

Systematic Review of the Health Effects of Pesticide Exposure Among Agricultural Workers

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Systematic Review

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Abstract

Background

Agricultural workers are routinely exposed to pesticides through their occupational activities, placing them at increased risk of adverse health outcomes. Although many studies have examined the health effects of pesticide exposure, the evidence remains fragmented across settings, exposure types, and health outcomes, limiting its usefulness for policy and practice.

Aim

This systematic review aimed to synthesise evidence on the health effects associated with occupational pesticide exposure among agricultural workers.

Methods

A systematic search was conducted in PubMed/MEDLINE, Scopus, Web of Science, Embase, and CINAHL for peer-reviewed quantitative studies published in English from 2015 onwards. Eligible studies involved agricultural workers with occupational pesticide exposure and reported health outcomes. Study selection followed PRISMA guidelines. Data were extracted using a standardised framework, and methodological quality was assessed using the Critical Appraisal Skills Programme checklist. Due to heterogeneity in study design and outcome measures, a narrative synthesis was undertaken.

Results

Six studies met the inclusion criteria, including cross-sectional and cohort designs conducted in Africa, Asia, and North America. Pesticide exposure was consistently associated with respiratory symptoms, neurological complaints, renal impairment, and systemic health effects. Adverse outcomes were observed even among younger workers and those with relatively short exposure durations. Unsafe handling practices, inadequate training, and limited use of personal protective equipment increased exposure risk.

Conclusion

Occupational pesticide exposure poses significant and preventable health risks to agricultural workers. Strengthened regulation, improved occupational safety practices, and further high-quality longitudinal research are essential to protect this vulnerable workforce.

1.0. Introduction

Pesticides are widely defined by scholars as chemical or biological substances that are intentionally applied to prevent, destroy, or control pests that threaten agricultural productivity [1, 2]. The Food and Agriculture Organization asserts that pesticides are essential to modern food systems because of their role in crop protection and yield optimisation [3]. According to the World Health Organization [4], pesticide use has increased significantly in recent decades, particularly in low- and middle-income countries, where agricultural intensification, population growth, and food security pressures have led to a greater reliance on chemical pest control methods. According to the Food and Agriculture Organisation [5], over 4 million tonnes of pesticides are used each year globally, with Asia and Africa witnessing the fastest growth rates, typically in contexts marked by lax regulatory monitoring and minimal occupational safety enforcement. Moreover, pesticides are classified by toxicologists into functional and chemical groups, including insecticides, herbicides, and fungicides, as well as organophosphates, carbamates, organochlorines, and synthetic pyrethroids, each with distinct toxicity, persistence, and biological mechanisms of action [6, 7]. Epidemiologists believe that agricultural workers are a particularly high-risk occupational group because of their frequent and sustained exposure to toxic toxins, sometimes without proper training or personal protective equipment [8]. According to occupational health specialists, pesticide exposure among agricultural workers is generally caused by skin absorption, aerosol and vapour inhalation, unintentional ingestion, and cumulative chronic low-dose exposure, particularly in small-scale farming systems [9]. Clinical and epidemiological studies consistently discuss a wide range of health outcomes linked to such exposures, including acute poisoning symptoms, chronic neurological disorders, respiratory diseases, endocrine disruption, reproductive impairments, and increased cancer risk [10]. According to public health reviews, despite extensive primary research, the evidence base is fragmented, with inconsistencies resulting from differences in study design, exposure assessment methods, outcome definitions, and regional contexts, limiting the generalisability of findings [11, 12]. Methodologists contend that these gaps require systematic evidence synthesis to thoroughly evaluate and integrate relevant data, and in this context, systematic reviews are recognised as strong methodological tools that allow for the transparent, reproducible, and comprehensive consolidation of existing literature, thereby supporting evidence-based policy, occupational health interventions, and future research prioritisation [13].

Despite an increasing body of epidemiological and clinical research on the health effects of occupational pesticide exposure among agricultural workers, the available evidence is fragmented and inconsistent across regions, pesticide classes, exposure assessment methods, and health outcome definitions [11, 12]. Many studies are context-specific and focus on isolated outcomes, limiting the comparability and generalisability of findings across agricultural contexts, especially in low- and middle-income countries with the highest occupational exposure [4, 5]. The lack of a contemporary, systematic synthesis that critically evaluates study quality and combines information from many health domains impedes the translation of research findings into effective occupational health policy, surveillance, and preventative interventions [13, 16]. Thus, the primary goal of this systematic review is to critically synthesise the available evidence on the health effects of occupational pesticide exposure among agricultural workers.

Research Question

Methodological academics contend that the PEO framework is especially suitable for observational and public health research in contexts where randomised interventions are neither ethical nor practicable [14]. In this context, the population comprises agricultural workers, a cohort acknowledged as occupationally sensitive due to consistent and extended exposure to pesticides, whereas the exposure component concentrates on pesticide exposure, including both acute and chronic occupational contact via several pathways, which epidemiological studies identify as primary factors influencing health risk, and the outcome factor encompasses a wide array of health impacts, including neurological, respiratory, reproductive, and carcinogenic outcomes, which toxicological and clinical evidence consistently correlates with pesticide exposure. Secondary sub-questions are designed to investigate particular outcome domains, facilitating nuanced synthesis across health categories and exposure types, thus enhancing interpretative depth and policy significance. Hence, the research question states

What are the health effects associated with occupational pesticide exposure that exist among agricultural workers?

