IJCE, Vol. 2, No. 1, July 2025, pp. 26–33

Indonesian Journal of Chemical Education

https://journal.uny.ac.id/index.php/ijce/index

Investigating the concept of chemical functionalization in forensic applications among pharmacy students: A questionnaire study

Khalid W. Zainulabdeen[1], Alaa A. Rashad[1], Shams A. Ismeal[2], Muna Bufaroosha[3], Shaimaa A. Hussein[4], Omar Al-Tameemi[5], Ziad Fidil[6], Wedad H. Al-Dahhan[1], Rahimi M. Yusop[7], Emad Yousif ✉ [1]

[1]Department of Chemistry, College of Science, Al-Nahrain University, Baghdad, Iraq
[2]Department of Medical Physics, College of Science, Al-Nahrain University, Baghdad, Iraq
[3]Department of Chemistry, College of Science, United Arab Emirates University, Al-Ain, United Arab Emirates.
[4]College of Medicine, Al-Nahrain University, Baghdad, Iraq
[5]Department of Mathematics and Computer Application, College of Science, Al-Nahrain University, Baghdad, Iraq
[6]College of Pharmacy, University of Thi-Qar, Nasiriyah, Iraq
[7]School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

Article Info

Received: Feb 6th, 2025
Revised: Mar 20th, 2025
Accepted: Jul 21st, 2025

Keywords:

Functionalizing, Pharmacology, Forensic, students, science, understanding

Abstract

Forensic science plays a crucial role in the criminal justice system by providing essential evidence and aiding the resolution of crimes. One significant aspect of forensic science is functionalizing pharmacology, which involves the analysis of drugs and their metabolites in biological samples to ascertain their origins and potential effects. It is imperative for future healthcare professionals, particularly pharmacy students, to gain a comprehensive understanding of the functionalization of pharmacology in forensic science. However, there is a paucity of research on pharmacy students' current knowledge and comprehension in this specific domain. Hence, the present study aimed to utilize a questionnaire-based approach to explore pharmacy students' understanding of functionalizing pharmacology in forensic science. The primary objective of this investigation was to identify strengths and weaknesses within this cohort's knowledge base, ultimately offering recommendations for enhancing pharmacy education in this field.

✉ Corresponding Author:
Emad Yousif
emad_yousif@hotmail.com

e-ISSN 2581-2645

INTRODUCTION

Forensic science is a highly specialized discipline in criminal investigations and legal matters (Roux et al., 2012). Conversely, pharmacology focuses on understanding the characteristics and impact of drugs on the human body (Zhou et al., 2016). The convergence of these two fields has given rise to forensic pharmacology, which encompasses the scrutiny of drugs and toxins to provide valuable insights for legal and criminal inquiries (Petoft & Abbasi, 2016). Functionalizing pharmacology assumes a vital role in forensic pharmacology, encompassing the examination of drug metabolism and its physiological effects (Peters & Steuer, 2019). Functionalization pharmacology assumes a critical role in forensic science by utilizing deliberate chemical modifications to augment the detection and characterization of particular compounds (Peters & Steuer, 2019). These modifications involve adding specific chemical groups or tags to target compounds, thus improving the sensitivity and specificity of analytical methods (Thieme et al., 2014). This, in turn, enables the more precise identification and quantification of compounds present in

intricate matrices (Thieme et al., 2014). Functionalization can be accomplished through diverse chemical reactions, including oxidation, reduction, or conjugation, employing reactive groups such as amines, carboxylates, or thiols, such as the surface functionalization of upconversion nanoparticles with different moieties for biomedical applications (Gee & Xu, 2018).

The significance of functionalization pharmacology in forensic science lies in its ability to detect and identify compounds that pose challenges to traditional analytical methods (Manousi & Samanidou, 2021). Forensic scientists rely on this technique to identify and quantify drugs, metabolites, and toxins in biological fluids such as blood, urine, and hair (Muehlethaler et al., 2016). Additionally, functionalization enhances the analysis of compounds in complex matrices, such as soil, water, and food, thereby playing a crucial role in environmental and food safety investigations (Jiang et al., 2019)

In recent years, significant progress has been made in functionalization pharmacology, leading to innovative and highly efficient methods for compound analysis (Aljamali, & Alsabri, 2020). Notably, researchers have made remarkable strides by introducing novel tags and chemistries that substantially enhance the specificity and sensitivity of detection methodologies (Kumar et al., 2023). In addition,, they successfully devised streamlined functionalization protocols that effectively reduced the time and cost associated with the analytical process (Welch, 2019).

