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A Retrospective Evaluation of Toxicological Case Results: Applying Non-Parametric Statistics to Forensic Data Sets

Bhumi Oza[1], Rudra Bhosale[2], Gaurang Rane[3] , Dr. Naresh Verma[4]
[1,2,3]*Department of Forensic Science, Sandip University, Mahiravni, Nashik, India*
[4]*Junior Scientific Assistant, Regional Forensic Science Laboratory, Udaipur, India*

***Abstract*—A comprehensive compilation of toxicology results is crucial for determining trends within drug use, improving analytical methods, and assisting in the investigation of crimes. Nevertheless, the complexity created by the heterogeneity of toxicology results due to differences between matrices, postmortem distribution, and poly-drug effects makes it difficult to compile and analyze statistics effectively. In this study, an effort was made to create a statistical compilation methodology that would enable identification of trends concerning the presence and concentrations of substances over time. A comprehensive statistical database can serve as a basis for forensic toxicologists and public health experts. Through a shift from individual case analyses to statistical modeling, experts will be able to estimate the lethal doses of different substances and update assays accordingly.**

***Index Terms*—Data Compilation, Forensic Toxicology, Postmortem Toxicology, Poisoning, Statistical Analysis.**

I. INTRODUCTION

The field of forensic toxicology contributes in bridging critical gaps between medical science and the legal system, providing the objective data necessary to determine the role of toxicants in morbidity and mortality. Morbidity and mortality among poisoning cases depends on the type of poisoning agent and country to country.[8] According to WHO (1999), more than 3 million poisoning cases have been reported out of which 2,52,881 deaths occur worldwide annually, of which 99% of fatal poisoning occur in developing countries, predominantly among farmers due to various kinds of poisoning, including poisonous toxins from natural products.[4] Respiratory failure is a common complications of organophosphorus (OPs) poisoning which is responsible for a high death, so patients usually arrived within 6-8 hours are most likely to be survive.[7] In recent years, the complexity of toxicological casework has developed drastically, driven by the rapid diversification of the illicit drug market and the proliferation of fatalities via poisons and pesticide consumption. As traditional screening methods, Thin Layer Chromatography, chemical shift analysis, Blood Alcohol Concentration detection, are used for a systematic, reliable approach for data analysis has been resilient. Historically, toxicological findings have been interpreted on a case-by-case basis, often relying on established "lethal range" tables that may not account for the recent complexities of modern polysubstance use. While individual case reports provide valuable unique evidence, they do not possess the statistical strength necessary to identify broader epidemiological patterns or to establish updated reference intervals for new compounds. The shift from qualitative observation to the gathering of quantitative statistics signifies a critical advancement in forensic practice. The factors taken into consideration during data compilation are multifaceted. Postmortem Redistribution (PMR) a crucial factor involving the movement of drugs after death, which can artificially increase peripheral blood concentrations. Matrix Heterogeneity, a pharmacological term that refers to the differences in drug stability and concentration across blood, vitreous humor and tissue samples. Synergistic Toxicity is associated with the concept of “dark matter” in physiology, where the combination of two sub-lethal doses can lead to a fatal outcome. This research paper provides a comprehensive statistical compilation of toxicological case results, aiming to convert raw laboratory findings into actionable intelligence. By utilizing advanced data normalization techniques and conducting trend analysis over time, this study aims to establish a more dynamic framework for interpreting drug concentrations. Ultimately, this data compilation not only serves as a reference for forensic professionals but also acts as an essential tool for monitoring public health, allowing for a proactive approach rather than reactive response to the continually changing landscape of chemical toxicity.

II. METHODS AND METHODOLOGY

The study was conducted using a retrospective, cross-sectional approach that integrated toxicological data sourced from cases collected over a period of two months (February-March). Cases were chosen based on strict inclusion criteria requiring confirmed toxicological results and standardized matrix sampling, while excluding records involving severely decomposed specimens or incomplete laboratory results to ensure analytical integrity. All findings were derived from standard forensic procedures, including screening through Thin Layer Chromatography, chemical shift analysis, Blood Alcohol Concentration detection and even UV-vis Spectroscopy. Before analysis, raw data underwent a thorough normalization process wherein case files were categorized based on monthly targets and units. Standardized excel spreadsheets were prepared according to set conventions and data evaluation from the final reports was systematically conducted. Statistical analysis was performed using Gemini Ai, employing the pie chart distribution technique. To maintain ethical standards, the dataset was completely anonymized, ensuring both integrity and confidentiality.

III. RESULT

A total of 135 cases were registered during the study period, February-March 2026. The statistical data was differentiated according to the gender, age, crime type, district from where the cases belonged and the month when they were registered in the laboratory.

Table 1.1: Gender-wise percentage of cases.

