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Review of human health impacts from pesticide use, analyzed through a gender perspective

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Abstract

This documentary review analyzes publications from the last 10 years (2014-2024) on the health effects of pesticides from a gender perspective, focusing specifically on the differential impacts on women in agricultural settings. A systematic mapping study was conducted following the methodology of Petersen, et al. [1]. Databases consulted included Scielo, PubMed, and Redalyc. Search strings combined keywords such as "pesticides, health AND cancer," "occupational health AND agriculture (gender)," and "pesticides AND women" using Boolean operators. From an initial pool of 2,400 documents, a refinement process applying inclusion and exclusion criteria resulted in a final corpus of 300 relevant studies. Of the selected documents, 29% addressed agrochemicals and health or cancer, 57% focused on occupational health and agriculture, and only 14% specifically examined pesticides and women's health. The review identifies multiple adverse health impacts on women, including reproductive disorders, specific cancers (breast, cervical, renal), respiratory diseases, endocrine disruption, and neuropsychological deficits. Women face heightened risks due to dual exposure pathways (direct field labor and indirect domestic contamination) compounded by systemic gender inequalities—limited access to information, inadequate personal protective equipment (PPE), and insufficient training on safe pesticide handling. Women are significantly underrepresented in pesticide health research (14% of selected corpus), despite evidence confirming greater biological susceptibility and distinct social vulnerabilities compared to men. Gender-sensitive occupational health policies are urgently required. These must include mandatory provision of appropriately fitted PPE for women, targeted educational programs on safe agrochemical handling, improved rural healthcare infrastructure, and the systematic inclusion of sex-disaggregated data in future epidemiological research.

Keywords: Health, Organophosphates, Pesticides, Toxics, Women.

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Institutional Review Board Statement: This study is a documentary review of publicly available literature and did not involve direct human participation or experimental animal subjects. Therefore, Research Ethics Committee (REC) approval was not required. The research was conducted in strict adherence to ethical standards regarding proper citation and avoidance of plagiarism.

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1. Introduction

The use of pesticides in agricultural activities is considered one of the most recurrent practices, since its main use is to prevent and exterminate pests or crop diseases [2]. To achieve their objective, these substances are composed of chemicals, such as carbamates, organophosphates, organochlorines and pyrethroids, which are classified according to their toxicity as extremely dangerous IA, highly dangerous IB, moderately dangerous II and slightly dangerous III [3]. Therefore, when evaluating the context, such as the Colombian one, it can be seen that organophosphates are the most used, since it is one of the countries that mainly produces fruits, vegetables and vegetables [4]. Regarding the use of these chemicals in the agricultural sector, and according to different scientific reports, the effects they have generated on human health and the environment have been evident. Due to their toxic nature, these substances have the ability to easily enter the body through oral, respiratory, dermal, and parental routes [5]. Research on the health effects of pesticides on agricultural women is crucial due to their unique exposure and the potential health risks they face [6, 7]. These studies not only shed light on the specific vulnerability of women in agricultural settings but also highlight the need for policies and practices that protect their well-being.

Research on the effects of pesticides on agricultural women is gaining momentum and is essential to understanding and addressing the specific risks these workers face. As noted in the study by Andreotti, et al. [8] agricultural women may be exposed to higher levels of pesticides due to their participation in agricultural activities such as planting and harvesting. This increased exposure can have serious health consequences, as indicated by research such as that of Andreotti, et al. [9] which found associations between pesticide exposure and the risk of kidney cancer. Currently, women are increasingly involved in agricultural work [10] and in turn, it has been shown how susceptible they are to these phytosanitary products, since they affect the reproductive system, can cause malformations in the fetus, abortions, contract breast cancer, among other diseases [11, 12]. This does not mean that men are not affected, but it has been shown that men are more resistant to pesticides than women [13]. These consequences are caused by poor practices when handling pesticides [14].

In relation to toxicological characteristics, it is considered that pesticides are characterized by being bioaccumulative and persistent both in animals and in the environment, being dependent on their properties, their active ingredient, the use and frequency of application, the climate, the temperature and the properties of the soil, among others. It is reported in different Studies have shown the significant impact on flora and fauna caused by the improper use of these pesticides [15-17]. One of the most affected ecosystems is the aquatic one, because these substances end up in water bodies through leaching, thus contaminating the water resource [18] mainly affecting fish, causing changes in their behavior, reactions in the nervous system and Bioaccumulating in them [18]. Crops are generally located a few meters from water sources, facilitating the arrival of these pollutants [19]. Consequently, it can be considered that pesticides can be found in other places inherent to the crop areas, affecting not only farmers but also people in the surrounding areas, causing health problems in the short, medium and long term, from mild poisoning to serious diseases such as cancer [20].

