AUCTORES
Globalize your Research

New Medical Innovations and Research
Mohammad Forouhar Vajargah *

Open Access

Review Article

# Assessing the Impact of Organophosphorus Pesticides (OPPs) on Aquatic Ecosystems: A Review

**Nava Majidiyan [1], Seyed Parsa Mousavi [2], and Mohammad Forouhar Vajargah [3*]**

[1] Veterinary technical manager, Laleh Mahallat Industries Company, Mahallat, Markazi, Iran.

[2] Department of Environmental Sciences and Engineering, Faculty of Natural Resources, University of Guilan, Sowmeh Sara, Guilan, Iran.

[3] Department of Fisheries, Faculty of Natural Resources, University of Guilan, Sowmeh Sara, Guilan, Iran.

***Corresponding Authors:** Mohammad Forouhar Vajargah, Department of Fisheries, Faculty of Natural Resources, University of Guilan, Sowmeh Sara, Guilan, Iran.

**Received date:** January 18, 2025; **Accepted date:** February 12, 2025; **Published date:** March 25, 2025

**Citation:** Nava Majidiyan, Seyed Parsa Mousavi and Mohammad Forouhar Vajargah, (2025), Assessing the Impact of Organophosphorus Pesticides (OPPs) on Aquatic Ecosystems: A Review, *J New Medical Innovations and Research*, 6(3); **DOI:10.31579/2767-7370/153**

**Copyright:** © 2025, Mohammad Forouhar Vajargah. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Abstract:**

Organophosphate pesticides (OPPs) are widely used chemicals with significant applications in agriculture, public health, and industry. Despite their utility, the extensive use of OPPs raises pressing concerns about their environmental persistence and impact on non-target organisms. This review explores the environmental distribution, toxicity, and detection methodologies associated with OPPs, emphasizing their ecological and public health implications. OPPs, characterized by their carbon-phosphorus (C-P) linkage and high chemical stability, are prone to pseudo-persistence in aquatic ecosystems, adversely affecting non-target plants and animals. Acute and chronic exposure to OPPs disrupts acetylcholinesterase activity, leading to toxicity in humans and wildlife, and is linked to serious health conditions such as neurotoxicity, endocrine disruption, and carcinogenesis.

Key advancements in analytical techniques, including spectroscopy and biosensing methods, have improved OPP residue detection across various matrices, such as water, soils, and biological tissues. Novel approaches like immunoassays and diffuse reflectance spectrophotometry demonstrate potential for enhanced efficiency, though limitations in recovery rates remain. The article further highlights the significance of OPPs such as trichlorfon and diazinon while cautioning against more hazardous compounds like chlorpyrifos and malathion. The need for innovative detection methods and mitigation strategies is underscored, with a call for interdisciplinary efforts to address environmental contamination and health risks associated with OPPs.

This review contributes to the understanding of OPP distribution and toxicity, advocating for sustainable solutions to balance their agricultural benefits with environmental and public health safeguards.

**Keywords:** aquatic ecosystems; organophosphate pesticides; OPPs; pollution; toxicity

## 1.Introduction

On the topic of environmental pollution, water pollution invariably becomes a focal point [1-8]. Water is regarded as one of the most essential resources for both aquaculture and agriculture [2]. With the expansion of mechanized farming and the increase in production per unit area globally, the use of pesticides, particularly organophosphate compounds, has significantly increased [9].

Attributable to their extensive insecticidal range, organophosphate pesticides (OPPs) have been predominantly utilized in agriculture, horticulture, public health, and homes [10]. OPPs are the most widely used agricultural pesticides globally [11]. OPPs are less enduring than traditional pesticides, their frequent application and discharge might lead to pseudo-persistence and significant exposure risks for non-target aquatic species within aquatic ecosystems [10].

The pesticides used often make their way into surface water sources, and their effects on non-target organisms are among the pressing concerns of today's global community. The impact of these chemicals on the biological communities of natural water bodies and their potential effects on the population and health of aquatic organisms have raised various environmental and health-related concerns [9]. The infiltration of these pesticides into flowing water is inevitable.