Research Aim

The general aim of this systematic review is to critically synthesise the health effects of pesticide exposure among people who are agricultural workers

Specific Objectives

- 1. To find and differentiate the number of health outcomes associated with pesticide exposure among agricultural workers.
- 2. To critically assess the strength, quality and methodological rigour of the available evidence on pesticide-related health effects.
- 3. To compare reported health effects across different pesticide classes and varying durations and intensities of occupational exposure.

2.0 Methodology

2.1 Research Approach

The methodological framework employed for this systematic review is based on the positivist paradigm, which contends that social and health phenomena may be objectively measured, quantified, and analysed through systematic observation and empirical investigation [15]. Methodological academics contend that positivism is especially appropriate for quantitative public health research, as it emphasises measurable variables, causal inference, and the detection of patterns among extensive populations [16]. As a result, the positivist paradigm offers a robust epistemological framework for integrating empirical knowledge regarding the health impacts associated with pesticides.

2.3 Search Strategy

This systematic review utilised a thorough and organised search method to locate pertinent empirical papers regarding pesticide exposure and health effects among agricultural workers. Major electronic databases like PubMed/MEDLINE, Scopus, Web of Science, Embase, and CINAHL were examined because they are well-known for having a lot of information on public health, occupational health, and epidemiology. Medical Subject Headings (MeSH) were used with free-text phrases to make searches more sensitive and accurate. This made it possible to find both indexed and non-indexed research. The main keywords were pesticides, pesticide exposure, agricultural workers, farm workers, occupational exposure, and health impacts. To merge fundamental ideas, Boolean operators like AND, OR were utilised to add similar terms, and NOT to leave out topics that weren't significant. We also used truncations (like "expos" to get "exposure" and "exposures"), wildcards (like "work*" to get "worker" and "workers"), and proximity operators (when they were available) to make the search more useful and relevant. To reduce publication omission, reference lists of eligible articles and pertinent reviews were manually scrutinised to uncover new research that might not have been included in the database search. Table 2.1 below carefully illustrates the search strategy.

Table 2.1
Search Strategy Table

Primary Keywords	MeSH Terms	Search Strings	Boolean / Search Operators	Databases Used
Pesticides	Pesticides	pesticides OR pesticide*	OR, truncation (*)	PubMed, Scopus, Web of Science, Embase, CINAHL
Pesticide exposure	Pesticide Exposure	("pesticide exposure" OR expos* to pesticide*)	OR, truncation	PubMed, Scopus, Web of Science, Embase, CINAHL
Agricultural workers	Agricultural Workers	("agricultural worker*" OR "farm worker*" OR farmer*)	OR, wildcard (*)	PubMed, Scopus, Web of Science, Embase, CINAHL
Occupational exposure	Occupational Exposure	("occupational exposure" OR workplace expos*)	OR, truncation	PubMed, Scopus, Web of Science, Embase, CINAHL
Health effects	Health Status / Occupational Diseases	("health effect*" OR disease* OR morbidity)	OR, truncation	PubMed, Scopus, Web of Science, Embase, CINAHL
Combined search	—	(pesticide* AND agricultural worker* AND health effect*)	AND	PubMed, Scopus, Web of Science, Embase, CINAHL
Exclusion filter	—	NOT (animal* OR laboratory study)	NOT	PubMed, Scopus, Web of Science, Embase, CINAHL

2.4 Eligibility Criteria

The eligibility criteria for this systematic review were formulated and organised utilising the PEO framework, which methodological academics contend is suitable for observational and exposure-based public health research [17, 18]. In this context, the population was characterised as agricultural workers, encompassing farm labourers and pesticide applicators, as occupational health literature indicates that this demographic endures direct and prolonged exposure to pesticides through regular work tasks. The exposure criterion included any type, length, or intensity of occupational pesticide exposure, which is supported by toxicological evidence indicating both short- and long-term exposures affect health. The outcome component encompassed physical, neurological, respiratory, reproductive, and carcinogenic health effects, aligning with epidemiological evidence that associates pesticide exposure with multi-system health repercussions. Methodologists assert that limiting eligibility to original peer-reviewed quantitative studies strengthens evidentiary rigour and mitigates interpretive bias [19]. However, to make sure that the research were still relevant and that the analysis was consistent, there were time and language limits. Only studies published in English from 2015 onwards were eligible. Table 2.2 below carefully illustrates the eligibility criteria for the study.

