An Empirical Study on the Application of Forensic Toxicology in Criminal Proceedings

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Abstract—**Forensic toxicology plays a crucial role in criminal proceedings by detecting and analyzing toxic substances in biological samples to determine their impact on a case. This paper explores the methodologies, applications, and limitations of forensic toxicology in criminal justice, highlighting its indispensable role in modern forensic investigations. The objectives include understanding how demographic variables like age, gender, educational qualification, occupation, and monthly income (independent variables) affect the application of forensic toxicology in criminal proceedings. A total of 204 samples were collected. These include the main challenges in applying forensic toxicology in criminal proceedings. However, challenges such as sample degradation, post-mortem redistribution, and interpretation complexities must be carefully managed to ensure the credibility of evidence. The aim of the study is to explore the use of sophisticated techniques such as gas chromatography-mass spectrometry and high-performance liquid chromatography, which enhance the accuracy and reliability of toxicological analysis. The findings serve as crucial evidence in court, helping establish whether a substance contributed to a crime, influenced a suspect's behavior, or played a role in accidental or intentional poisoning. The study concludes that the integration of artificial intelligence in toxicological analysis will further strengthen the role of forensic toxicology in criminal justice.**

Keywords—**Forensic toxicology; Offenses; Application; Criminal procedure; Evidence**

I. Introduction

Forensic toxicology plays a pivotal role in criminal proceedings by bridging the gap between science and law. It involves the study and application of toxicology, which focuses on the detection, identification, and quantification of toxic substances in biological and non-biological specimens. The credibility and reliability of forensic toxicological evidence have a direct impact on the justice delivery system. With the advancement of technology and increasing awareness of forensic applications, courts are relying more heavily on scientific evidence to arrive at fair judgments. Therefore, understanding how forensic toxicology is being applied empirically in real-life criminal proceedings is essential for improving its effectiveness and integration into the legal framework. This study aims to explore the application of forensic toxicology in criminal proceedings, emphasizing its significance in identifying and interpreting toxic substances in legal contexts and also to analyze the role of forensic toxicology in investigating and solving crimes.

The evolution of forensic toxicology originated in the early 19th century, driven by the need to identify poisons in suspicious deaths. After World War II, the discovery of more sophisticated tools, such as mass spectrometry and liquid chromatography, revolutionized the field. These technologies allowed for the detection of minute traces of toxic substances, improving the accuracy and reliability of toxicological analyses. The mid-20th century saw the rise of drug-related crimes and drug abuse, prompting the integration of drug testing in forensic toxicology. Cases involving narcotics, alcohol-impaired driving, and drug-facilitated crimes became focal points for toxicological research and application. In India, forensic

science, including toxicology, began to take shape during the British colonial period, with the establishment of chemical examiner laboratories in the early 20th century. Over time, the field has evolved with better instrumentation such as Gas Chromatography-Mass Spectrometry (GC-MS), Liquid Chromatography-Mass Spectrometry (LC-MS), and Enzyme-Linked Immunosorbent Assays (ELISA), which allow precise detection of toxins even in trace amounts.

The key factors affecting the application and effectiveness of forensic toxicology in criminal proceedings include infrastructure and resource constraints, as many labs face shortages of advanced equipment and trained toxicologists; backlogs in labs that can delay justice; chain of custody, sample contamination, and improper documentation that can lead to evidence being rejected in court; a lack of understanding about toxicological methods that can hinder effective application; and variability in lab procedures and lack of accreditation that affect the credibility of reports. The chemical complexity and diversity of toxins, including synthetic drugs, novel psychoactive substances (NPS), and biotoxins, make detection challenging. Addressing these factors is crucial to enhance the accuracy, reliability, and legal utility of forensic toxicology in criminal proceedings.

The Government of India has implemented several initiatives to enhance forensic toxicology and forensic science within the criminal justice system, such as the National Forensic Infrastructure Enhancement Scheme (NFIES), which established nine off-campus centers of the National Forensic Sciences University (NFSU) and set up seven new Central Forensic Science Laboratories (CFSLs). Established in 2020, NFSU focuses on providing quality education and training in forensic science. Training programs are also conducted by institutions like Lok Nayak Jayaprakash Narayan National Institute of Criminology & Forensic Science (LNJN NICFS). These initiatives reflect the government's commitment to integrating scientific methods into the criminal justice system, ensuring timely and accurate forensic examinations, and enhancing the overall efficiency of legal proceedings in India.

Current trends in forensic toxicology reflect advancements in technology, an increasing focus on novel substances, and the growing integration of science into legal frameworks. With the rise of synthetic drugs such as synthetic cannabinoids and cathinones, forensic toxicology is evolving to detect and analyze these rapidly changing substances. Key trends include automation and AI in toxicology through the use of software tools for pattern recognition and data analysis; integration of genetic profiling with toxicology to understand individual susceptibility to toxins; combining toxicology reports with mobile, digital, and surveillance data to build stronger cases; and improved global cooperation for cross-border toxicological investigations, especially in narcotics and trafficking cases. In the case of Rajkishorsingh Ranvirsingh Tomar vs. The State Of Maharashtra (2021), the Bombay High Court upheld that forensic toxicology reports could be admitted as evidence without the expert's testimony unless the court deemed it necessary or the accused requested the expert's examination, underscoring the critical role of forensic toxicology reports in legal proceedings.

The application of forensic toxicology in criminal proceedings varies significantly when comparing India with other countries due to differences in infrastructure, technological advancements, legal systems, and expertise. India has a limited number of forensic laboratories, often resulting in delays in processing samples. Countries like the USA, UK, and Germany have well-funded forensic laboratories equipped with state-of-the-art technologies, including HRMS and DNA-based toxicogenomics, automated and integrated with AI tools to enhance accuracy and speed. While the field has evolved significantly and gained greater importance in the Indian criminal justice system, challenges remain in terms of infrastructure, awareness, standardization, and legal integration.

II. Objectives

The objectives of this study are: to analyse the main challenges in applying forensic toxicology in criminal proceedings; to explore the effectiveness of the existing guidelines for the analysis and interpretation of forensic toxicology evidence; and to analyse whether forensic toxicology provides scientifically valid evidence and its effects in criminal cases.

III. Review of Literature

Johnson and Carter (2010) aimed to evaluate the reliability of forensic toxicology methods in criminal investigations. Their findings revealed that when forensic laboratories adhere to standardized protocols, the accuracy of substance identification improves markedly, thereby enhancing the reliability of evidence presented in court. The study concluded that standardization plays a crucial role in strengthening the credibility of toxicological results.

Smith et al. (2012) investigated the challenges associated with interpreting toxicology reports in criminal cases. The study found that issues such as sample degradation and matrix interferences significantly impact the validity of test results, often leading to misinterpretation in legal settings. The researchers emphasized the urgent need for stricter quality control measures and standardized testing protocols in forensic laboratories.

Davis and Lee (2013) assessed the contribution of forensic toxicology to postmortem investigations, particularly in cases involving ambiguous or unexplained deaths. The results highlighted that comprehensive toxicological profiling is critical in determining the cause of death, especially when external injuries or signs are minimal. The study concluded that integrating advanced analytical techniques with conventional autopsy methods can greatly enhance forensic accuracy.