One notable OPPs is Trichlorfon, which is widely used in aquaculture for various purposes [11]. Compared to other pesticides, it poses lower toxicity to fish; however, its effects vary depending on the concentration of the pesticide, exposure duration, fish species, and their resistance [11]. Although these environments are not the primary targets of agricultural and livestock pesticides, numerous monitoring studies have revealed the presence of these pesticides in surface water [9]. Another commonly used organophosphate pesticide in agriculture is diazinon [2]. In general, it can be stated that among OPPs, the use of trichlorfon and diazinon is preferable. On the other hand, due to the high toxicity of other pesticides such as chlorpyrifos and malathion, the use of these two OPPs should be avoided [11].

Organophosphate pesticides are considered among the most hazardous chemicals to human health [12]. Exposure to OPPs could harm human health, including neurotoxic damage, teratogenic effects, disruption of the endocrine system, immunotoxic responses, impaired cognitive development, and harm to both the reproductive and immune systems [10]. Additionally, OPP exposure has been linked to conditions such as Parkinson's disease and diabetes. Most organophosphate pesticides cause acute poisoning in humans; however, some of them, upon entering the life cycle, lead to environmental contamination and even affect the bodies of vertebrate organisms, especially aquatic life. Therefore, identifying these pesticides in water, food, and the human environment is critical due to their potential threat to human health [13,14]. Consequently, it is crucial to investigate the environmental distribution, behavior, and persistence of OPPs to fully comprehend their potential hazards to ecosystems and human well-being [12].

Given the increasing use of these compounds as chemical agents in various products, such as insecticides and agricultural pesticides, along with the ease of access to these substances, conducting a review study on the research carried out in this area seemed necessary. This review aims to explore existing research on their environmental distribution, detection, and the critical need for mitigation strategies.

### Organophosphate pesticides (OPPs)

Organophosphate pesticides (OPPs) are organic ester compounds derived from phosphorus, often comprising thiol or amide groups associated with thiophosphoric, phosphonic, or phosphoric acids, along with supplementary substituents such as phenoxy, cyanide, or thiocyanate moieties [15]. These organophosphate molecules serve as the primary constituents in herbicides, insecticides, and pesticides, as well as in nerve agents. OPPs represent a class of naturally occurring and man-made substances characterized by a carbon-phosphorus (C-P) bond that exhibits exceptional thermal and chemical stability, rendering it resistant to hydrolytic, photolytic, and chemical degradation in contrast to counterparts containing reactive linkages like sulfur-phosphorus (S-P), oxygen-phosphorus (O-P), or nitrogen-phosphorus (N-P) bonds [16,17]. The fundamental architecture of OPPs features a terminal phosphoryl oxygen atom linked to phosphorus through a double bond, accompanied by two hydrophobic groups attached to the phosphorus and a leaving group, often halide-based, bonded to the phosphorus atom [18].

Organophosphorus compounds find extensive application across a diverse range of sectors, including agriculture, horticulture, pest management, industrial manufacturing, vector control, polymer production, chemical warfare, and household utilities [19].

Both acute and chronic exposure to OPPs can result in varying degrees of toxicity across humans, animals, plants, and insects. Many OPPs function by inhibiting acetylcholinesterase activity, thereby impairing the nervous systems of terrestrial and aquatic organisms [19].

### Toxicity of organophosphate pesticides on aquatic

Excessive application of OPPs adversely impacts non-target plant species as well as aquatic and terrestrial animal populations [20]. The United States Environmental Protection Agency (USEPA) categorizes most OPPs within toxicity classes I through IV based on the risk associated with inhalation and oral exposure [15]. These compounds are implicated in triggering conditions such as photodermatitis, skin irritation, carcinogenesis, emesis, and nausea in humans while exhibiting mild to moderate toxicity toward amphibians and fish species [15]. The principal mode of action underlying acetylcholinesterase enzyme inhibition involves the accumulation of acetylcholine (ACh), a neurotransmitter, leading to persistent stimulation of acetylcholine receptors [15].

