Seasonal Variability of Pesticide Residues in Vellode Bird Sanctuary: Implications for Ecosystem Health

Abstract

This research provides a comprehensive examination of the seasonal fluctuations in pesticide residues within the Vellode Bird Sanctuary, with a particular emphasis on the detection and quantification of organochlorines, organophosphates, synthetic pyrethroids, and herbicides in the sanctuary's aquatic environment. The pesticide analysis was conducted from July 2019 to May 2020. This study period spanned three seasons: monsoon, winter, and summer. Gas Chromatography-Mass Spectrometry (GC-MS) from Perkin Elmer was used to analyze the pesticide residues in lake water. The pesticide analysis showed that aldrin, α-cypermethrin, α-HCH, β-HCH, bifenthrin, butachlor, chlorpyrifos, dimethoate, endosulfan-α, γ-HCH, pendimethalin, phorate, profenophos, p,p'-DDT, and quinalphos were recorded at higher levels during the monsoon season. The values of pesticide residues in the winter and summer seasons were below the level of detectable quantification (less than 0.5 µg/l). The study shows that increased pesticide concentrations during the monsoon are due to runoff from nearby agricultural fields caused by heavy rainfall. In contrast, lower pesticide levels in winter and summer are likely due to reduced pesticide use and rainfall. These findings highlight the significant impact of seasonal variations on pesticide contamination, with greater ecological risks during the monsoon. The sanctuary's aquatic ecosystem is particularly vulnerable during periods of high rainfall, emphasizing the need for targeted conservation and management strategies.

Keywords:-*Vellode bird sanctuary, Wetland, Seasonal variation, Pesticide analysis*

1. Introduction

Water is indeed a precious gift of nature, essential for all forms of life, including human beings. However, with the rapid pace of urbanization, water pollution has become a significant environmental issue. This phenomenon refers to the contamination of water bodies, such as rivers, lakes, oceans, and groundwater, due to various human activities. Water pollution occurs when harmful substances, such as chemicals, waste products, and microorganisms, are introduced into water bodies, leading to the deterioration of water quality. These pollutants can come from a variety

of sources, including industrial discharges, agricultural runoff, sewage, and the improper disposal of household waste (Sivakumar *et al.,* 2018). Chemical pesticides are widely used in agriculture for pest control and in public health to prevent and manage insect-borne diseases such as dengue, malaria, cholera, filariasis, and encephalitis. They are crucial inputs in modern agriculture and play a significant role in controlling communicable diseases. Pesticides are chemical substances or mixtures designed to control, eradicate, repel, or mitigate pests and weeds (Arias-Estévez *et al*., 2008; Rajan *et al.,* 2023). Over the past few decades, pesticide usage has dramatically increased in India; however, the country's average pesticide consumption remains among the lowest globally, at 0.5 kg per hectare, compared to 10.7 kg in Japan and 4.5 kg in the US. This low usage is primarily due to limited awareness among farmers and the high cost of pesticides (Naresh *et al.*, 2009).

The toxicity of these compounds poses significant risks to human health, the environment, and non-target organisms. The impact and mobility of pesticides are influenced by their chemical and physical properties, soil characteristics, groundwater infiltration, vadose zone behavior, vegetation, and local weather conditions. These compounds are often resistant to degradation by chemical, physical, or biological means. For instance, the degradation of DDT in soil can range from 75% to 100% over a period of 4 to 30 years (Sankararamakrishnan *et al*., 2005; Naresh *et al*., 2009). Studies have found that only 10% of applied pesticides reach their intended targets, while the remaining 90% contaminate various environmental matrices, including air, soil, and water (Bose *et al.,* 2021; Rajan *et al.,* 2023). Among these, the hydrogeo-environment, encompassing groundwater, surface water, soil, and sediment, is particularly vulnerable to pesticide contamination. Elevated levels of pesticide residues have been observed globally and regionally in groundwater, surface water, soil, and sediments (Duttagupta *et al*., 2020; Chaza *et al*., 2018). Wetlands provide essential services such as water filtration, flood control, and habitat for wildlife. Pesticide pollution can reduce the capacity of wetlands to perform these services by degrading plant life and reducing the abundance and diversity of species that maintain wetland health (US EPA, 2024). Certain pesticides, particularly those that are fat-soluble, can accumulate in the tissues of organisms. As these chemicals move up the food chain, they become more concentrated in predators, such as birds of prey and large fish, leading to harmful effects like reproductive failure, developmental

problems, and population declines (Ray and Shaju, 2023). This study will discuss the accumulation of pesticides percentage in Vellode bird sanctuary.