Martin (2014) focused on evaluating the reliability of toxicological screening techniques used in the criminal justice system. Findings demonstrated that while current screening techniques generally offer high accuracy, inconsistencies in sample handling and processing can lead to variable outcomes. Martin concluded that continuous improvements in screening protocols and technician training are necessary.

Patel and Rodriguez (2015) examined emerging trends in the application of forensic toxicology to drug-related crimes, with a particular focus on the detection of novel psychoactive substances (NPS). Their findings indicated that new technologies have significantly improved the ability to identify NPS, which are frequently undetectable using older systems.

Green et al. (2016) explored the application of forensic toxicology in criminal cases involving impaired driving. Their findings revealed that toxicological evidence, particularly blood alcohol concentration and presence of controlled substances, plays a critical role in substantiating charges and securing convictions in DUI cases.

Thompson (2016) investigated the interpretative challenges associated with poly-drug intoxication in forensic toxicology. The findings indicated that poly-drug use often complicates the analysis, leading to ambiguous results and potential misjudgments in court. The author concluded that there is a pressing need to develop integrated and standardized interpretative frameworks to more accurately assess the implications of multi-drug exposures.

Hernandez and Wu (2017) evaluated the utility of forensic toxicology in sexual assault cases, with a particular focus on drug-facilitated crimes. The study found that toxicological analyses are essential for confirming whether the victim was drugged, often providing the key scientific basis for corroborating testimony and supporting the prosecution.

Clark and Nguyen (2017) analyzed the effectiveness of forensic toxicology in criminal poisoning cases. The findings demonstrated that accurate and precise identification of toxins significantly contributes to successful prosecutions by providing clear cause-effect relationships between the toxic substance and the victim's symptoms or death.

Williams et al. (2018) assessed the impact of sample preservation techniques on the outcomes of forensic toxicological analyses. The findings revealed that improper handling or delays in sample processing can significantly alter toxicological profiles, potentially leading to compromised or inadmissible evidence.

O'Brien (2018) studied the contribution of forensic toxicology in solving homicide cases, applying advanced mass spectrometry techniques. The study found that such evidence often served as the critical factor in resolving ambiguous deaths. Li and Kim (2019) examined the limitations of current forensic toxicology practices, identifying significant inconsistencies resulting from methodological variability across different forensic labs.

Kumar et al. (2019) evaluated forensic toxicological profiles in overdose cases involving synthetic opioids using liquid chromatography-tandem mass spectrometry (LC-MS/MS). Their findings highlighted

the difficulty of detecting these potent compounds using conventional methods and emphasized the growing threat of novel opioids.

Romero and Patel (2020) investigated the role of forensic toxicology in determining the cause of death in ambiguous criminal cases by integrating toxicological data with traditional autopsy findings. Baker (2020) explored the evidentiary value of forensic toxicology in the reexamination of cold cases, finding that retrospective analyses using updated methods often led to significant breakthroughs.

Martinez and Davis (2021) assessed the detection of novel psychoactive substances (NPS) using high-resolution mass spectrometry (HRMS), confirming that HRMS techniques are capable of detecting a wide range of NPS that traditional methods may overlook. Singh et al. (2021) examined challenges associated with toxicological analysis in cases involving mixed substance ingestion, finding that such complexity often leads to misclassification or inconclusive results.

Chen (2022) evaluated the emerging role of forensic toxicology in addressing environmental poisoning cases linked to criminal activities, highlighting the increasing intersection between environmental hazards and criminal offenses. Ahmed and Silva (2022) investigated the integration of forensic toxicology with digital evidence in modern criminal proceedings, demonstrating that this convergence significantly enhances case reconstruction and strengthens prosecutorial arguments.

Evans et al. (2023) conducted a comprehensive review to analyze current trends and future directions in the application of forensic toxicology within the criminal justice system. Findings highlighted the rapid pace of technological innovation, including automation and AI-based analysis, alongside persistent issues such as standardization and interpretation complexity.

IV. Methodology

The primary source of data was obtained by conducting an empirical study seeking responses from the general public in and around Chennai. The data was collected through questionnaires and also relied on secondary sources of data such as books, journals, e-sources, articles, and newspapers. The research methodology used here is based on empirical research. The sampling size of the paper is 204. SPSS software is used for analysis purposes. The sampling frame includes respondents from all kinds of age groups. The independent variables are age, gender, educational qualification, occupation, and monthly income. The dependent variable represents the application of forensic toxicology in criminal proceedings. The research tools used are graphs and chi-square tests.
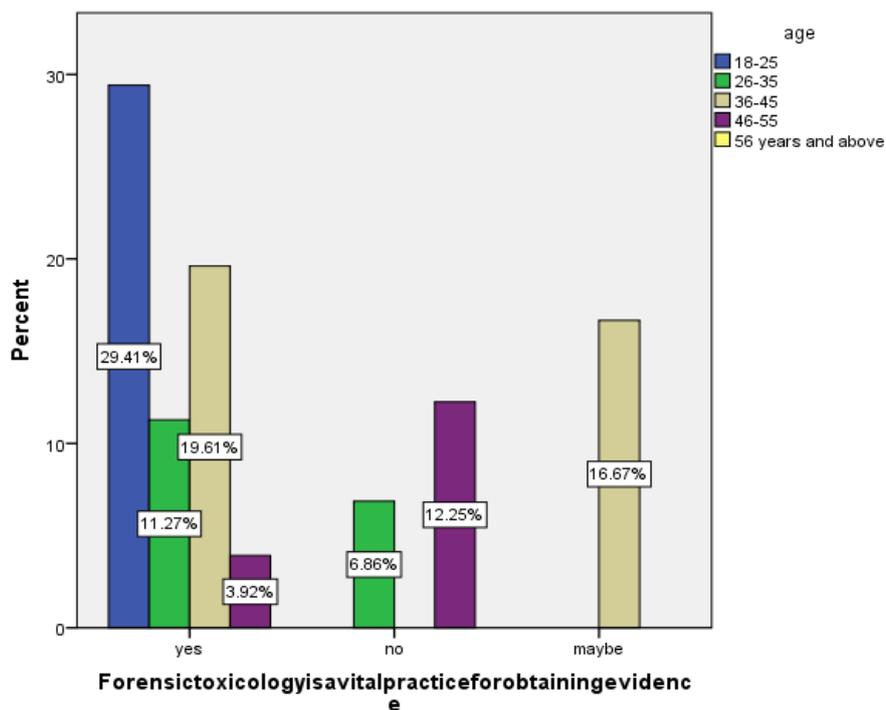
V. Analysis

