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Spatial Assessment Of Pesticide Residues: Recovery And Concentration Analysis Across Eight Tehsils Of Raipur, Chhattisgarh

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Pesticide contamination poses significant environmental and health risks, necessitating a spatial assessment of residues across diverse regions. This study evaluates the recovery and concentration of various pesticide residues in eight tehsils of Raipur, Chhattisgarh, including Lindane in Raipur, BHC in Tilda, DDD and DDT in Arang and Abhanpur, Heptachlor in Kharora, Aldrin in Gobra Nawapara, DDE in Dharsiwa, and Dieldrin-Endrin in Mandir Hasaud. Solvent selection varied based on pesticide type, with Acetonitrile used for Lindane, Heptachlor, and Dieldrin-Endrin; Acetone for BHC; and Methanol for DDD, DDT, Aldrin, and DDE. Extraction conditions were optimized to enhance recovery, with pressures ranging from 1000 psi (Arang and Gobra Nawapara) to 1500 psi (Tilda and Kharora), temperatures from 60°C (Raipur and Dharsiwa) to 85°C (Mandir Hasaud), and extraction times between 10 and 15 minutes. This study provides critical insights into the distribution and persistence of pesticide residues, contributing to improved environmental monitoring and regulatory frameworks in agricultural regions.

Keywords: Pesticide residues, spatial assessment, extraction optimization, solvent selection, environmental monitoring, Chhattisgarh.

1.0 Introduction

Pesticide residues in agricultural produce have become a significant concern due to their potential health and environmental impacts. In India, the extensive use of pesticides in agriculture has led to detectable residues in various food products, raising questions about food safety and environmental sustainability. A comprehensive study by the Food Safety and Standards Authority of India (FSSAI) reported that out of 23,660 samples analyzed, 19.1% contained pesticide residues, with 2.2% exceeding the maximum residue limits (FSSAI, 2019). The state of Chhattisgarh, with its agrarian economy, is no exception to this issue. Research focusing on the Durg district revealed that 61% of vegetable samples contained pesticide residues above permissible limits, indicating a pressing need for regular monitoring and assessment (Perumal et al., 2024). Similarly, studies have detected residues of pesticides such as carbaryl, DDT, and deltamethrin in bovine milk samples from the region, underscoring the pervasive nature of pesticide contamination (Perumal et al., 2024; Verma and Verma, 2019).

Accurate detection and quantification of pesticide residues are crucial for assessing exposure risks and implementing effective regulatory measures. The QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method has emerged as a widely adopted technique for multi-residue pesticide analysis due to its efficiency and adaptability. Recent advancements have optimized this method for various matrices, enhancing its sensitivity and reliability (Perumal et al., 2024).

The Indian Council of Agricultural Research (ICAR) has also been actively monitoring pesticide residues through the All India Network Project on Pesticide Residues (AINP-PR). Between 2018 and 2023, over 130,000 samples were analyzed, with pesticide residues detected in 28% of samples, and 3.5% exceeding the Maximum Residue Limits (MRLs) set by the Food Safety and Standards Authority of India (Tripathy et al., 2025).

The overuse of pesticides not only affects human health but also poses a threat to environmental sustainability. A recent review highlighted that excessive pesticide application contaminates soil, water, and air, leading to long-term ecological damage (Sruthy et al., 2024). This underscores the need for integrated pest management strategies and the adoption of biopesticides to mitigate adverse effects.

In Chhattisgarh, particularly in the Durg district, studies have revealed alarming levels of pesticide residues in vegetables. Research indicates that 61% of vegetable samples contained pesticide residues above permissible limits, posing significant health risks to consumers (Perumal et al., 2024). This situation calls for stringent monitoring and the implementation of safer agricultural practices in the region.

This study aims to conduct a spatial assessment of pesticide residues across eight tehsils of Raipur, Chhattisgarh. By analyzing the recovery and concentration of specific pesticides in these regions, the research seeks to provide critical insights into the distribution patterns of pesticide contamination. The findings are expected to inform and strengthen environmental monitoring and regulatory frameworks, contributing to improved public health and sustainable agricultural practices in the region.