There is a widespread practice in exposed communities of not using personal protective equipment (PPE) properly, its use is considered highly relevant for the prevention of poisoning, in addition to the communication of risks and dangers to health as part of raising awareness among the population, given this panorama, it is pertinent to consider that agricultural activities are very important for the economy of countries and their social, political, environmental dynamics, among others [21]. For this reason, It is necessary to implement a health and safety system at work, in order to recognize the exposure factors and their effects, carrying out an adequate surveillance system epidemiological information that helps characterize risks and exposure based on environmental measurements, to prevent or control the effects that may arise in the short, medium, and long term [22]. Taking the above into account, the objective of this article was to conduct a bibliographic review on the use of pesticides and the effects on women's health due to their work in the fields.

2. Methodology

2.1. Search for Information

The present review article took as its main topic "pesticides, health and women." A systematic mapping search was developed applying the methodology of Petersen and collaborators [1] which initially consists of formulating questions,

selecting databases, applying inclusion and exclusion criteria and selecting documents with an adequate analysis. The second step consisted of the search for scientific studies, carried out through databases such as Scielo, Pubmed and Redalyc, highlighting the main documents from 2014 to 2024, through a consequent review of keywords or search strings such as "pesticides, health AND cancer", "occupational health AND agriculture (gender)", "pesticides AND women"; in turn applying Boolean tools such as AND OR, selecting articles in Spanish and English, with areas related to the main topic. Taking into account the above, the guiding questions were formulated as shown in Table 1.

Table 1.

Guiding questions.

Research Questions	
RQ1	How much research has been conducted on topics related to pesticides and human health, occupational health, and the effects on women in databases such as Scielo, Pubmed, and Redalyc between 2014 and 2024?
RQ2	What are the health effects of pesticide exposure on women in agriculture, and how do gender inequalities influence their access to health care and protection?
RQ3	What are the main risks to human and occupational health associated with the use of pesticides, and what measures can be implemented to reduce their negative effects?

2.2. Statistical Analysis

Data from scientific articles were recorded by search strings, methods, author, year and reference in Excel, descriptive statistical analysis was performed, and an average was established by search strings represented as a percentage.

3. Review Results

3.1. Document Refinement

In the search for studies, a total of 2,400 were found, of which 832 were on pesticides and health or cancer, 1,021 on occupational health and agriculture, and 547 on agrochemicals and women, as shown in Figure 1. The inclusion criteria were documents found that provided comprehensive information related to the topic, with a focus on health, primarily quality articles and/or documents. The exclusion criteria were that the search data did not relate to the title or abstract of the research, that the studies were incomplete, or that the information was confusing. The inclusion and exclusion criteria clearly classified the final results as shown in Figure 2.