Moreover, functionalization pharmacology has diverse applications in forensic analysis, particularly in identifying and quantifying drugs, toxins, and other compounds in biological and environmental samples (Yao et al., 2014). Furthermore, this technique can potentially monitor drug metabolism and pharmacokinetics in vivo, providing valuable insights into drug development and clinical trials (Madabushi et al., 2022). It is worth noticing that functionalization pharmacology techniques can improve the accuracy and sensitivity of drug toxicology analyses, which is essential in drug abuse investigations and post-mortem examinations (Dragan et al., 2021). For instance, functionalization can enhance the detection of drug metabolites, providing crucial information regarding the timing and dosage of drug intake (Roszkowska et al., 2019). Furthermore, Functionalization pharmacology can play a significant role in drug metabolism and pharmacokinetics studies (Caldwell, 1996). By tagging drugs with specific functional groups, researchers can monitor their distribution, bioavailability, and elimination in vivo (Zrazhevskiy et al.,). They can also identify and quantify drug metabolites, providing insights into drug interactions and toxicity (Zhang et al., 2020).

Functionalization Techniques for Analyzing Different Types of Compounds

Functionalization techniques vary depending on the compound being analyzed (Zhang et al., 2020). For instance, different tags and chemistries can be used to functionalize drugs, toxins, or environmental pollutants (Chaudhary et al., 2023). In addition, different functionalization methods may be required, depending on the sample matrix, such as blood, urine, or soil (Yantasee et al., 2010). For example, various functionalization methods can be used in forensic science, each with advantages and limitations (Yaseen et al., 2018). Researchers must choose the most appropriate functionalization method based on the specific analytes, sample matrices, and detection methods (Yaseen et al., 2018). Common functionalization approaches include derivatization, enzymatic reactions, and click chemistry (Ansari et al., 2022).

Potential Applications of Functionalization Pharmacology in Criminal Investigations

Functionalization pharmacology, the process of adding functional groups to molecules, can potentially revolutionize the field of forensic science (Ansari et al., 2022). It can provide new insights into identifying and analyzing evidence and assisting in criminal investigations and prosecution (Zhou et al., 2016). Functionalization pharmacology can modify the chemical structure of evidence, making it easier to detect and analyze (Rathinavel et al., 2021). This can be particularly useful in cases where traditional forensic techniques fail (Peters & Steuer, 2019). For example, the functionalization of drugs and poisons can help identify the specific drug or poison used in a crime or overdose (Nadar et al., 2021). Moreover, functionalization pharmacology can aid in criminal investigations and prosecution by providing key evidence that may be difficult to obtain using traditional methods (Mayr & Machin, 2011). For example, DNA sample functionalization can aid in identifying degraded or contaminated victims or suspects (Sijin & Harbison, 2021). It can also aid in identifying individuals from hair, saliva, and tissue samples, which is important in cases where DNA samples are limited (Castillo-Peinado & De Castro, 2017).

Limitations and Challenges in the Use of Functionalization Pharmacology in Forensic Science

Although functionalization pharmacology shows enormous potential in forensic science, several limitations and challenges must be overcome for its development and implementation (Yao et al., 2014). Functionalization pharmacology is a relatively new area of research that faces several technical challenges, such as the difficulty in controlling the specific functional groups added to molecules, the potential for altering the evidence being analyzed, and the lack of standardized protocols (Vivero-Escoto et al., 2010).

Ethical and Legal Issues Related to the Use of Functionalization Pharmacology in Forensic Science

Another challenge is the ethical and legal issues that arise with functionalization pharmacology in forensic science (Buchan et al., 2022). There are concerns about privacy, informed consent, and the potential for misuse or abuse of technology (Abbate et al., 2018). These concerns must be addressed to ensure functionalization pharmacology is used responsibly and ethically (Iavicoli et al., 2017).

