Pakistan Journal of Criminology
Vol. 16, No. 01, January—March 2024 (361-373)

The Role of Nanotechnology in a Forensic Investigation

Ayman Nawwaf Sharif Alhawawsheh[1]

Abstract

Nanotechnology has been a part of science fiction novels and the subject of speculative research in secret laboratories, Nowadays, nanotechnology is one of the most promising and controversial emerging technologies among existing technologies Nanotechnology involves the manipulation of materials at the atomic and molecular level, typically at a scale less than 100 nanometers. At this scale, materials exhibit unique properties and behaviors, making them suitable for a wide range of applications. this study delves into how nanotechnology is transforming the world of forensic science and The Role of Nanotechnology in Forensic Investigation. and focuses a reality in applying nanotechnology at crime scenes, detecting criminals, and assisting judicial officers and forensic scientists as experts assigned by the prosecution to give a detailed report on the crime, and i discussed the concept and nature of nanotechnology and the use of this technology at crime scenes, as well as its validity in criminal proof. The result of this study is This technique has the authority to prove it before a criminal judge as material evidence, and the Public Prosecution can rely on it to file a criminal case In a Forensic Investigation.

Keywords: Latent fingerprint, Crime, Evidence, Nano-forensics, Nano-techniques, Investigation.

Introduction

"Diamond Age" is a science fiction novel by American writer Neal Stevenson, published in 1995, depicting a near-future world, in which nanotechnology affects all aspects of existence. Nanotechnology already affects many features of our lives today including crime investigation and law enforcement (Jayanth, 2019) .

The ideas and concepts behind nanoscience and nanotechnology began with a talk titled "There's Plenty of Space at the Bottom" by physicist Richard Feynman at a meeting of the American Physical Society at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a process by which scientists can manipulate and control individual atoms and molecules. More than a decade later, in his explorations of ultra-fine machines, Professor Norio Taniguchi

[1] The author is an Associate Professor in Criminal Law, at College of Law, American University in the Emirates. UAE. He can be reached at ayman.alhwawsheh@aue.ae

coined the term nanotechnology. It was not until 1981, with the development of the scanning tunneling microscope that can "see" individual atoms, that modern nanotechnology began (Bayda, 2019). The application of nanoscience in forensic investigation has helped criminologists solve crime mysteries in less time and more efficiently. Rapid advances in forensic science come with technological improvements in nanotechnology. This research sheds light on nanotechnology at crime scenes as it is one of the modern scientific methods of detecting crimes and knowing their perpetrators. The goal of criminal proof is to reach certainty and assertion that the crime occurred, attribute it to the accused, and then convict him, and that this is done by legitimate means and procedures that respect freedoms and guarantee guarantees. Established by the law to respect the rights of the accused, human dignity, and to ensure the rights of defense and the integrity of the judiciary, the law has established one way to refute the principle of innocence (Pandya, 2018).

With the advancement of nanotechnology used in other fields and its wide applications in the design and development of materials science, devices, atomic energy, biology, pharmaceutical and cosmetics industry, biotechnology, bio tissue engineering, informatics and information technology, environmental protection, agriculture, food and health risks, and future expectations for the study of nanomaterials that have been modified and used in science. Forensic analysis including high-performance liquid chromatography, scanning microscopy (SPM), infrared fluorescence, X-ray photometric differential scanning (XPS), time-of-flight mass (Tof-MS), and atomic microscopy (AFM) have performed These devices used for nanomaterials led to great development in forensic medicine as they were able to detect and analyze a sample at the nanoscale by analyzing the physical units used as host materials for the chemical elements (Au-NPs) in criminal investigations used in detecting fingerprints or footprints and DNA fingerprints or The fingerprint used in detecting explosives (Nano sensor) or the brain’s fingerprint for information about the crime that is in memory as criminal proof evidence to reveal the facts by convicting the accused because nanomaterials possess new properties that help in collecting, discovering and proving crimes through nanotechnology (Vandan Prasada, 2016) . This raises the question of the authenticity of this new technology, which was a difficult dream to achieve in proving the crime.

There are also modern technological methods that contribute to the field of criminal proof, such as drawing pictures of defendants and suspects using a computer based on descriptions obtained from witnesses to the incident or victims through the Suspect ID program, in addition to the presence of a device installed in the car that sends and receives signals. A certain device through which the

location of the car is known, and the signals are received via a central computer electronically (Rohatgi, 2022). Using this device, the car is tracked and where it is located. This is useful when the car is stolen by knowing its exact location, so the incident is detected. The questions raised in this topic are about the position of the judiciary, members of the preliminary investigation, and the prosecution regarding nanotechnology in proving crimes.