Table 2.2
Eligibility Criteria Table

Item	Inclusion Criteria	Exclusion Criteria
Population (P)	Agricultural workers, farm workers, pesticide applicators	General population, non-agricultural workers
Exposure (E)	Occupational pesticide exposure (acute or chronic)	Non-occupational or environmental exposure only
Outcome (O)	Health effects, including neurological, respiratory, reproductive, endocrine or carcinogenic outcomes	Studies not reporting health outcomes
Study design	Original quantitative peer-reviewed studies (cohort, case-control, cross-sectional)	Systematic reviews, commentaries, opinions, letters to editors, magazines, mixed-methods studies.
Publication type	Peer-reviewed journal articles	Qualitative studies, Preprints, unpublished reports, short communications, grey literature
Study period	Studies published from 2015 to 2026	Studies published before 2015
Language	English-language publications	Non-English publications
Data source	Human studies with empirical data	Animal, laboratory or in-vitro studies

2.5 Study Selection

The study selection process was rigorous and transparent, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. All records obtained through electronic database searches were transferred into Zotero reference management software, where duplicates were discovered and eliminated before screening. Two reviewers independently screened the titles and abstracts, comparing all unique records to predetermined inclusion criteria based on demographic, exposure, outcomes, study design, publication year, and language. Studies that obviously did not match the inclusion criteria were removed at this stage.

The same two reviewers then conducted independent full-text screening on all records that seemed possibly eligible after title and abstract screening. Full-text papers were thoroughly assessed to ensure eligibility, with a focus on the study population (agricultural workers), occupational pesticide exposure, reported health outcomes, and study methodology.

Disagreements amongst reviewers during either screening stage were handled by discussion and consensus. Where disagreements remained, eligibility judgements were made through a mutual re-examination of the inclusion criteria until agreement was reached. Studies were rejected at the full-text stage for the following reasons: failure to focus on occupational pesticide exposure among agricultural workers, lack of health-related outcomes, publication outside the specified time frame, non-English language, or insufficient methodological detail to support critical appraisal. Following this thorough screening process, six studies met all of the inclusion criteria and were considered eligible for inclusion in the final narrative synthesis. The PRISMA flow diagram (Fig. 1.0) summarises the study selection procedure.

2.6 Data Extraction

Data extraction is the systematic process of gathering relevant and predetermined information from included studies to guarantee consistency, accuracy, and transparency in evidence synthesis, as delineated in systematic review methodology literature [13]. This review utilised Microsoft Excel as the principal data extraction tool, owing to its adaptability, auditability, and efficacy in handling structured datasets within public health research. A systematic data extraction form was created to consistently record essential study characteristics and results. The extracted variables encompassed the author(s) and publication year, country and study setting, study design, sample size, characteristics of the study population, type and duration of pesticide exposure, exposure assessment methods, health outcomes evaluated, outcome measurement tools, principal findings, and acknowledged limitations. Methodologists contend that standardisation mitigates extraction bias and improves repeatability among reviewers [14]. To ensure reliability, the extraction form was pilot tested on a selection of included studies and improved accordingly before full data extraction occurred, thereby improving clarity, consistency, and data accuracy throughout the review process.

2.7 Quality Assessment

The Critical Appraisal Skills Programme (CASP) checklist was used in this review because it is a systematic but flexible way to look at quantitative observational studies that are widespread in occupational health research [22]. The CASP domains evaluate the clarity of research objectives, the suitability

of the technique, the validity of exposure and outcome assessment, the consideration of confounding variables, the precision of results, and the applicability of findings. Research of inferior methodological quality was not excluded but was analysed with caution during synthesis.

2.8 Data Synthesis

Data synthesis in systematic reviews refers to the integration of findings from several research to produce cohesive and significant conclusions, hence enhancing the overall evidence base [20]. This study utilised a narrative synthesis methodology, categorising findings by health outcome types and directly confronting heterogeneity to guarantee clear and contextually relevant interpretation.

3.0 Results

3.1 Overview of the search process

3.2 Characteristics of the included studies

The six studies reviewed exhibited variability in design, site, and demographics, although they collectively concentrated on occupational pesticide exposure among agricultural workers. The investigations were conducted across many geographical areas, including Asia (China and Thailand), Africa (Ethiopia and Kenya), and North America (United States), encompassing a broad spectrum of agricultural practices and regulatory frameworks. Methodologically, the evidence base included both cross-sectional studies and prospective cohort studies, with sample sizes varying from 173 to more than 55,000 participants. The study populations comprised smallholder farmers, horticultural workers, irrigation farmers, and licensed pesticide applicators, exhibiting diverse levels of education, training, and access to personal protective equipment. Self-reported questionnaires were the primary method for estimating pesticide exposure; however, some studies also used intensity-weighted exposure metrics or objective clinical assessments. The evaluated health outcomes were extensive, including respiratory, neurological, renal, haematological, and acute toxic symptoms, assessed via self-reports, clinical examinations, laboratory testing, or registry-based data. Together, these studies provided more information about the short- and long-term health impacts of pesticide exposure among farm labourers. The characteristics of the included studies are clearly illustrated in Table 3.1 below.