Fig. 1. Comparison between age and forensic toxicology as a vital practice for obtaining evidence.
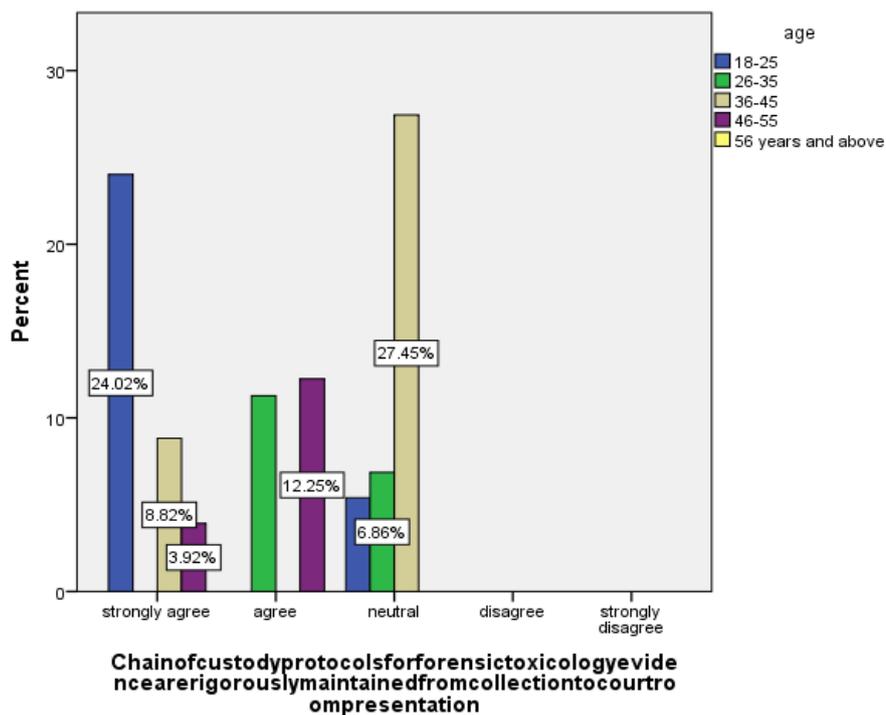

Fig. 2. Comparison between age and chain of custody protocols for forensic toxicology evidence rigorously maintained from collection to courtroom presentation.
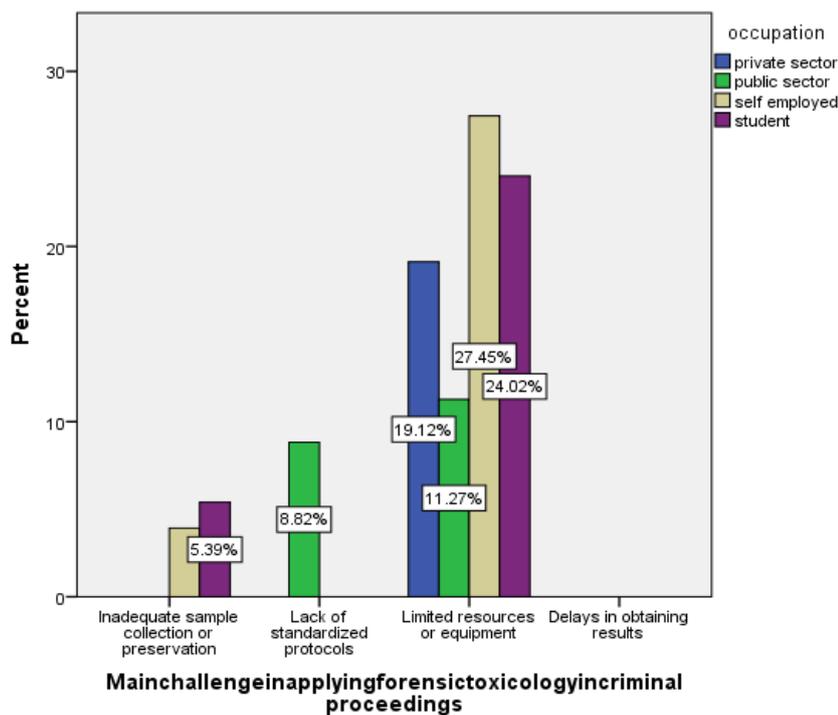
Fig. 3. Main challenge in applying forensic toxicology in criminal proceedings with special reference to occupation.
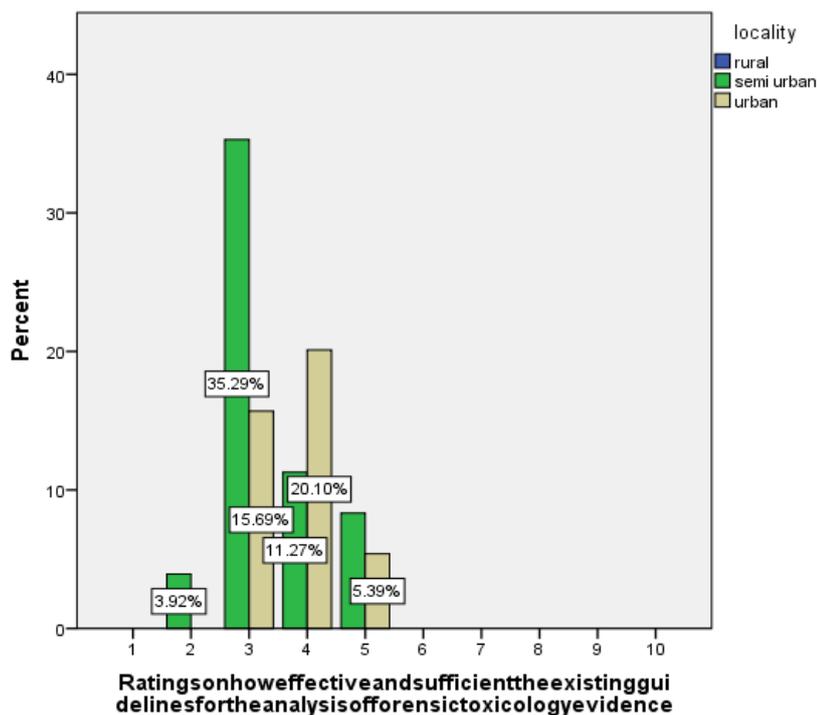