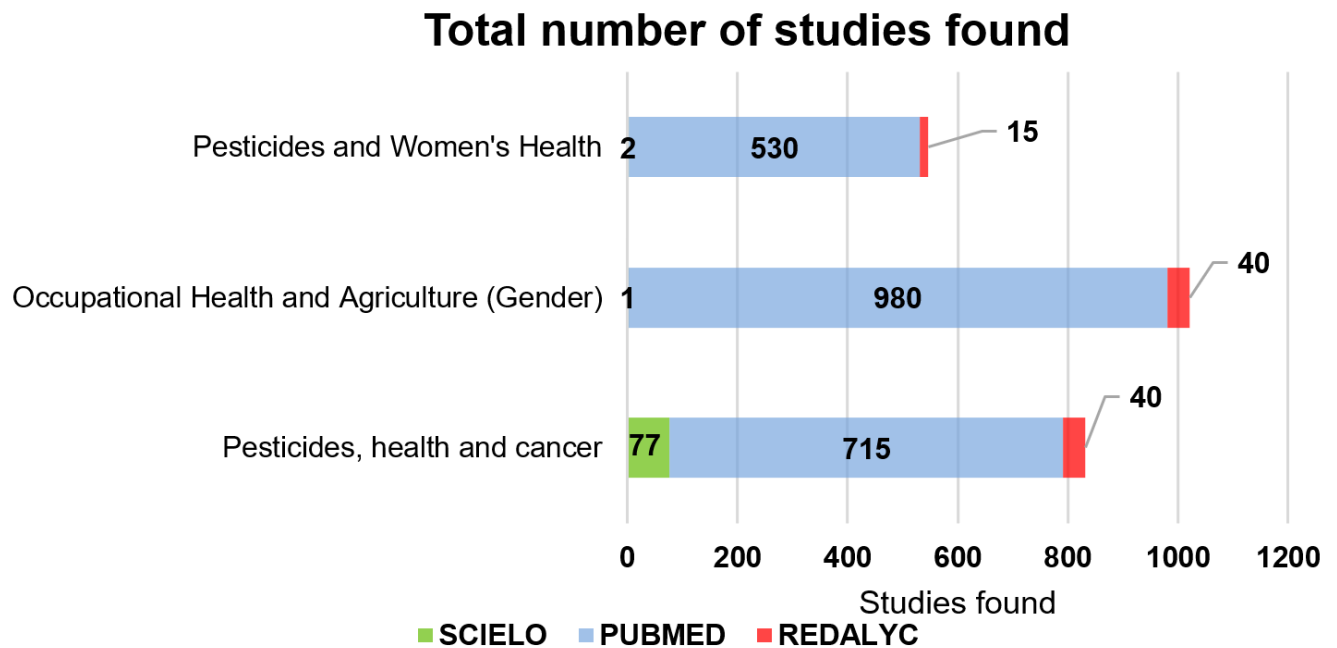


Figure 1.

Total number of studies found by topic in selected databases.

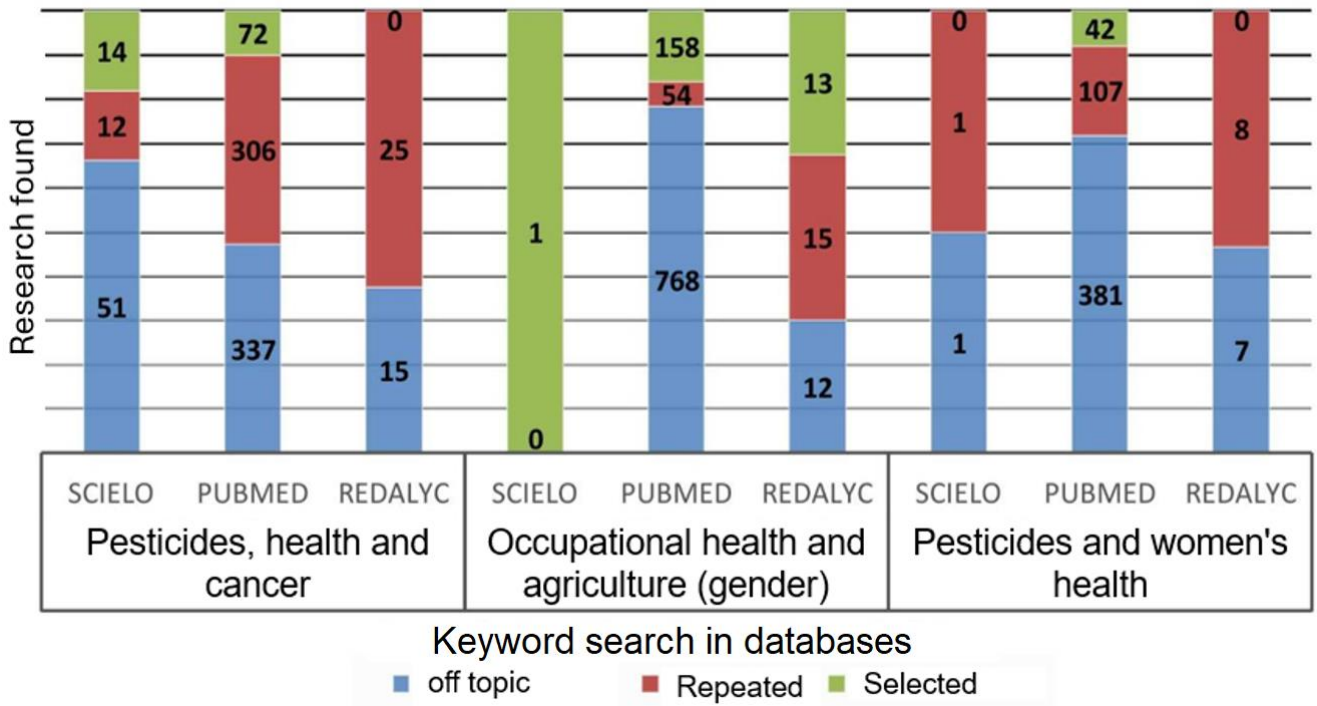


Figure 2.
Refinement of studies found.

