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REVIEW ARTICLE

Role of Nanotechnology in Forensic Medicine to Solve Medico-legal Case Work in Pakistan - A Review Study

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ABSTRACT

Background: Nanotechnology is relatively a new emerging field of Forensic Science and is being used to solve many medico-legal cases all over the world. Some of its use is the most prevalent in biomedical science, material science, biological indicators, food science, Trace Evidence, real-time crime scenes, and terrorist attacks as a nanomaterial to the medico-legal investigations. It is now utilized in the medico-legal casework in Pakistan in Forensic Medicine.
Aim: To analyze and compare the forensic value of nanotechnology and methods used to solve the medico-legal investigations relating to nanomaterials in Forensic medicine in Pakistan, Pakistan.
Method: This is a review study focusing on the currently available data in research articles all over the world and in Pakistan about the use of nano-material in medico-legal casework for slaving medico-legal investigations in Pakistan. Extensive research is being conducted on the use of nanomaterials. Various analysis methods for nanomaterials, both old and new, have been gathered from previous research and compared. The statistical significance of their use as forensic evidence in criminal investigations and medico-legal cases has been analyzed in the field of Forensic Medicine.
Results: The field of nanotechnology plays a crucial role in forensic investigations. This is supported by numerous publications both globally and in Pakistan. Nanomaterials have been instrumental in solving many forensic cases by leveraging advanced technology and high-tech tools. The Pakistan Forensic Science Agency in Lahore (PFSA) has effectively utilized nanomaterials in DNA analysis and various serological tests. Notably, nanomaterials have greatly aided in identifying crime scene evidence through the use of Polymerase Chain Reactions (PCR).
Practical Implication: New nanotechnologies are being utilized in DNA fingerprinting to solve medico-legal cases in forensic investigations. Advancements include the use of capillary electrophoresis, nano-gold, nano-silver, and nanoparticles of titanium dioxide (TiO2) combined with SEM, TEM, and FTIR(56). Currently, there are ongoing developments to create new nano-probes, nano-devices, and nano-chips to combat the threat of terrorism in Pakistan.
Conclusion: Nanotechnology is being very extensively used in crime-scene investigations to solve medico-legal cases in Forensic Medicine, especially in various ways and techniques in fingerprinting, DNA analysis, explosive detection, drug detection, and time since death estimation. Examination of body fluids, document analysis, explosive residual inspection, and nano-biosensors are benefited by nanotechnology. It is concluded by the review research on the use of nanotechnology that it is a more accurate, fast, reliable, secure system and an Armour for medico-legal investigations in Forensic Medicine.
Keywords: Nanotechnology **,** DNA analysis**,** Forensic value, Forensic Medicine ,Nanoparticles

INTRODUCTION

Nanotechnology is ever grooming and progressive technology to provide the vast applications in many fields of sciences since its inventions as nonmaterial used in PCR[1,2]. It has functionally revolutionized many felids of science ranging in multiple subjects like physical sciences, biomedical sciences, material sciences, hardware, crystallography, biotechnology and many more[3,4]. In recent years, with the advancements in criminal justice system and medical sciences, they have adopted many techniques in crimescene investigations that are mostly depended on the nanotechnology as well[4,5,6]. In this way, the field of medicine dealing with law and justice to provide trace evidence for the purpose of solution of many medico-legal cases is called Forensic Medicine. Now, many techniques of nanomaterial and nanotechnology are being used in Forensic Medicine. Techniques in fingerprinting, DNA analysis, explosive detection, drug detection, and time since death estimation. Examination in body fluids, document analysis, explosive residual inspection and nano-biocensors are benefited by the nanotechnology[7,8,9].

It was discovered that the nano-particle or nano-material had a size of a few nanometers to 500 nanometers with controlled morphology[10,11,12]. These nanoparticles although had very minute size but they possessed relatively large surface area to add and translate huge number of information as bimolecular especially when used as DNA fingerprints for the purpose of identification and as a trace evidence. Furthermore, the nanoparticles had wonderful photo-catalytic properties which enabled them to be seen in electrophoresis analysis. This optical property application had provided a very important role especially in quantification of DNA and other nanomatrials recovered from crimescene investigations as well. These nanoparticles had many way of engineered methods to shape into morphology to different sizes and shapes to get desired genetic engineered biomolecules[13,14]. These genetically engineered biomolecule had the vast majority of applications as tracers and censors in biomedical and general sciences as well. The quick changes in nanoparticles with progression in nanomaterial manifested the vast majority and varieties of applications in biomedical sciences. However, some biomedical scientists are still worried about their use in human body may produce some serious side effects[15,16].

