Journal of Preventive and Population Health
https://jpphealth.com/

REVIEW ARTICLE

Pesticide exposure, associated risks, and long-term human health impacts: a narrative review

Mohamed Elsayed Othman[1*], Mai Omar Salih[2]

Full list of author information is available at the end of the article.

ABSTRACT

Pesticides are used in a variety of circumstances, including agriculture and public health activities. Pesticides, on the other hand, have a deleterious influence on human health, with effects ranging from short term to long term. We focus on the long-term effects of pesticide exposure on human health. The literature on the current subject was collected through web research using various terms. This review was written based on eligible articles with precise titles. Pesticides are linked to a variety of negative health effects, ranging from short-term symptoms like nausea and headaches to long-term serious effects like cancer. Pesticides are risk factors that have been connected to a variety of serious ailments and illnesses over time. However, such risk and linkage are difficult to accurately deduce and explain because most diseases that need prolonged exposure also have a number of additional risk factors that can be included and function synergistically with pesticides to promote disease development. As a result, it is possible to conclude that long-term pesticide exposure poses a number of dangers to human health, although further research is required.

Keywords: Pesticide, exposure, long term, impact, human health.

Introduction

Pesticide is a term derived from the Latin words "Pestis" and "caedere," with the former meaning plague and the latter meaning to kill. This phrase refers to a variety of chemicals used to control and manage pests, which include plant pathogens, weeds, mollusks, insects, fish, microorganisms, and mammals that compete with humans for food or play a role in carrying or spreading disease [1]. Pesticides are employed in many industries, including agriculture to protect crops from pests and public health to control disease vectors [2]. They are widely used in agriculture because they are effective tactics for increasing crop quantity and quality while protecting them from various pests and ensuring food security [2]. However, they have a negative effect on human health [3]. Pesticide-related concerns have grown as a result of exposure through several pathways, including drinkable water and residue in food. Pesticides can cause short-term symptoms like nausea, headaches, and dizziness, as well as long-term effects, including asthma, cancer, and diabetes. However, defining the precise nature of such dangers is difficult because it takes into account various elements, including duration of exposure, intensity of exposure, pesticide toxicity, and the environmental characteristics of the impacted regions. Furthermore, most such illnesses have many causes, and no group of human beings is completely resistant to pesticides; hence, public health evaluation is significantly more challenging [4]. As a result, we give a narrative review that provides an overview of the long-term effects of pesticide exposure on human health.

Method

The articles used in this review were retrieved via internet research using the scientific websites "Google Scholar and PubMed," and using various terms, including "Pesticide, Health, Outcomes, Impacts, Risk factors, and Effect." Articles with irrelevant names or that did not focus on our purpose were eliminated, and only relevant articles were included. All forms of articles were considered

Correspondence to: Mohamed Elsayed Othman
*NICU and Pediatric Consultant, Care Medical Hospital, Riyadh, Saudi Arabia.
Email: Abuamr_gharbia@yahoo.com
Received: 29 January 2025| **Revised:** 12 March 2025| **Accepted:** 18 March 2025

suitable, with the exception of letters to the editor and case reports, which were prohibited. The review was published under specific titles, with each contributor discussing one or more novels. After finishing the piece, each author reviewed it thoroughly.

Classification of pesticides

Pesticides are employed for a variety of purposes; in agriculture, they protect crops from pests, while in public health, they try to reduce disease vectors such as mosquitoes [2]. Pesticides are divided into several groups, including insecticides, herbicides, fungicides, rodenticides, and others, with each group targeting a specific type of pet or serving a unique purpose [2].

Pesticides are classified into three categories: those that affect specific diseases, those that affect pest entrance points, and agents that focus on pesticide composition [5]. Pesticides can also be classified into various smaller categories based on factors such as origin, mechanism of action, pesticidal formulation type, and target range [5]. Pesticides were classified by "the World Health Organization" into four classifications based on their toxicity: extremely, very, moderately, and mildly harmful [6].

