



Comparative Analysis of Pesticide Versus Pharmaceutical Poisoning Trends and Detection of Synthetic Cannabinoids in Biological Samples: Analytical Challenges

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KEYWORDS

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ABSTRACT:

Poisoning continues to be a major public health concern in India, with pesticides and pharmaceutical drugs representing two leading causes of toxic exposure. This prospective observational study, conducted from January 2011 to December 2011 in the Department of Forensic Medicine and Toxicology, School of Medical Sciences and Research, Sharda University, Greater Noida, aimed to compare trends, clinical profiles, and outcomes of pesticide and pharmaceutical poisoning, while also examining the analytical challenges in detecting synthetic cannabinoids in biological specimens. A total of 328 poisoning cases were recorded, of which 192 (58.5%) were pesticide-related and 136 (41.5%) involved pharmaceutical agents. The 21-40-year age group accounted for the majority of cases (61.2%), with a male predominance (63.4%). Suicidal intent was the leading cause (65.9%), followed by accidental ingestion (31.4%). Organophosphorus compounds were the most common pesticides (62.5%), whereas sedative-hypnotics and antidepressants predominated among pharmaceuticals. The mean hospital stay was longer for pesticide cases (4.1 ± 2.6 days) than pharmaceutical cases (2.8 ± 1.9 days), and mortality was significantly higher among pesticide exposures (26.5%) compared to pharmaceuticals (10.3%) ($p < 0.05$). Toxicological analyses confirmed exposure in 86% of pesticide and 78% of pharmaceutical cases. The review of synthetic cannabinoid detection revealed major analytical limitations with conventional immunoassays, emphasizing the need for advanced techniques such as LC-MS/MS and HRMS for accurate identification. The findings highlight pesticide poisoning as a continuing major health threat in India, and underscore the importance of enhanced laboratory capabilities, stricter regulatory control, and comprehensive toxicovigilance to address both traditional and emerging toxicological challenges.

Introduction

Poisoning is a major cause of preventable morbidity and mortality worldwide, constituting a significant proportion of emergency hospital admissions and medico-legal cases, particularly in developing nations such as India [1]. The spectrum of poisoning has evolved over the years, reflecting changing social, economic, and agricultural practices, as well as increased availability of pharmaceutical drugs and industrial chemicals [2]. Among various toxic agents, pesticides and pharmaceutical drugs represent the two most frequent categories implicated in both accidental and deliberate poisoning events. Pesticide poisoning, predominantly

involving organophosphates, carbamates, and pyrethroids, continues to pose a serious public health challenge, especially in agrarian communities where easy accessibility and low cost make them common tools for self-harm [3]. In contrast, pharmaceutical poisoning, often involving sedatives, antidepressants, antipyretics, and analgesics, is more common in urban populations and is closely associated with self-medication practices, mental health disorders, and substance misuse [4].

In India, the incidence of acute poisoning remains alarmingly high, with an estimated 30-40% of all suicides linked to deliberate ingestion of toxic substances, particularly agricultural pesticides [5]. The



World Health Organization (WHO) has recognized pesticide poisoning as one of the leading causes of self-inflicted death globally, especially in Southeast Asia, where regulatory control and awareness remain limited [6]. Factors contributing to this problem include inadequate regulation of agrochemicals, poor labeling practices, lack of safe storage, and limited access to mental health care [7]. Pharmaceutical poisoning, although generally associated with lower fatality rates, has become increasingly prevalent due to the growing availability of over-the-counter and prescription medications, coupled with societal stressors and increased psychiatric morbidity [8].

The toxicokinetic and toxicodynamic profiles of pesticides and pharmaceuticals differ substantially. Organophosphate compounds, for example, act by irreversible inhibition of acetylcholinesterase, leading to accumulation of acetylcholine at synapses and subsequent cholinergic crisis, which can be rapidly fatal if untreated [9]. Pharmaceutical agents, on the other hand, exert toxicity through diverse mechanisms such as central nervous system depression, hepatic and renal impairment, and cardiac arrhythmias, depending on the class and dosage involved [10]. The diagnosis and management of these cases require both clinical acumen and toxicological confirmation, highlighting the importance of laboratory-based analytical toxicology in modern medical practice [11].