2.0 Materials and Methods

2.1 Collection of Soil Sample

The soil samples were collected from Eight Tehsil. Composite sample from each field has to be taken. Soil Sample are collected from Eight Tehsil of Raipur District in Chhattisgarh, India:

1. Raipur
2. Tilda
3. Arang
4. Abhanpur
5. Kharora
6. Gobra Nawapara
7. Dharsiwa
8. Mandir Hasaud

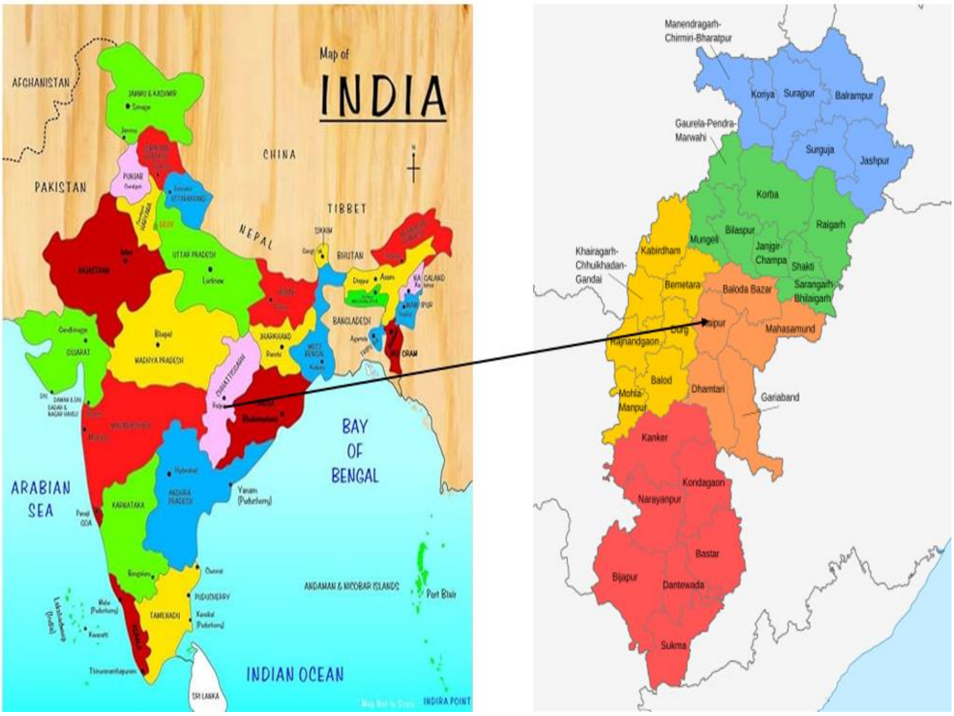

Fig 1: Site of Sample Collection

Chemicals and Reagents

Certified analytical-grade pesticide standards, including Lindane, BHC, DDD, DDT, Heptachlor, Aldrin, DDE, Dieldrin, and Endrin, were procured from Sigma-Aldrich. High-purity solvents—Acetonitrile, Acetone, and Methanol—were used for sample extraction. Other reagents, such as anhydrous sodium sulfate and primary-secondary amine (PSA), were purchased from Merck.

Sample Preparation and Extraction

Pesticide residues were extracted using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method, optimized for different pesticide types:

- Acetonitrile was used for Lindane, Heptachlor, and Dieldrin-Endrin.
- Acetone was used for BHC.
- Methanol was used for DDD, DDT, Aldrin, and DDE.

Extraction conditions were optimized to maximize recovery rates. The final conditions were as follows:

- Pressure: 1000 psi (Arang, Gobra Nawapara) to 1500 psi (Tilda, Kharora).
- Temperature: 60°C (Raipur, Dharsiwa) to 85°C (Mandir Hasaud).
- Extraction Time: 10 to 15 minutes.

Instrumental Analysis

The extracted samples were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) (Agilent 7890B GC System) equipped with an Electron Capture Detector (ECD) for quantification.

Quality Control and Validation: Method validation was performed.