Table 3.1
Characteristics of the Included Studies

Author(s) & Year	Country & Study Setting	Study Design	Sample Size	Study Population Characteristics	Type & Duration of Pesticide Exposure	Exposure Assessment Methods	Health Outcomes Assessed	Outcome Measurement Tools
Kongtip et al., 2018	Thailand; agricultural farms across three provinces	Cross-sectional survey	424 farmers	Informal-sector agricultural workers; 60% women; mean age 53 years (18–87); mostly primary education; five farm types (rice, vegetable, flower, mixed)	Use of > 27 pesticides; mostly monthly use during the past year; varying by farm type	Self-reported questionnaire on pesticide use, work conditions, and PPE practices	Respiratory symptoms, allergies, musculoskeletal problems, acute pesticide-related symptoms	Self-reported health symptoms and working-condition survey
Negatu et al., 2017	Ethiopia; commercial farms (greenhouses and irrigated systems)	Cross-sectional (two survey waves)	Survey 1: 1,104; Survey 2: 387	Young farmers and farm workers (mean age 27 years); pesticide applicators, re-entry workers, and unexposed controls	Occupational exposure over ~ 4 years; routine pesticide application and re-entry exposure	Job classification (applicator/re-entry); exposure status comparison	Chronic cough, shortness of breath, lung function impairment	Standardised respiratory questionnaire; spirometry (FEV ₁ , FVC, FEV ₁ /FVC)
Hu et al., 2015	China; rural farming communities in three provinces	Prospective cohort study	246 farmers	Adult farmers from Guangdong, Jiangxi, and Hebei provinces	Long-term exposure (2009–2011); short-term exposure (10 days in 2012 cropping season)	Retrospective interviews and prospective personal pesticide-use records	Haematological, hepatic, renal, and neurological outcomes	Blood tests; nerve conduction studies; neurological examinations
Marete et al., 2021	Kenya; horticultural farms in Meru County	Cross-sectional survey	173 farmers	Horticultural farmers in three sub-counties; smallholder and commercial growers	Frequent use of organophosphates, organochlorines, and pyrethroids; including banned pesticides	Structured questionnaires to farmers, extension workers, and healthcare workers	Acute pesticide-related health symptoms (intoxication)	Self-reported symptoms following pesticide use
Leboy et al., 2016	USA; Iowa and North Carolina	Prospective cohort (Agricultural Health Study)	55,580 applicators; 320 ESRD cases	Male licensed pesticide applicators	Chronic lifetime exposure to 39 pesticides (1993–2011)	Self-administered questionnaires; intensity-weighted lifetime exposure index	End-stage renal disease (ESRD)	Linkage to US Renal Data System; medical records
Gesesew et al., 2016	Ethiopia; rural irrigation villages, Jimma Zone	Community-based cross-sectional study	796 farmers	Irrigation farmers from 20 kebeles; mixed age and education levels	Past and current exposure through ingestion and inhalation; frequent pesticide handling	Face-to-face structured questionnaire	Neurological and gastrointestinal symptoms; skin irritation	Self-reported health complaints and exposure history

Author(s) & Year	Country & Study Setting	Study Design	Sample Size	Study Population Characteristics	Type & Duration of Pesticide Exposure	Exposure Assessment Methods	Health Outcomes Assessed	Outcome Measurement Tools

3.3 Quality Assessment

The included studies had methodological quality ranging from medium to high. Two studies [24, 25] exhibited superior methodological quality, attributed to their robust cohort designs, enhanced clarity in exposure–result timing, and the employment of objective outcome measures. Three studies [26–28] were evaluated as medium quality, mainly because they employed cross-sectional designs, depended on self-reported exposure and outcomes, and exhibited insufficient control of confounding variables. One study [29] received a poor to medium quality rating, mostly due to its emphasis on knowledge and beliefs related to subjective health outcomes, and its deficiency in objective exposure or outcome verification. Across research, prevalent limitations encompassed self-reported pesticide exposure, inadequate exposure quantification, and constrained causal inference. A clearer illustration of the quality assessment is presented in Table 3.2 below.

Table 3.2
Quality Assessment

Study	Clear Aim	Appropriate Design	Recruitment Strategy	Exposure Measurement	Outcome Measurement	Confounding Addressed	Follow-up Adequate	Statistical Analysis	Precision of Results	Applicability
Kongtip et al., 2018	2	2	1	1	1	1	0	2	1	1
Negatu et al., 2017	2	2	2	1	2	1	0	2	2	1
Hu et al., 2015	2	2	2	2	2	2	1	2	2	1
Marete et al., 2021	2	2	1	1	1	1	0	1	1	1
Lebov et al., 2016	2	2	2	2	2	2	2	2	2	1
Gesesew et al., 2016	2	2	1	1	1	1	0	1	1	1