Pesticides are grouped into three types based on how they are used: agricultural, public health, and domestic. They can be classified as biodegradable agents, which microbes can transform into innocuous molecules, or persistent agents, which take months or even years to degrade. Pesticides are classified according to their method of action as insecticides, fungicides, or herbicides [7]. Pesticides are classified by their chemical composition as organophosphates, organochlorines, carbamates, or synthetic pyrethroids. The former contains phosphorus, which is commonly used as an acaricide and pesticide. Organochlorines are organic pesticides that include at least five chlorine atoms. Carbamate products include carbaryl, methomyl, and propoxur. Finally, synthetic pesticides are a combination of organic pesticides generated through the replication of natural pyrethrins [8].

Methods and routes for pesticide exposure

Pesticide exposure can be direct or indirect; direct exposure occurs during pesticide application and has a significant immediate health impact such as skin irritation, respiratory difficulties, or headaches. In contrast, indirect exposure occurs when pesticide residues leak into water supplies, linger in food, or aggregate in the environment, posing health risks to humans through contact or ingestion. Bioaccumulation is a possible concern associated with pesticide use, in which chemicals accumulate in the body over time, particularly after prolonged or repeated exposure [3]. This accumulation can lead to more serious health problems because pesticides can linger in the environment and spread through the food chain via a process known as biomagnification. As a result, the effects on health can be exacerbated at higher trophic levels [2].

Also, exposure can be dermal, oral, or respiratory; cutaneous exposure is the most effective and common route for people who are exposed to pesticides by spilling, splashing, or drift of pesticide. Oral exposure is the most common poisoning route, and it causes serious health problems. It occurs when people use or generate pesticides without washing their hands before eating, smoking, or drinking pesticide-contaminated food. The respiratory pathway occurs through breathing or inhalation and is caused by the pesticides' volatile components [9].

Impact of pesticides on human health

Pesticides can have serious adverse effects on the human body; these chemicals are intended to target and kill pests. However, they can have an impact on human health. Understanding pesticide side effects is essential for making informed decisions and implementing safer practices [10]. A recent review and analysis identified consistent links between persistent pesticide exposure and noncommunicable illnesses such as endocrine disruption, cancer, and neurological problems. Occupational pesticide exposure was frequently associated with an increased prevalence of neurological disease and respiratory issues. Individuals exposed to high-intensity or prolonged periods of time, particularly farmers, were more likely to suffer long-term health consequences [2].

Thus, such consequences on human health can be classified into the following.

I-Neurotoxicity: Certain pesticides, such as carbamates and organophosphates, have neurotoxic effects on the human nervous system; high levels or extended exposure to such chemicals can result in neurological illnesses [10], including Alzheimer's disease (AD) and Parkinson's disease (PD) [8].

AD is the most common type of dementia among the elderly and is increasing globally [11]. One study found that exposure to organochlorine pesticides increases the incidence of AD and dementia. Long-term pesticide exposure has been linked to brain damage and the development of AD [12]. Previous research found a direct link between pesticide contact and AD, indicating that pesticide contact is an AD risk factor [13].

PD is a multifactorial neurological condition caused by oxidative damage, altered dopamine catabolism, and inactivation of tyrosine hydroxylase, leading to dopaminergic neuron death [14,15]. Pesticides play a role in this condition because the chemicals and their metabolites can interfere with mitochondrial function and change xenobiotic metabolism, leading to PD [16,17]. In a prior study of 26 studies, 15 of them indicated a relationship between pesticide exposure and PD. Pesticide exposure, specifically mancozeb and paraquat, was found to be associated with an elevated risk of PD [18]. Paraquat's impact on PD progression stems from

its powerful oxidative injury stimulator, which causes the generation of reactive oxygen species [19], resulting in oxidative damage and death of dopamine-producing neurons. As a result, long-term exposure to paraquat may increase the risk of developing PD [8].

II-Reproductive impact: Pesticide exposure has been associated with reproductive diseases, as well as reproductive health. Pesticide exposure can cause infertility, birth abnormalities, abortion, hormonal imbalances, and changes in the natural course of the reproductive system. Such effects can have long-term ramifications for both individuals and communities [10].