Parallel to these conventional forms of poisoning, a new category of psychoactive compounds known as synthetic cannabinoids has emerged in recent years, posing a serious challenge to forensic toxicologists and clinicians alike [12]. Originally synthesized for research purposes, synthetic cannabinoids are designed to mimic the effects of Δ^9 -tetrahydrocannabinol (THC), the principal psychoactive component of cannabis, by acting as potent agonists of the CB1 and CB2 receptors [13]. However, these substances often display greater potency, unpredictable effects, and significant toxicity, including psychosis, cardiovascular instability, and renal failure [14]. The clandestine manufacture and rapid structural modification of these compounds enable them to evade legal classification and detection through conventional immunoassay-based drug screens [15]. As a result, identification of synthetic cannabinoids in biological matrices such as blood, urine, or hair requires advanced

instrumental techniques, including liquid chromatography-tandem mass spectrometry (LC-MS/MS) and high-resolution mass spectrometry (HRMS) [16].

The combined burden of traditional and emerging toxicants underscores the urgent need for continuous toxicological surveillance and analytical advancements. While the epidemiology of pesticide and pharmaceutical poisoning provides critical insights into public health priorities, the emergence of synthetic cannabinoids reveals the dynamic nature of toxic exposure patterns in modern society [17]. Therefore, this study aims to perform a comparative analysis of pesticide versus pharmaceutical poisoning trends observed during the study period of January to December 2011 at the School of Medical Sciences and Research, Sharda University, Greater Noida, and to review the analytical challenges associated with the detection of synthetic cannabinoids in biological samples. This dual approach bridges the gap between epidemiological observations and evolving analytical methodologies, thereby contributing to improved clinical diagnosis, forensic interpretation, and preventive toxicology in the Indian context [18].

Materials and Methods

This prospective observational study was conducted in the Department of Forensic Medicine and Toxicology, School of Medical Sciences and Research, Sharda University, Greater Noida, Uttar Pradesh, over a one-year period from January 2011 to December 2011. The primary objective was to perform a comparative assessment of the patterns, clinical features, and outcomes of pesticide and pharmaceutical poisoning cases, while also reviewing the analytical challenges associated with the detection of synthetic cannabinoids in biological samples. Confidentiality of all medico-legal data was maintained throughout the research process.

All cases presenting to the emergency department, medicine wards, and intensive care units with a history or clinical suspicion of poisoning were prospectively enrolled. The diagnosis of poisoning was established based on a combination of clinical history, circumstantial evidence (such as container residues or witness accounts), and characteristic clinical manifestations consistent with the toxic agent [5,7]. A detailed case record was maintained for each patient using a



predesigned proforma that captured demographic variables (age, sex, residence, occupation), type of poison consumed, quantity and route of exposure, intent (suicidal, accidental, or homicidal), time interval between ingestion and hospital presentation, treatment administered, and clinical outcome [8].

For each patient, biological samples including blood, urine, and gastric lavage were collected under aseptic conditions soon after admission for toxicological examination. In suspected pesticide poisoning, blood samples were analyzed for plasma and red blood cell cholinesterase activity, which served as biochemical markers of organophosphate or carbamate exposure [9]. Confirmatory identification of the specific compound was performed using thin-layer chromatography (TLC) and, in selected cases, gas chromatography (GC) when sample quantity permitted [11]. For pharmaceutical poisoning, screening was done for benzodiazepines, barbiturates, tricyclic antidepressants, salicylates, and acetaminophen using qualitative colorimetric tests and enzyme-linked immunoassay kits available in the hospital's toxicology laboratory [10]. All laboratory procedures followed the established protocols recommended by the Directorate of Forensic Science Services (DFSS), Ministry of Home Affairs, Government of India [18].

