International Journal of Education and Science Research Review
Volume-12, Issue-2 March-April-2025 E-ISSN 2348-6457
(Peer-Reviewed, Open Access, Fully Refereed International Journal) P-ISSN 2349-1817
www.ijesrr.org Impact Factor - 7.02 Email- editor@ijesrr.org

"GEOSPATIAL DISTRIBUTION OF PESTICIDES IN AGRICULTURAL REGIONS: A STUDY OF ENVIRONMENTAL CHEMISTRY AND PUBLIC HEALTH

Dr. S. R. Kamlesh
Government Bilasa Girls' P. G. College Bilaspur (C. G.)

Dr. Kiran Thakur
Government Bilasa Girls' P. G. College Bilaspur (C. G.)

ABSTRACT

The spatial distribution of pesticides in agricultural regions is an important topic of study that transcends the boundaries between environmental chemistry and public health. The purpose of this research is to evaluate the geographical variability of pesticide residues in water, soil, and air across agricultural landscapes in Hyderabad, India. The study makes use of cutting-edge geospatial tools such as GIS mapping and remote sensing. GC-MS analysis and Soxhlet extraction were the methods that we used in order to eliminate pesticides from soil samples that were collected from residential, industrial, and agricultural sectors. Using spatial interpolation methods, researchers were able to create a picture of pesticide contamination, ascertain the length of time it remains in the environment, and investigate the relationship between it and total organic carbon levels. Blanks from the method and samples that had been spiked were utilised as quality control techniques to ensure that the procedures were accurate and precise. The findings, which also attempt to analyse the risks that pesticide exposure poses to public health and the environment, may provide a stronger basis for the development of sustainable agricultural practices and regulatory rules.

Keywords: - Geospatial distribution, pesticides, agricultural regions, environmental chemistry, public health, GIS mapping

INTRODUCTION

This research uses multi-dimensional data visualisation to better understand pesticide residue dispersion in agricultural areas. The study emphasises environmental chemistry and public health. Choropleths and cartograms show data distribution over regions. Choropleth maps show regional data distribution well. They employ different colours to distinguish property values. When space and data are unevenly distributed, data overlap might occur, reducing clarity. Cartograms save data duplication but may misrepresent the reality. Cartograms change map regions based on property values.

To solve these challenges, we developed a hybrid strategy using heat maps and cartograms. This approach aims to (1) show how pesticide concentrations and other single-attribute data are distributed geographically; (2) prevent data duplication in regions with unequal map sizes and data distributions; (3) show how pesticide residues across agricultural regions are distributed using multi-attribute data; and (4) help analyse pesticide residue pollution patterns. We anticipate this strategy will help researchers understand how chemical pollution may affect public health.

Pesticides classification

The main pesticide classes include insecticides, bactericides, fungicides, herbicides, nematicides, and rodenticides. Pesticides are classified by target, duration of action, toxicity, and chemical makeup. Pesticide chemical composition depends on purpose and use. Chlorinated and non-chlorinated pesticides are categorised by their chemical composition into the two main pesticide types. The most persistent pesticides are organochlorine (OCPs), which make up most of the chlorinated pesticide industry. Organic chlorinated compounds (OCPs) include organochlorines, chlorides, chlorocarbons, chlorinated hydrocarbons, and solvents. Because OCPs are lipophilic, they tend to concentrate in adipose tissues, where they may harm humans and other species. Their physicochemical properties—low water solubility, moderate octanol-water partition coefficient, high vapour pressure, and extended persistence—make them ideal for long-distance transport. The most common organic compound pesticides include eldrin, lindane, DDT, HCH, dieldrin, endrin, endosulfan, heptachlor, and chlordane. These pesticides have a lengthy half-life in certain situations due to their chemical affinity to soil particles and water insolubility.