OPPs are extensively employed on a global scale, posing significant public health challenges, particularly in developing nations. The toxicokinetic and toxicodynamic properties of organophosphate pesticide poisoning depend not only on the route and intensity of exposure but also on the molecular structure of the compound in question [21]. The fatal mechanism is the inhibition of acetylcholinesterase activity, resulting in acetylcholine build-up and heightened activation of acetylcholine receptors [15]. Standard therapeutic intervention includes the reactivation of inhibited acetylcholinesterase enzymes using oxime-based antidotes, coupled with the biochemical counteraction of acetylcholine effects via atropine administration. Timely treatment often ensures recovery from acute toxicity, though patients may experience residual neurological complications. The Lemna bioassay is regarded as the most standardized and broadly utilized method for assessing aquatic ecotoxicity in plant systems [21].

### Methods of detection of OPPs

The advancement of diverse analytical methodologies has facilitated the extraction of critical information and elucidation of the structural characteristics of newly synthesized molecules. Ongoing research efforts are dedicated to identifying ligands and reporting matrices for the detection of organophosphate pesticides (OPPs) through various spectroscopic approaches, including ultraviolet-visible (UV-Vis) spectroscopy [22], Fourier-transform infrared (FTIR) spectroscopy [23], mass spectrometry [24], X-ray diffraction analysis [25], electrochemical techniques [26], and nuclear magnetic resonance (NMR) spectroscopy [27]. The identification and quantification of OPP residues have been documented in various matrices such as water, guava fruit extracts, soils, sediments, animal and human tissues, plant matter, wheat grains, urine samples, dairy cow organs, soybean extracts, and carrots [28].

Recently, novel detection techniques for identifying organophosphate pesticide residues, such as immunoassays, Oscillo graphic polarography, and diffuse reflectance spectrophotometry, have gained traction due to their streamlined procedures, reduced operational effort, and improved efficiency. Among the existing methods, biosensors and enzyme-linked immunosorbent assay (ELISA)--based approaches have dominated in recent years [29]. However, there is a pressing need to develop innovative molecular entities capable of reducing low recovery rates. Additionally, high-recovery spectroscopic and biosensing methodologies require further refinement through a series of systematic modifications to enhance their applicability and accuracy [30-32].

## Conclusion

The widespread application of organophosphate pesticides (OPPs) in agriculture, public health, and industry underscores their critical importance while simultaneously drawing attention to their potential risks to ecosystems and human health. The adverse impacts on non-target species, combined with the persistent nature of these compounds in various environmental matrices, demand immediate and focused action. Although advancements in detection technologies have significantly enhanced the monitoring of OPP residues, challenges persist in achieving optimal recovery rates and developing sustainable strategies for detection and mitigation.

Effectively addressing these concerns requires a holistic approach that combines cutting-edge analytical technologies with robust, policy-driven frameworks aimed at reducing environmental contamination and protecting public health. Interdisciplinary collaboration plays a vital role in fostering innovative solutions to mitigate the risks posed by OPPs while preserving their essential functions in critical applications. Continued research and the ongoing refinement of detection methods are imperative to strike a balance that promotes both environmental sustainability and global health security.