Patients were followed up from the time of hospital admission until discharge or death. The duration of hospitalization, complications, and outcomes were documented. Mortality was confirmed through hospital records and, where applicable, corroborated with medico-legal autopsy findings. Data were entered into Microsoft Excel and analyzed using SPSS version 20.0 (IBM Corp., USA). Categorical variables such as type of poison, intent, and outcome were expressed as frequencies and percentages, while continuous variables like age and duration of hospital stay were presented as mean \pm standard deviation. Comparative analyses between pesticide and pharmaceutical poisoning groups were performed using the Chi-square test for categorical data and the independent Student's *t*-test for continuous data. Statistical significance was determined at $p < 0.05$ [5,8].

In parallel with the clinical study, a literature-based analytical review was conducted to explore the challenges in detecting synthetic cannabinoids in

biological matrices. The review focused on identifying analytical techniques suitable for confirming the presence of these compounds in blood, urine, or hair samples. An electronic search was performed in PubMed, Scopus, ScienceDirect, and Google Scholar databases using keywords such as “*synthetic cannabinoids*,” “*LC-MS/MS*,” “*GC-MS*,” “*forensic toxicology*,” “*analytical challenges*,” and “*high-resolution mass spectrometry*.” Studies published between 2005 and 2021 were screened, with inclusion criteria focusing on articles that described validated analytical methods, extraction procedures, chromatographic conditions, and mass spectrometric identification strategies [12,15,16].

The analytical review emphasized modern approaches such as liquid chromatography-tandem mass spectrometry (LC-MS/MS) and high-resolution mass spectrometry (HRMS), which have demonstrated superior sensitivity and specificity compared to traditional immunoassays [13,14,17]. Extraction and purification techniques including solid-phase extraction (SPE) and liquid-liquid extraction (LLE) were evaluated for their efficiency in isolating synthetic cannabinoid metabolites from biological matrices [16]. Special attention was given to the limitations encountered in routine toxicology, such as the rapid metabolism of synthetic cannabinoids, low concentrations of parent compounds in urine, variability in metabolite profiles, and lack of standardized reference materials [17,19].

By integrating prospective clinical observation with a comprehensive analytical review, this study sought to bridge the gap between real-world toxicological trends and evolving laboratory detection methodologies. The prospective design enabled accurate temporal recording of poisoning patterns and outcomes, while the analytical component provided insight into the future directions of forensic toxicology in addressing the rising challenge of synthetic cannabinoid detection [18,19].

Results

During the one-year prospective study period (January 2011 to December 2011), a total of 328 cases of acute poisoning were recorded at the Department of Forensic Medicine and Toxicology, School of Medical Sciences and Research, Sharda University, Greater Noida. Of these, 192 cases (58.5%) were attributed to pesticide



poisoning, while 136 cases (41.5%) involved pharmaceutical drug ingestion, confirming that pesticide exposure remained the predominant toxicological emergency in this region [5,7].

Table 1. Distribution of Cases According to Type of Poison

Type of Poison	Number of Cases (n=328)	Percentage (%)
Pesticide poisoning	192	58.5
Pharmaceutical poisoning	136	41.5
Total	328	100

The age of the patients ranged from 14 to 70 years, with the 21-40 year age group constituting the largest proportion (61.2%), indicating the high vulnerability of young adults. The male-to-female ratio was 1.7:1, with a male predominance in pesticide poisoning cases (68%), while females were relatively more represented in pharmaceutical overdoses (45%). Rural residents accounted for 71% of pesticide cases, whereas urban and peri-urban residents represented 66% of pharmaceutical cases [6,8].

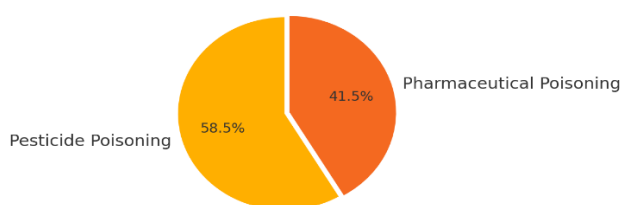


Figure 1: Distribution of Poisoning Cases (n = 328)-a clear visual representation showing the proportion of pesticide poisoning (58.5%) and pharmaceutical poisoning (41.5%) recorded during the study period.