Fig. 4. Ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence with special reference to locality.
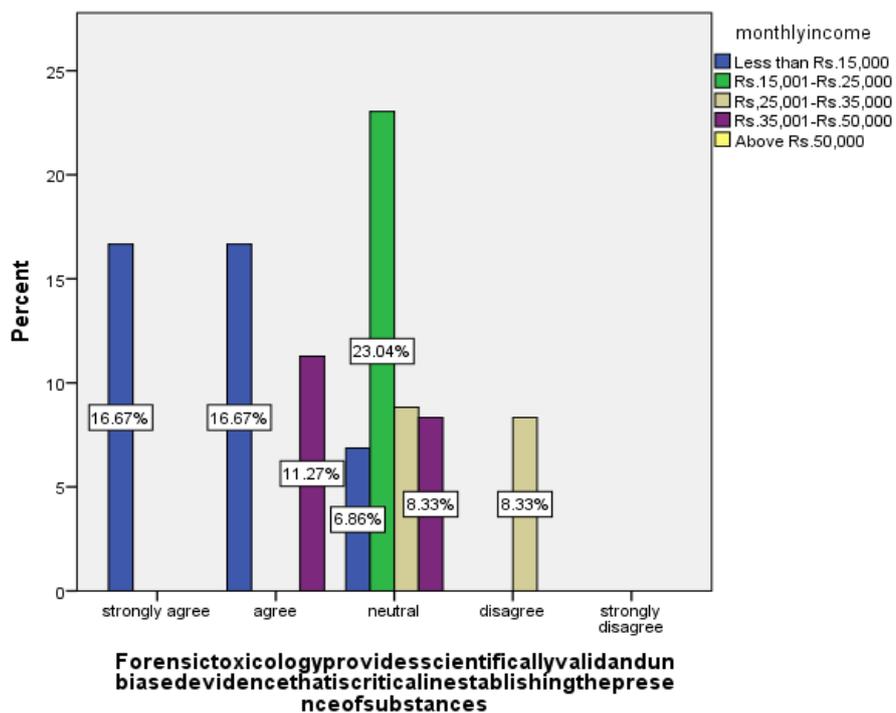
Fig. 5. Comparison between monthly income and forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substances.
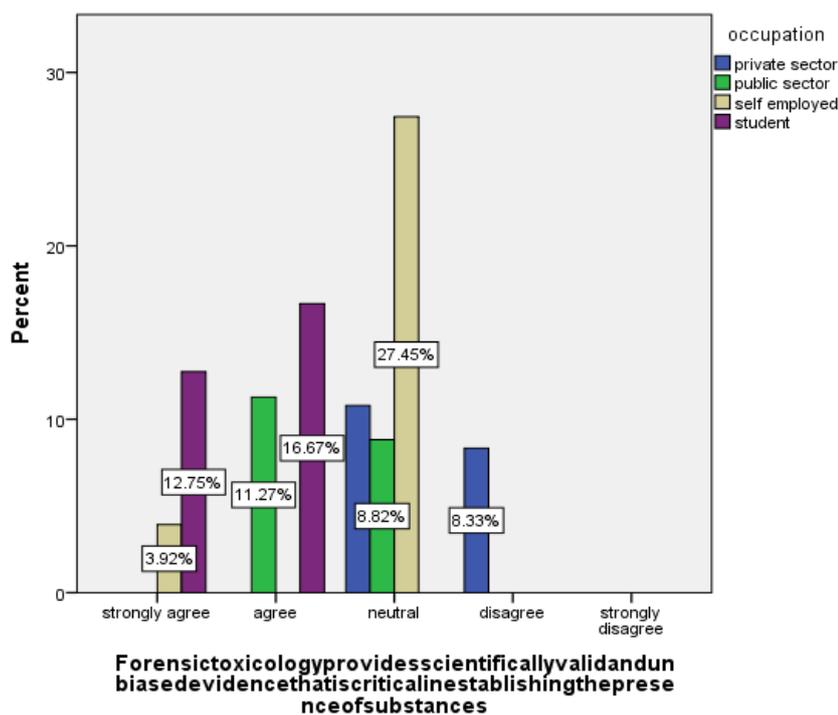

Fig. 6. Comparison between occupation and forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substances.
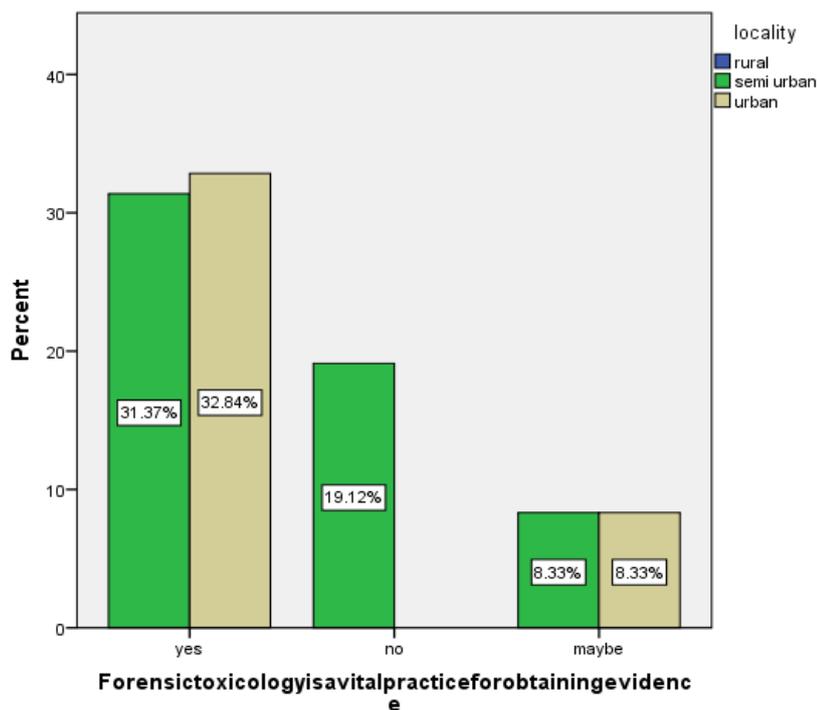
Fig. 7. Comparison between locality and forensic toxicology as a vital practice for obtaining evidence.
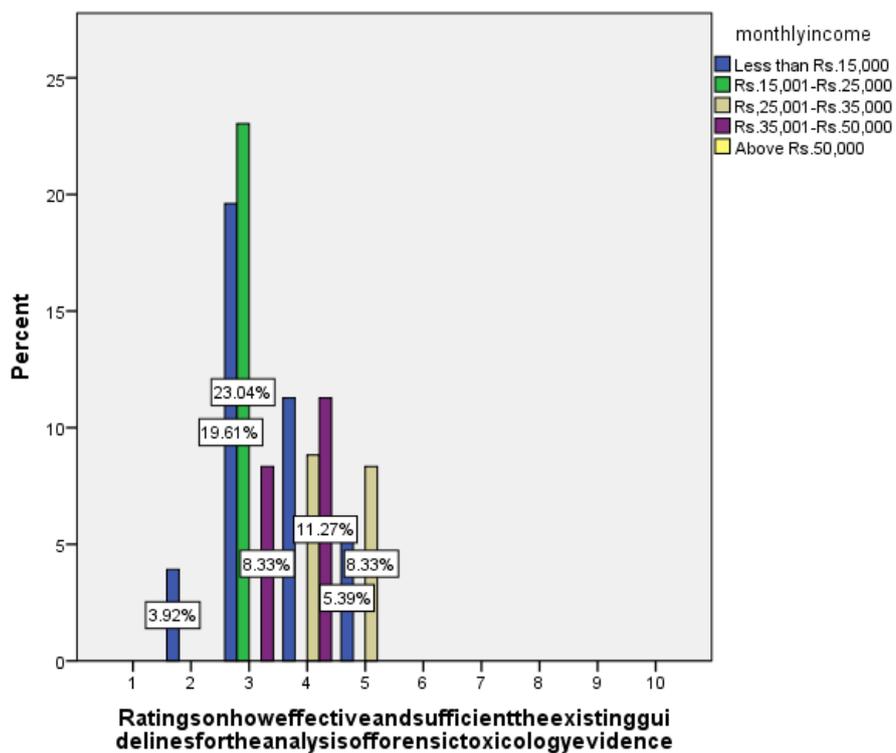

Fig. 8. Comparison between monthly income and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