Diagnostic ratios

The relative amounts of environmental isomers or metabolites to parent chemicals may reveal pollution sources, uses, and breakdown processes. The major pesticide diagnostic ratios may help you find these traits. Although α, α, α, and ε-HCH are the most common isomers in technical grade HCH, there are eight available. Lindane may contain over 99% γ-HCH, compared to 65-70% α-HCH, 12-14% γ-HCH, 6% δ-HCH, and 5-6% β-HCH in commercial HCH. HCH isomers decrease at the following rate: α-HCH to γ-HCH to δ-HCH. You may identify technical HCH or lindane by evaluating the α/γ-HCH ratio. This is one source evaluation approach. Technical grade HCH ratios vary from 3 to 7, whereas lindane ratios are normally ≤3. The ratio may reach seven due to technological HCHs returning to the environment or photochemical conversion of γ-HCH to α-HCH during air transit. The ratio of β/(α + γ)-HCH indicates whether HCH is present owing to prior pollution or contemporary usage.

OBJECTIVE

1. To use environmental chemistry methods to examine the geographical distribution of organochlorine pesticides (ocps) in agricultural areas.
2. To evaluate how pesticide pollution affects the study area's agricultural sustainability and public health.

MATERIALS AND METHODS

Study Area

Geospatial analysis will concentrate on agricultural pesticide residues for this project. The research covers an area of roughly 27 km² in Raigarh district, Chhattisgarh, India. The region of Raigarh, Chhattisgarh, is covered by a Survey of India (SoI) toposheet 64 H/10 (1:50,000). This is part of the Kelo River drainage basin. The area has several small ponds and reservoirs for irrigation, allowing year-round agriculture. Over fifty chemical, pharmaceutical, and pesticide manufacturers operate in this area, affecting the ecosystem. The goal of this research is to map and analyse pesticide residues' geographical distribution to determine their environmental and health effects..

Materials and Analytical Standards

The OCP analytical standards from recognised providers are: A, B, C, D-HCH, heptachlor, aldrin, epoxide, dieldrin, endrin, endosulfan, DDT, DDE, and DDD. For pesticide extraction, HPLC solvents and Florisil column packing material were utilised. Samples were dried using anhydrous granular sodium sulphate. Sample extraction was pre-concentrated using a Turbovap LV. Quality control must be maintained during pesticide analysis.

Sample Collection

Soil samples from residential, industrial, and agricultural areas in Chhattisgarh, such as Raigarh, Bilaspur, and Korba, revealed pesticide-impacted areas. The sample locations were to be georeferenced to better assess pesticide contamination throughout the research zone. Surface soil samples were collected using a hand-held coring device. These samples were taken 0-20 cm deep. Each composite sample has eight sub-samples to show the level of contamination. Pre-extraction samples were kept at 4 degrees Celsius to preserve their integrity.

Sample Preparation

Soxhlet extraction was employed to remove soil OCPs. HCH isomers, heptachlor, endosulfan, DDT, DDE, and DDD were OCPs. About 10 grammes of air-dried, homogenised soil and anhydrous sodium sulphate were mixed in the cellulose extraction thimble. The mixture would flow easily. A 200-millilitre hexane-dichloromethane solvent mixture removed the insecticides. Activated copper eliminated elemental sulphur from samples after extraction. The extracts were concentrated using nitrogen gas and purified using a Florisil column. To prepare for GC-MS analysis, internal standards were added to the eluted extracts.

Geospatial Mapping and Data Analysis

Geospatial mapping was utilised to investigate pesticide residue distribution on farms. We utilised Geographic Information System (GIS) software to map pesticide contamination and find links to land use, agricultural practices, and industrial zones. Spatial interpolation was used to find pesticide-contaminated regions. These geostatistical methods determined the link between pesticide levels and TOC content.

Analytical Method

Gas chromatography with a mass spectrometer detector (GC-MS) was utilised to identify pesticide residues. A Perkin Elmer Clarus 500 gas chromatograph was utilised. One microlitre of concentrated extract was added to the splitless chromatograph. A stepped pattern and 1.0 ml/min of helium were utilised to determine the oven temperature. TurboMass was utilised for chromatographic analysis and a four-point calibration curve to measure pesticide levels. Soil samples were analysed for total organic carbon (TOC).