3.4. Narrative Synthesis

3.4.1 Respiratory and Neurological Morbidity

A recurring issue in the examined studies is the substantial burden of respiratory and neurological health problems linked to occupational pesticide exposure among agricultural labourers. Respiratory morbidity was notably pronounced in cross-sectional studies undertaken in low- and middle-income nations. Negatu et al. [28] showed strong links between being around pesticides and having a chronic cough, shortness of breath, and poor lung function, such as lower FEV₁ (Forced Expiratory Volume in 1 Second) and aberrant FEV₁/FVC (Forced Vital Capacity) ratios. Significantly, these negative effects were seen in people who were not very old and had only been exposed for an average of four years, which shows that respiratory problems might start early. Kongtip et al. [27] also documented a significant prevalence of respiratory problems, including wheezing, nasal congestion, and allergies, among Thai rice farmers, who exhibited more severe symptoms post-pesticide application compared to other agricultural categories. These results indicate that both the magnitude and nature of agricultural practices affect respiratory outcomes. The Chinese cohort study by Hu et al. [25] provided the most comprehensive documentation of neurological consequences, linking long-term pesticide exposure to aberrant nerve conduction, especially in sensory nerves. Short-term exposure was associated with temporary neurological and haematological alterations, which were reversible within a few days. Farmers in Ethiopia and Kenya regularly reported self-reported neurological problems, including headaches [26, 29], hence substantiating the likelihood of neurotoxicity in many contexts.

3.4.2. Chronic Systemic Health Effects

In addition to acute and organ-specific symptoms, the literature examined, highlight the systemic and chronic health effects of prolonged or high-intensity pesticide exposure. Lebov et al. [24] established substantial exposure–response correlations between lifetime exposure to several herbicides and insecticides and the risk of end-stage renal disease (ESRD). Significantly, pesticide exposures leading to medical consultations or hospitalisation were correlated with a substantially heightened risk of end-stage renal disease (ESRD), indicating that severe or recurrent poisoning events may yield enduring renal repercussions. Hu et al. [25] further illustrated that prolonged pesticide exposure negatively impacted various physiological systems, encompassing haematological parameters, liver function, renal function, and peripheral nerves. These results bolster apprehensions that prolonged pesticide exposure may lead to cumulative systemic toxicity rather than localised organ harm. In resource-poor countries, whereas chronic illness outcomes were infrequently assessed with objective instruments, indirect evidence indicates comparable risks. Kongtip et al. [27] highlighted the absence of data regarding chronic

disorders, including metabolic diseases and cancer, among Thai farmers, despite extensive and sustained pesticide exposure. Marete et al. [26] also described the ongoing use of prohibited pesticides in Kenya, eliciting worries of enduring harmful effects that are inadequately recorded due to insufficient surveillance systems.

3.4.3 Unsafe Work Practices, Inadequate Training, and PPE Use

A pervasive issue throughout all six research is the contribution of unsafe pesticide handling techniques and insufficient use of personal protective equipment (PPE) to heightened health risks among agricultural workers. Numerous research indicated elevated exposure levels that were significantly associated with behavioural and structural characteristics, rather than pesticide application alone. Kongtip et al. [27] discovered significant disparities in exposure avoidance strategies among different farm types in Thailand, with vegetable farmers indicating the least use of personal protective equipment (PPE) during pesticide application. This trend was also seen in Kenya, where Marete et al. [26] found that even though many farmers knew how to handle things safely, a lot of them didn't wear protective apparel. The ongoing utilisation of prohibited pesticides underscores inadequate regulatory enforcement and restricted access to training. Evidence from Ethiopia clearly supports this theme. Gesesew et al. [29] found that about 42% of farmers had never utilised PPE, even though they had been exposed to it through breathing and eating. Unsafe behaviours were linked to frequent self-reported health problems such as nausea, headaches, and skin irritation. Negatu et al. [28] also pointed out that pesticide applicators and re-entry workers are at a higher risk because they are exposed to the chemicals directly and repeatedly. Across research, inadequate formal training and deficient occupational health systems were identified as persistent challenges. In environments with heightened regulatory scrutiny, like the United States, high-intensity exposures resulting in physician consultations were significantly correlated with adverse health outcomes [24].

4.0 Discussion

4.1 Summary of findings

This study critically synthesised evidence from six research investigating the health consequences of pesticide exposure among agricultural labourers in various geographic and socioeconomic settings. A consistent finding across the research was the significant correlation between occupational pesticide exposure and negative health effects, mainly impacting the respiratory, neurological, renal, and systemic systems of affected workers. Respiratory problems, including chronic cough, wheeze, and diminished lung function, were commonly observed, even among relatively young workers and following brief exposure periods. Neurological symptoms, such as headaches and irregular nerve transmission, were frequently noted, with cohort studies demonstrating both transient and enduring deficits. Another important tendency was the dose–response link between long-term or high-intensity pesticide exposure and chronic disease outcomes, especially end-stage renal disease. Prospective cohort studies provided more robust causal inferences than cross-sectional studies, emphasising the cumulative effects of pesticide-related harm. In low- and middle-income settings, pervasive unsafe handling practices, inadequate training, and minimal utilisation of personal protective equipment repeatedly heightened exposure and health hazards. In general, the evidence was of moderate to high strength. Cross-sectional research offered significant contextual and prevalence data; however, the incorporation of well-constructed cohort studies with objective outcome measures enhanced the overall conclusions. Nonetheless, dependence on self-reported exposure in many studies and the scarcity of longitudinal data in low-resource environments underscore the necessity for additional high-quality research to comprehensively delineate long-term health impacts.