Fig. 9. Comparison between locality and main challenge in applying forensic toxicology in criminal proceedings.
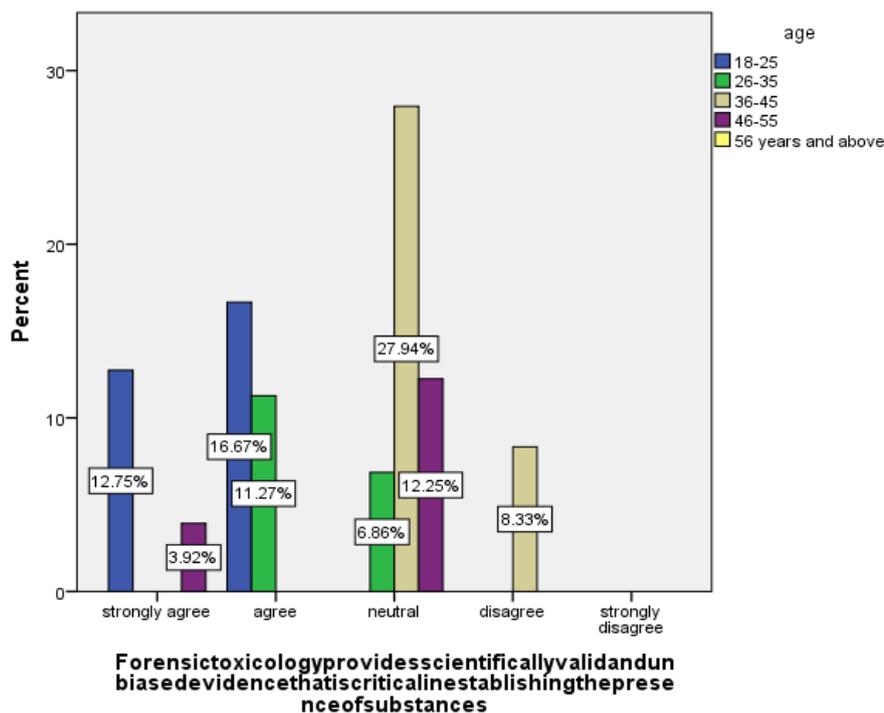
Fig. 10. Comparison between age and forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substance.

Fig. 11. Comparison between gender and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.
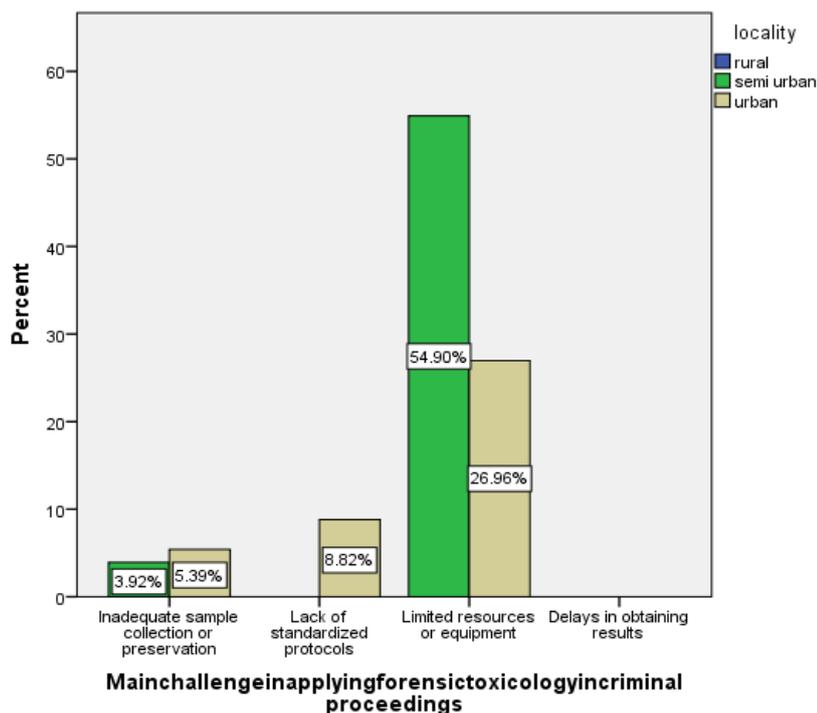

Fig. 12. Comparison between occupation and forensic toxicology as a vital practice for obtaining evidence.
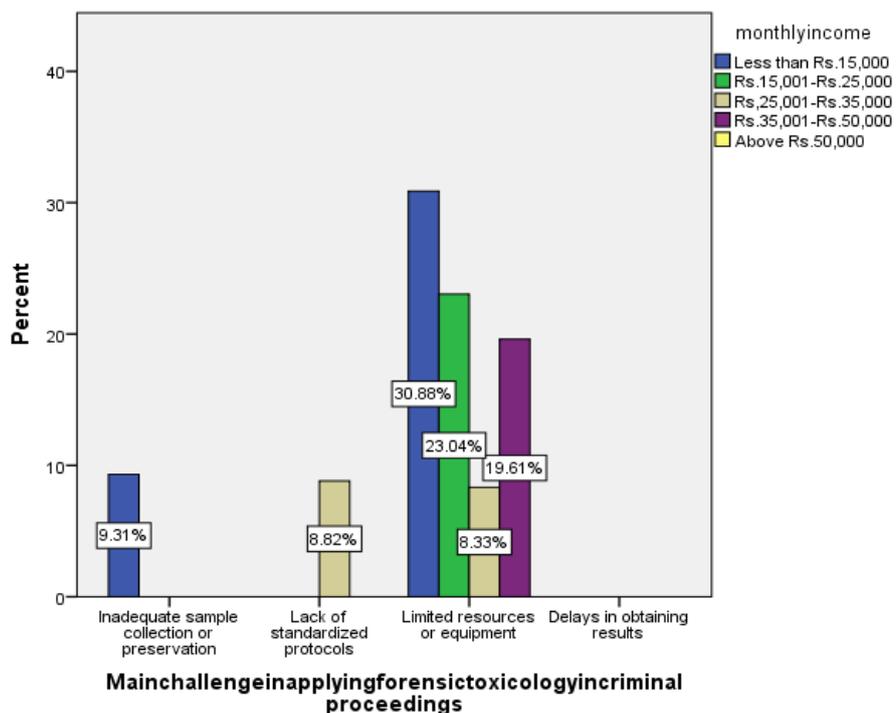
Fig. 13. Comparison between monthly income and main challenge in applying forensic toxicology in criminal proceedings.

Fig. 14. Comparison between gender and chain of custody protocols for forensic toxicology evidence rigorously maintained from collection to courtroom presentation.

