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Nanosensors to Scrutinise Illegal Drugs, Explosives, and Food Adulterants at a Molecular Level - Forensic Perspective

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Editorial

The development of nanobiosensors has advanced significantly in recent years since they are an essential necessity that could be combined with point-of-care testing for a variety of applications, including healthcare, the environment, energy harvesting, electronics, food industry and forensics [1]. The combination of forensic science with nanotechnology has ushered in an entirely new phase in investigative and analytical methods, opening the door to more potent strategies for combating criminal activities. An increasing number of crimes with unusual complexities makes it difficult for forensic science experts to evaluate the particular crime [2]. Border policing for homeland security faces major challenges worldwide because of threats from national and international terrorism and drug smuggling [3]. The usage of explosives, food adulterants, and illegal drugs is growing worldwide, causing a number of serious crimes, hence it is critical to detect as well as quantify these substances. Additionally, conventional analysis methods are expensive and lack the sensitivity and selectivity to detect traces of analytes involving serious crimes such as nuclear explosions, drug trafficking, underground mine investigations, the use of chemical and biological warfare agents, etc. Furthermore, the majority of crime scenes display incomplete, deteriorated, or even contaminated specimens. Because of the various legal jurisdictions involved, gathering this evidence and detecting for DNA, illegal drugs, or any other crucial component involves a significant amount of accuracy and authenticity [2].

There are numerous conventional methods frequently employed in forensics. Nevertheless, conventional approaches do have notable drawbacks. One of the prominent reasons is readily available synthetic or designer drugs which possess enormous chemical diversities making isolation and identification challenging. These strategies are paving the way towards a quest for better techniques to eliminate existing drawbacks. Considering these above-mentioned facts, an advanced solution is required to overcome these hurdles, such as integrating nanotechnology with forensic science, leading to improved and precise results, quick investigation, and the development of more sensitive devices that ultimately help monitor and reduce criminal activities [2]. Existing mainstream technology for bulk or trace detection has limitations [3]. Analytical instrument-based techniques that are highly sensitive, powerful, and well-known, such as NMR, GC-MS/MS, or UHPLC-MS/MS, are frequently used. But these techniques require the use of large and complex equipment that is challenging to operate and time-consuming, hence increasing the overall workload. With a growing interest in precise and sensitive diagnosis for criminal investigations, nanoparticles have intrigued scientific minds working in the field of forensic science due to their exceptional properties [2].

In the last decades of research, molecular recognition-based diagnostics have produced varied and promising results in terms of sensing technology. A sensor is a device which detects a variable quantity, usually electronically, and converts the measurement into specific signals [4]. Nanosensors are chemical or mechanical sensing devices that contain nanoscale elements and are engineered to respond to the presence of certain analytes or environmental conditions. Nanomaterials can also be easily adjusted; their size, structure, and makeup all impact the characteristics of these factors and are combined [5].

Nanomaterials are distinguished from fine particles used for numerous applications as a result of being unique in properties [1]. Because of their exclusive properties, nanostructures present a new avenue for the development of cutting-edge, high-performing instruments that have a significant impact on detection of contaminants [6]. Nanosensors based devices can be applied for detection of illicit drugs, environmental and food contaminants, biochemicals in cellular organelles, measuring nanoscopic particles, etc., [4]. This facilitates examination of various evidence in much more efficient, selective, and cost-effective manner [5].

Nanosensors require least amount of sample to detect analytes with speed, accuracy, and selectivity. They can be fabricated with the aim of enhancing portability, cost reduction, and the detection of analytes from complex matrices. Furthermore, economic factors should be taken into account while commercializing and scaling up nanosensors for regulatory bodies. Conversely, ensuring uniformity and consistency across testing protocols is a difficulty when integrating nanosensors into portable devices for on-the-spot testing. Despite the high sensitivity of nanosensors, stringent validation and calibration procedures are required to reduce the possibility of false positives or negatives. This demands the development of complete guidelines and protocols to govern the usage of sensors to reduce potential variations and maintain overall efficiency. Heading in advance, forensic analysis has a promising future because of the current advancements in nanosensor technology. These nanosensors are anticipated to improve and broaden their applications with continued research and development, potentially leading to novel approaches for analysing and classifying a wider variety of analytes at the molecular level.

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