4.2 Discussion of Findings

The results of this analysis are very similar to the larger body of data that shows that agricultural workers who are exposed to pesticides at work are more likely to have a number of negative health impacts, especially on their respiratory, neurological, and chronic systemic systems. Prior systematic reviews have consistently recognised respiratory problems as one of the most prevalent consequences of pesticide exposure. A systematic review by Hoppin et al. [30] indicated markedly elevated probabilities of chronic cough and wheeze in pesticide-exposed farmers, with pooled odds ratios varying from 1.5 to over 3.0, contingent upon exposure intensity. This aligns with the current review, which demonstrated respiratory damage even in younger workers and during brief exposure periods, indicating early and cumulative toxicity. The neurological consequences found in this analysis, such as headaches and altered nerve conduction, are consistent with findings from prior cohort and cross-sectional investigations. Kamel and Hoppin [31] indicated that prolonged pesticide exposure correlated with neurobehavioral impairments and peripheral neuropathy, hence reinforcing the biological plausibility of the neurological outcomes identified in the analysed research. The cohort data in this review enhances causal inference relative to previous research that predominantly depended on self-reported symptoms. A primary conclusion of this review is the correlation between prolonged pesticide exposure and chronic systemic disease, especially kidney dysfunction. Previous evidence strongly supports this. A meta-analysis conducted by Ordunez et al. [32] revealed that pesticide exposure correlated with a 1.4–2.0-fold elevated risk of chronic kidney disease, especially among applicators subjected to recurrent high-intensity exposure. This review strengthens this link by showing dose-response correlations and a higher risk after medical visits connected to pesticides, which is in line with toxicological theories of cumulative organ damage. The results on risky work habits and PPE usage are strongly aligned with prior research conducted in low- and middle-income countries. Ndirangu et al. [33] found that less than 50% of smallholder farmers in sub-Saharan Africa and Asia used PPE. This was mostly because it was too expensive, uncomfortable, and they didn't get enough training. This is similar to the studies that were looked at, which all showed that people were aware of the dangers of pesticides but still didn't use PPE very often. Studies from high-income contexts, on the other hand, indicate stronger enforcement of rules and training, but they still report negative consequences, suggesting that legislation alone may not be enough to reduce risk [34, 35]. However, it was clear that there were variances in context between locations. Research conducted in low-resource environments indicated more severe symptoms and hazardous practices, while studies from high-income nations recorded chronic consequences by extended observation. This discrepancy is due to disparities in health systems, exposure monitoring, and regulatory competence, and it also shows how important it is to have solutions that are specific to the situation.

4.3 Strengths and Limitations

4.3.1 Strengths

One of the best things about this review is how thorough and systematic it is in finding and putting together studies. This made it possible to include evidence from a wide range of agricultural settings and geographical areas. The review offers a comprehensive and equitable perspective on the health consequences of pesticides among agricultural workers by integrating studies from both low- and middle-income countries and high-income contexts. The adoption of strict critical evaluation procedures, guided by the CASP tool, made the review more transparent and credible by letting researchers systematically look at the methodological quality and risk of bias of the studies that were included. This evaluation helped separate evidence of better and lower quality, which made it easier to understand the results. Another key quality of the review is that it is very relevant to occupational health practice and policy. The findings directly pertain to actual working conditions, hazardous pesticide handling practices, and insufficient utilisation of personal protective equipment, providing evidence relevant to occupational health interventions, regulatory enforcement, and worker training programs in agricultural contexts.

4.3.2 Limitations

Even if these are good things, there are certain problems that need to be recognised. First, the possibility of publication bias cannot be disregarded, as studies indicating statistically significant health outcomes may be more prone to publication, whereas null or negative results are often under-represented. Second, there was a lot of variation between studies in terms of how they were set up, how they measured exposure, how they measured outcomes, and the groups of people they studied. This variability hindered direct comparability of data and obstructed quantitative synthesis or meta-analysis. Third, the evidence base was hampered by a scarcity of high-quality longitudinal studies, especially from low- and middle-income countries where pesticide exposure is frequently elevated. Numerous included research utilised cross-sectional designs and self-reported exposure and outcomes, so limiting causal inference and elevating the possibility of misclassification bias. These limitations underscore the necessity for subsequent research utilising standardised exposure metrics, objective health outcomes, and extended follow-up to enhance the evidentiary foundation.