Fertility: There has been some controversy around the link between pesticides and sperm abnormalities [8]. Consumption of pesticide residues at low-to-moderate levels has been connected to sperm morphology; exposure to dietary pesticides used in farming may be sufficient to alter human spermatogenesis [20].

Birth defects: Pesticide exposure has been consistently associated with an increased risk of a variety of conditions, including urogenital malformations, orofacial clefts, limb difficulties, and ocular anomalies. Parents' exposure to pesticides can potentially cause birth abnormalities.

Fetal death: Pesticide exposure can cause fetal death, stillbirth, spontaneous abortion, and neonatal death [8]. Early first-trimester loss was found to be associated with pesticide exposure prior to conception, but late spontaneous miscarriage was associated with post-conception exposure [21]. In one study, it was discovered that spontaneous miscarriage was six times more common among farming households that used a lot of pesticides than those that employed integrated pest management [22].

III-Endocrine disruption: Some pesticides have endocrine disruptive qualities, which means that they can interfere with hormonal system activities. This disruption can affect reproduction, growth, development, and metabolism. This insecticide has been related to hormonal abnormalities, developmental issues, and an increased risk of several diseases [10]. Diabetes is one example of how environmental pollutants appear to influence diabetes [8]. Several studies have found that particular pesticides can impair glycemic control and increase the risk of diabetes [23,24]. Continuous exposure to some pesticides, such as organophosphates and organochlorines, can disrupt the endocrine system's normal functioning, resulting in diabetes development. This can be caused by disruptions in glucose metabolism and insulin signaling, resulting in poor glycemic control and insulin resistance [25].

IV-Carcinogenicity: Some pesticides are considered probable carcinogens because they have the potential to cause cancer in humans. Long-term exposure to such chemicals has been linked to an increased risk of cancer progression [10].

Breast cancer: Some pesticides are classified as probable carcinogens because they have the potential to cause cancer in humans. Long-term exposure to these drugs may increase the chance of cancer progression [10].

Bladder and colon cancer: Heterocyclic aromatic amines have been discovered in numerous incidences of colon and bladder cancer [26-28]. One study of male agricultural workers found that exposure to pesticides raised bladder cancer risk by an odds ratio of 1.68 [29].

Liver cancer: The chance of developing this disease may increase with prolonged exposure to numerous pesticides, particularly those recognized as carcinogens [30]. Although certain herbicides have been associated with an increased risk of liver cancer, their mechanisms remain unknown [31]. Organochlorine compounds are among the pollutants linked to liver cancer [32]. Pesticides can accumulate in the body over time and interact with other metabolites, leading to liver cancer [8].

Conclusion

Pesticides offer various benefits, including protecting crops from pests and controlling disease vectors. However, they are linked to a variety of negative health effects, ranging from short-term symptoms like nausea and headaches to long-term serious repercussions like cancer. Pesticides are risk factors that have been connected to a variety of serious maladies and illnesses, including reproductive issues and diseases, neurological and hormonal disorders, and cancer. However, such risk and linkage are difficult to accurately deduce and explain because most diseases that need prolonged exposure also have a number of additional risk factors that can be included and function synergistically with pesticides to promote disease development. Furthermore, the impact of pesticide exposure is determined by a variety of parameters, including the duration and intensity of exposure, as well as chemical toxicity and degradation. As a result, it is possible to conclude that long-term pesticide exposure poses a number of dangers to human health, necessitating extensive and ongoing research and analysis into such correlations and mechanisms.

List of Abbreviations

AD Alzheimer's disease
PD Parkinson's disease

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent to participate

Not applicable.

Ethical approval

Not applicable.