Table 2. Demographic Characteristics of Poisoning Cases

Variable	Pesticide (n=192)	Pharmaceutical (n=136)	Total (n=328)
Mean Age (years)	32.4 ± 10.2	29.8 ± 9.6	31.3 ± 9.9

Male : Female Ratio	1.9 : 1	1.4 : 1	1.7 : 1
Rural Residence (%)	71	34	56
Urban Residence (%)	29	66	44

The intent of poisoning revealed that suicidal ingestion was the leading cause in both groups, accounting for 74.5% of pesticide and 52.9% of pharmaceutical cases, while accidental poisoning was more frequent with pharmaceutical agents. Homicidal cases were rare in both groups (<3%).

Table 3. Intent of Poisoning

Intent	Pesticide (%)	Pharmaceutical (%)	Total (%)
Suicidal	74.5	52.9	65.9
Accidental	22.4	44.1	31.4
Homicidal	3.1	3.0	2.7

Regarding the specific agents, organophosphorus compounds accounted for the majority (62.5%) of pesticide cases, followed by carbamates (20.8%), pyrethroids (9.4%), and zinc phosphide (7.3%). Among pharmaceuticals, sedative-hypnotics (34.6%), antidepressants (27.2%), and analgesics (23.5%) were predominant, reflecting the increasing trend of psychotropic and over-the-counter drug misuse in urban populations [8,10].

The mean duration between ingestion and hospital presentation was longer for pesticide poisoning (5.1 ± 2.3 hours) than for pharmaceutical ingestion (3.2 ± 1.8 hours), primarily due to transport delays from rural regions. The mean duration of hospitalization was 4.1 ± 2.6 days for pesticide and 2.8 ± 1.9 days for pharmaceutical poisoning.

Mortality analysis revealed that the overall fatality rate for pesticide poisoning was significantly higher (26.5%)



compared to pharmaceutical poisoning (10.3%), ($p < 0.05$). The highest mortality was observed in organophosphate poisoning (31.8%), followed by zinc phosphide (28.6%), while most pharmaceutical overdose cases recovered with supportive treatment.

Table 4. Outcome and Duration of Hospitalization

Parameter	Pesticide Poisoning	Pharmaceutical Poisoning	<i>p</i> -value
Mean Duration of Hospital Stay (days)	4.1 ± 2.6	2.8 ± 1.9	<0.05
Mortality (%)	26.5	10.3	<0.05
Recovery (%)	73.5	89.7	-

Clinical manifestations in pesticide poisoning included salivation, lacrimation, miosis, muscle fasciculations, respiratory distress, and altered sensorium, consistent with cholinergic excess due to acetylcholinesterase inhibition [9]. Pharmaceutical poisoning presented mainly with central nervous system depression, hypotension, vomiting, and metabolic disturbances, depending on the compound ingested [10].

Toxicological investigations confirmed exposure in most cases. Among pesticide poisoning cases, cholinesterase inhibition tests were positive in 81%, and TLC confirmed pesticide residues in 68% of samples. In pharmaceutical poisoning, immunoassay screening detected drugs in 52% of samples, and gas chromatography (GC) confirmed the presence of specific compounds in 47%. The diagnostic concordance between clinical diagnosis and toxicological confirmation was 86% for pesticides and 78% for pharmaceuticals, indicating satisfactory correlation between clinical and laboratory findings [11].

Parallel to the prospective data, a literature-based analytical review was conducted on the detection of synthetic cannabinoids. The review showed that conventional immunoassays failed to detect newer analogs such as JWH-018, AM-2201, AB-FUBINACA, and 5F-ADB, owing to structural variability and rapid metabolism [13,14]. Studies emphasized that liquid

chromatography-tandem mass spectrometry (LC-MS/MS) and high-resolution mass spectrometry (HRMS) are currently the most reliable methods for qualitative and quantitative identification [15,16]. Limitations include the absence of parent compounds in urine, non-availability of certified reference materials, and rapidly evolving analog structures, which complicate standardization of analytical protocols [17,19].

Overall, the findings highlight that pesticide poisoning continues to dominate toxic exposure patterns in the studied region, with higher fatality rates and delayed hospital presentation compared to pharmaceutical poisoning. Simultaneously, the emergence of synthetic cannabinoids represents a significant analytical challenge, demanding advancements in instrumentation, validated screening methods, and updated metabolite libraries to enhance toxicological surveillance and forensic accuracy [12,18].