Fig. 15. Comparison between locality and chain of custody protocols for forensic toxicology evidence rigorously maintained from collection to courtroom presentation.
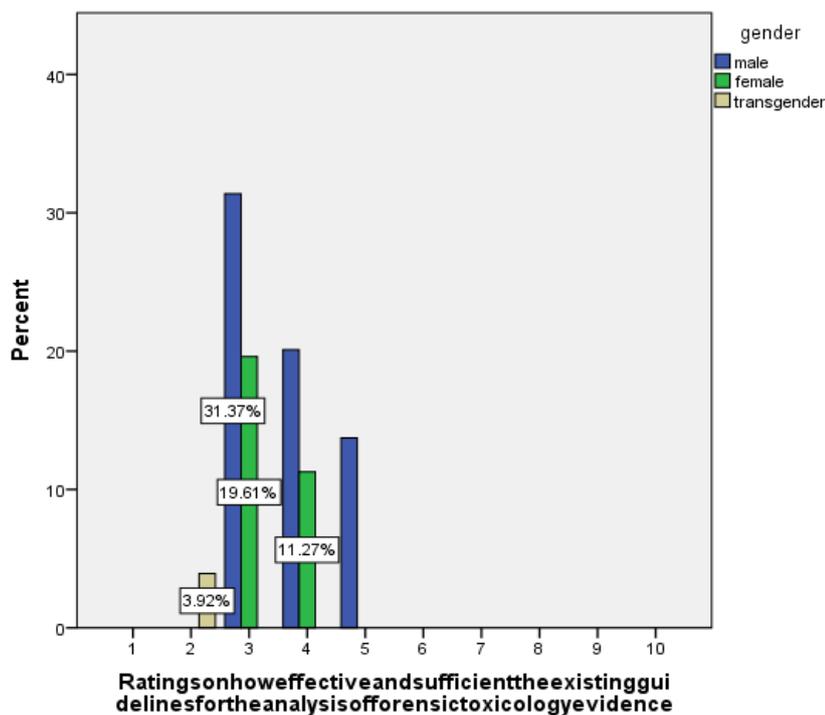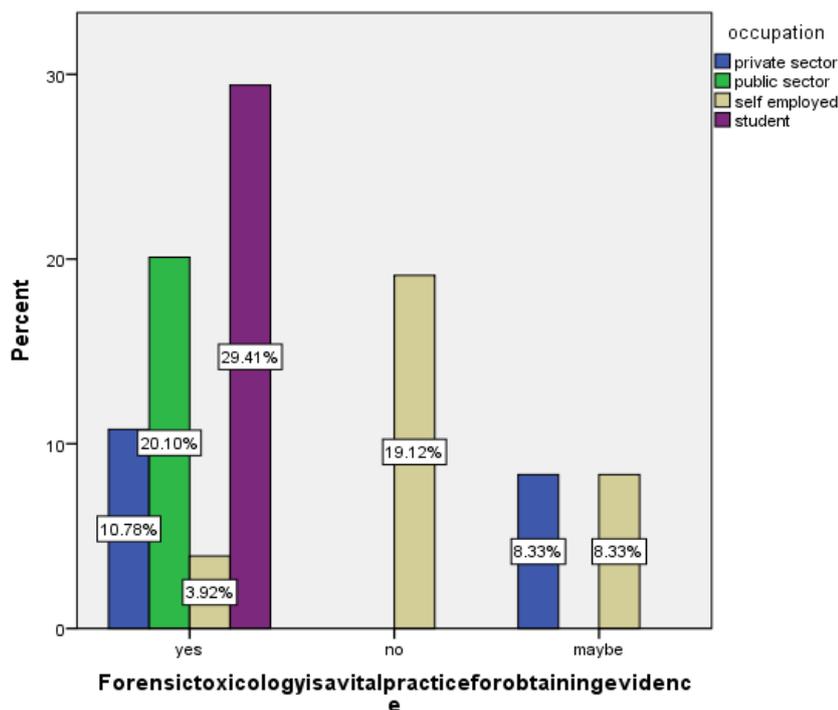

Fig. 16. Comparison between age and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

H_0: There is no significant association between gender and chain of custody protocols for forensic toxicology evidence that are rigorously maintained from collection to courtroom presentation.

H_a: There is a significant association between gender and chain of custody protocols for forensic toxicology evidence that are rigorously maintained from collection to courtroom presentation.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
gender * Chainofcustodyprotocolsforforensictoxicologyevidencearerigorouslymaintainedfromcollectiontocourtroompresentation	204	100.0%	0	0.0%	204	100.0%

gender * Chainofcustodyprotocolsforforensictoxicologyevidencearerigorouslymaintainedfrom collectiontocourtroompresentation Crosstabulation

Count

		Chainofcustodyprotocolsforforensictoxicologyevidencearerigorouslymaintainedfromcollectiontocourtroompresentation			Total
		strongly agree	agree	neutral	
gender	male	52	25	56	133
	female	15	23	25	63
	transgender	8	0	0	8
Total		75	48	81	204

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	22.802[a]	4	.000
Likelihood Ratio	24.896	4	.000
Linear-by-Linear Association	1.401	1	.236
N of Valid Cases	204		

a. 3 cells (33.3%) have expected count less than 5. The minimum expected count is 1.88.
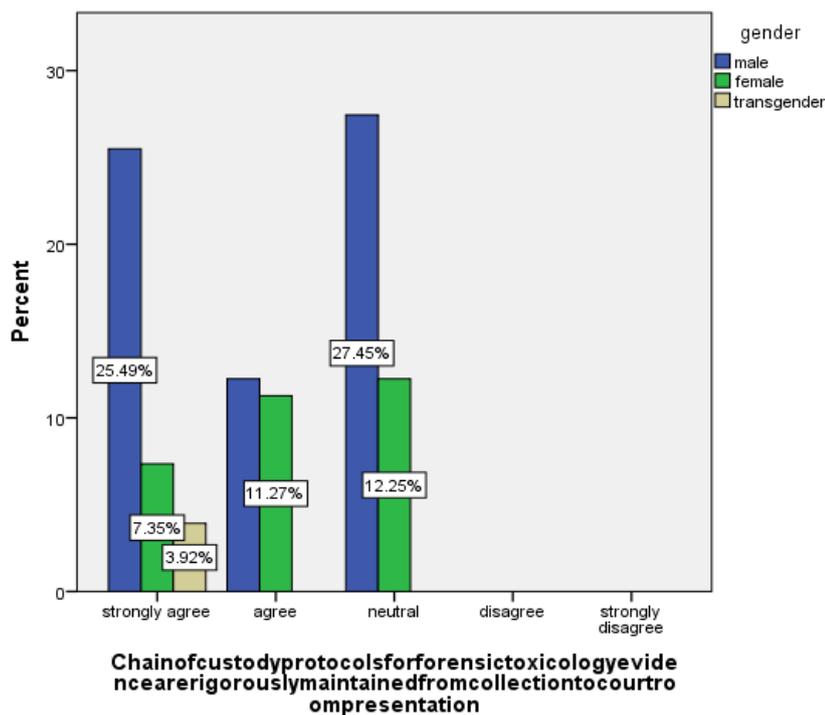
Legend: The Chi-square test shows the significant association between gender and chain of custody protocols for forensic toxicology evidence that are rigorously maintained from collection to courtroom presentation.
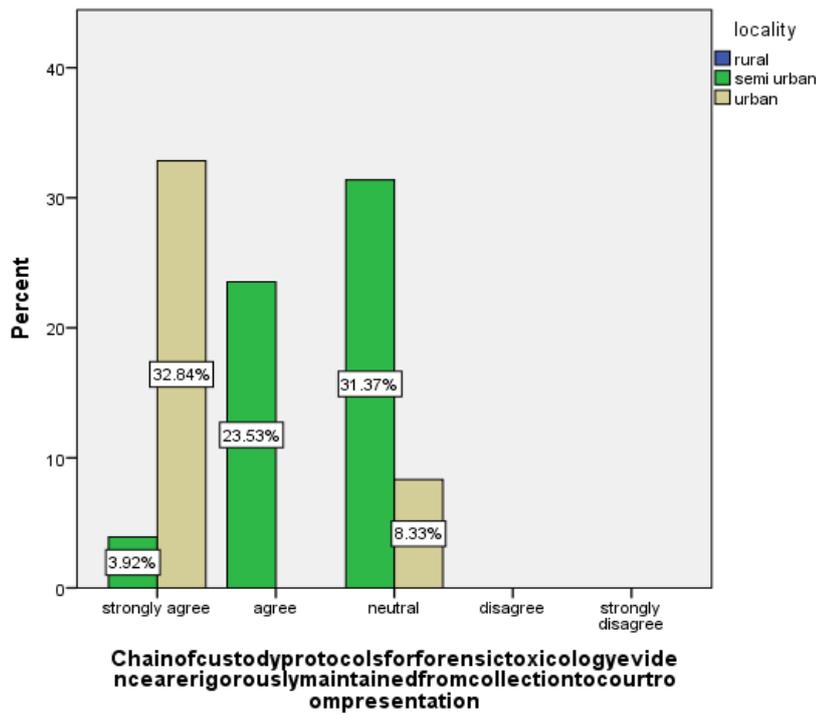
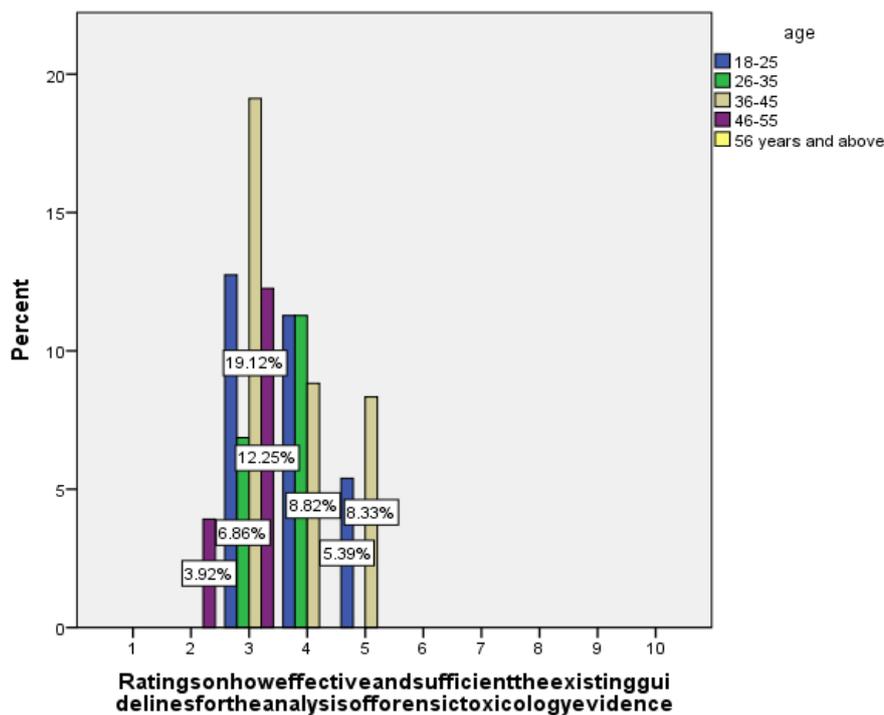H_0: There is no significant association between occupation and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