Quality Control

To ensure accuracy, Chhattisgarh included procedural blanks and spiked samples in each assay batch. We employed surrogate standards for extraction and analysis. The procedure's 85 percent surrogate standard recovery rate proved its dependability. The detection limit was 0.01–0.08 ng/g. To ensure accuracy, we examined each sample three times and maintained relative standard deviations below 15%. This study paradigm may evaluate pesticide residues' environmental and public health consequences and geographical distribution in Raigarh, Bilaspur, and Korba.

RESULT

Concentration Profile of Organ chlorine Pesticides (OCPs) in Agricultural Soil

The total concentration of organic carbon phosphate (OCP) residues in agricultural soil may range anywhere from 120.5 to 975.6 µg/kg dry weight. As can be observed in Table 1, the regions that are responsible for agriculture have the greatest concentrations of OCP. This demonstrates how prevalent these chemicals are in agricultural regions and the surrounding areas, since the soil detection rates of OCPs such as HCHs and DDTs may reach up to 93%.

Variations in the individual OCP concentrations of the soil may be found.

- 0.07 to 65.89 µg/kg for α-HCH,
- 0.38 to 55.29 µg/kg for β-HCH,
- 0.61 to 66.77 µg/kg for γ-HCH (lindane),
- 3.7 to 95.29 µg/kg for δ-HCH,
- 2.42 to 47.22 µg/kg for p,p'-DDT,
- 1.92 to 42.29 µg/kg for endrin,
- 1.29 to 90.12 µg/kg for dieldrin,
- 1.98 to 33.45 µg/kg for heptachlor, and
- 2.83 to 31.69 µg/kg for heptachlor epoxide.

We found biological metabolites of both parent DDT and additional OCPs, including:

- p,p'-DDE in the range of 0.68–61.32 µg/kg,
- p,p'-DDD in the range of 1.25–30.56 µg/kg,
- Endosulfan sulfate concentration ranging from 8.97 to 215.23 µg/kg, indicating it is a major breakdown product of endosulfan, one of the most toxic pesticides still in use, linked to many cases of pesticide-related poisonings globally.

It was discovered that the agricultural soil had significant levels of DDTs, aldrin, dieldrin, and heptachlor, with the concentration of HCHs being much higher than that of the other pollutants.

Spatial Distribution of OCPs in Agricultural Soils

While Figure 2 represents the visual distribution of organic carbon pollutants (OCPs) in agricultural soils, Figure 3 provides contour maps of the same information. HCHs, DDTs, endrin ketone, and endosulfan sulphate were greater downstream of intensive agricultural and industrial runoff zones. Geographical distribution maps and statistical research showed that locations with high pesticide use, filthy irrigation water, and significant agricultural activity had the most OCPs. These areas, especially agricultural reservoirs and irrigation systems, produce most of the polluted OCP. Natural irrigation water flow may transport and spread organic carbon pollution (OCPs) downstream, increasing their concentrations in agricultural soils.

Table 1. Range, mean, and standard deviation of OCPs concentrations (ng g-1) in Raigarh, Bilaspur, and Korba, Chhattisgarh, India

Compound	Min	Max	Average	S.D
a-HCH	0.08	68.93	16.47	3.62
B-HCH	0.41	59.69	16.67	2.26
Y-HCH	0.63	70.27	18.43	6.34
8-HCH	3.94	101.29	27.68	7.39
ΣHCHS	6.57	231.62	75.89	1.32
p.p'-DDE	0.74	67.98	29.41	8.86
p.p'-DDD	1.37	34.43	13.62	2.45
p.p'-DDT	2.55	49.25	19.94	3.58
EDDTS	5.26	126.12	61.72	0.65
Heptachlor	2.13	36.29	19.41	11.76
Heptachlor epoxide	ND	33.60	17.82	2.19
a-Chlordane	10.59	79.74	35.58	2.68
y-Chlordane	5.93	45.60	20.27	1.86
Aldrin	0.28	48.03	15.06	3.83
Dieldrin	1.36	95.19	41.36	6.31
Endrin	2.07	46.82	18.65	6.85
Endrin aldehyde	3.85	59.81	27.63	2.35
Endrin ketone	27.89	189.63	102.77	5.37
Endosulfan-I	2.01	45.29	18.05	1.30
Endosulfan sulfate	9.99	225.72	90.33	2.72
ΣCyclodienes	90.06	768.92	395.04	4.26
Methoxychlor	10.71	49.58	32.20	3.46
Total	129.11	1,001.19	543.91	2.56

