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Hair Analysis for Pesticide Biomonitoring: Advances in Exposure Assessment and Forensic Applications

Aim: Pesticide exposure poses major health risks due to persistence in the environment, toxicity, and rising cases of self-harm. This review evaluates hair as a non-invasive matrix for pesticide biomonitoring, focusing on commonly detected pesticides, general extraction and analytical techniques, and recent improvements that enhance sensitivity and accuracy.

Methods: A systematic search was conducted in PubMed, Scopus, and Web of Science for studies reporting pesticide detection in human hair. Thirty studies were included after screening. Information was summarized on pesticide types, sample preparation, analytical techniques (GC–MS and LC–MS), and overall performance indicators. Methods were compared broadly on their sensitivity, recovery, and reliability.

Results: Hair has been successfully used to detect a range of pesticides, most often organophosphates, pyrethroids, organochlorines, and neonicotinoids. Extraction methods included simple solvent extraction, QuEChERS, and SPE. Analytical detection mainly relied on GC–MS for stable compounds and LC–MS for more polar pesticides. Many studies reported good sensitivity and acceptable recovery, although results varied due to differences in protocols. Overall, hair proved useful both in environmental exposure assessment and in forensic contexts.

Conclusions: Hair offers a practical and non-invasive option for pesticide biomonitoring. While results across studies are promising, standardization of methods is needed to improve comparability. Advances in eco-friendly extraction and modern MS technologies continue to improve reliability and broaden applicability.

Keywords: Pesticide, Biomonitoring, Hair, GC–MS, LC–MS, Sensitivity, Toxicology, Extraction

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