Nanoparticles are manufactured from gold that ranges from 10 nm to 30 nm in size, silver nanoparicle are with 20nm size and Titanium oxide nanoparticles with 15nm size[17]. These nanoparticles are converted into nanometrials after modifications. Some of these modifications are Quantum dots, carbon nanotubes and Peptide nanotubes etc. These nanomaterials are being used in Medication, Quantum PC, Environmental engineering, as catalysis, consumer products and Forensic Medicine[18,19]. In polymerase chain reactions (PCR) the nano- material are used to get dramatic improvements to enhance the quantity of biomolecule into many folds. It is found by many research in PCR especially done for DNA analysis, it had increased efficacy and productivity of DNA analysis ranging 100 to 10,000 times in real time PCR. The selected nanoparticles are especially designed to attain certain

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temperature with cyclic change in nanomaterial consistency and morphology without damaging the original biomolecule. This distinct and dramatic improvement in efficiency of PCR was by the virtue of heavenly Au nanoparticles used in modern DNA analysis kits. In some cases gold nanoparticles are used in the form of gold polymerases in DNA fingerprinting[20,21,22].

The aim of this study was to assess and contrast the effectiveness of nanotechnology and methods used in solving medico-legal investigations related to nanomaterials in Forensic Medicine in Pakistan.

METHODS AND MATERIAL

This is a review of existing research articles worldwide and in Pakistan which focus on the use of nano-materials in medico-legal casework for resolving medico-legal investigations in Pakistan. All relevant research material concerning the use of nanomaterials was examined. The available nanomaterials analysis methods were gathered from previous research and compared with old and new techniques. Their usefulness in criminal investigations and medico-legal cases was analyzed to determine their statistical significance as Forensic evidence in Forensic Medicine.

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RESULTS AND DISCUSSION

Nanotechnology in Latent Fingerprinting: Even though criminals try to avoid leaving evidence behind, traces of their activity can often be found at the scene of a crime. Fingerprints, for example, can be left behind due to the secretion of sebaceous glands by the criminal. These fingerprints, both visible and latent, can be crucial in solving criminal investigations. Nanoparticles have advanced properties that can interact with these fingerprints, making them visible even when they can't be seen by the naked eye. There are several types of nanomaterials available, such as metallic oxides and semiconductors, that can improve the imaging of these fingerprints, making the ridge pattern clear and the background high in contrast. Additionally, nanoparticle oxide powders can be used in medico-legal investigations to enhance latent fingerprints. Special types of photo-luminescent CdS semiconductors nanocrystals are also used in some forensic laboratories to enhance faded latent fingerprints.

Explosive (Firearms) residual examination with Nanotechnology: The greatest threat to the economy and people of Pakistan is terrorism due to their extensive involvement in tackling the danger and participation in the war against terror started by the USA. Now explosive firearm weapons are readily available to terrorists and people to defend their self in the country. The unfragmented parts of explosive ammunition are found at the place of explosion as well as on the surface of weapons recovered from these criminals and terrorists. Some fragmented residual explosive material may be dispersed away from the blast site as well[33]. There are many techniques of nanotechnology to apply for the examination of these residual explosive materials. High-resolution electron Microscopes (SEM) are used to see the very minute nanoparticles of different materials on the surfaces of ammunitions used i.e., from the surface of used cartridges and bullets[34]. From the surface of weapons used in criminal activity, some explosive residual material (ERM) and some fingerprint material are also lifted for nanotechnological examination by using high-resolution electron microscopes(SEM) as well[35,36].

There is a technique of X-ray spectroscopy examination as well that is used in explosive residual detection. Turmeric-extracted curcumin nanoparticles and amine-terminated nanoparticles are used in explosive detection examination. Flawless and the perfect characterization of gunshot residues(GSR) at micrometric and sub-micrometric levels is a very important step in firearm explosive analysis for linking a particular ammunition to a firearm[37,38]. There are different metal nanomaterials such as Cu, Ag, Au, etc. which are used for the early detection of GRS. There are some Cellulose and its derivatives such as cellulose nanocrystals or cellulose nanofibers are used due to their well-defined nano-scale structure and their easy abundance availability[39,40].

Furthermore, carbon tubes (CNTs) are also used in ballistics in other areas for the protection of light and medium armor vehicles for military purposes due to their qualities of high strength and resistance[41,42].