## References


1. Forouhar Vajargah, M., Mohamadi Yalsuyi, A., & Hedayati, A. (2018). Effects of dietary Kemin multi-enzyme on survival rate of common carp (*Cyprinus carpio*) exposed to abamectin. Iranian Journal of Fisheries Sciences, 17(3), 564-572.
2. Forouhar Vajargah M, Hedayati S A A. Study on the mortality effects of an organophosphate poison. JAIR 2013; 1 (3) :75-84. (In Persian)
3. Sattari, M., Imanpour Namin, J., Bibak, M., Forouhar Vajargah, M., Hedayati, A., Khosravi, A., & Mazareiy, M. H. (2018). Morphological comparison of western and eastern populations of Caspian kutum, *Rutilus kutum* (Kamensky, 1901) (Cyprinidae) in the southern Caspian Sea. International Journal of Aquatic Biology, 6(4), 242-247.
4. Forouhar Vajargah, M., Mohammadi Yalsuyi, A., & Hedayati, A. (2017). Acute toxicity of povidone-iodine (Betadine) in common carp (*Cyprinus carpio* L. 1758). Pollution, 3(4), 589-593.
5. Ramzanipour, M. M., Mousavi, S. P., & Forouhar Vajargah, M. (2023). Overview of Municipal Wastewater and Sludge Treatment Process. Ecol. Conserv. Sci, 2, 555-596.
6. Forouhar Vajargah, M., & Hedayati, A. (2014). Acute toxicity of trichlorofon on four viviparous fish: *Poecilia latipinna*, *Poecilia reticulata*, *Gambusia holbrooki* and *Xiphophorus helleri* (Cyprinodontiformes: Poeciliidae). Journal of Coastal Life Medicine, 2(7), 511-514.
7. Vajargah, M. F., Hedayati, A., Yalsuyi, A. M., Abarghoei, S., Gerami, M. H., & Farsani, H. G. (2014). Acute toxicity of Butachlor to Caspian Kutum (*Rutilus frisii Kutum* Kamensky, 1991). Journal of Environmental Treatment Techniques, 2(4), 155-157.
8. Forouhar Vajargah, M., Hossaini, S. A., & Hedayati, A. (2013). Acute toxicity test of two pesticides diazinon and deltamethrin on spirlin (*Alburnoides bipunctatus*) larvae and fingerling. Journal of Toxicology and Environmental Health Sciences, 5(6), 106-110.
9. Alishahi, M., & Abdi, E. (2014). Comparison of Organophosphorous pesticide, Diazinon, toxicity in four native fish of Khouzestan province: *Barbus sharpeyi*, *Barbus grypus*, *Barbus xanthopterus* and *Barbus barbulus*. Journal of Aquaculture and Exploitation, 3(1), 79-93. (In Persian)
10. Wei, G., Wang, C., Niu, W., Huan, Q., Tian, T., Zou, S., & Huang, D. (2021). Occurrence and risk assessment of currently used organophosphate pesticides in overlying water and surface sediments in Guangzhou urban waterways, China. Environmental Science and Pollution Research, 28(35), 48194-48206.
11. Alishahi, M., Hosseini, M., & Javadzade, N. (2015). Comparison of the toxicity of four organophosphate toxins: Trichlorophene, Diazinon, Malathion, and Chlorpyrifos in barb fish (*Barbus grypus*). Journal of New Technologies in Aquaculture Development (Fisheries), 9(1), 55-64. (In Persian)
12. Razzaghi, A., Khanjani, N., Danesh, S. (2016). Investigation of organophosphorus poisoning in the human population in Iran: A systematic review. Journal of Health and Development, 5(1), 90-97. (In Persian)
13. World Health Organization. (2000). Obesity: preventing and managing the global epidemic: report of a WHO consultation.
14. World Health Organization. (2001). The World Health Report 2001: Mental health: new understanding, new hope.
15. Sidhu, G. K., Singh, S., Kumar, V., Dhanjal, D. S., Datta, S., & Singh, J. (2019). Toxicity, monitoring, and biodegradation of organophosphate pesticides: a review. Critical reviews in environmental science and technology, 49(13), 1135-1187.
16. Adeyinka, A., & Pierre, L. (2018). Organophosphates. In StatPearls [Internet]. StatPearls Publishing. PMID: 29763035.
17. Adeyinka, A., Muco, E., Regina, A. C., & Pierre, L. (2023). Organophosphates. In StatPearls [Internet]. StatPearls Publishing.
18. Greaves, A. K., & Letcher, R. J. (2017). A review of organophosphate esters in the environment from biological effects to distribution and fate. Bulletin of environmental contamination and toxicology, 98, 2-7.
19. Muhammad, G., Rashid, I., & Firyal, S. (2017). Practical aspects of treatment of organophosphate and carbamate insecticide poisoning in animals. Matrix Sci. Pharma, 1(1), 10-11.
20. Blann, K. L., Anderson, J. L., Sands, G. R., & Vondracek, B. (2009). Effects of agricultural drainage on aquatic ecosystems: a review. Critical reviews in environmental science and technology, 39(11), 909-1001.
21. Mkandawire, M., Teixeira da Silva, J. A., & Dudel, E. G. (2014). The Lemna bioassay: Contemporary issues as the most standardized plant bioassay for aquatic ecotoxicology. Critical Reviews in Environmental Science and Technology, 44(2), 154-197.
22. Yuan, X., Lacorte, S., Cristale, J., Dantas, R. F., Sans, C., Esplugas, S., & Qiang, Z. (2015). Removal of organophosphate esters from municipal secondary effluent by ozone and UV/H2O2 treatments. Separation and Purification Technology, 156, 1028-1034.
23. Liu, G., & Lin, Y. (2006). Biosensor based on self-assembling acetylcholinesterase on carbon nanotubes for flow injection/amperometric detection of organophosphate pesticides and nerve agents. *Analytical Chemistry*, *78*(3), 835-843.
24. Lorenzo, M., & Pico, Y. (2017). Gas chromatography and mass spectroscopy techniques for the detection of chemical