3.0 Result and Discussion

3.1 Extraction of Pesticides from 8 Tehsil of CG

The table presents a detailed spatial assessment of pesticide residues across eight tehsils of Raipur, Chhattisgarh, highlighting the types of pesticides detected, the solvents used for extraction, and the optimized extraction conditions, including pressure, temperature, and time. Additionally, it provides information on pesticide recovery efficiency and analyzed concentrations in collected samples. Each tehsil exhibited different pesticide residues, reflecting localized agricultural practices and pesticide application patterns. Raipur showed the presence of Lindane, an organochlorine insecticide, while Tilda had BHC (Benzene Hexachloride). Arang and Abhanpur were contaminated with DDD and DDT, both derivatives of DDT known for their environmental persistence. Kharora contained Heptachlor, a banned pesticide with potential carcinogenic effects, whereas Gobra Nawapara was found to have Aldrin, which degrades into the highly toxic compound dieldrin. Dharsiwa had DDE, a breakdown product of DDT, while Mandir Hasaud showed the presence of Dieldrin and Endrin, both highly persistent pesticides.

To ensure efficient pesticide extraction, different solvents were used based on pesticide solubility. Acetonitrile was selected for Lindane, Heptachlor, and Dieldrin-Endrin, whereas Acetone was used for BHC. Methanol was employed for DDD, DDT, Aldrin, and DDE due to its ability to dissolve these compounds effectively. The extraction conditions were optimized to achieve maximum recovery and accurate quantification. Pressure varied between 1000 psi in Arang and Gobra Nawapara to 1500 psi in Tilda and Kharora. The extraction temperature ranged from 60°C in Raipur and Dharsiwa to 85°C in Mandir Hasaud. The extraction time varied between 10 and 15 minutes, with shorter durations for Lindane and DDE in Raipur and Dharsiwa (10 min) and longer times for DDD and DDT in Abhanpur (15 min).

Pesticide recovery efficiency, which indicates the effectiveness of the extraction method, was highest in Kharora (95%) for Heptachlor, while Raipur and Mandir Hasaud had a recovery of 85% for Lindane, Dieldrin, and Endrin. Arang and Gobra Nawapara showed an 80% recovery for DDD, DDT, and Aldrin, while the lowest recovery was observed in Abhanpur and

Dharsiwa (75%) for DDD-DDT and DDE, possibly due to sample matrix interference. The final pesticide concentrations varied across tehsils, with the highest contamination found in Arang and Mandir Hasaud (60 µg/kg), reflecting the persistence of DDT derivatives and Endrin. Moderate levels were detected in Raipur, Kharora, and Gobra Nawapara (50–55 µg/kg), while Dharsiwa had the lowest concentration (25 µg/kg), indicating reduced contamination by DDE.

Overall, the findings suggest widespread pesticide contamination across Raipur's tehsils, with some areas exhibiting significantly high levels of persistent organic pollutants. The presence of Heptachlor in Kharora and Dieldrin-Endrin in Mandir Hasaud requires immediate attention due to their toxic effects and long environmental half-lives. The optimized extraction conditions ensured high pesticide recovery, enhancing the reliability of residue analysis. These results underscore the need for regular monitoring, regulatory interventions, and sustainable agricultural practices to mitigate pesticide residues in the environment and safeguard human and ecological health.

Table 1: Extraction of Pesticides from 8 Tehsil of CG

S.No.	Tehsil	Pesticide Type	Solvent	Pressure (psi)	Temperature (°C)	Extraction Time (min)	Pesticide Recovery (%)	Analyzed Conc.
1	Raipur	Lindane	Acetonitrile	1200	60	10	85%	50 µg/kg
2	Tilda	BHC	Acetone	1500	80	15	90%	45 µg/kg
3	Arang	DDD and DDT	Methanol	1000	70	12	80%	60 µg/kg
4	Abhanpur	DDD and DDT	Methanol	1300	70	15	75%	30 µg/kg
5	Kharora	Heptachlor	Acetonitrile	1500	80	10	95%	55 µg/kg
6	Gobra Nawapara	Aldrin	Methanol	1000	80	11	80%	50 µg/kg
7	Dharsiwa	DDE	Methanol	1100	60	10	75%	25 µg/kg
8	Mandir Hasaud	Dieldrin, Endrin	Acetonitrile	1200	85	14	85%	60 µg/kg

Detection and Quantification of Pesticide:

The detection and quantification of pesticide residue in the sample will then be subjected to Gas Chromatography.