Pharmacy students are professionals who will play an important role in forensic pharmacology. Therefore, it is crucial to have a good understanding of functionalizing pharmacology. This study assessed pharmacy students' understanding of functionalizing pharmacology in forensic sciences. It aims to identify specific areas of strengths and weaknesses in their knowledge and highlight the implications of the findings for pharmacy education and forensic science.

The Prevalence of Exploring the Understanding of Functionalizing Pharmacology in Forensic Science among Pharmacy Students

Exploring undergraduate pharmacy students' comprehension of integrating pharmacological principles into forensic science is a nuanced and intricate subject. As a discipline, forensic pharmacology entails applying pharmacological knowledge to legal contexts, encompassing aspects such as legal disputes, drug regulatory procedures, and the criminal justice system. This field involves a detailed examination of the actions and interactions of various chemicals within living organisms (Malve, 2016).

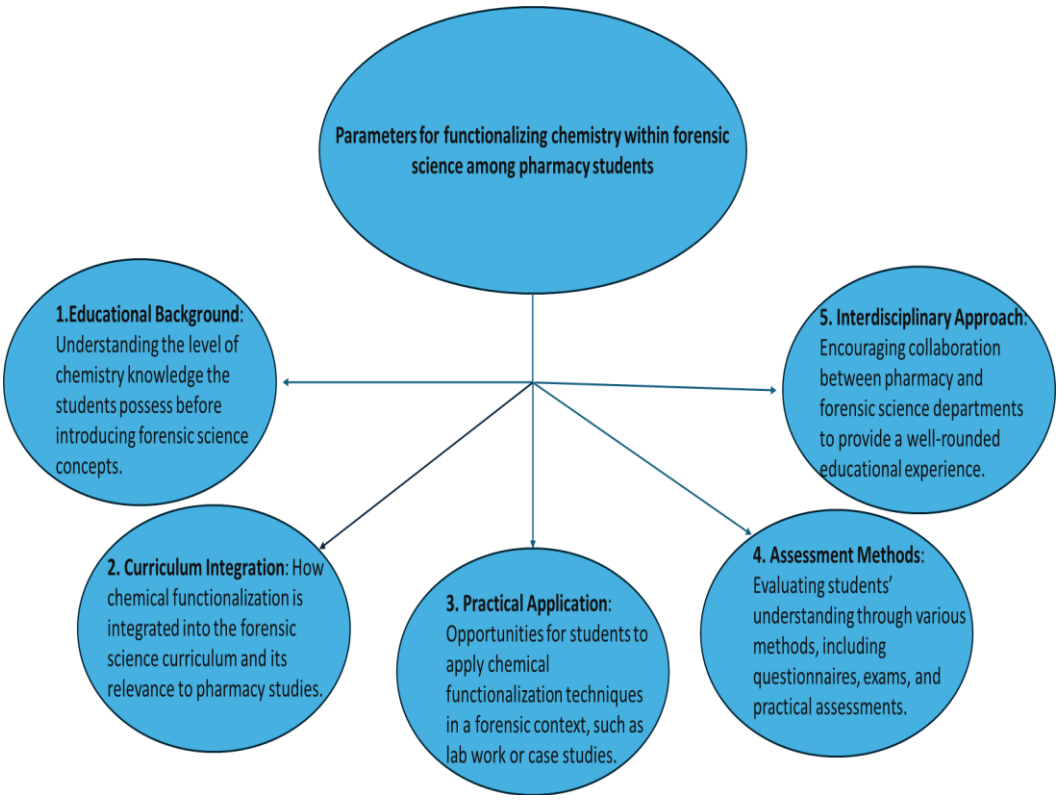
This research focused on assessing undergraduate pharmacy students' understanding of functionalizing pharmacology in forensic science. It aims to evaluate their knowledge, skills, and attitudes concerning forensic pharmacology and its practical applications. Additionally, it strives to pinpoint gaps and challenges in the current pharmacy curriculum by proposing enhancements to forensic pharmacology teaching and learning methodologies.

Recent investigations in this field, such as the study by Alomi et al., surveyed 402 pharmacists and interns in Saudi Arabia. The findings indicate an insufficiency in pharmacists' knowledge of forensic pharmacy services, highlighting the need for additional training and education. Similarly, a study by Alshammari et al. involving 413 pharmacy students and 20 faculty members in Kuwait revealed that while students exhibited good knowledge of antibiotic usage, they lacked awareness of antimicrobial resistance and its relevance to forensic pharmacology.