4.3 Implications

The results of this review have significant consequences for policy, employment, and public health. The persistent correlation between pesticide exposure and detrimental respiratory, neurological, and chronic systemic effects underscores pesticide exposure as a significant yet controllable occupational health risk. Because of this, policymakers need to see farm workers as a high-risk population and make sure that protections for their health and safety at work are a top priority in national health and labour laws. For occupational safety, the research shows that unsafe handling and not using enough PPE greatly increase health risks. This means that improving workplace standards could greatly lower the burden of disease, even if pesticides are still used. The data indicate that pesticide-related morbidity leads to enduring healthcare expenses, diminished output, and increased social vulnerability within farming communities, especially in informal agricultural sectors. The regional differences we saw suggest that weaker regulatory regimes and limited access to healthcare make health problems worse in places with few resources. The scarcity of high-quality longitudinal data hampers risk quantification and policy evaluation, underscoring the necessity for enhanced surveillance systems and occupational health registries. In general, these results show that pesticide exposure is not simply a problem at work, but also a bigger problem for the environment and public health that needs coordinated solutions from many different sectors. The results of this review have significant ramifications for policy, workplace safety, and public health. The persistent correlation between pesticide exposure and detrimental respiratory, neurological, and chronic systemic effects underscores pesticide exposure as a significant yet controllable occupational health risk. Because of this, policymakers need to see farm workers as a high-risk population and make sure that protections for their health and safety at work are a top priority in national health and labour laws. For occupational safety, the research shows that unsafe handling and not using enough PPE greatly increase health risks. This means that improving workplace standards could greatly lower the burden of disease, even if pesticides are still used. The data indicate that pesticide-related morbidity leads to enduring healthcare expenses, diminished output, and increased social vulnerability within farming communities, especially in informal agricultural sectors. The regional differences we saw suggest that weaker regulatory regimes and limited access to healthcare make health problems worse in places with few resources. The scarcity of high-quality longitudinal data hampers risk quantification and policy evaluation, underscoring the necessity for enhanced surveillance systems and occupational health registries. In general, these results show that pesticide exposure is not simply a problem at work, but also a bigger problem for the environment and public health that needs coordinated solutions from many different sectors.

4.4 Conclusion

In conclusion, this systematic review shows that occupational pesticide exposure among agricultural workers is consistently linked to poor respiratory, neurological, renal, and systemic health effects across multiple geographic locations. These findings emphasise pesticide exposure as a preventable occupational health risk, especially in low- and middle-income countries where regulatory enforcement, training, and access to personal protective equipment are restricted. Pesticide regulation must be strengthened, occupational safety training and access to personal protective equipment improved, and longitudinal surveillance of exposed workers expanded in order to reduce pesticide-related morbidity and inform evidence-based policy and practice.

Declarations

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Consent for publication

Not applicable.

Availability of data and materials

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Authors Contributions

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Competing Interests

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References

1. Egedigwe-Ekeleme CA, Famurewa AC, Egedigwe UO et al. Comparative studies on the amino acids, pesticide residue content, biogenic and toxic elements in an underutilized nut: Bambara groundnut (*Vigna subterranea*). *Journal of Trace Elements and Minerals*; 3.
2. TOADER M, GEORGESCU E, EPURE LI, THE EVOLUTION OF PESTICIDES USE IN THE CONTEXT OF SUSTAINABILITY OF AGRI-FOOD SYSTEMS. *Scientific Papers Series A Agronomy*; 67.
3. Food and Agriculture Organization (FAO). International Code of Conduct on Pesticide Management.
4. World Health Organization (WHO). Preventing Disease Through Healthy Environments: Exposure to Highly Hazardous Pesticides.
5. Food. and Agriculture Organization (FAO). FAOSTAT: Pesticides Use Database.
6. Aktar MW, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary Toxicol.* 2009;2:1.
7. BRIEF FA. Pesticides use, pesticides trade and pesticides indicators. *FAO, Rome, Italy*.
8. DATA EOA. Pesticides use and trade: methodological changes and exploration of alternative data sources.
9. Kim KiHyun KK, Kabir E, Jahan S. Exposure to pesticides and the associated human health effects.
10. Mostafalou S, Abdollahi M. Pesticides: an update of human exposure and toxicity. *Arch Toxicol.* 2017;91:549–99.
11. Bassil KL, Vakili C, Sanborn M, et al. Cancer health effects of pesticides: systematic review. *Can Fam Physician.* 2007;53:1704–11.
12. World Health Organization, Inter-Organization Programme for the Sound Management of Chemicals. The international code of conduct on pesticide management. Food & Agriculture Organization of the UN (FAO); 2014.
13. Higgins J, Thomas J, Chandler J et al. *Cochrane Handbook for systematic reviews of interventions version 6.2* (London, United Kingdom: The Cochrane Collaboration).
14. Bettany-Saltikov J, McSherry R. *How to do a Systematic Literature Review in Nursing: A Step-by-Step Guide*, 3/e.
15. Creswell JW, Creswell JD. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage; 2017.
16. Bryman A. *Social research methods*. Oxford University Press; 2016.
17. Polit D, Beck C. *Essentials of nursing research. Ethics.* 2012;23:145–60.
18. Bettany-Saltikov J. *How to do a systematic literature review in nursing: a step-by-step guide*.
19. Higgins JP, Li T, Deeks JJ. Choosing effect measures and computing estimates of effect. *Cochrane Handb Syst reviews interventions* 2019; 143–76.
20. Higgins JP, Morgan RL, Rooney AA, et al. A tool to assess risk of bias in non-randomized follow-up studies of exposure effects (ROBINS-E). *Environ Int.* 2024;186:108602.
21. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg.* 2010;8:336–41.
22. CASP. CASP Qualitative Checklist., <https://casp-uk.net/> (2023).
23. Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*; 372.
24. Lebov JF, Engel LS, Richardson D, et al. Pesticide use and risk of end-stage renal disease among licensed pesticide applicators in the Agricultural Health Study. *Occup Environ Med.* 2016;73:3–12.
25. Hu R, Huang X, Huang J, et al. Long-and short-term health effects of pesticide exposure: a cohort study from China. *PLoS ONE.* 2015;10:e0128766.
26. Marete GM, Lalah JO, Mputhia J et al. Pesticide usage practices as sources of occupational exposure and health impacts on horticultural farmers in Meru County, Kenya. *Heliyon*; 7.