It was found that studies related to exposure to agrochemicals and their effects on women's health are few and old (42/300 selected, representing 14%). It has been shown that women are the most susceptible gender to contact with these pesticides, given that they perform various household chores that involve contact with these substances. Even if they do not work directly in the fields, these substances can be easily absorbed through the skin or enter through the respiratory tract, and in turn, are more persistent in the body compared to men. The search string "Pesticides, health, and cancer" is second in number, with 86/300, corresponding to 29%. The third most represented is "Pesticides and occupational health," with 57% of the total articles selected.

3.2. Effects of Pesticides on Women's Health and the Impact of Gender Inequalities.

Research on the health effects of pesticides on women in agricultural work is crucial due to their exposure and the potential health risks they face. Based on this thematic focus [23-25] 42 studies were found in the PUBMED database, which represents only 14% of the total number of studies evaluated, as shown in Figure 3. There is a need for gender-sensitive research. Although these studies are few and far between, they shed light on the specific vulnerability of women in agricultural settings, highlighting the need for policies and practices that protect their well-being. Links have been identified between pesticide exposure and reproductive health problems, specific cancers, neurological disorders, and child health risks [26]. Furthermore, they highlight gender inequalities in access to protection and risk information, underlining the importance of addressing these disparities [27]. By understanding and addressing these effects, we can work toward safer and more equitable agricultural environments for everyone involved.

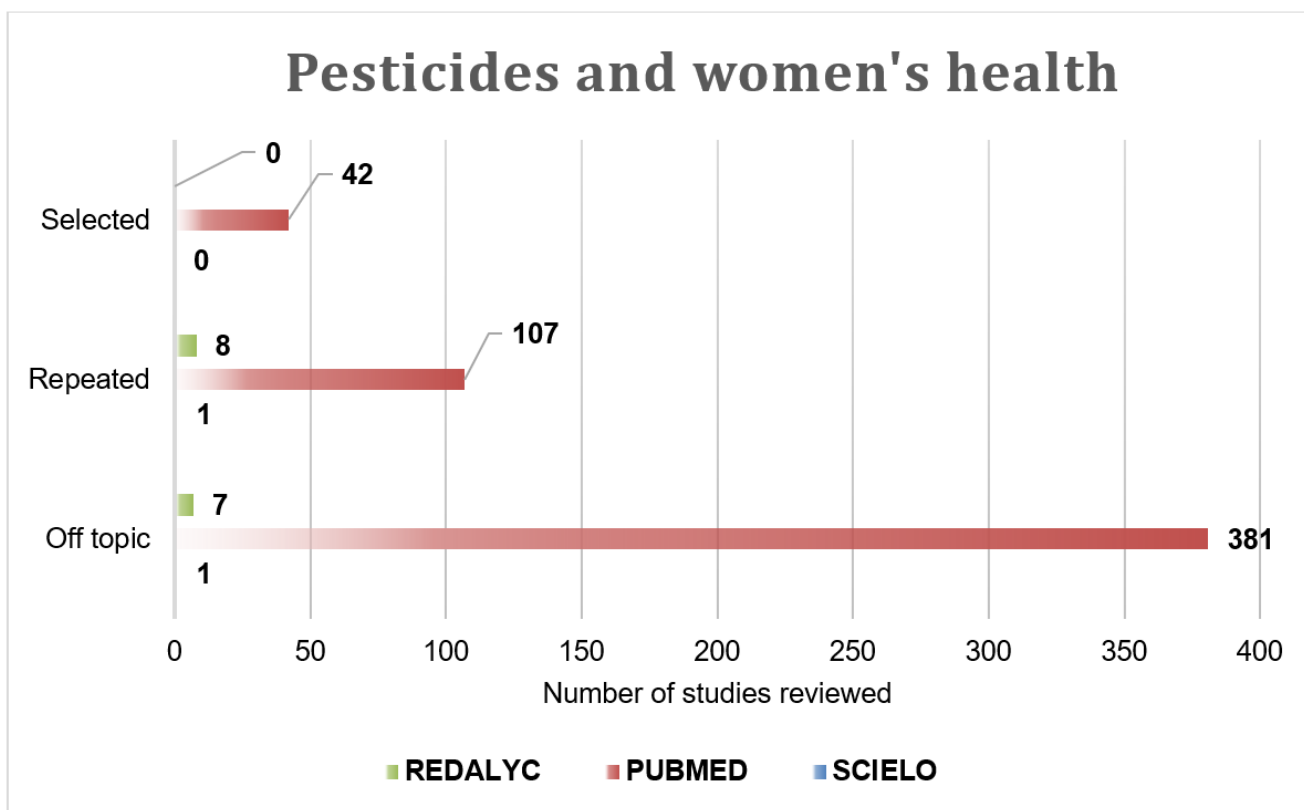


Figure 3.
Refinement of studies on pesticides and women's health.