These studies underscore the necessity for further research and development in forensic pharmacology, particularly in the Middle East, where drug-related crimes and fatalities are prevalent. It is crucial for pharmacy students, as future healthcare professionals, to be well-versed in forensic pharmacology, enabling them to address related issues and actively contribute to the prevention and resolution of legal challenges involving drugs and chemicals.

METHOD

This questionnaire-based study was conducted with 60 undergraduate pharmacy students at the University of Thi-Qar. The teaching staff were asked online survey questions. This study aimed to analyze the participants' knowledge of forensic science regarding medical and chemical signs. The key findings are as follows:



Participants expressed their opinions according to the following statements:

1. The distinction between the entry and exit points of the bullet color from the surrounding tissues was dark brown. Ans (False)
2. Which is more toxic, Ethanol or Methanol? Ans (Methanol)
3. The time to death was estimated by measuring the potassium concentration. Ans (True).
4. Is the concentration of sodium and calcium in vitreous fluid after death reliable? Ans (True).
5. Blood should be taken from the right side of the heart because it contains a low glucose concentration. Ans (No).
6. Does the blood urea concentration give the impression that the deceased person had a state of renal insufficiency due to its rise in the last period before death? Ans (Yes).
7. Vitreous fluid is not considered to be one of the best body fluids because of its dissociation immediately after death. Ans (False).
8. The disintegration of the corpse did not cause H2S (sewage gas). Ans (False).
9. Corrosive substances do not leave traces if taken. Ans (False).
10. In the case of oral poisoning, the substance causing death can be inferred from the odor emanating from the stomach. Ans (True)
11. A high concentration of carbon monoxide gas is not sufficient to cause death if it is under high pressure. Ans (True)
12. However, insecticides are not considered fatal to humans. Ans (False)
13. Skin marks (bluish hands, snake bites, etc.) are important in determining the cause of death. Ans (True)
14. There is an antidote to each toxin. Ans (False).
15. Before starting the autopsy, the body of the deceased was examined outward to confirm the prominent signs. Ans (True).
16. Some materials have distinctive characteristics such as blood and tissue color, skin color change, or a distinctive smell that can be inferred. Ans (False).

RESULT AND DISCUSSION

Figures (1-a) and (1-b) reveal the participants' understanding of chemical science in forensics. Figure (1-a) shows that the students had fair knowledge of the effects of some chemicals on the human body. Most students realized that methanol was more toxic than ethanol. Approximately 50% of the patients were aware of the life-threatening high concentration of carbon monoxide under high pressure and the reliability of the concentration of calcium and sodium in the vitreous fluid after death. However, figure (1-b) explains that students lack information about the effects of some chemicals on the human body. It can be seen that the majority of the participants did not comprehend the impact of pesticides and corrosive substances on the human body. In addition, around two-thirds of the students did not recognize that not every toxic substance had an antidote, as well as the fact that emissions of hydrogen sulfide gas during the decomposition of the corpse.

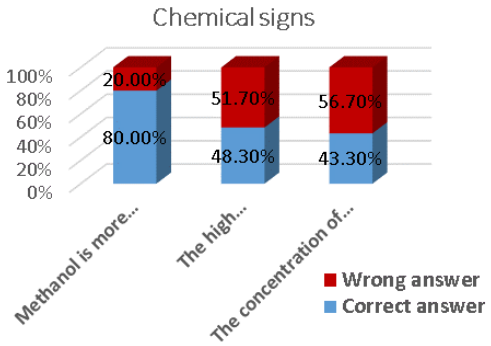


Figure 1-a. Participants' knowledge about chemical signs in forensics.