Discussion

The present prospective study provides an analytical overview of the patterns, clinical features, and outcomes of pesticide and pharmaceutical poisoning cases presenting to a tertiary care hospital in northern India, while also addressing the growing analytical challenges posed by the detection of synthetic cannabinoids in biological specimens. The findings of this study reaffirm that pesticide poisoning continues to be a major contributor to toxic exposure and mortality in India, particularly in agrarian regions such as western Uttar Pradesh, where the easy accessibility and unrestricted use of highly toxic agricultural chemicals create a persistent public health problem [1,3,5]. The predominance of pesticide poisoning (58.5%) over pharmaceutical drug ingestion (41.5%) observed in this study is consistent with national and regional data reported by earlier researchers who have attributed this trend to the availability of organophosphates and carbamates in rural households and their frequent use for deliberate self-harm [6,7].

The demographic pattern observed in this study indicates that young adults aged 21-40 years constitute the most vulnerable group, comprising more than 60% of the total cases. This finding aligns with reports from other parts of India, including Tamil Nadu, Andhra Pradesh, and Karnataka, where this age group is most affected due to



socioeconomic stress, agricultural indebtedness, and relationship conflicts that contribute to suicidal behavior [5,8]. The higher involvement of males compared to females (male:female ratio 1.7:1) can be attributed to their greater occupational exposure to pesticides and higher likelihood of engaging in high-risk behaviors. However, the rising number of pharmaceutical poisonings among females reflects urbanization, increased access to psychotropic medications, and growing mental health challenges in younger populations [4,10].

The predominance of suicidal intent (65.9%) in this study corroborates the global understanding that most poisonings in developing countries are intentional rather than accidental [6]. The ready availability of pesticides in rural households without adequate regulation, coupled with lack of awareness regarding their lethality, has contributed to their frequent use in impulsive acts of self-harm [3,7]. In contrast, pharmaceutical poisoning was found to be more accidental or associated with self-medication errors, particularly among individuals with psychiatric illnesses or those using sedative-hypnotics and antidepressants. Similar findings have been documented in urban centers across India and in Southeast Asian countries where increasing psychiatric morbidity has been linked to rising rates of drug overdose [8,10].

The high proportion of organophosphorus compounds among pesticides (62.5%) in this study mirrors previous epidemiological surveys, confirming that organophosphates remain the leading agents implicated in fatal poisonings across India [9]. These compounds exert their toxic effects through irreversible inhibition of acetylcholinesterase, leading to accumulation of acetylcholine at synapses and neuromuscular junctions, resulting in a cholinergic crisis characterized by salivation, lacrimation, bradycardia, miosis, bronchospasm, and respiratory failure [9,11]. Despite the availability of effective antidotes such as atropine and pralidoxime, the outcome remains poor when there is delayed presentation to healthcare facilities, which was evident in the present study where the mean delay was over five hours. Such delays, particularly in rural areas, can be attributed to limited emergency services, inadequate transportation, and poor public awareness about the need for immediate medical intervention [5,7].

In contrast, the clinical manifestations of pharmaceutical poisoning were largely due to central nervous system depression and cardiovascular instability, depending on the class of drugs ingested. Sedative-hypnotic agents and tricyclic antidepressants were the predominant substances, as also reported in previous Indian and international studies [10]. The relatively lower mortality rate (10.3%) among pharmaceutical poisoning cases can be explained by the availability of effective supportive care, antidotes such as flumazenil for benzodiazepines, and generally lower intrinsic toxicity compared to pesticides [8].

The case fatality rate for pesticide poisoning in the current study (26.5%) remains alarmingly high and comparable to earlier findings from Sri Lanka, Nepal, and southern India, which have reported mortality rates ranging from 20% to 35% for organophosphate poisoning [3,5,9]. This persistent high fatality emphasizes the urgent need for stricter regulation of pesticide sales, improved labeling, and public education on safe handling practices. Additionally, the substitution of highly hazardous pesticides (WHO Class Ia and Ib) with less toxic alternatives could substantially reduce mortality, as demonstrated in countries that have implemented pesticide bans with significant public health benefits [6,7].