Among the articles found on the subject, effects on the body were found related to the inhibition of cholinesterase ChEs [28-30] breast cancer - cervix, abortions, congenital malformations [28, 31, 32] reproductive - respiratory problems and residues of agrochemicals in breast milk [33, 34]. Studies that relate health effects due to pesticides and sex stand out Alvarado et al., in which in the states of Sonora and Guerrero (Mexico), in alfalfa crops, farmers dedicated to alfalfa crops participated, including women who carried out the harvesting task; whose agrochemical used was methamidophos 600 [33] categorized as highly dangerous and with a history of causing a major health risk [35]. It was found that 5 women (> 40 years old) had values of 3930 IU/L, indicating an inhibition of ChEs. Consequently, it was concluded that women are the most vulnerable when exposed to agrochemicals [36, 37].

Along the same lines, Martins, et al. [38] conducted a study on 142 pregnant women in the city of Rio de Janeiro (Brazil) [38] a place where pyrethroid-type substances are commonly used, where women throughout their state of pregnancy and for some time have been exposed to these substances, for which reason analyses of creatinine levels in the urine of mothers and children at birth in their first months of life were carried out. It was possible to identify that exposure to pyrethroids throughout the entire gestation stage of women affected the babies, being found in them from birth and as the months went by the concentrations increased from 0.18 ng / mg to 0.36 ng / mg [38, 39]. Baumert agrees with the results of the previous research, since they took into account pesticides of organophosphate type, pregnant women provided 2 samples during the middle and end of pregnancy, the results indicated that the level of these substances was higher than the detection limits [40].

A number of negative health effects have been identified associated with pesticide exposure in agricultural women. This includes reproductive health problems, such as menstrual disorders and difficulty conceiving, as highlighted by research such as that of Bradman, et al. [41] and Cotes Torres and Cotes Torres [42]. Furthermore, studies such as that of Weichenthal, et al. [43] have found associations between pesticide exposure and the risk of specific cancers, such as kidney cancer [43].

However, it is important to recognize the limitations of existing research. Studies on this topic often face methodological challenges, such as the difficulty in accurately measuring pesticide exposure and establishing definitive causal relationships. Furthermore, most studies have focused on specific regions or population groups, limiting the generalizability of the findings. These studies highlight the need for policies and practices that protect the health of agricultural women, including strengthening regulations on pesticide use, promoting safer agricultural practices, and improving agricultural women's access to protective equipment and health services. Addressing gender inequalities in access to information and protection is crucial, as underscored by studies such as that by Damalas and Eleftherohorinos [25].

3.3. Health Risks Associated with the Use of Pesticides in Agriculture

Pesticides are widely used in agricultural production to prevent or control pests, diseases, weeds, and other plant pathogens in an effort to reduce or eliminate yield losses and maintain high product quality [44]. Through this thematic axis, 86 of 832 studies were selected from the databases of Scielo (14) and PubMed (72), as shown in Figure 4. Although these compounds are developed through very strict regulatory processes to operate with reasonable certainty and minimal impact on human health and the environment; serious concerns have been raised about health risks resulting from occupational exposure and residues in food and drinking water [45].