H$_a$: There is a significant association between occupation and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
occupation * Ratingsonhoweffectiveandsufficienttheexistingguidelinesfortheanalysisofforensictoxicologyevidence	204	100.0%	0	0.0%	204	100.0%

occupation * Ratingsonhoweffectiveandsufficienttheexistingguidelinesfortheanalysisofforensictoxicologyevidence Crosstabulation

Count

		Ratingsonhoweffectiveandsufficienttheexistingguidelinesfortheanalysisofforensictoxicologyevidence				Total
		2	3	4	5	
occupation	private sector	0	22	0	17	39
	public sector	0	0	41	0	41
	self employed	8	56	0	0	64
	student	0	26	23	11	60
Total		8	104	64	28	204

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	191.531[a]	9	.000
Likelihood Ratio	224.985	9	.000
Linear-by-Linear Association	6.900	1	.009
N of Valid Cases	204		

a. 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.53.

Legend: The Chi-square test shows the significant association between occupation and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

H$_0$: There is no significant association between monthly income and forensic toxicology provides scientifically valid and unbiased evidence that is critical in establishing the presence of substance.

H$_a$: There is a significant association between monthly income and forensic toxicology provides scientifically valid and unbiased evidence that is critical in establishing the presence of substance.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
monthlyincome * Forensictoxicologyprovidesscientificallyvalidandunbiasedevidencethatiscriticalinestablishingthepresenceofsubstances	204	100.0%	0	0.0%	204	100.0%

monthlyincome * Forensictoxicologyprovidesscientificallyvalidandunbiasedevidencethatiscriticalinestablishingthepresenceofsubstances Crosstabulation

Count

		Forensictoxicologyprovidesscientificallyvalidandunbiasedevidencethatiscriticalinestablishingthepresenceofsubstances				
		strongly agree	agree	neutral	disagree	Total
monthlyincome	Less than Rs.15,000	34	34	14	0	82
	Rs.15,001-Rs.25,000	0	0	47	0	47
	Rs,25,001-Rs.35,000	0	0	18	17	35
	Rs.35,001-Rs.50,000	0	23	17	0	40
Total		34	57	96	17	204

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	217.436[a]	9	.000
Likelihood Ratio	224.145	9	.000
Linear-by-Linear Association	40.021	1	.000
N of Valid Cases	204		

a. 3 cells (18.8%) have expected count less than 5. The minimum expected count is 2.92.

Legend: The Chi-square test shows the significant association between monthly income and forensic toxicology provides scientifically valid and unbiased evidence that is critical in establishing the presence of substance.

H_0: There is no significant association between locality and forensic toxicology is a vital practice for obtaining evidence.

H_a: There is a significant association between locality and forensic toxicology is a vital practice for obtaining evidence.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
locality * Forensictoxicologyisavital practiceforobtainingevidence	204	100.0%	0	0.0%	204	100.0%

locality * Forensictoxicologyisavitalpracticeforobtainingevidence Crosstabulation

Count

		Forensictoxicologyisavitalpracticeforobtainingevidence			Total
		yes	no	maybe	
locality	semi urban	64	39	17	120
	urban	67	0	17	84
Total		131	39	34	204

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	33.767[a]	2	.000
Likelihood Ratio	47.748	2	.000
Linear-by-Linear Association	3.497	1	.061
N of Valid Cases	204		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.00.

Legend: The Chi-square test shows the significant association between locality and forensic toxicology is a vital practice for obtaining evidence.

VI. Results

In Figure 1, 29.41% of respondents between the age group of 18–25 years opted yes for forensic toxicology as a vital practice for obtaining evidence and 19.61% of respondents between the age group of 36–45 years also opted yes. In Figure 2, 27.45% of respondents between the age group of 36–45 years were neutral that chain of custody protocols for forensic toxicology evidence are rigorously maintained from collection to courtroom presentation, and 24.02% of respondents between the age group of 18–25 years strongly agreed. In Figure 3, 27.45% of self-employed respondents opted that limited resources of equipment is the main challenge in applying forensic toxicology in criminal proceedings. In Figure 4, 35.29% of semi-urban respondents opted 3 on the scale of 10 on the ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

In Figure 5, 23.04% of respondents with monthly income of Rs.15,001–Rs.25,000 were neutral that forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substance. In Figure 6, 27.45% of self-employed respondents were neutral that forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substance. In Figure 7, 32.84% of urban respondents opted yes that forensic toxicology is a vital practice for obtaining evidence. In Figure 8, 23.04% of respondents with monthly income of Rs.15,001–Rs.25,000 rated 3 on the scale of 10 on the ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

In Figure 9, 54.90% of urban respondents opted that limited resources of equipment are the main challenge in applying forensic toxicology in criminal proceedings. In Figure 10, 27.94% of respondents between the age group of 36–45 years were neutral that forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substance. In Figure 11, 31.37% of male respondents rated 3 on the scale of 10 on the ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence. In Figure 12, 29.41% of student respondents opted yes that forensic toxicology is a vital practice for obtaining evidence.