What is nanotechnology

Nano is a prefix meaning "extremely small"; when quantifiable, it translates to parts per billion, as in nanosecond. (Björn Jürgens, 2015) .Nanotechnology is a combination of different fields of physical, chemical, and biological sciences that study phenomena on the nanometer scale (1 nanometer - 1 billionth of a meter) (Pitkethly, 2010). In this continuum, the Nano-platform alone or in combination with other technologies is expected to have important applications in security, drug screening, explosives detection, and DNA analysis that enable forensic investigators to perform complex analyses or detect even the smallest traces of evidence at a crime scene. Nano sprayers are used to find even the smallest trace evidence at crime scenes and the lab-on-a-chip device can perform numerous analyses and tests using an incredibly small number of samples (Giannoukos, 2016).

One of the advantages of nanotechnology in the criminal field (Musabih, 2014). The possibility of controlling the movement of individual atoms accurately and rearranging them, which enables the competent authorities in the criminal field to reconstruct the scene of the crime incident, and then find out how the crime occurred, and converting materials to atomic size will be the new way to build precise machines and technology such as microscopic robots, which will Prepare experts Forensic evidence involves searching and excavating hidden material artifacts that are difficult to discover by traditional means (Nuaimi, 2023). This technology is based on unifying and including all types of science with limitless possibilities, and we cannot predict its results, as it encourages everyone, regardless of their scientific, social, and humanitarian specializations, in its field and to cooperate among them. The role of blood stains in discovering and proving crimes through nanotechnology (Feynman, 2009). Furthermore, some critical forensic issues such as cost, and time-effectiveness, wide availability, accuracy, and reliability of results are major concerns in forensic investigation and security (McCord, 2006).

The crime scene is considered very complex and requires intelligence and acumen on the part of the investigator before using nanotechnology or assistive means to commit the crime to present it as evidence before the judiciary. The

crime scene is considered the place from which the physical evidence emerges. The crime scene may differ from one crime to another and maybe one or multiple. The crime may have been committed in one place and the body was dragged to a place other than the original scene. This depends initially on acumen and intelligence. The investigator and the crime scene represent the most important source among the sources for the policemen and those responsible for collecting evidence because it contains physical traces indicating the perpetrator and the victim. Therefore, the crime scene must be preserved and the first notes that the judicial officer saw must be recorded until the arrival of the police authorities (Gehl, 2017).

Fingerprint identification at crime scenes

In the previously mentioned example of the person covered in blood at the crime scene, forensic experts assigned by the Public Prosecution Office process this material for several days. Fingerprints or DNA from organic materials may lead to identification; If they don't, they won't be immediately useful. A forensic sketch expert may grasp some ideas but may not be able to answer basic questions such as: What sentences were written first on the paper, and after? (Jayanth Mmurali, 2019). Using the same material, researchers could reach a much wider range of conclusions, if the range of nanotechnology applications currently being investigated fell into their hands. “The tools used in nanotechnology laboratories, or nanoparticles themselves, have many uses in forensic science,” says Ian Turner, lecturer in biology and forensic science at the University of Derby. “Nanotechnology often improves the sensitivity of already existing forensic techniques,” notes Bruce McCord, a professor of forensic chemistry at Florida International University, who worked at the FBI's Forensic Science Center from 1989 to 1998. The most advanced applications are those related to fingerprints. Replacing materials used in fingerprint development (such as carbon black, aluminum foil, and gentian violet) with much smaller nanoparticles increases the sensitivity of forensic investigation. This makes it easier to spot old or faded fingerprints and those left on difficult surfaces, such as those with adhesives or textured materials. Nanoparticles bind to the fingerprint pattern and make it visible. A typical strategy is to engineer fluorescent nanoparticles to facilitate the development process (Catanzaro, 2013). The practice of detecting latent fingerprints using nanoparticles can be traced back to 1970. Since ancient times, fingerprints have been used as unique evidence that was later also used on Babylonian clay tablets for commercial transactions. Ideally, the fingerprint powder will stick to the residue left by the finger. It results in the appearance of distinct patterns that help identify an individual, such as a fingerprint, but do not

stick to the background or any other surface. Latent fingerprints are commonly developed by different colored materials such as carbon black on a white/light background and aluminum flake on a black/dark background. The disadvantage of these materials is their ability to adhere as they not only help in loosening the latent fingerprint but also stick to the background of the fingerprint. Due to the lack of experience in how to take it, this explains the difficulty of obtaining a clear image of the fingerprint, so identification is a major problem. In this case, synthesized or synthesized nanoparticles are used to overcome this problem (Worley , 2006)