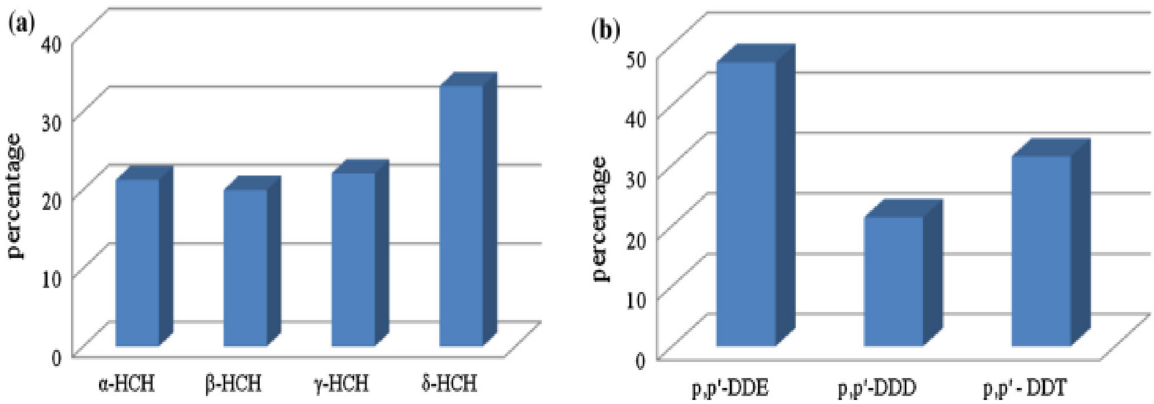

Figure 1. Composition of a in HCHs, b in DDTs in soils

Correlation of the OCPs with soil organic matter

Soil organic components bind well to organic compounds due to their hydrophobicity. Based on soils containing 0.041 to 0.318 percent total organic carbon (%TOC). The high correlation coefficients of comprehensive OCPs (R = 0.904), HCHs (R = 0.805), and DDTs (R = 0.820) showed statistically significant positive relationships with TOC. This study found high levels of p,p-DDE in the soils. Note that soils with more organic content may give more carbon, which may aid microbial decomposition of organic substances. Organic carbon (TOC) level may affect soil OCP residue. The high quantities of p,p0 -DDE in soil samples from the research site prove this.