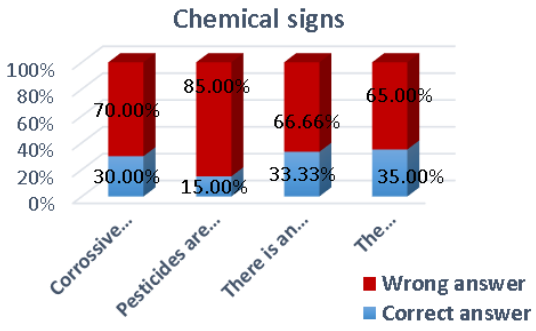


Figure 1-b. The participants' knowledge about Chemical signs in forensic

Figures (2-a) and (2-b) explain the students' understanding of medical signs in forensics. From Figure (2-a), one can conclude that the participants had good knowledge of the medical signs in forensics. It can be seen that there is an excellent understanding of the effect of some substances on the blood and skin color, the examination of the corpse prior to the autopsy, as well as the distinction between the entrance and exit location of the bullet and the color of the surrounding tissue. Furthermore, more than three-quarters of the participants had a good perception of the effect of some toxins and poisonous substances as well as some biological tests (blood urea) on the human body after death.

However, Figure (2-b) reveals that the students had a fair understanding of the physical fluids (vitreous fluid) and the side of the human body from which blood should be taken after death for forensics.

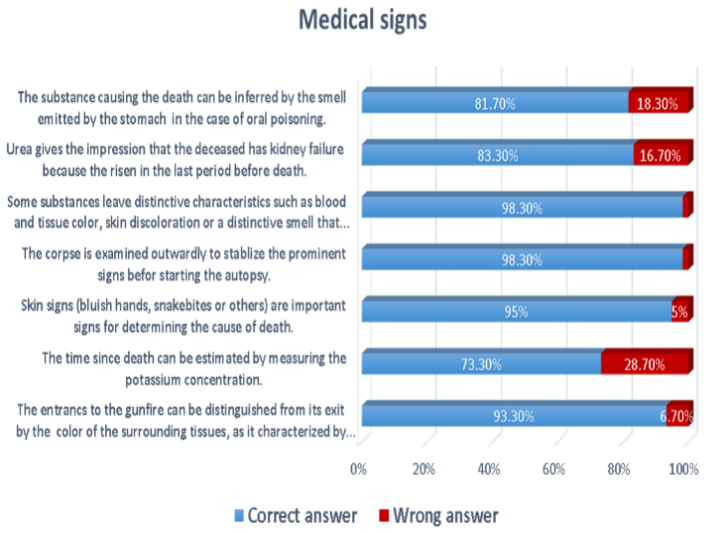


Figure (2-a). Participants' knowledge about forensic medical signs.

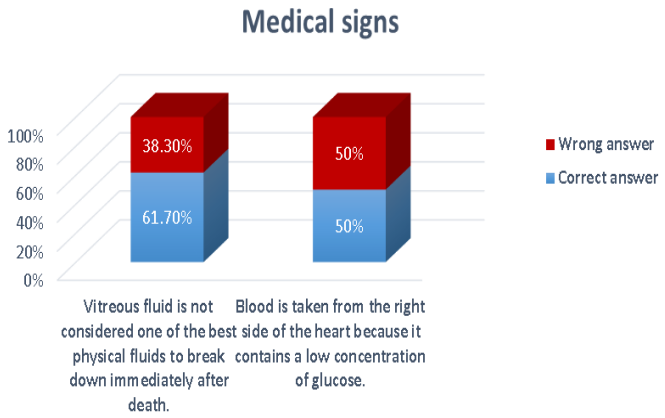


Figure (2-b). Participants' knowledge of medical signs in forensics.

CONCLUSION AND SUGGESTIONS

The present questionnaire study sheds light on pharmacy students' understanding of functionalizing pharmacology in forensic science. These results underscore the importance of comprehensive education in this field for future healthcare professionals. By identifying areas of strengths and weaknesses, this study serves as a foundation for developing tailored educational programs that can address the specific knowledge gaps identified. Improved pharmacy education in functionalizing pharmacology will ultimately contribute to the competence and proficiency of pharmacy students in forensic science, enabling them to contribute effectively to the criminal justice system and to provide optimal healthcare services in related domains.

Based on the findings of this questionnaire study, I would suggest that educational institutions and pharmacy programs consider implementing the following.