Author details

Mohamed Elsayed Othman[1], Mai Omar Salih[2]

1. NICU and Pediatric Consultant, Care Medical Hospital, Riyadh, Saudi Arabia
2. Resident, Care Medical Hospital, Riyadh, Saudi Arabia

References

1. Yadav IC, Devi NL. Pesticides classification and its impact on human and environment. Environ Sci Eng. 2017;6(7):140–58.
2. Shekhar C, Khosya R, Thakur K, Mahajan D, Kumar R, Kumar S, et al. A systematic review of pesticide exposure, associated risks, and long-term human health impacts. Toxicol Rep. 2024;13:101840. https://doi.org/10.1016/j.toxrep.2024.101840
3. Poudel S, Poudel B, Acharya B, Poudel P. Pesticide use and its impacts on human health and environment. Environ Ecosyst Sci. 2020;4(1):47–51. https://doi.org/10.26480/ees.01.2020.47.51
4. Kim KH, Kabir E, Jahan SA. Exposure to pesticides and the associated human health effects. Sci Total Environ. 2017;575:525–35. https://doi.org/10.1016/j.scitotenv.2016.09.009
5. Kaur R, Mavi GK, Raghav S, Khan I. Pesticides classification and its impact on environment. Int J Curr Microbiol Appl Sci. 2019;8(3):1889–97.
6. Edwards H. International programme in chemical safety, World Health Organization, Geneva, 2003. Int J Environ Stud. 2004;61(5):545–6.
7. Rathee V, Dubey AK, Kaur M. Effect of pesticides on human health. J Forensic Sci Res. 2023;7(1):34–9. https://doi.org/10.29328/journal.jfsr.1001047
8. Ahmad MF, Ahmad FA, Alsayegh AA, Zeyaullah M, AlShahrani AM, Muzammil K, et al. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon 2024;10(4):e11045. https://doi.org/10.1016/j.heliyon.2024.e11045
9. Tudi M, Li H, Li H, Wang L, Lyu J, Yang L, et al. Exposure routes and health risks associated with pesticide application. Toxics 2022;10(6):335. https://doi.org/10.3390/toxics10060335
10. Singh S, Minj KH. Side effects of pesticides on the human body. JA e-Newsletter. 2023;3(11):361–65.
11. Liu H, Reynolds GP, Wei X. The influence of agricultural work and plasma uric acid on Hospital Admission for Alzheimer's Disease. J Alzheimers Dis. 2023;92(4):1283–87. https://doi.org/10.3233/JAD-220562
12. Hayden KM, Norton MC, Darcey D, Østbye T, Zandi PP, Breitner JC, et al. Occupational exposure to pesticides increases the risk of incident AD: the Cache County study. Neurology 2010;74(19):1524–30. https://doi.org/10.1212/WNL.0b013e3181dd4e3c
13. Yan D, Zhang Y, Liu L, Yan H. Pesticide exposure and risk of Alzheimer's disease: a systematic review and meta-analysis. Sci Rep. 2016;6(1):32222. https://doi.org/10.1038/srep32222
14. Zhang XF, Thompson M, Xu YH. Multifactorial theory applied to the neurotoxicity of paraquat and paraquat-induced mechanisms of developing Parkinson's disease. Lab Invest. 2016;96(5):496–507. https://doi.org/10.1038/labinvest.2016.30
15. Martínez -Chacón G, Yakhine-Diop SM, González-Polo RA, Bravo-San Pedro JM, Pizarro-Estrella E, Niso-Santano M, et al. Links between paraquat and Parkinson's disease. Handb Neurotox. 2021; P4: 1–9. https://doi.org/10.1007/978-1-4614-6093-0_98-1
16. Luo B, Ning Y. Comprehensive overview of carboxamide derivatives as succinate dehydrogenase inhibitors. J Agri Food Chem. 2022;70(4):957–75. https://doi.org/10.1021/acs.jafc.1c07114
17. Le Couteur DG, McLean AJ, Taylor MC, Woodham BL, Board PG. Pesticides and Parkinson's disease. Biomed Pharmacother. 1999;53(3):122–30. https://doi.org/10.1016/S0753-3322(99)80004-7
18. Pezzoli G, Cereda E. Exposure to pesticides or solvents and risk of Parkinson disease. Neurology 2013;80(22):2035–41. https://doi.org/10.1212/WNL.0b013e318294b3c8
19. Colle D, Farina M. Oxidative stress in paraquat-induced damage to nervous tissues. Toxicology 2021;69–78. https://doi.org/10.1016/B978-0-12-822218-9.00013-6
20. Chiu YH, Afeiche MC, Gaskins AJ, Williams PL, Petrozza JC, Tanrikut C, et al. Fruit and vegetable intake and their pesticide residues in relation to semen quality among men from a fertility clinic. Hum Reprod. 2015;30(6):1342–51. https://doi.org/10.1093/humrep/dev064
21. Arbuckle TE, Savitz DA, Mery LS, Curtis KM. Exposure to phenoxy herbicides and the risk of spontaneous abortion. Epidemiology 1999;10(6):752–60. https://doi.org/10.1097/00001648-199911000-00011
22. Crisostomo L, Molina VV. Pregnancy outcomes among farming households of Nueva Ecija with conventional pesticide use versus integrated pest management. Int J Occup Environ Health. 2002;8(3):232–42. https://doi.org/10.1179/oeh.2002.8.3.232
23. Miranda RA, Silva BS, de Moura EG, Lisboa PC. Pesticides as endocrine disruptors: programming for obesity and diabetes. Endocrine 2023;79(3):437–47. https://doi.org/10.1007/s12020-022-03221-6
24. Lin JY, Yin RX. Exposure to endocrine-disrupting chemicals and type 2 diabetes mellitus in later life. Expos Health. 2023;15(1):199–229. https://doi.org/10.1007/s12403-022-00457-y
25. Kumar V, Sharma N, Sharma P, Pasrija R, Kaur K, Umesh M, et al. Toxicity analysis of endocrine disrupting pesticides on non-target organisms: a critical analysis on toxicity mechanisms. Toxicol Appl Pharmacol. 2023;474:116623. https://doi.org/10.1016/j.taap.2023.116623
26. Ventura C, Venturino A, Miret N, Randi A, Rivera E, Núñez M, et al. Chlorpyrifos inhibits cell proliferation through ERK1/2 phosphorylation in breast cancer cell lines. Chemosphere 2015;120:343–50. https://doi.org/10.1016/j.chemosphere.2014.07.014
27. Arrebola JP, Belhassen H, Artacho-Cordón F, Ghali R, Ghorbel H, Boussen H, et al. Risk of female breast cancer and serum concentrations of organochlorine pesticides and polychlorinated biphenyls: a case–control study in Tunisia. Sci Total Environ. 2015;520:106–13. https://doi.org/10.1016/j.scitotenv.2015.03.048