27. Kongtip P, Nankongnab N, Mahaboonpeeti R, et al. Differences among Thai agricultural workers' health, working conditions, and pesticide use by farm type. *Annals work exposures health*. 2018;62:167–81.
28. Negatu B, Kromhout H, Mekonnen Y, et al. Occupational pesticide exposure and respiratory health: a large-scale cross-sectional study in three commercial farming systems in Ethiopia. *Thorax*. 2017;72:498–9.
29. Gesesew HA, Woldemichael K, Massa D, et al. Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, Southwest Ethiopia. *PLoS ONE*. 2016;11:e0162527.
30. Hoppin JA, Umbach DM, Long S, et al. Pesticides are associated with allergic and non-allergic wheeze among male farmers. *Environ Health Perspect*. 2016;125:535.
31. Kamel F, Hoppin JA. Association of pesticide exposure with neurologic dysfunction and disease. *Environ Health Perspect*. 2004;112:950.
32. Ordunez P, Nieto FJ, Martinez R, et al. Chronic kidney disease mortality trends in selected Central America countries, 1997–2013: clues to an epidemic of chronic interstitial nephritis of agricultural communities. *J Epidemiol Community Health*. 2018;72:280–6.
33. Ndirangu ZW, Zoltan E, Muhoro AM. Determinants of Pesticide Safety Adherence among Tomato Farmers in Kenya: Individual and Structural Factors for Sustainable Agriculture. *Journal of Sustainability Research*; 7. https://wap.hapres.com/htmls/JSR_1724_Detail.html (2025, accessed 1 February 2026).
34. Kapeleka JA, Mwema MF. State of nano pesticides application in smallholder agriculture production systems: human and environmental exposure risk perspectives. *Heliyon*; 10. [https://www.cell.com/heliyon/fulltext/S2405-8440\(24\)15256-5](https://www.cell.com/heliyon/fulltext/S2405-8440(24)15256-5) (2024, accessed 1 February 2026).
35. Parks CG, Hoppin JA, De Roos AJ, et al. Rheumatoid arthritis in agricultural health study spouses: associations with pesticides and other farm exposures. *Environ Health Perspect*. 2016;124:1728.

Figures

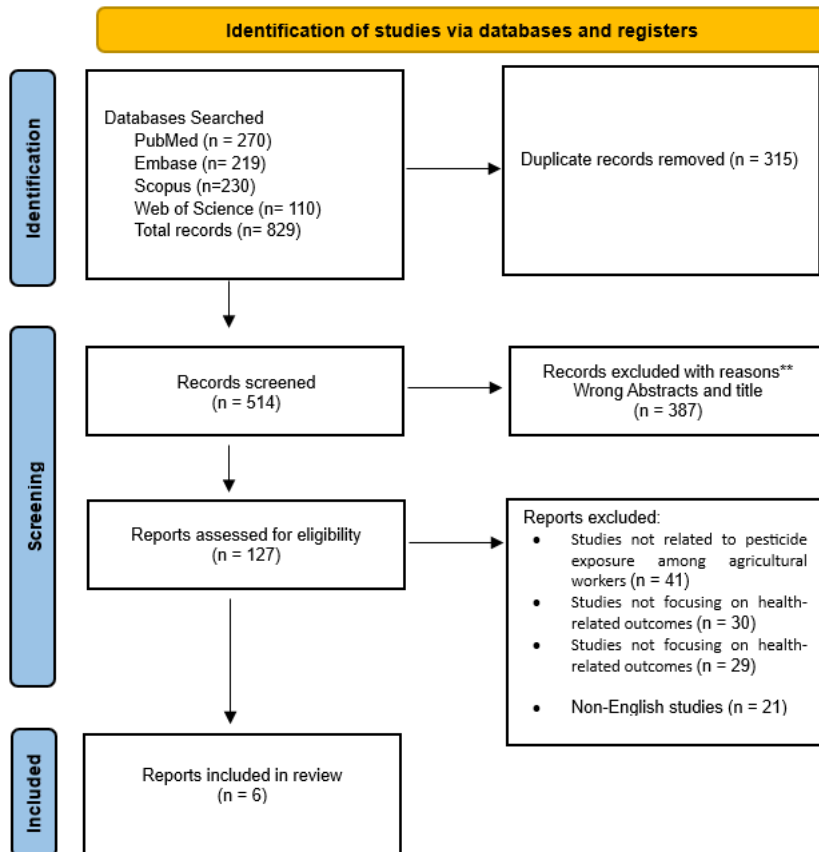


Figure 1

PRISMA Flow Diagram illustrating the study selection process [23].