1. Incorporate forensic science modules: Integrate specific modules or courses in forensic science within the pharmacy curriculum. This will help pharmacy students to better understand functionalizing pharmacology in a forensic context.
2. Enhance practical training: Provide pharmacy students with hands-on training opportunities in forensic laboratories or through simulation exercises. This will enable them to apply their theoretical knowledge and gain practical experience in forensic pharmacology.
3. Offer specialized elective courses: Offer elective courses or workshops that focus specifically on functionalizing pharmacology in forensic science. These courses can cover drug analysis, toxicology, pharmaceutical crimes, and expert witness testimonies.
4. Collaboration with forensic professionals: Foster collaborations between pharmacy programs and forensic experts or professionals. This can include guest lectures, mentorship programs, or research collaborations that expose students to real-world forensic scenarios.
5. Provide continuous education: Encourage pharmacy students to participate in continuing education programs or conferences focusing on forensic science. This will enable them to remain updated on the latest advancements and trends in the field.

ACKNOWLEDGMENT

The authors of this work are grateful to the efforts of the University of Al-Nahrain/ Chemistry Department for providing the facilities required to conduct this study

REFERENCES

Abbate, V., Schwenk, M., Presley, B. C., & Uchiyama, N. (2018). The ongoing challenge of novel psychoactive drugs of abuse. Part I. Synthetic cannabinoids (IUPAC Technical Report). *Pure and Applied Chemistry*, 90(8), 1255-1282.

Aljamali, N. M., & Alsabri, I. K. (2020). Development of Trimethoprim Drug and Innovation of Sulfazane-Trimethoprim Derivatives as Anticancer Agents. *Biomedical and Pharmacology Journal*, 13(2), 613-625.

Alomi, Y. A., Najim, R. S., Aqeeli, M. M. (2021). Pharmacist's Knowledge of Forensic Pharmacy Services. *International Journal of Pharmacology and Clinical Sciences*, 10, 92–101. https://doi.org/10.5530/ijpcs.2021.10.14

Alshammari, T. M., Alhindi, S. A., Alenzi, K. A., Alshammari, A. H., & Alshammari, M. A. (2019). Knowledge of antibiotic usage and awareness of antimicrobial resistance among pharmacy students and faculty members in Kuwait. *Journal of Infection and Public Health*, 12(6), 819-823.

Ansari, A. A., Aldajani, K. M., AlHazaa, A. N., & Albrithen, H. A. (2022). Recent progress of fluorescent materials for fingermarks detection in forensic science and anti-counterfeiting. *Coordination Chemistry Reviews*, 462, 214523.

Buchan, E., Hardy, M., Gomes, P. D., Kelleher, L., Chu, H. O., & Oppenheimer, P. G. (2022). Emerging Raman spectroscopy and saliva-based diagnostics: from challenges to applications. *Applied Spectroscopy Reviews*, 1-38.

Caldwell, J. (1996). The importance of drug metabolism studies for efficient drug discovery and development. *Drug Metabolism and Pharmacokinetics*, 11(1), 119-126.

Castillo-Peinado, L. S., & De Castro, M. L. (2017). An overview on forensic analysis devoted to analytical chemists. *Talanta*, 167, 181-192.

Chaudhary, R. G., Mahmood, S., & Jotania, R. B. (2023). Green Nanomaterials for Clean and Sustainable Environment. *Current Nanoscience*, 19(6), 746-747.

Dragan, A. M., Parrilla, M., Feier, B., Oprean, R., Cristea, C., & De Wael, K. (2021). Analytical techniques for the detection of amphetamine-type substances in different matrices: A comprehensive review. *TrAC Trends in Analytical Chemistry*, 145, 116447.

Gee, A., & Xu, X. (2018). Surface functionalisation of upconversion nanoparticles with different moieties for biomedical applications. *Surfaces*, 1(1), 96-122.

Iavicoli, I., Leso, V., Beezhold, D. H., & Shvedova, A. A. (2017). Nanotechnology in agriculture: Opportunities, toxicological implications, and occupational risks. *Toxicology and Applied Pharmacology*, 329, 96-111.

Jiang, H. L., Li, N., Cui, L., Wang, X., & Zhao, R. S. (2019). Recent application of magnetic solid phase extraction for food safety analysis. *TrAC Trends in Analytical Chemistry*, 120, 115632.