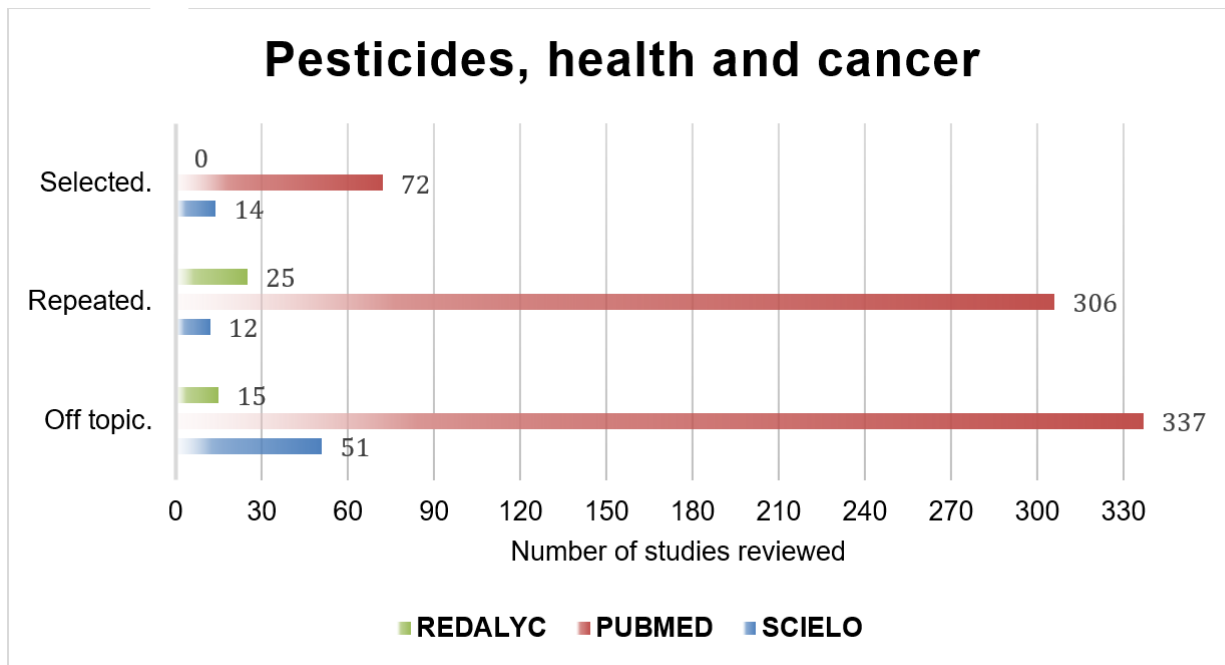


Figure 4. Refinement of studies on pesticide use and health conditions.

There are representative cases of research, which in the case of this review are 29%, indicating that the use of pesticides in daily agricultural activities is recurrent, largely considered inappropriate, because farmers are not trained before handling these toxic substances [42, 46-48]. Several studies have been carried out on these effects, which yield results that tend to make visible that pesticides can cause irreversible damage to humans, such as eye damage, respiratory conditions, abortions, malformations, reproductive problems, kidney diseases, and cancer [49-51].

At the national level, realities are evident in contexts where the eradication of illicit crops increases the use of some agrochemicals. This is the case in the department of Nariño (Colombia), in the towns of San José de Robles, Tórtola, and Casa Grande of the San José de Bacao Indigenous Reserve, where an indigenous ethnic group called "Esperará Siapidaara" lived. They were dedicated to growing fruits and vegetables; however, they were also surrounded by illicit crops. The impact on the area and the indigenous population was the aerial spraying of glyphosate, which caused the loss of most of their crops. Children suffered nausea, vomiting, coughing, respiratory problems, and fever. Although the children were taken to the nearest hospital in Tumaco (Colombia), three of them died [52]. There are also reports of health effects in communities exposed to Glyphosate in the studies [53-56].

It can be seen that 10% of the selected articles show a lack of proper handling of agrochemicals, which can impact people's health. However, one appropriate practice is the use of eye protection, especially when working in areas where fumigation is carried out. According to the Costa Rican Ophthalmology Association, when chemicals come into contact with the eyes, they can cause mild irritation to serious internal ocular injuries. One of the most common conditions is dry eye, which affects the tear film [57] since farmers are regularly exposed to these chemicals. This can be observed in research such as that conducted by Acevedo, who argues that there is a significant difference between people who were in contact with agrochemicals and those who were not [58].

Given this panorama, the review leads to consider that the relationship between pesticides and eye health problems require improved protocols and measures so that the use of these substances has a lower impact on the health of people who are directly exposed or who suffer the consequences indirectly.

Another health impact from pesticide use can be cancer. This is why research teams address these categories in their analyses. Some countries insist on their use despite the fact that different types of these substances have been classified as carcinogenic, neurotoxic, and teratogenic [26, 50]. A urine analysis of children and adolescents from rural areas of Jalisco (Mexico) revealed up to 12 highly hazardous agrochemical residues, the most common of which is glyphosate. Of the 146 samples taken, all presented at least two residues of different agrochemicals [59]. In this regard, despite several studies confirming the health effects that glyphosate can cause [60, 61] companies dedicated to selling these products insist on

their lack of [62]. However, the situation worsens when the negative consequences for humans persist despite its prohibition for certain uses. This is the case in Colombia, where it is still used to eradicate illicit crops, but it has been banned for other uses, which means that cases of diseases such as cancer and deaths caused by this herbicide still occur [63].