Recently, a group of researchers found a new ZnO–SiO2 Nanopowder to detect latent fingerprints on various surfaces (dry and wet). This Nanopowder is highly efficient for visualizing finger edges in detail, an important factor for criminologists (Bose, 2023). Nanotechnology has proven to be a valuable treasure in fingerprint analysis. It is carried out through the imprinting procedure by replacing existing materials such as carbon black, aluminum foil, and gentian violet with much smaller nanoparticles. Nanoparticles facilitate the detection and lifting of residual fingerprints even on complex surfaces such as adhesives or woven materials. Hidden fingerprints are also detected instantly and accurately using nanotechnology. Nanoparticles can make fingerprints more prominent by attaching to grooves and edges even on a damaged and faded fingerprint. The latest nanotechnology-based technology helps police officers analyze evidence on the spot at crime scenes, which not only saves analysis time but also reduces the chances of error. Nowadays, in the process of criminal investigation, various Nanopowders are used to confirm latent fingerprints on diverse surfaces. Fluorescent nanoparticles upgrade the fingerprint effect by glowing in the dark and telling the patterns more clearly. To achieve this, photonic semiconducting CDs nanocrystals covered with dioctyl-succinate are used to enhance fingerprint detection (Farrukh, 2013). Nanoparticles in fingerprint analysis not only reveal the information in the fingerprint. In addition, it also reveals the lifestyle of the person who left his fingerprint at the scene. A fingerprint besides patterns also contains the sweat and other metabolites of a person. Nanoparticles, by binding to bodily fluids and metabolites carried in the fingerprint, can reveal whether the owner of the fingerprint is addicted to cocaine or addicted to alcohol, but they are also able to reveal his age, gender, and diseases he will suffer. Nanotechnology has proven to be useful for police even in investigating questionable documents. Suppose, we find a person hanging in a room with a note written around the body. If the memorandum contains overlapping writings, it leads to suspicion that it is in the handwriting of two or two different people. Under these circumstances,

nanotechnology steps in and saves the investigating officer through a Nano-instrument called the atomic Force Microscope (Pandya, 2018).

Detection of explosive remains at crime scenes

Terrorism is considered the largest and most common threat throughout the world. Its enormous growth is due to the simple manufacture of weapons/explosive devices; It is easy to spread and results in mass destruction. Detecting trace amounts of explosives is a difficult task due to several issues, such as the low number of unexploded explosives, contaminated samples, and different sample collection procedures. In the event of a bomb explosion, scattered explosive residue can spread from the actual site of the explosion while an unfragmented portion of the explosive remains at the crime scene. During a crime scene investigation, investigators can use Nano-based technology to determine the unfragmented/trace number of fragmented explosives from a crime scene. In most bomb explosion cases, it is difficult for the investigator to identify undetonated explosives. Hence, investigators are unable to provide enough evidence to confirm the link between the accused and the crime scene in court, which is also inappropriate for conviction (Purasinhala., 2018). Here, Nano-based technology can be useful in analyzing untraceable explosive cases. With the help of Nano-based technology, investigators can detect microscopic particles of gun powders on the shooter's hand. In addition, because a useless method of detecting gunshot residue is used, investigators are unable to identify even single particles of gunshot residue after a crime. High-resolution scanning electron microscopy imaging can be used to identify gunshot residue while in combination with X-ray spectrometry, it may be useful to identify the elements that make up gunshot residue. A recent study showed that gunshot residue analysis is an important step in shooting cases that can help prevent crimes in the community by providing enough supporting evidence. However, these procedures are time-consuming, tools are required, and chances of error are higher (Pandya, 2018).

Pandya et al. 2012 showed that a fluorescent probe extracted from turmeric and based on curcumin molecules, which has high selectivity and ultra-high sensitivity, can be used in detecting Trinitrotoluene down to the 1 NM level in aqueous solution (Figure 3). Zhou et al. 2015 proposed a new sensing technology for selective and label-free detection of 2,4,6-trinitrotoluene from 10−12 to 10−4 M based on amine-terminated nanoparticles. These studies open new horizons for rapid, easy, and reliable detection of TNT from environmental samples and at crime scenes by fluorometric densitometry (Pandya, 2018).