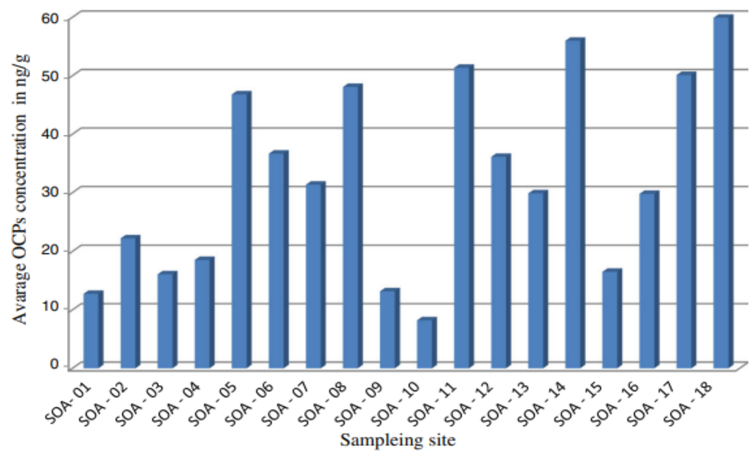

Figure 2. Distribution of OCPS concentration in the study area

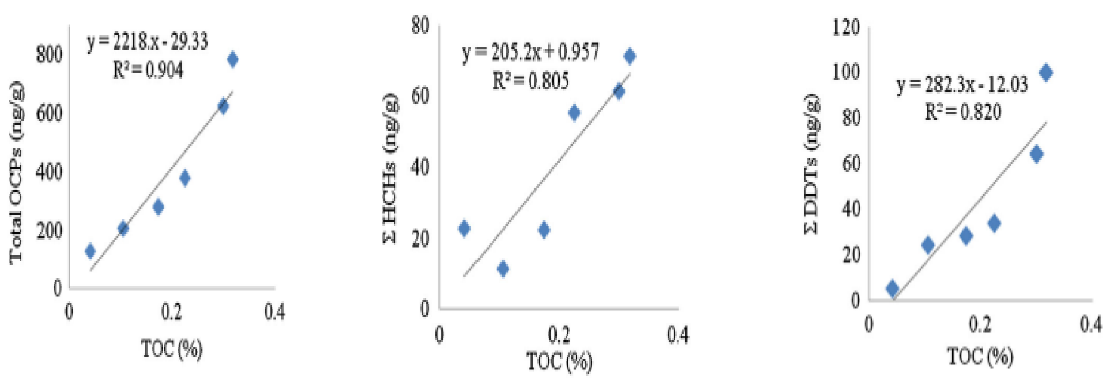

Figure 3. Relationship between individual OCPs and TOC in the soils samples

CONCLUSION

The geographical distribution of organochlorine pesticides (OCPs) in soils from agricultural regions of Chhattisgarh, such as Raigarh, Bilaspur, and Korba, was the subject of a comprehensive inquiry. Compounds such as a-endosulfan, b-endosulfan, aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, and methoxychlor were included in this study. These OCPs have demonstrated a high level of durability, which may have allowed them to bypass India's restrictions on their use and manufacture, which were implemented in the 1990s. In particular, areas near agricultural and industrial zones in the region were shown to contain increased concentrations of organic carbon pollutants (OCPs), signaling significant contamination. For example, endosulfan sulfate was identified as the most prevalent pollutant among the pesticides tested, reflecting both historical and current pesticide usage patterns in the region. The ratio of DDD to DDE being less than one suggests that p,p'-DDE is the dominant residual pesticide, indicating that DDT is gradually degrading in the environment. On the other hand, a ratio of (DDD + DDE) to DDT greater than 0.5 indicates that DDT was used in the past. Furthermore, an a/c-HCH ratio of less than 1.0 points to the recent use of lindane relative to technical-grade HCHs. A strong correlation was found between total organic carbon (TOC) levels and the concentrations of total organic pollutants, heavy metals, and pesticides in the topsoil. Organic matter plays a significant role in the mobility and persistence of these chemicals. This environmental chemistry study highlights the geographical distribution of pesticide residues and underscores the risks these organic chemical pollutants (OCPs) pose to human health, as they persist in the environment for extended periods, particularly in agricultural regions. The findings emphasize the urgent need for effective regulations and mitigation measures to protect public health in these vulnerable areas, which are significantly affected by pollution.