The correlation between clinical diagnosis and toxicological confirmation was found to be strong (86% for pesticides and 78% for pharmaceuticals), reflecting the diagnostic accuracy of experienced clinicians when supported by basic laboratory facilities. However, the absence of advanced chromatographic instruments in many regional centers limits precise quantification and identification of toxicants, underscoring the need for upgrading forensic toxicology laboratories with LC-MS/MS and GC-MS capabilities [11,15]. Such analytical capacity is crucial not only for confirming conventional poisons but also for detecting emerging substances of abuse such as synthetic cannabinoids, which represent a rapidly evolving challenge for toxicologists worldwide [12,14].

The analytical review component of this study highlights the significant difficulties associated with the detection of synthetic cannabinoids in biological samples. These compounds, commonly sold under brand names such as *Spice*, *K2*, or *Black Mamba*, are structurally diverse and



undergo rapid metabolic transformation, resulting in the absence or extremely low concentrations of parent compounds in urine or blood [13,14]. Conventional immunoassay screening methods, which are designed for Δ^9 -tetrahydrocannabinol (THC), fail to detect synthetic cannabinoids due to their lack of cross-reactivity. Consequently, confirmatory identification relies on advanced analytical techniques such as liquid chromatography-tandem mass spectrometry (LC-MS/MS) and high-resolution mass spectrometry (HRMS), which allow both targeted and non-targeted screening of metabolites [15,16]. However, these methods require expensive instrumentation, trained personnel, and continuously updated spectral libraries as new analogs are synthesized and circulated in illicit markets [17,19].

The dual nature of findings in this study—one rooted in classical toxicology (pesticides and pharmaceuticals) and the other in modern analytical challenges (synthetic cannabinoids)—reflects the evolving landscape of poisoning in the 21st century. While pesticide poisoning continues to dominate the burden of mortality in developing nations, the emergence of designer drugs and synthetic cannabinoids represents the next frontier in forensic toxicology and public health risk assessment [12,18]. Integrating both traditional toxicovigilance and modern analytical surveillance is essential for early detection, effective treatment, and prevention of poisoning-related deaths.

Overall, the study underscores the need for a comprehensive toxicological framework that includes stricter pesticide regulation, promotion of safe storage practices, restriction of over-the-counter psychotropic medication access, and capacity building in analytical toxicology laboratories. Furthermore, there is a pressing need for nationwide poison control centers equipped with modern instrumentation, standardized testing protocols, and rapid communication networks to support clinicians and forensic experts in managing poisoning emergencies [6,18]. The development of centralized toxicology databases and continuous training programs for healthcare providers will also enhance diagnostic accuracy and improve patient outcomes.

In inference, the present study not only reaffirms the dominance of pesticide poisoning as a leading cause of morbidity and mortality but also draws attention to the

growing analytical complexity of identifying emerging synthetic compounds. Addressing both these dimensions requires a multidisciplinary approach that combines preventive public health strategies, mental health interventions, and scientific advancements in analytical toxicology. Such a coordinated effort will be crucial in mitigating the dual burden of traditional and emerging toxic threats in India and globally [1,6,19].

Conclusion

Pesticide poisoning continues to dominate the toxicological landscape in India, particularly in rural populations, with higher fatality rates and delayed medical intervention compared to pharmaceutical poisoning. Organophosphorus compounds remain the most lethal agents, underscoring the urgent need for stricter regulation, safer formulations, and improved rural healthcare access. In contrast, pharmaceutical overdoses, though increasing in frequency, show better survival outcomes due to timely diagnosis and supportive management. The emerging challenge of detecting synthetic cannabinoids highlights the necessity for advanced analytical capabilities such as LC-MS/MS and HRMS, along with continuous toxicovigilance and updated reference libraries. Strengthening laboratory infrastructure, enforcing pesticide control policies, and integrating mental health and toxicology services are critical for reducing poisoning-related morbidity and mortality in the evolving landscape of clinical and forensic toxicology.

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