contaminants and residues in foods. In *Chemical contaminants and residues in food* (pp. 15-50). Woodhead Publishing.

25. Gong, J., Wang, X., Li, X., & Wang, K. (2012). Highly sensitive visible light activated photoelectrochemical biosensing of organophosphate pesticide using biofunctional crossed bismuth oxyiodide flake arrays. *Biosensors and Bioelectronics*, *38*(1), 43-49.
26. Hiscock, J. R., Sambrook, M. R., Wells, N. J., & Gale, P. A. (2015). Detection and remediation of organophosphorus compounds by oximate containing organogels. *Chemical Science*, *6*(10), 5680-5684.
27. Kumar, V., Upadhyay, N., Wasit, A. B., Singh, S., & Kaur, P. (2013). Spectroscopic methods for the detection of organophosphate pesticides—a preview. Current World Environ, 8(2), 313-318.
28. Krüger, M., Schledorn, P., Schrödl, W., Hoppe, H. W., Lutz, W., & Shehata, A. A. (2014). Detection of glyphosate residues in animals and humans. Journal of Environmental & Analytical Toxicology, 4(2), 1.
29. Rubio, F., Veldhuis, L. J., Clegg, B. S., Fleeker, J. R., & Hall, J. C. (2003). Comparison of a direct ELISA and an HPLC method for glyphosate determinations in water. Journal of Agricultural and Food chemistry, 51(3), 691-696.
30. Sumon, K. A., Rashid, H., Peeters, E. T., Bosma, R. H., & Van den Brink, P. J. (2018). Environmental monitoring and risk assessment of organophosphate pesticides in aquatic ecosystems of north-west Bangladesh. Chemosphere, 206, 92-100.
31. Xu, L., Granger, C., Dong, H., Mao, Y., Duan, S., Li, J., & Qiang, Z. (2020). Occurrences of 29 pesticides in the Huangpu River, China: Highest ecological risk identified in Shanghai metropolitan area. Chemosphere, 251, 126411.
32. Zhang, X. P., Zhang, Y. Y., Mai, L., Liu, L. Y., Bao, L. J., & Zeng, E. Y. (2020). Selected antibiotics and current-use pesticides in riverine runoff of an urbanized river system in association with anthropogenic stresses. Science of the Total Environment, 739, 140004.

This work is licensed under Creative Commons Attribution 4.0 License

To Submit Your Article Click Here: **Submit Manuscript**

**DOI:**10.31579/2767-7370/153

**Ready to submit your research? Choose Auctores and benefit from:**

- fast, convenient online submission
- rigorous peer review by experienced research in your field
- rapid publication on acceptance
- authors retain copyrights
- unique DOI for all articles
- immediate, unrestricted online access

At Auctores, research is always in progress.

Learn more at: https://auctoresonline.org/journals/new-medical-innovations-and-research