A New Way to Detect and Identify Forensic Bloodstains

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APRIL 2025

doi.org/10.33548/SCIENTIA1281

LIFE SCIENCES & BIOLOGY

Scientia

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Accurately identifying bodily fluids at crime scenes is vital to aid forensic examinations and obtain information for use in criminal proceedings. However, collecting viable material for analysis can be challenging, especially if samples are difficult to access or the amount is minute. Dr Lamyaa Almehmadi and Professor Igor K Lednev at the University at Albany, State University of New York, USA, have introduced a new technique to assist in analysing bloodstains for forensic examination without compromising sample integrity.

Understanding Forensic Analysis Techniques

During criminal forensic investigations, extracting DNA from bodily fluids is crucial in revealing a victim's or suspect's identity and traits. Currently, several biochemical tests are available to detect and identify biological stains. However, many of these destroy sample material and may only be relevant to a single type of body fluid, thus limiting their use. Furthermore, confirmatory tests are labour-intensive, time-consuming, and restricted to the laboratory environment. Therefore, a universal confirmatory test is needed for all main body fluids, which can be easily performed at the crime scene itself.

Spectroscopy involves the study of light-matter interaction to identify the origins and structure of biological matter. The significant potential of spectroscopy for the forensic science sector to verify the presence of blood and other bodily fluids has been demonstrated. Chemometrics describes the extraction of the data acquired during spectroscopy using computerised mathematical systems.

There are numerous categories of spectroscopy techniques with a wide range of applications, and several complementary technologies are now being developed which can detect and identify all types of body fluids pertinent to forensic examinations. One such technique, Raman spectroscopy, involves scanning the area of interest with a monochromatic light, collecting the scattered light using an optical objective and analysing it with a spectrometer. As a result, a vibrational fingerprint of the material is acquired, which is the most specific spectroscopic characteristic of the material. Since each bodily fluid has a unique composition, its presence can be identified using the vibrational fingerprint. Confirmation of the body fluid type is then possible using advanced statistical analyses.

This method is non-destructive and requires no or minimal sample preparation. Moreover, handheld spectroscopy devices are widely available, making them an ideal candidate for detecting and verifying body fluid traces at crime scenes.

Distanced Sample Collection with Statistical Validation

Using a portable Raman device usually requires close contact between the equipment and the sample, which can cause issues if the crime scene is structurally unsafe, inaccessible, or biohazardous. Further, such contact may cause sample contamination, thus rendering it unsuitable for further analysis. To overcome this, a special fixture called a stand-off device can be attached to the spectrometer to capture the light emitted by samples from a distance.

Dr Lamyaa Almehmadi and Professor Igor K Lednev in the Department of Chemistry at the University at Albany in New York, USA, have recently conducted a groundbreaking study to demonstrate the suitability of stand-off Raman spectroscopy in combination with chemometrics for detecting and identifying bloodstains, mimicking the type of biological sample most commonly found at violent crime scenes. The statistical model used was previously developed by members of the Lednev laboratory. The results of the analysis were then compared with those attained using standard laboratory-based equipment to determine the accuracy of the technique.

Previously, Professor Ledenv and students have demonstrated the effectiveness of Raman spectroscopy combined with computational data extraction in obtaining specific information from body fluid stains. Using this adjunct model, they were able to distinguish between animal and human specimens, determine

the age, sex, and race of humans and establish how long ago the sample had been deposited (time since deposition). The integration of Raman spectroscopy with chemometrics allows for fast, automated identification, minimising human bias. Additionally, confidence intervals can be calculated, increasing the reliability of the results used in criminal court proceedings.

Validating the System

Recognising the limitations of current forensic procedures, Dr Almehmadi and colleagues set out to compare the results achieved using their system with those generated using a regular Raman benchtop microscope.

Visual assessment of the stand-off spectrometer output indicated that the acquired Raman spectra were consistent with previously published data and displayed proven molecular features of blood. Statistical methods applied to predict the accuracy of sample type detection showed that all the bloodstains were correctly identified. Their comparison studies also confirmed that their previously developed statistical model was suitable for use with various instruments, thus increasing the potential usability of their method by various users.

Commercialising the Research

To further address procedural shortcomings, a world-leading expert in Raman spectroscopy and forensic analysis of body fluids, as well as a prominent scientist and esteemed colleague of Dr Almehmadi's, Professor Lednev, together with his colleagues, is developing an automated non-destructive test to identify all major body fluids on common substrates. Once fully developed, this method will be invaluable to law enforcement agencies during criminal investigations. The patented model is being commercialised by SupreMEtric LLC.

The Future of Forensics

Dr Almehmadi and Professor Lednev have elegantly described, for the first time, a technique that involves obtaining in-depth information from biological samples using a handheld device with a stand-off attachment that facilitates remote collection for use in forensic settings. Furthermore, they have pioneered a complementary mathematical model to act as a confirmatory step in the analytical process. Their work has highlighted many vital considerations and introduced invaluable solutions to mitigate the problems associated with hazardous conditions. This impressive technique could revolutionise crime scene diagnostics and significantly widen the practical scope of the method. The researcher's hypothesis that this unique combination of advanced technologies could be used to feasibly gather evidence of a comparable standard to that obtained using the benchtop equipment utilised during laboratory testing has been realised.