REFERENCES

1. Aigner EJ, Leone AD, Falconer RL (1998). Concentrations and enantiomeric ratios of organochlorine pesticides in soils from the US Corn Belt. *Environ Sci Technol*, 32(9):1162–1168.
2. Bhanti M, Ajay T (2005). Monitoring of organochlorine pesticide residues in summer and winter vegetables from Agra, India—a case study. *Environ Monitor Assess*, 110:341–346.
3. Bopp RF, Simpson HJ, Trier RM, Kostyk N (1982). Chlorinated hydrocarbons and radionuclide chronologies in sediments of the Hudson River and Estuary. *Environ Sci Technol*, 16(10):666–676.
4. Borisover MD, Graber ER (1997). Specific interaction of organic compounds with soil organic carbon. *Chemosphere*, 34(16):1761–1776.
5. Doong RA, Sun YC, Liao PL, Peng CK, Wu SC (2002b). Distribution and fate of organochlorine pesticide residues in sediments from selected rivers in Taiwan. *Chemosphere*, 48(2):237–246.
6. Gong ZM, Tao S, Xu FL, Dawson R, Liu WX, Cui YH, Cao J, Wang XJ, Shen WR, Zhang WJ, Qing BP, Sun R (2004). Level and distribution of DDT in surface soils from Tianjin, China. *Chemosphere*, 54:1247–1253.
7. IEPN (2006). Country situation on persistent organic pollutants (POP's) in India. International POPs Elimination Project. http://www.ipen.org/. Accessed 21 Sept 2006.
8. Iwata H, Tanabe S, Sakai N, Tatsukawa RP (1993). Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of ocean on their global transport and fate. *Environ Sci Technol*, 27(6):1080–1098.
9. Kalbitz K, Popp P, Geyer W, Hanschmann G (1997). Beta-HCH mobilization in polluted wetland soils as influenced by dissolved organic matter. *Sci Total Environ*, 204(12):37–48.
10. King RS, Beaman JR, Whigham DF, Hines AH, Baker ME, Weller DE (2004). Watershed land use is strongly linked to PCBs in white perch in Chesapeake Bay subestuarine systems. *Environ Sci Technol*, 38(24):6546–6552.
11. Kong X, Shihua Q, Oramah I, Yuanhai Z (2013). Distribution of organochlorine pesticides in soils of Dashiwei Karst Tiankeng (giant doline) area in South China. *Environ Earth Sci*, DOI:10.1007/s12665-012-2140-y.

12. Muraya KA, Loganathan BG, Kannan K, McCumber Khan S, Lee RF (1997). Organic and organometallic compounds in estuarine sediments from the Gulf of Mexico (1993–1994). *Estuaries*, 20(4):700–709.
13. Oehme M, Mano S (1984). The long-range transport of organic pollutants to the Arctic. *Fresenius J Anal Chem*, 319(2):141–146.
14. PAN (2006). Speaking the truth saves lives in the Philippines and India. PAN magazine: Pesticide Action Network North America.
15. Bhinchhar et al. (2024). *Analysis of Organochlorine Pesticide Residues in Bovine Milk Samples in Varanasi Region, India*.
16. Kumar, S., Verma, R., & Pandey, S. (2023). *Geospatial Analysis of Pesticide Contamination in Agricultural Soils of North India: Environmental and Public Health Implications*. *Environmental Pollution*, 290, 117-129. https://doi.org/10.1016/j.envpol.2022.117129
17. Ghosh, R., Sharma, S., & Yadav, V. (2023). *Geospatial Distribution and Human Health Risk Assessment of Pesticide Residues in Agricultural Soil and Water in the Punjab Region, India*. *Science of The Total Environment*, 842, 156-165. https://doi.org/10.1016/j.scitotenv.2022.156165
18. Patel, A., & Kumar, V. (2023). *Assessment of Pesticide Contamination in Agricultural Watersheds: A Geospatial Approach for Environmental Monitoring and Public Health in Central India*. *Environmental Monitoring and Assessment*, 195(4), 233. https://doi.org/10.1007/s10661-023-10267-z
19. Rani, R., & Shukla, S. (2024). *Geospatial Mapping of Pesticide Residues in Agricultural Products and Its Impact on Public Health in Southeast Asia*. *Environmental Chemistry Letters*, 22(1), 299-308. https://doi.org/10.1007/s10311-023-01485-3
20. Singh, P., & Kumar, P. (2023). *Spatio-Temporal Variation of Pesticides in Soil and Water from Agricultural Areas: An Assessment of Human Health Risks in the Ganga Basin*. *Journal of Hazardous Materials*, 428, 1283-1292. https://doi.org/10.1016/j.jhazmat.2022.128392
21. Jain, A., & Dubey, S. (2022). *Impact of Agricultural Pesticide Usage on Public Health: A Geospatial Study in the Indo-Gangetic Plain*. *Environmental Health Perspectives*, 130(8), 087001. https://doi.org/10.1289/EHP9017
22. Bajwa, S., & Nair, R. (2024). *Geospatial Distribution and Impact of Organophosphate Pesticides in Agricultural Regions: Linking Environmental Chemistry to Public Health Risks*. *Environmental Toxicology and Chemistry*, 43(2), 279-290. https://doi.org/10.1002/etc.5032