The effects of pesticides on human health, particularly their potential relationship with cancer, have been the subject of numerous studies and debates in the scientific community. Exposure to pesticides has been linked to several types of cancer in different populations, including agricultural workers and people living in rural areas where these chemicals are frequently used. Some associated cancers described in the scientific literature are: Hematological Cancer; the study by Rodríguez, et al. [64] found that pesticide applicators have an increased risk of developing non-Hodgkin lymphoma and chronic myeloid leukemia. Breast Cancer; the study by Brody and Rudel [65] suggests that women exposed to organochlorine pesticides may have an elevated risk of developing breast cancer, due to the ability of these compounds to act as endocrine disruptors. Prostate Cancer; research has also found associations between pesticide exposure and prostate cancer. For example, a study in the Agricultural Health Study (AHS) cohort showed that certain pesticides are associated with an increased risk of prostate cancer in men with a family history of the disease [8]. Lung and Other Cancers: Although less common, some studies have also suggested a link between pesticide exposure and lung cancer, as well as other types of cancer. For example, the study by Alavanja identified a possible association between the use of certain pesticides and an increased risk of lung cancer.

According to the review, the main biological mechanisms that associate the explosion with pesticides and health effects are endocrine disruptors. Many pesticides act as endocrine disruptors, interfering with the body's hormonal system and potentially increasing the risk of hormone-sensitive cancers, such as breast and prostate cancer [66]. Additionally, they cause genetic damage, directly to cells, which can lead to mutations and, eventually, the development of cancer. This damage may be the result of pesticide-induced oxidative stress, which causes DNA mutations [67]. Based on the findings, cancer is a disease that is sometimes associated with agrochemicals, which urges us to consider that their manipulation persists uncontrolled, combined with the lack of knowledge of protective measures for their exposure [68].

A significant challenge in research on pesticides and cancer is the variability in exposure among different individuals and populations. Application methods, duration of exposure, and the use of protective equipment can influence exposure levels and, consequently, cancer risk. Most of the evidence comes from epidemiological studies, which can suffer from limitations such as recall bias and difficulty establishing definitive causal relationships. Despite these limitations, the consistency of findings across multiple studies strengthens the evidence for an association between pesticide exposure and certain cancers.

3.4. Occupational Health in Agriculture

Occupational health applied to agriculture is focused on the prevention of occupational risks. 57% of articles were found, most of which are oriented towards risk prevention and little compliance with regulations. However, a series of guidelines, controls, and protection are suggested for possible problems that can be found in agriculture, such as muscular problems and other more internal problems such as exposure to agrochemicals [69]. Consistent results are reported in the study [70] in which the most represented occupational risks are chemical risk and biomechanical risk due to postures, especially in land preparation and harvesting, tasks in which women are more represented. A gender approach is essential in this discussion, since women in agriculture face specific challenges that are often not experienced by their male counterparts.

Table 2 presents gender inequalities in agricultural occupational health, to which agricultural women are frequently exposed to pesticides, often in conditions of greater vulnerability than men. According to Damalas and Eleftherohorinos [25] women often have less access to adequate personal protective equipment and less training on safe pesticide handling. This can increase their risk of adverse health effects, such as respiratory illnesses, reproductive problems, and cancers related to exposure to toxic chemicals.

Table 2.
Inequalities with a gender perspective in Colombian agriculture.

Relevant fact	Risk/Problem	Affected group	Main consequence	Study or source
Gender inequality in protection and training	Exposure to pesticides	Agricultural women	Greater vulnerability and health risk	Damalas and Eleftherohorinos [25]
Double workload (agriculture and home)	Work overload	Agricultural women	Physical, mental problems and stress	WHO and ILO [71]
Decreased IQ in children due to prenatal exposure to pesticides	Prenatal exposure	Children of agricultural workers	IQ decline in childhood	Andreo-Martínez, et al. [61]
High exposure to pesticides without protection in Latin America	Toxic pesticides	Agricultural women	Reproductive problems and cancer	Madeley [72]
Decreased reflexes, performance, and IQ due to pesticide exposure	Neurotoxicity	Agricultural women	Low performance and IQ	Zúñiga-Venegas [6]

One of the key points of the discussion concerns workload and gender roles. Women in agriculture not only participate in agricultural tasks but also often assume domestic responsibilities, which increases their overall workload. This dual role can have negative consequences for their physical and mental health. The International Labor Organization (ILO) and the World Health Organization (WHO) emphasize that long working hours combined with exposure to hazardous working conditions can lead to chronic health problems and stress [71].