The use of stand-off Raman spectroscopy to quickly and precisely scan entire crime scenes to detect and identify bodily fluids is undoubtedly possible, and the impact that this could have on forensic investigations is undeniably huge. Further work is needed to test the compatibility of the team's analytical model with other Raman instruments and to evaluate the efficiency of this technique for biological samples other than blood. However, the results presented here are promising, and with the dedicated team continuing to work on this pivotal topic, there is little doubt that the expansion of this newly disclosed method is imminent.

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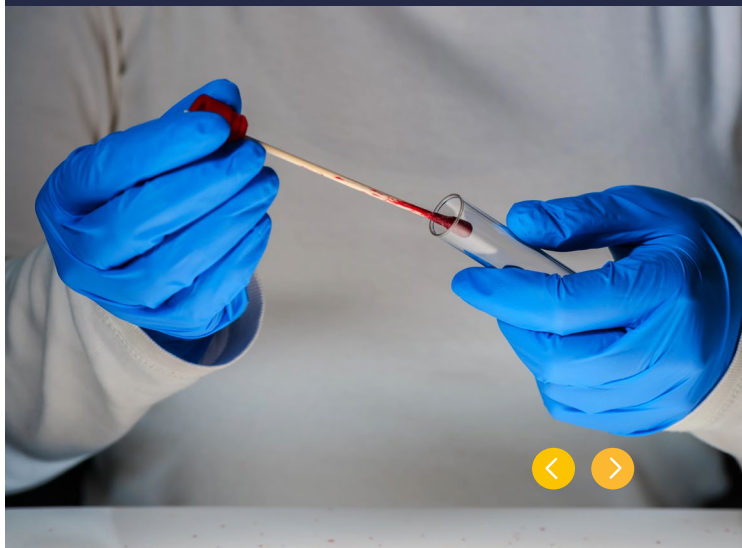

MEET THE RESEARCHERS

Professor Igor K Lednev
University at Albany, Albany, NY, USA

Igor K Lednev is Williams-Raycheff Endowed Professor in Chemistry and SUNY Distinguished Professor at the University at Albany, State University of New York. He is an Adjunct Professor in the Department of Biological Sciences and a faculty member of the RNA Institute. Lednev's research is focused on the development and application of novel laser spectroscopy for forensic purposes, biomedical applications, and fundamental biochemistry. He is a founder and CTO of SupreMEtric LLC, commercialising a universal method for the identification of body fluid traces for forensic purposes, and Early Diagnostics LLC, developing saliva and blood screening tests for Alzheimer's disease. Lednev co-authored over 280 publications in peer-reviewed journals and 10 patents and currently has an H-index of 79. His work has been substantially covered by the media, including TV interviews and articles in the Wall Street Journal, Chemical & Engineering News, and Forensic Magazine.

US Congressman Paul Tonko acknowledged Lednev's research accomplishments at the US House of Representatives Hearing on Advancements in Forensic Science in the US in September 2019. Lednev was recruited by the United Nations to give a week-long 'National Training Course on using Vibrational Techniques to Enhance the Forensic Analysis' for the National Crime Laboratory of Chile in Santiago in January 2020. Lednev served as an advisory member on the White House Subcommittee for Forensic Science. Together with the National Institute of Justice (NIJ), he founded the NIJ Forensic Science Symposium at Pittcon in 2018, which became an annual event since then including 34 invited talks and a poster session.

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Before accepting her postdoctoral post at the Massachusetts Institute of Technology (MIT), Dr Lamyaa Almehmadi completed her PhD in Chemistry at the University at Albany. Her work there focused on using enhanced Raman Spectroscopy techniques for varied applications, including detecting and identifying bloodstains. Dr Almehmadi has received several prestigious awards, including the MIT IBK Postdoctoral Fellowship, the Coblentz student award, the Society for Applied Spectroscopy Barbra Stull award, and the Rising Star in Analytical Chemistry (ACS analytical chemistry division). She was elected president of her local Society for Applied Spectroscopy chapter for two consecutive years. She was appointed chair of the 2022 First Annual New York Capital Region Applied Spectroscopy Symposium. Additionally, she has participated in teaching general chemistry as an instructor of record in the University at Albany's Chemistry Department and has co-organised numerous educational outreach sessions.

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FUNDING

This project was supported by the National Science Foundation (NSF), Award No 2304318. The opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect those of the NSF.

FURTHER READING

LM Almehmadi, IK Lednev, Stand-off Raman spectroscopy is a promising approach for the detection and identification of bloodstains for forensic purposes, *Journal of Raman Spectroscopy*, 2024, 55(2), 227–231. DOI: https://doi.org/10.1002/jrs.6609

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