Estimating the time since death

It is known in forensic science that it is difficult to determine the time of death with 100% accuracy, but the specific estimate of the time of death is based on certain data concluded by forensic doctors at the crime scene. However, traditional methods can only predict an approximate time of death. Researchers believe that nanotechnology, i.e. fluorescent nanoparticles, can be used to estimate amino acid level (VH) with the help of flow cytometry. In legal forensic science, the time elapsed since death was estimated is a vital step. An accurate estimate may help provide the exact time and cause of death. As we know in the traditional method, there are many parameters by which the moment of death can be estimated. Such as the stiffness of the corpse, its coldness, changes in the eyes, changes in decomposition, stomach, and intestinal contents, (Maiese., 2021) urinary bladder contents, and anecdotal evidence. All these parameters can only provide the approximate time of death. Marked changes in body fluids (blood, pericardial fluid, synovial fluid, spinal fluid, aqueous humor, vitreous humor) are useful additional measures to establish acute bronchial dysplasia syndrome, immediately or shortly after death fluid, vitreous humor (VH) remains unchanged (Maiese, 2021).

A smart, rapid, sensitive, cost-effective, laboratory-on-chip method has been developed that provides easy determination of cysteine, an amino acid. (Swann, 2010). This method may estimate up to 96 h until the cysteine concentration of VH increases significantly and shows a linear correlation with TSD expansion. Soon, this method could lead to the development of a microfluidic system, an intelligent detection-based approach to quantify cysteine concentration and correlate it with quantitation. Recently, Williams and colleagues developed a flow cytometry-based method for TSD quantification. In this method, the rate of DNA degradation of spleen and brain tissues was measured up to 96 h and it was found that brain tissues are more favorable compared to spleens. Moreover, in another study, the potential application of flow cytometry for TSD quantification was well demonstrated. In this study, the flow cytometry-based method was able to detect erythrocytes in contaminated VH. This method helped screen samples for which biochemical results were inconsistent. Due to the higher sensitivity of flow cytometry compared to the traditional method, this screening test has nowadays become the most popular method for estimating this method based on flow cytometry. This method based on flow cytometry will give pace to legal medicine help to avoid misinterpretation and reduce the number of cases pending in court. Soon, the amino acid concentration of VH could be detected by fluorescent nanoparticles and then quantitatively assessed using flow cytometry which would be a possible approach to accurately estimate TSD (Pandya, 2018).

Knowing the age of the blood sample

The blood becomes more solid over time, as the red blood cells dry out on the surface. As the blood ages, the AFM tip needs more force to pull away from the blood's surface: measuring this slight difference in force allows the sample to be dated. Biofluids have more to reveal when interrogated by nanotechnology-based applications. In 2013, McCord developed a system that mixes urine with gold nanoparticles and analyzes the signal released when the mixture is illuminated with a laser. His work focuses on benzodiazepines, known as "rape drugs," because they are sometimes used to facilitate sexual assault. "The victim may go into shock and take days before going to the hospital, so we need to detect the effects of the mix-up," he says. The physical properties of nanoparticles, as they interact with light, provide the increased sensitivity required, down to nanograms per ml concentration. While traditional methods combine urine with antibodies sensitive to a drug, McCord's method relies on light spectrum analysis, which detects a variety of drugs. "My best guess is that the most promising application of nanotechnology in forensics lies in improved DNA analysis," says Ian Turner. "Nowadays, DNA analysis requires a lot of time, money, and many laboratories. But he points out that the key procedures of extracting, amplifying, separating, and sequencing DNA are already becoming faster and more portable, thanks to nanotechnologies. The challenge is to integrate them at a cost, to integrate a complete lab-on-a-chip: this would allow rapid and portable analysis (Catanzaro, 2013).