Sr. no.	Gender	Total Cases Received (%)
1	Male	68.89%
2	Female	31.11%

Table 1.2: Age-group wise distribution of cases

Sr. no.	Age Group Range (Years)	Total Cases Received (%)
1	0-20	20%
2	21-40	42.96%
3	41-60	30.37%
4	61-80	5.93%
5	81-100	0.74%

Table 1.3: Distribution of cases according to the nature of incident

Sr. no.	Nature of Incident	Total Cases Received (%)	Phosphide Positive (%)	Alcohol Positive (%)
1	Suicide	21.48%	65.52%	17.24%
2	Intentional Homicide	6.67%	11.11%	0.00%
3	Unintentional Homicide	8.89%	16.67%	8.33%
4	Accidental	39.26%	35.85%	35.85%
5	Natural	14.81%	0.00%	0.00%
6	Suspicious death	8.89%	41.67%	8.33%

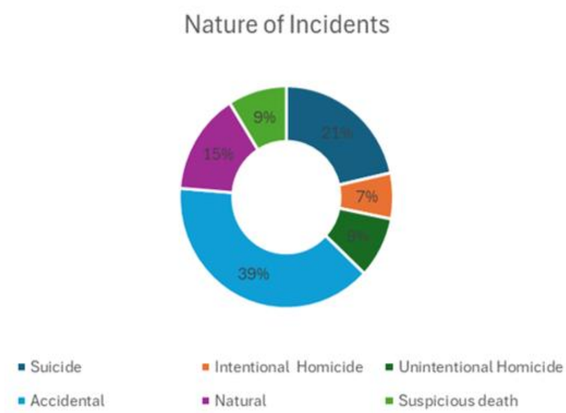

Figure 1: Percentage of the nature of crime

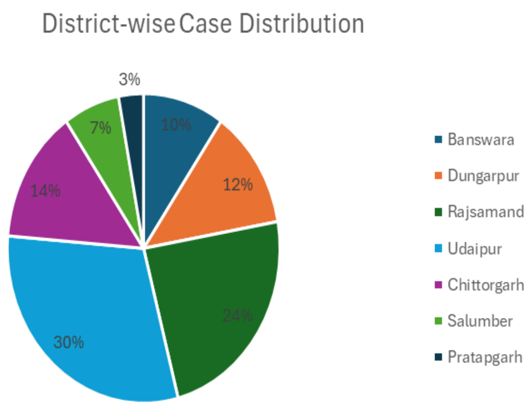

Figure 2: District-wise distribution of cases

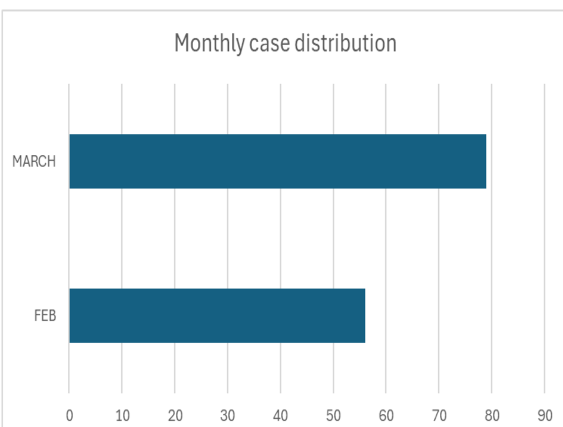

Figure 3: Month-wise distribution of cases

IV. DISCUSSION

A total of 135 cases were reassessed throughout the two-month study period. During this time, there was a notable increase of 41% in the case volume from February (56 cases) to March (79 cases). This rise suggests an increase in forensic referrals and potential improvement in the coordination between law enforcements and the forensic laboratory during the month of March. The provided data presents a compelling overview of mortality trends associated with toxicological screenings, particularly emphasizing the prevalence of phosphide and alcohol across various manners of death. The high occurrence of phosphide in suicidal (65.52%) and accidental (35.85%) cases, often alongside alcohol, suggests complex toxicokinetic interactions that are critical for forensic interpretation.

Table 1.1 and Table 1.2 displays the demographic data which reveals a distinct unevenness towards specific populations. In Table 1.1, males accounted for the vast majority of the cases (68.89%), double than the female representation (31.11%). This aligns with the global forensic stats where males are oftentimes more frequently involved in external causes of death like road traffic accidents, high-risk occupations or criminal activity.

Table 1.2 shows the age of individuals involved in these cases. The demographic between ages 21 to 40 is the most impacted, comprising 42.96%. When merging individuals aged 41 to 60 (30.37%) with those ages 21 to 40, more than 73% of the cases involve individuals who are in their working years. This age group majorly contributes to the economy of this area. The high mortality rate in this specific age group suggests that forensic cases are intrinsically linked to travelling for work, higher levels of social activity and occupational hazards, particularly among farmers exposed to various poisonous toxins and pesticides. The age group of 81-100 years old makes up a small percentage of cases (0.74%) suggesting that forensic intervention is less required for the elderly age group, likely due to a higher prevalence of expected natural death in the group.