Access to health services is another area where agricultural women may be disadvantaged. They often live in rural areas with limited medical infrastructure and may face additional barriers to receiving adequate health care due to economic, social, and cultural factors [73]. Women may also have less time and resources to access health services due to their multiple responsibilities. Agricultural women often receive lower wages and have less access to labor benefits compared to men. According to a FAO report [74] women in agriculture often work in informal or seasonal jobs that do not offer the same legal protections and benefits as formal jobs, exacerbating economic inequalities and increasing their vulnerability to adverse working conditions.

In Latin America, research has shown that female agricultural workers are exposed to high levels of pesticides without adequate protection and training. A study in Nicaragua found that women working in the banana industry were exposed to toxic pesticides, resulting in a high incidence of health problems, including reproductive issues and cancer [72]. In sub-Saharan Africa, women represent a significant portion of the agricultural workforce. However, they face significant barriers to accessing agricultural technologies and training, which limits their ability to implement safer and more sustainable agricultural practices. These barriers also impact their ability to protect themselves from occupational hazards [74].

Within the range of research, it is observed that studies have been carried out on cassava farmers in Nigeria (Africa), who were in contact with pesticides, highly and moderately dangerous, such as those from the organophosphate chemical group, belonging to WHO classes II and III, which can enter the body and spread to the heart, kidneys, and lungs [75]. Additionally, it was found that 77% of workers in 24 localities do not use personal protective equipment (PPE), since they did not have information about them.

Muñoz Quezada analyzed 93 day laborers involved in the handling and application of organophosphate agrochemicals. Ninety-four workers in the control group underwent a physical examination and a Folstein mini-mental test. This assessment evaluated the neuropsychological development of agricultural workers, taking into account sex (men and women), educational level, income, and age. The results showed that female workers exposed to these substances had reflex problems, lower performance in their work (-3 points less compared to workers without contact), verbal difficulties (-4 points), information processing problems, and a low IQ (-4 points) [6]. This last result is relevant because the research team compared IQs among people exposed to pesticides, and others that were not, finding that those who were exposed had lower scores on this assessment index. This would be related to the findings of Andreo-Martínez, et al. [61]. In the study Pesticide Residues and Autism Spectrum Disorder, a relationship is found between organophosphates in pregnant mothers with a decrease of 5.5 points of the IQ of 7-year-old children [61].

Recommendations for improving occupational health with a gender perspective include implementing specific education and training programs for women on the safe handling of pesticides and other agricultural practices. This includes providing information on the use of personal protective equipment and necessary safety measures. Additionally, developing and implementing policies that guarantee safe and fair working conditions for women in agriculture. This includes regulating pesticide use, providing protective equipment, and implementing measures to reduce workload. Improving access to health services in rural areas and ensuring that agricultural women have access to adequate health care. This may include providing mobile clinics and community health programs that address women's specific needs. Finally, promoting the economic empowerment of agricultural women through programs that provide them with access to credit, skills training, and formal employment opportunities.

4. Conclusions

According to the review, women are underrepresented in search strings (14%) of selected documents, which is considered a knowledge gap for further advancing research related to exposure to agrochemicals and their effects on women's health. It has been shown that women are the most susceptible gender when in contact with these pesticides, especially during tasks such as land preparation, vector control, and harvesting. Pesticides can be easily absorbed through the skin or enter through the respiratory tract, and in turn, are more persistent in the body compared to men, due to their ability to activate metabolically as endocrine disruptors. Hence, associated chronic diseases are related to the reproductive system, fertility problems, breast cancer, lung cancer, kidney cancer, and stomach cancer. Reports of problems with visual health, child development, and occupational health, among others, were also found. One of the reasons for the illnesses suffered is a lack of knowledge about the proper use and handling of pesticides, as well as a lack of use of PPE.

Gender inequalities in agricultural occupational health must be addressed in order to improve the quality of life and health of women in this sector. By implementing specific policies and programs that address these inequalities, it is possible to create a safer and more equitable work environment for agricultural women.

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