; III = slightly hazardous; U = unlikely to present acute hazard in normal use [3].

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