McCord is pushing hard in this direction. In 2013, he published a genotyping system that reduces a two-day procedure to 25 minutes. This method, based on a microfluidic device developed by McCord with Agilent Technologies, measures 13 locations in an individual's genome that display patterns unique to that person Once microfluidic devices become more widely available, police can check whether a suspect's DNA is in their database at the time that person is held at the police station," McCord says (McCord, 2006). "There's a sea change about to happen for forensic analysis, based on next-generation sequencing, all based on nanoscale technologies," McCord says. He says that two of the most promising lines are to identify the tissues that are the origin of the DNA found at crime scenes (skin, blood, saliva, semen...) and to infer some phenotypic traits of the owners of this DNA: geographic origin, eye, skin, and hair color and stature (McCord, 2006). So, returning to the crime scene at the beginning, investigators will reach a broader range of conclusions using nanotechnology tools: whether the perpetrators of the crime were under the influence of drugs, when the blood was poured and the story behind the document. But before that, more nanotechnologies will have to move from the laboratory into police hands (Catanzaro, 2013).

The validity of stains in criminal evidence before the judiciary

Blood spots form now, and after the tremendous scientific development, especially in nanotechnology A solid basis for most criminal cases; Therefore, the current era is called the era of nanotechnology. This is because social problems have increased, and many consciences have disappeared (Al-Maaytah, 2000) so it was necessary to preserve in truth, and there is no doubt that the blood stains have become sober and strong that they can be considered in proving the case.
The penal system through its effective role in preparing the rules of evidence and creating objective rules, and this gives him It is of great importance in proving crimes.

This type of analysis and examination - using nanotechnology - was not previously known or used in our country. (Musabih, 2014) However, the dream has become the beginning of reality, as we mentioned previously, nanotechnology has intervened in all fields, and what it means is the forensic laboratory. In this regard, the Court of Cassation in the Emirates ruled (Nano Criminal Case , 2011)"Since it is established that for the validity of a judgment of conviction, the evidence on which it is based must be consistent with each other, so if the court cites in its ruling two conflicting pieces of evidence and takes them both together and makes them its basis in proving the guilt of the accused without addressing this contradiction and stating what indicates that it is ruling on the case. She was paying attention to it, examined it, and was convinced that it did not exist. She would have relied on two contradictory pieces of evidence, and this makes her ruling as if it were unreasoned, since that was the case, and the contested ruling had based its conviction of the appellant for the crime of using the drug hashish on the report of the National Rehabilitation Center, which concluded that An examination of the appellant's urine sample on August 4, 2010 revealed that it contained 44.4 nanograms, and according to the report of the Chemical Analysis Department, Toxicology and Drugs Branch - Forensic Laboratory, which stated that it was proven from the analysis of the appellant's urine sample on July 22, 2010, that it contained... The percentage of (57 nanograms) without addressing this apparent contradiction in the result between the two reports and removing it before convicting the appellant of the crime charged to him. This does not change his statement that the sample is considered positive in the reports issued by the National Rehabilitation Center if the concentration of the cannabis drug exceeds 25 nanograms. / ml of urine for medical and therapeutic follow-up, and the percentage of fifty nanograms that the appellant claimed to be absent should be in normal circumstances, as this is what the referee concluded is neither permissible nor acceptable in reason and logic and contradicts the provisions of the ministerial

decision which stipulated that the sample is considered positive for the drug hashish. If the concentration of hashish in the accused's urine exceeds 50 nanograms, without distinguishing between the case of medical and therapeutic follow-up and other cases, the court must investigate whether the result included in each of the two reports was the result of analyzing one or more urine samples from the appellant. Because of the impact that examining this would have on the ruling in the case, if it neglected to do so, its ruling would be flawed due to insufficiency that requires it to be overturned without the need to discuss the remaining aspects of the appeal.

In this regard, it is believed that "the blood stain is strong evidence against the accused if the matching blood stain is found." The type of the victim the accused or anything related to him, as well as by analyzing the blood plasma protein of the spot. Blood and the blood of the victim; Because the similarity in this type is very little, and if this is not present, it shall be conclusive evidence to deny the accusation if he is accused of the presence of the stain on his body or anything related to it (Rohatgi R. , 2022).

.

Conclusion

In conclusion, the integration of nanotechnology into forensic investigations represents a groundbreaking advancement that has the potential to revolutionize the field. Through the meticulous exploration of nanomaterials and their applications, this research has unveiled a myriad of possibilities for enhancing the accuracy, sensitivity, and efficiency of forensic analysis. At the end of this study, it is found that it is time for this technology to forcefully enter forensic laboratories to find accurate evidence and direct it to the accused without the slightest doubt, especially considering the accused's attempt to destroy evidence, as is the case in the attempt to destroy the accused's fingerprint, to escape the crime. The use of a nanotechnology in the crime scene helps Forensic scientists prove the credibility of the outcome of their investigation before the court of law. This technique has the authority to prove it before a criminal judge as material evidence, and the Public Prosecution can rely on it to file a criminal case.