In Figure 13, 30.88% of respondents with monthly income less than Rs.15,000 opted that limited resources of equipment are the main challenge in applying forensic toxicology in criminal proceedings. In Figure 14, 27.45% of male respondents were neutral that chain of custody protocols for forensic toxicology evidence are rigorously maintained from collection to courtroom presentation. In Figure 15, 32.84% of urban respondents strongly agreed that chain of custody protocols for forensic toxicology evidence are rigorously maintained from collection to courtroom presentation. In Figure 16, 19.12% of respondents between the age group of 36–45 years rated 3 on the scale of 10 on the ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence.

In Table 1, the chi-square test P value is less than 0.05, showing a significant association between gender and chain of custody protocols for forensic toxicology evidence rigorously maintained from collection to courtroom presentation. In Table 2, the chi-square test P value is less than 0.05, showing a significant association between occupation and ratings on how effective and sufficient the existing guidelines for the analysis of forensic toxicology evidence. In Table 3, the chi-square test P value is less than 0.05, showing a significant association between monthly income and forensic toxicology provides scientifically valid and unbiased evidence critical in establishing the presence of substance. In Table 4, the chi-square test P value is less than 0.05, showing a significant association between locality and forensic toxicology as a vital practice for obtaining evidence.

VII. Discussion

Figure 1 suggests that younger individuals may have a greater awareness or trust in forensic toxicology's role in criminal investigations. The difference in responses could be attributed to varying levels of exposure to forensic sciences through education, media, or professional experiences. Figure 2 implies that younger individuals might have stronger confidence in forensic procedures, whereas older individuals may have reservations or lack sufficient knowledge about the implementation of these protocols. Figure 3 suggests that those who work independently may experience firsthand the financial and infrastructural limitations in forensic investigations, which could hinder the effectiveness of toxicological analysis.

Figure 4 could reflect a lack of awareness or dissatisfaction with the implementation of forensic standards in semi-urban areas, where access to forensic resources might be more limited compared to urban settings. Figure 5 reveals that the neutrality suggests individuals in this income group may neither strongly trust nor doubt forensic toxicology, possibly due to limited direct exposure or varying levels of confidence in the legal system. Figure 6 suggests some level of uncertainty or skepticism about the reliability and impartiality of forensic evidence in legal proceedings, which may stem from perceived flaws in forensic infrastructure or legal processes.

Figure 7 may indicate greater exposure to forensic sciences in urban areas, where law enforcement and judicial institutions are more advanced, leading to higher awareness and acceptance of forensic toxicology's role in investigations. Figure 8 could reflect concerns about the accessibility and implementation of forensic procedures within this income group, possibly due to experiences with legal proceedings or forensic

investigations. Figure 9 suggests that despite better infrastructure in urban areas, there are still concerns about resource availability, funding, and technological advancements in forensic toxicology.

Figure 10 neutrality could stem from limited knowledge, skepticism about forensic science's reliability, or concerns about the judicial system's ability to handle forensic evidence effectively. Figure 11 could indicate a need for more comprehensive and transparent forensic regulations to ensure confidence in forensic toxicology among male respondents. Figure 12 may reflect an academic understanding of forensic science's importance, as students are more likely to be exposed to scientific advancements and forensic methodologies through education.

Figure 13 suggests that lower-income individuals may perceive financial and technological constraints as significant barriers to effective forensic investigations, possibly due to a lack of government funding or forensic facilities in lower-income areas. Figure 14 neutrality may indicate a lack of confidence or awareness regarding procedural integrity, which could be influenced by personal experiences or exposure to cases where forensic evidence handling was questioned. Figure 15 positive response could be attributed to better forensic facilities and stricter legal enforcement in urban settings. Figure 16 highlights the need for clearer, updated guidelines to enhance the credibility and application of forensic toxicology in legal proceedings.

From Table 1, the test reveals a significant association between gender and chain of custody protocols in forensic toxicology ($p < 0.05$). From Table 2, a significant association was found between occupation and ratings on the sufficiency of forensic toxicology guidelines ($p < 0.05$). From Table 3, a significant relationship was identified between monthly income and perceptions of forensic toxicology as scientifically valid and unbiased ($p < 0.05$). From Table 4, a significant association was found between locality and perceptions of forensic toxicology as a vital practice ($p < 0.05$).

VIII. Limitations

In postmortem cases, the decomposition of a body can alter toxicological findings. Some drugs break down over time, making it difficult to determine the exact levels at the time of death. Detecting a drug or toxin does not always mean it caused death or impairment. Factors like metabolism, tolerance, and interactions with other substances can complicate interpretation.

IX. Conclusion

In conclusion, forensic toxicology is an evolving field that bridges science and law, ensuring that toxicological evidence is not only scientifically valid but also legally admissible in courts. To maximize its effectiveness, ongoing research, technological advancements, and adherence to standardized protocols are essential in enhancing the accuracy, efficiency, and credibility of forensic toxicology in criminal proceedings. A total of 204 samples were collected. Forensic toxicology plays a pivotal role in modern criminal investigations by providing critical scientific evidence that aids in establishing facts related to cause of death, substance use, poisoning, and impairment. Through advanced analytical techniques such as gas chromatography-mass spectrometry (GC-MS), liquid chromatography-mass spectrometry (LC-MS/MS), and immunoassays, forensic toxicologists can detect and quantify drugs, alcohol, toxins, and other chemicals in biological samples, ensuring objective and reliable evidence for the justice system.

The reliability and admissibility of forensic toxicology evidence depend on standardized methodologies, rigorous quality control, and expert interpretation. Cases involving postmortem toxicology, drug-facilitated crimes, impaired driving, and workplace substance abuse testing highlight the discipline's diverse applications. However, challenges such as sample degradation, poly-drug interactions, and evolving synthetic drugs require continuous advancements in analytical techniques and regulatory policies. It is suggested to implement high-resolution mass spectrometry and next-generation sequencing to improve the detection of rare or unknown substances and to establish uniform guidelines for sample collection, storage, and analysis to minimize errors and ensure consistency across forensic laboratories.

Future developments, including the integration of artificial intelligence (AI) in toxicological analysis, improved sensitivity of analytical instruments, and enhanced interpretative models, will further strengthen the role of forensic toxicology in criminal justice. With continued government support, technological advancements, and training of legal and forensic professionals, India can enhance the reliability and impact

of forensic toxicology in the courtroom. Learning from best practices in countries like the United States can also help accelerate reforms and build a robust forensic ecosystem.

X. References

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