2. Materials and Methods

2.1. Study Area

The Vellode Bird Sanctuary, a renowned haven for bird enthusiasts in Tamil Nadu, is located near Erode, a temple town. Established in 1996 by the Ministry of Environment and Forests, Government of India, it is one of the sixteen protected bird sanctuaries in Tamil Nadu. The sanctuary is unique as it is centered around the Periyakulam Lake, rather than woodlands, unlike other sanctuaries in the state. This beautiful sanctuary offers a serene environment for various bird species, making it a must-visit for nature lovers. It is one of the avian rich and second largest bird sanctuary in Tamil Nadu. Vellode Bird Sanctuary is located between 11°15’20” N to 11°04’50” N and 77°38'40” E to 77°39'30” E and it located above 240 MSL. The total area of the sanctuary is 77.185 ha. This sanctuary is totally surrounded by paddy fields and irrigation channels. The wetland within Vellode Bird Sanctuary acts as a natural sponge, buffering against floods and extreme rainfall, and serving as a crucial source of groundwater recharge. No sand or silt mining is allowed here, preserving its integrity as a storage tank for irrigating nearby agricultural fields. The tank primarily receives water through seepage from the Lower Bhavani Project canal system and rainwater from the northeast monsoon, though no direct inflow from the canal exists. Despite this, some water remains in the deeper parts of the lake even during dry periods.

2.2. Methodology

Water samples from the Vellode Bird Sanctuary were collected during three different seasons—Monsoon, Winter, and Summer—using pre-cleaned polyethylene bottles. The five locations for water sample collection were selected randomly for further analysis and sampling intensity was 0.05%.These samples were stored in cold storage containers and transported to a laboratory for analysis. The pesticide residues in the lake water were analyzed using the Clarus SQ 8C GC-MS (Gas Chromatography-Mass Spectrometry) from Perkin Elmer, providing detailed insights into the seasonal variations in pesticide contamination within the sanctuary.

3. Results and Discussion

3.1. The Winter (December 2019 to February 2020) and Summer seasons (March-2020 to May-2020)

The amount of pesticide residues detected during the winter and summer seasons in Vellode Bird Sanctuary was found to be below the level of quantification, meaning they were less than 0.5 µg/l. This indicates that the concentration of pesticide residues during these seasons was extremely low, making them difficult to detect with the available analytical methods. As a result, the presence of pesticide residues in both the winter and summer seasons was minimal and not measurable, suggesting limited or negligible contamination during these periods. Pesticide applications are typically lower outside of the growing season, leading to less runoff and contamination.A detailed explanation should address factors such as changes in agricultural practices, runoff patterns, and seasonal dilution effects. Additionally, environmental factors such as lower rainfall in these seasons may contribute to reduced leaching of pesticides from agricultural lands into the sanctuary's water bodies, further diminishing residue levels.

3.2. The Monsoon season (July 2019 to Nov 2019)

Organochlorines are known for their long-term persistence in the environment and their ability to bioaccumulate in the food chain. These pesticides are highly effective against pests but are linked to significant environmental and health concerns, including toxicity to wildlife (particularly birds) and potential carcinogenic effects in humans. The current study found organochlorines such as Aldrin (1.261 ± 0.06 µg/l), α-HCH (0.511 ± 0.03 µg/l), β-HCH (0.518 ± 0.01 µg/l), Endosulfan-α (1.172 ± 0.17 µg/l), γ-HCH (1.042 ± 0.11 µg/l), and p,p'-DDT (0.923 ± 0.16 µg/l) in the monsoon season (Table 1). Organophosphates are highly toxic and pose significant health risks, including acute poisoning and long-term neurological damage, while also impacting non-target species. In this study, organophosphates such as Chlorpyrifos (1.401 ± 0.17 µg/l), Dimethoate (0.737 ± 0.06 µg/l), Phorate (0.615 ± 0.08 µg/l), Profenophos (1.352 ± 0.24 µg/l), and Quinalphos (0.974 ± 0.09 µg/l) were recorded in Vellode Bird Sanctuary (Table 1). Synthetic pyrethroids can significantly impact the environment due to their high toxicity to aquatic life and persistence in soil, leading to long-term contamination. They can also harm non-target species, including beneficial insects, disrupting ecosystems. In the study, synthetic pyrethroids such as α-Cypermethrin (0.712 ± 0.09 µg/l) and Bifenthrin (0.593 ± 0.08 µg/l) were detected. Herbicides like Butachlor (1.510 ± 0.18 µg/l) and Pendimethalin (1.016 ± 0.16 µg/l) were also observed during the monsoon season at Vellode Bird Sanctuary (Table 1).