Kumar, R. R., Kumar, A., Chuang, C. H., & Shaikh, M. O. (2023). Recent advances and emerging trends in cancer biomarker detection technologies. *Industrial & Engineering Chemistry Research*, 62(14), 5691-5713.

Malve, H. O. (2016). Forensic pharmacology: An important and evolving subspecialty needs recognition in India. *Journal of Pharmacy & Bioallied Sciences*, 8(2), 92.

Manousi, N., & Samanidou, V. (2021). Green sample preparation of alternative biosamples in forensic toxicology. *Sustainable Chemistry and Pharmacy*, 20, 100388.

Mayr, A., & Machin, D. (2011). *The language of crime and deviance: An introduction to critical linguistic analysis in media and popular culture*. Bloomsbury Publishing.

Muehlethaler, C., Leona, M., & Lombardi, J. R. (2016). Review of surface enhanced Raman scattering applications in forensic science. *Analytical Chemistry*, 88(1), 152-169.

Nadar, S. S., Kelkar, R. K., Pise, P. V., Patil, N. P., Patil, S. P., Chaubal-Durve, N. S., ... & Patil, P. D. (2021). The untapped potential of magnetic nanoparticles for forensic investigations: A comprehensive review. *Talanta*, 230, 122297.

Peters, F. T., & Steuer, A. E. (2019). Antemortem and postmortem influences on drug concentrations and metabolite patterns in postmortem specimens. Wiley Interdisciplinary Reviews: Forensic Science, 1(1), e1297.

Petoft, A., & Abbasi, M. (2019). A historical overview of law and neuroscience: From the emergence of medico-legal discourses to developed neurolaw. *Journal on European History of Law*, 10(2).

Rathinavel, S., Priyadharshini, K., & Panda, D. (2021). A review on carbon nanotube: An overview of synthesis, properties, functionalization, characterization, and the application. *Materials Science and Engineering*: B, 268, 115095.

Roszkowska, A., Miękus, N., & Bączek, T. (2019). Application of solid-phase microextraction in current biomedical research. *Journal of Separation Science*, 42(1), 285-302.

Roux, C., Crispino, F., & Ribaux, O. (2012). From forensics to forensic science. Current Issues in Criminal Justice, 24(1), 7-24.

Sijen, T., & Harbison, S. (2021). On the identification of body fluids and tissues: A crucial link in the investigation and solution of crime. *Genes*, 12(11), 1728.

Thieme, D., Sachs, H., & Uhl, M. (2014). Proof of cannabis administration by sensitive detection of 11-nor-Delta (9)-tetrahydrocannabinol-9-carboxylic acid in hair using selective methylation and application of liquid chromatography-tandem and multistage mass spectrometry. *Drug Testing and Analysis*, 6(1-2), 112-118.

Vivero-Escoto, J. L., Slowing, I. I., Trewyn, B. G., & Lin, V. S. (2010). Mesoporous silica nanoparticles for intracellular controlled drug delivery. *Small*, 6(18), 1952-1967.

Welch, C. J. (2019). High throughput analysis enables high throughput experimentation in pharmaceutical process research. *Reaction Chemistry & Engineering*, 4(11), 1895-1911.

Yao, J., Yang, M., & Duan, Y. (2014). Chemistry, biology, and medicine of fluorescent nanomaterials and related systems: new insights into biosensing, bioimaging, genomics, diagnostics, and therapy. *Chemical Reviews*, 114(12), 6130-6178.

Yaseen, T., Pu, H., & Sun, D. W. (2018). Functionalization techniques for improving SERS substrates and their applications in food safety evaluation: A review of recent research trends. *Trends in Food Science & Technology*, 72, 162-174.

Zhang, X. W., Li, Q. H., & Dou, J. J. (2020). Mass spectrometry-based metabolomics in health and medical science: A systematic review. *RSC Advances*, 10(6), 3092-3104.

Zhou, W., Wang, Y., Lu, A., & Zhang, G. (2016). Systems pharmacology in small molecular drug discovery. *International Journal of Molecular Sciences*, 17(2), 246.

Zrazhevskiy, P., Sena, M., & Gao, X. (2010). Designing multifunctional quantum dots for bioimaging, detection, and drug delivery. *Chemical Society Reviews*, 39(11), 4326-4354.