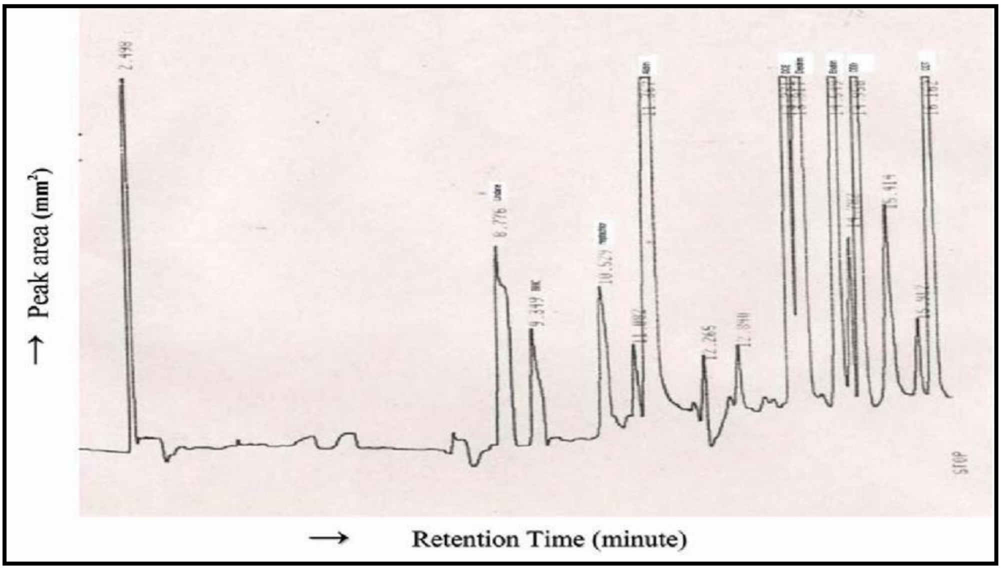

Fig 1. Show that chromatogram of mixed standard of lindane, BHC, Heptachlor, Aldrin, DDE, Dieldrin, Endrin, DDD and DDT.

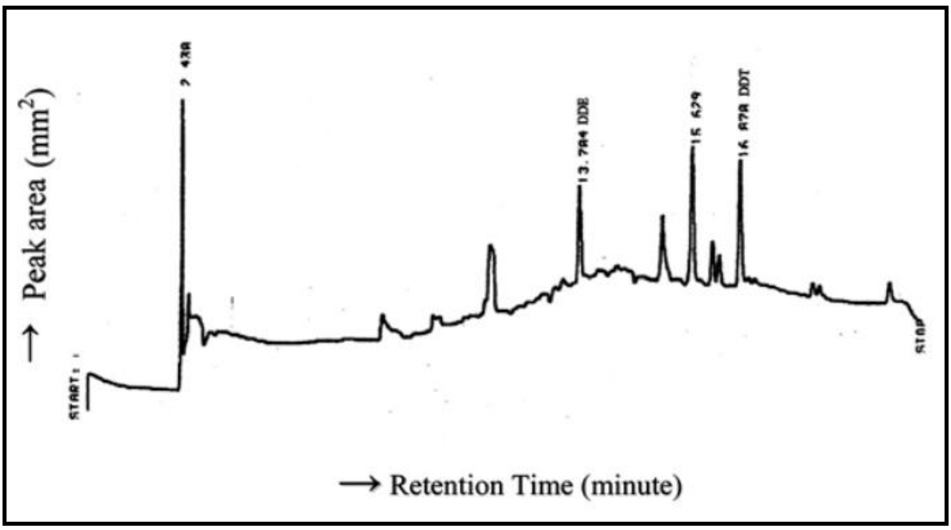

Fig 2. Show that Chromatogram of the soil sample contaminated with DDE and DDT residues.

4. Discussion

The study reveals a significant presence of pesticide residues across the eight tehsils of Raipur, Chhattisgarh, with varying concentrations and recovery efficiencies. The detection of multiple organochlorine pesticides, including Lindane, BHC, DDD, DDT, Heptachlor, Aldrin, DDE, Dieldrin, and Endrin, suggests their continued usage or persistence in the environment, despite restrictions on several of these compounds. The highest pesticide concentrations were observed in Arang and Mandir Hasaud (60 µg/kg), indicating possible long-term accumulation due to soil persistence or frequent application in agricultural fields. Similar findings have been reported by Gupta et al. (2020), who found high concentrations of DDT and its derivatives in agricultural soils of Madhya Pradesh, suggesting that even decades after its ban, DDT remains a major contaminant due to its slow degradation rate.