The permissible levels for pesticides are as follows: Aldrin (0.003 µg/l), α-HCH (0.01 µg/l), β-HCH (0.01 µg/l), γ-HCH (0.01 µg/l), Endosulfan-α (0.003 µg/l), p,p'-DDT (0.001 µg/l), Dimethoate (0.002 µg/l), Chlorpyrifos (0.0035 µg/l), Butachlor (0.01 µg/l), Quinalphos (0.65 µg/l), Phorate (0.248 µg/l), Pendimethalin (0.009 µg/l), α-Cypermethrin (0.4 µg/l), and Bifenthrin (0.00018 µg/l). In the pesticide analysis of Vellode Lake, levels of Aldrin, α-HCH, β-HCH, Endosulfan-α, γ-HCH, and p,p'-DDT (organochlorines), Chlorpyrifos, Dimethoate, Phorate, Profenophos, and Quinalphos (organophosphates), α-Cypermethrin and Bifenthrin (synthetic pyrethroids), and Butachlor and Pendimethalin (herbicides) were found to be higher during the monsoon season. These concentrations exceeded permissible levels, potentially having deleterious effects on aquatic organisms. However, the higher rainfall during the monsoon season may have mitigated some of these impacts. Runoff from agricultural lands surrounding the lake likely contributed to the increased pesticide residues. These results are consistent with the findings of Rao *et al.* (2009) in the Kolleru Lake basin, where monocrotophos (7.35 ppm), profenophos (14.1 ppm), tricyclazole (10.7 ppm), and atrazine (13.00 ppm) were observed during the rainy season.

Table 1. Pesticide residues in Monsoon season of Vellode Bird Sanctuary (July 2019 to Nov 2019)

Organochlorines (OC)		**Monsoon**	**Winter**	**Summer**
S.No.	**Pesticides name**		**Residues (µg/l)**	
1.	Aldrin	1.261 ± 0.06	BDL	BDL
2.	α-HCH	0.511 ± 0.03	BDL	BDL
3.	β-HCH	0.518 ± 0.01	BDL	BDL
4.	Endosulfan-α	1.172 ± 0.17	BDL	BDL
5.	γ-HCH	1.042 ± 0.11	BDL	BDL
6.	p, ṕ -DDT	0.923 ± 0.16	BDL	BDL
Organophosphates (OP)				
S.No.	**Pesticides name**		**Residues (µg/l)**	
1.	Chlorpyrifos	1.401 ± 0.17	BDL	BDL
2.	Dimethoate	0.737 ± 0.06	BDL	BDL
3.	Phorate	0.615 ± 0.08	BDL	BDL
4.	Profenophos	1.352 ± 0.24	BDL	BDL
5.	Quinalphos	0.974 ± 0.09	BDL	BDL
Synthetic Pyrethroids (SP)				
S.No.	**Pesticides name**		**Residues (µg/l)**	
1.	α-Cypermethrin	0.712 ± 0.09	BDL	BDL
2.	Bifenthrin	0.593 ± 0.08	BDL	BDL

Herbicides				
S.No.	**Pesticides name**	**Residues (µg/l)**		
1.	Butachlor	1.510 ± 0.18	BDL	BDL
2.	Pendimethalin	1.016 ± 0.16	BDL	BDL

***BDL - Below Detectable Level (<0.05)**

4.Conclusion

The study reveals that during the monsoon season, pesticide residues, particularly organochlorines, organophosphates, and synthetic pyrethroids, were found in higher concentrations, often exceeding permissible levels. This elevated contamination is likely due to increased pesticide runoff from agricultural lands, exacerbated by heavy rainfall. However, during the winter and summer seasons, pesticide residues were minimal and below detectable levels, likely due to reduced pesticide application and lower rainfall, which limited runoff and leaching. Consequently, the contamination in these periods was negligible, indicating that the environmental impact of pesticides in Vellode Bird Sanctuary varies significantly across seasons.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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