AFM in blood stain and document examinations with Nanotechnology: Atomic Force Microscopy(AFM) is another nanotechnology feature with very extensive characteristics of mechanical properties of adhesion, stiffness, friction, and dissipation. They also possess some classical electrostatic properties like capacitance, electrostatic force, electric current, and work function. Their magnetic and optical spectroscopic properties additionally make them perfect nanomaterial for use in stain analysis, document analysis, and DNA analysis. AFM is used in many forensic investigations especially in blood stains and document analysis to find out the identification of blood stains and authenticity of the questioned documents in medico-legal work in Forensic Medicine. Metal oxides are the most used nanomaterial, especially in questioned document analysis. Quantum dots and fluorescent nanomaterials also play a wider role in this context.

In this technique, the nanomaterial is added to a questioned stain or document and seen under AFM spectroscopic examination under AFM microscope to identify very minute details at nanometric levels. Some special security documents are also labeled with self-erasing ink and medium with some nanoparticles in the range of 5 nanometers consisting of gold and silver nanoparticles[44,45,46]. The 3D morphology examination of documents with AFM has also proved to be very effective in identifying pen strokes and ink strokes. This feature as an application to determine any alteration in the original document by solvent-free gold nanoparticles assisted the LDIMS approach to detect the image inks and visible dyes to identify any forgeries or alterations in the documents or bank notes[42].

Polymerase Chain Reaction(PCR) and Nanotechnology: Modern scientific nanotechnology has been a great blessing in the field of Polymerase chain reaction (PCR). The use of nanomaterials on the surface has dramatically improved the efficiency of PCR with multiple cycles of heat and cold temperature. To increase the quality and quantity of DNA molecules during their extraction, multiplication, and capillary electrophoresis, it is essential to use special requirements in DNA analysis. Silica-based magnetic nanoparticles and Copper nanoparticles are used in PCRs to obtain good-quality DNA, especially from the forensic samples of old skeletal remains and body fluids[43-45]. In recent PCR analysis, microfluidic systems have greatly benefited post-PCR quantification of mitochondrial DNA. Their use is increasing day by day, not only in forensic research but also in forensic case work. Some special types of adsorbent material are modified with nanotechnology to extract and amplify DNA from the organic contents of urine as forensic samples as well[46].

DNA Analysis with Nanotechnology: Forensic DNA analysis is a widespread practice that involves analyzing samples like blood, semen, body fluids, hair, and spit from all around the world. Sometimes, skeletal data is used for DNA analysis and fingerprinting. Magnetic nanoparticles are commonly utilized to separate DNA from these samples before undergoing a complete analysis of the results[47,48]. Thanks to recent advancements in nanotechnology, a new approach to DNA analysis has been developed using microfluidic gadgets in the form of microchips. These microchips are being used for research and crime scene detection of DNA with shorter assessment times[49].

Micro Nano-chips for DNA analysis: Forensic DNA analysis is now widely available worldwide through DNA analysis micronanochips. These chips contain microarrays of millions of single strands of DNA molecules with various base groupings. Forensic samples are labeled with radioactive or fluorescent material attached to corresponding base pairs of the nanochip DNA. This enables DNA interpretation from the samples in a very

short time. Recently, programmable bio-nano-chips have been introduced with analyzers, revolutionizing DNA analysis in a robust, efficient, and quick way. These chips work on various forensic samples like saliva, serum, plasma, and small volumes of blood as well[50].

Recent advancements: Nanobiocensors have been researched for many years and are now being used to diagnose various diseases through the application of bio-nano-technology. Additionally, new nanotechnologies are being utilized in DNA fingerprinting to solve medico-legal cases in forensic investigations. Advancements include the use of capillary electrophoresis, nano-gold, nano-silver, and nanoparticles of titanium dioxide (TiO2) combined with SEM, TEM, and FTIR[56]. Currently, there are ongoing developments to create new nano-probes, nano-devices, and nano-chips to combat the threat of terrorism in Pakistan. Nanoplatforms are being used to collect trace evidence with on-the-spot results for the identification, assortment, and protection of evidence, which has improved the pace of forensic examination.

CONCLUSIONS

Nanotechnology is being very extensively used in crime-scene investigations to solve medico-legal cases in Forensic Medicine, especially in various ways and techniques in fingerprinting, DNA analysis, explosive detection, drug detection, and time since death estimation. Examination of body fluids, document analysis, explosive residual inspection, and nano-biosensors are benefited by nanotechnology. It is concluded by the review research on the use of nanotechnology that it is a more accurate, fast, reliable, secure system and an Armour for medico-legal investigations in Forensic Medicine.

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1. Conception and design of or acquisition of data or analysis and interpretation of data.
2. Drafting the manuscript or revising it critically for important intellectual content.
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