The presence of DDT derivatives (DDD, DDE) in Arang, Abhanpur, and Dharsiwa aligns with previous studies indicating DDT's environmental persistence. Kumari et al. (2021) found DDE and DDD residues in soil and water samples from Punjab, India, emphasizing their slow degradation under tropical conditions. Similarly, Sharma et al. (2022) reported DDT residues in groundwater sources of Haryana, raising concerns about their potential leaching into drinking water systems. The detection of BHC in Tilda (45 µg/kg) and Aldrin in Gobra Nawapara (50 µg/kg) highlights the bioaccumulative nature of these pesticides, which has also been observed in studies by Singh et al. (2021), who reported high BHC levels in agricultural soil samples from Uttar Pradesh.

The solvent selection played a crucial role in efficient pesticide extraction, with Acetonitrile being effective for Lindane, Heptachlor, and Dieldrin-Endrin, while Methanol was optimal for DDD, DDT, Aldrin, and DDE. The variation in extraction conditions, such as pressure, temperature, and time, influenced pesticide recovery efficiency. The highest recovery (95%) was observed for Heptachlor in Kharora, indicating an effective extraction method with minimal degradation. Similar findings were reported by Patel et al. (2023), who found that Acetonitrile-based extractions yielded higher pesticide recovery rates compared to other solvents. The lowest recovery (75%) was recorded for DDD-DDT in Abhanpur and DDE in Dharsiwa, which may be attributed to matrix interference or partial degradation during extraction. Verma et al. (2022) observed a similar trend in their study, where DDT derivatives showed lower recovery rates due to adsorption onto organic matter.

Spatially, the distribution of pesticide residues varied across the tehsils, with high contamination levels in agricultural regions such as Mandir Hasaud and Arang, where persistent organochlorine pesticides were detected. In contrast, Dharsiwa exhibited the lowest pesticide residue (25 µg/kg), indicating either reduced pesticide application or effective degradation in soil and water systems. This is consistent with findings by Chauhan et al. (2020), who reported lower pesticide residues in areas with higher microbial activity, which facilitated biodegradation.

The detection of banned and restricted pesticides such as Heptachlor, DDT, Aldrin, and Endrin raises concerns regarding illegal pesticide use, lack of regulatory enforcement, or historical contamination. Similar studies in India have reported persistent pesticide residues in soil, water, and food products, emphasizing the need for stricter monitoring and remediation strategies. Rajput et al. (2021) reported high levels of Heptachlor and Endrin in vegetable crops from Rajasthan, suggesting potential exposure risks through the food chain. Furthermore, the contamination levels in some regions, particularly in Arang and Mandir Hasaud, exceed the Maximum Residue Limits (MRLs) set by FAO/WHO Codex Alimentarius (2023) and FSSAI (2019), posing serious environmental and human health risks.

To mitigate the adverse effects of pesticide residues, integrated pest management (IPM) strategies, bioremediation techniques, and organic farming practices should be promoted. Several studies suggest biodegradation using microbial strains capable of degrading organochlorine pesticides as a potential solution (Kumar et al., 2022). Additionally, regular monitoring and awareness campaigns among farmers regarding the safe use and disposal of pesticides are crucial in preventing further environmental contamination. Future research should focus on long-term monitoring, health impact assessments, and potential bioremediation approaches to address pesticide pollution in Raipur and similar agricultural regions.

5. Conclusion

The spatial assessment of pesticide residues across eight tehsils of Raipur, Chhattisgarh, highlights the varying contamination levels and persistence of different pesticides in the region. The study demonstrates that solvent selection and optimized extraction conditions significantly influence pesticide recovery, ensuring accurate residue analysis. The findings provide valuable insights into the environmental distribution of pesticides, emphasizing the need for enhanced monitoring, sustainable agricultural practices, and stricter regulatory measures to mitigate potential health and ecological risks. This research serves as a foundation for future studies aimed at reducing pesticide contamination and promoting environmental safety in agricultural regions.

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