**Commentary**

# Accelerator-based techniques: A multidisciplinary addition to revolutionize forensic science curricula for social justice?

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I recently attended the World Science Forum in Cape Town, South Africa. In one of the thematic sessions organized by the International Centre for Theoretical Physics (ICTP) and Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME), the role of physics and accelerators for science and social justice was discussed. If we project this discussion into forensic sciences, crime remains a worldwide social injustice. Multidisciplinary facilities such as the ICTP and SESAME do not only offer a scientific diplomatic tool to bring together global networks of forensic scientific communities with a mission to finely advance science intermixes to address important multidisciplinary challenges as a vital pathway towards social justice, but can also grow and develop scientific and technological innovation and excellence, and build scientific and cultural bridges between global scientific societies in the field of forensic research. Most importantly, such facilities also provide access to training and education for students and researchers. Yet, the role of accelerator-based techniques in answering complex questions in the field of forensics combined with its position in multidisciplinary curricula in forensic sciences have unfortunately remained rather limited.

Accelerator-based techniques include for example synchrotron radiation, micro-proton-induced X-ray emission (PIXE), external beam PIXE, neutron activation analysis, and secondary ion mass spectrometry using MeV ions. Accelerator-based techniques alone or in combination with other methods present as very powerful tools to uncover forensic evidence, with ion beam accelerators and synchrotrons being the most commonly explored in forensic science. These techniques employ particle accelerators to produce a beam of charged ion particles such as protons or electrons accelerated to high energy that interact with atoms in the forensic sample to release X-rays or secondary ions that are analysed by a detector to determine the sample’s elemental or chemical composition. These techniques can provide spatially resolved qualitative and quantitative elemental and molecular mapping in sample regions that remain intact during analysis and that can also be subsequently analyzed by complementary benchtop techniques. Other benefits include fast analysis, low detection limits, and the traceability of results. A detailed overview comparing chemical imaging methods can also be found in (1).

Illustrative themes exploring the utility of accelerator-based techniques include fingerprint and document analysis, gunshot residue analysis, drug screening, and for studying provenance, counterfeiting, mislabelling and adulteration of samples. For cultural heritage forensics, the ion beam laboratory in the Louvre Museum in Paris has been quite eminent. Accelerator-based techniques also find its application within the field of systemic intoxication studies using hair. To illustrate, synchrotron longitudinal hair mapping provides a retrospective or chronological profile of acute or chronic exposure to xenobiotics including toxic metals, whilst cross-sectional mapping across the hair morphological regions may allow differentiation between exogenous chemicals on the hair surface deposited via air pollution or drug vapours and endogenous chemicals deposited via the bloodstream, which remains an area of great debate in hair research. An illustrative and famous case study that comes to mind and utilized synchrotrons is that of Phar lap, for which synchrotron radiation analysis with high resolution X-ray fluorescence and X-ray absorption near edge structure showed a longitudinal change in the intensity signal with time progression linked to metabolic changes incorporated during hair formation that ultimately indicated arsenic poisoning of the famous race horse (2). Another study that comes to mind is that of the world-renowned Danish astronomer Tycho Brahe who died in Prague in 1601 after a short, 11-day illness in which neutron activation analysis was used for hair analysis. The analysis showed that the astronomer was exposed to Pb and several other toxic elements from his alchemical activities that most likely contributed to his demise (3). Interestingly, to reconstruct the dose associated with the Hiroshima detonation, accelerator mass spectrometry has also been used to analyse neutron activation products such as 63Ni in copper samples (4).

In conclusion, to promote the diverse and robust applications of accelerator-based techniques to answer complex forensic questions, knowledge cross-fertilization focused on the development of international curricula delineating the fundamental and applied science underscoring accelerator-based techniques, complementary methods, the use of chemometrics and rigorous statistical models, and case studies should be developed to train interdisciplinary forensic scientists capable of more robustly conducting inquiries supported by a diverse set of analytical techniques that meet scientific quality standards and interlaboratory reliability in order to assist the criminal judicial system in firmly connecting legal rulings to the existing forensic evidence.

**References**

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