Table 1.3, consists of the categorization of cases according to the nature of incidents. This categorization of cases provides an insight into the prevailing social and safety issues. At 39.26%, accidental deaths are the leading cause of forensic cases in this study. The data indicates a high correlation of alcohol and phosphide in accidental cases. In clinical toxicology, the co-ingestion of ethanol and metal phosphides (e.g., Zinc Phosphide) creates a state of synergistic toxicity. Ethanol functions as both a surfactant and a vasodilator, potentially facilitating the release and systemic absorption of phosphine gas (PH_3). This "multi-hit" mechanism inhibits mitochondrial cytochrome c oxidase (CcO) and induces severe oxidative stress, often resulting in a rapid shift from sub-lethal to fatal outcomes that might not occur with either substance alone. This high statistical figure also necessitates further investigation into road safety, agriculture and industrial risks and domestic incidents within these districts. Suicide represents a significant portion of the data (21.48%), highlighting a critical health concern among the public. These suicide rates often involve the ingestion of highly toxic substances such as Organophosphorus (OP) and Zinc phosphide compounds, which are recognized as a leading factor in respiratory failure. The differing percentages of phosphide positive in Suicide cases highlights the challenge of matrix heterogeneity. Toxicological concentrations are inconsistent; PH_3 gas may accumulate in lipid-rich tissues or remain concentrated in gastric residues, while alcohol distributes according to water content.

The combined homicide rates (Intentional and Unintentional homicide) account for almost 15.56%, indicating a notable level of interpersonal violence among the individuals in the area requiring criminal investigation. A significant portion of these cases, particularly the natural (14.81%) and unintentional homicide (8.89%) cases, may involve what is referred to as physiological "Dark matter". This refers to the vast array of metabolites, endogenous compounds and "designer" synthetic analogs that escape standard screening protocols (e.g., GC-MS or LC-MS). Although 14.81% were ruled as natural deaths, the absence of alcohol and phosphide positive findings in these cases do not necessarily imply the absence of chemical influence: rather, they may reflect the limitations of current targeted assays in detecting novel psychoactive substances or subtle biochemical imbalances that contribute to sudden mortality. Nearly 8.89% remained classified as "Suspicious" deaths; in these cases, relying on a single matrix like peripheral blood can be misleading. A thorough examination utilizing various matrices (vitreous humor, bile, and liver) is essential to differentiate between acute exposure and localized concentration gradients. In these cases, low-level detections of multiple substances - which might individually be deemed "safe"- likely combined to produce a fatal outcome, reinforcing the need for the quantitative statistics advocated in this study.

A critical challenge in interpreting these results is Postmortem Redistribution. This occurrence pertains to the movement of drugs or toxins from high-concentration areas (like stomach to lungs) into the bloodstream and surrounding tissues following death. Aluminium phosphide, which degrades into phosphine gas, readily diffuses across tissue boundaries. Additionally, ethanol may be formed internally through microbial fermentation after death, potentially resulting in false-positive results or unreasonably high concentrations. In cases of Suspicious death (41.67% phosphide positive), it is essential to distinguish between toxicity occurring around the time of death and postmortem artifacts to accurately determine the cause of death.

The geographical allocation of cases displayed considerable unevenness across the seven districts. Udaipur (30%) and Rajsamand (24%) contributed to over half of the overall case count. Given that Udaipur is a major urban and administrative hub, the higher volume of cases correlates with both, the higher population density and more centralized reporting facilities in the area as compared to rural districts. In these urban and semi-urban hubs, the transition from qualitative TLC screening to quantitative analysis is vital. Specifically, the "Dark matter" of physiology becomes apparent when analyzing samples from these regions: variations in drug stability across different matrices (blood vs gastric lavage) in the Udaipur cases suggest that Postmortem Redistribution (PMR) must be strictly accounted to avoid false interpretations of lethal concentrations. Districts such as Chittorgarh (14%), Dungarpur (12%) and Banswara (10%) reported moderate levels of activity, while Salumber (7%) and Pratapgarh (3%) documented the least cases. The lower numbers in Pratapgarh could be attributed to its smaller population or a reduced rate of forensic investigations.

V. CONCLUSION

For 135 cases, where forensic analysis was conducted, the study found an unnatural mortality workload based mainly on accidental deaths (39.26%) and suicides (21.48%). Natural or sudden death accounted for approximately 14.81% of the cases. The finding reveals a significant public health risk caused by the high accessibility of agricultural toxicants, specifically organophosphate insecticides and phosphide, which were detected in 25% of all cases, often in combinations with alcohol consumption. The finding also reveals a significant gender gap, with males accounting for 68.89% of cases compared to 31.11% for females, likely due to their increased exposure to workplace hazards, substance misuse, and external socio-economic pressures. The research finds that many unnatural deaths in the region are linked to poisoning especially Organophosphorus (OPs) and Phosphides and also alcohol -related incidents. This suggests the urgent needs for public-awareness campaign aimed at preventing accidental poisoning and suicides, tighten controls on agricultural toxins, expand mental health support, especially for young and middle-aged adults.

Conflict of interest
We author hereby declare no conflict of interest.

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