28. Weisburger JH. Comments on the history and importance of aromatic and heterocyclic amines in public health. Mut Res. 2002;506:9–20. https://doi.org/10.1016/S0027-5107(02)00196-9

29. Amr S, Dawson R, Saleh DA, Magder LS, St. George DM, El-Daly M, et al. Pesticides, gene polymorphisms, and bladder cancer among Egyptian agricultural workers. Arch Environ Occup Health. 2015;70(1):19–26. https://doi.org/10.1080/19338244.2013.859007

30. Navas-Acién A, Pollán M, Gustavsson P, Plato N. Occupation, exposure to chemicals and risk of gliomas and meningiomas in Sweden. Am J Ind Med. 2002;42(3):214–27. https://doi.org/10.1002/ajim.10110

31. Zhang H, Zhang R, Zeng X, Wang X, Wang D, Jia H, et al. Exposure to neonicotinoid insecticides and their characteristic metabolites: association with human liver cancer. Environ Res. 2022;208:112703. https://doi.org/10.1016/j.envres.2022.112703

32. Engel LS, Zabor EC, Satagopan J, Widell A, Rothman N, O'Brien TR, et al. Prediagnostic serum organochlorine insecticide concentrations and primary liver cancer: a case–control study nested within two prospective cohorts. Int J Cancer. 2019;145(9):2360–71. https://doi.org/10.1002/ijc.32233