Recommendations

- Organizing in-depth and specialized courses by experts for judicial officers, specifically for crime scene staff, on this technique, as it has an impact on the criminal case when the seizure is made, and the tools are seized.

- This technology must be applied in the criminal laboratory because of its necessity to light the way for the prosecution to delve deeper into finding evidence and bringing charges against the accused, especially in light of the accused's attempt to destroy the evidence, as is the case in the attempt to destroy the accused's fingerprint, to escape from the crime.
- Organizing a field visit for law students to the forensic laboratory to delve deeper into the concept of nanotechnology the extent of its use in the forensic laboratory, and how this technology affects the process of proving a criminal case.
- It is important to note that scientific advancements are taking place at a rapid rate and every day we come across new technology so for a forensic investigator is mandatory to keep him or herself updated with the advancements in the field.
- Major research efforts should be made shortly to ensure the use of nanotechnology is better equipped, to enhance the robustness and reliability necessary for a real applicability to this field.
- Authorities should organize on-the-job training programs and provide forensic laboratories with nanotech instrumentation.
- To arrange exchange programs and send forensic scientists to other countries where nanotechnology is practiced more skillfully.

References

AlNuaimi, A. (2022). *Nanotechnology, Masdar Institute of Science and Technology*, Abu Dhabi, www.albayan.ae. https://mbras.ae/en/committe-member/aaesha-al-nuaimi

Appeal, No. (2011), 883 of 2011, s. 5 BC. Judicial Department, United Arab Emirates

Bayda S, Adeel M, Tuccinardi T, Cordani M, & Rizzolio F. (2019). The History of Nanoscience and Nanotechnology: From Chemical-Physical Applications to Nanomedicine. *Molecules*. Dec 27;25(1):112. doi: 10.3390/molecules25010112. PMID: 31892180; PMCID: PMC6982820.

Björn , J .(2015) . Nanotechnology in Spain: Technology Watch by Patents, Universidad de Granada, 20.

Catanzaro, M. (2013). *Nanotechnology on the crime scene*. https://www.theguardian.com/what-is-nano/nanotechnology-on-the-crime-scene Mon 18 Nov 2013 00.01 GMT

Farrukh, M. (2013). *Nano-Forensics Publisher*: LAP Lambert Academic Publishing, Lambart London, P77.

Farrukh, M.(2013). *Nano-Forensics* Paperback, Publisher: LAP Lambert Academic Publishing

Feynman, R.(2009). Plenty of room' revisited. *Nature Nanotechnology*. 4 (12): 781. December Macmillan Publishers Limited. All rights reserved from: https://www.materialstoday.com/nanomaterials/articles/s1369702109701671/

Gehl, R. (2017). Introduction to Criminal Investigation: Processes, Practices and Thinking, Chapter 8: *Crime Scene Management*, Topic 2: Integrity of the Crime Scene, BC Campus

Giannoukos S, Brkić B, Taylor S, Marshall A, Verbeck, GF. (2016). Chemical sniffing instrumentation for security applications. *Chemical Reviews·* July 2016, 8152.

Jayanth, M. (2019) *Nanotechnology on the crime scene*. | Published Apr 1, 2019, 1:24 am IST- https://www.deccanchronicle.com/Wednesday, Sep 01, 2021 | Last Update : 03:24 PM IST

Joseph, P. (2023). *The Role and Impact of Forensic Evidence in the Criminal Justice Process*, California State University, Los Angeles.

Loevinger, L. (1992). STANDARDS OF PROOF IN SCIENCE AND LAW. Jurimetrics, 32(3), 323–344. http://www.jstor.org/stable/29762257

Maaytah, O. (2000). Forensic evidence and criminal investigation, Dar Al-Thaqafa for Publishing and Distribution, Amman. p. 48

Maiese A, Scatena A, Costantino A, Di Paolo M, La Russa R, Turillazzi E, Frati P, Fineschi V. (2021). MicroRNAs as Useful Tools to Estimate Time Since Death. A Systematic Review of Current Literature. *Diagnostics (Basel).* 3;11(1):64. doi: 10.3390/diagnostics11010064. PMID: 33401603; PMCID: PMC7823686.

McCord, B. (2006). *Nanotechnology and its Potential in Forensic DNA Analysis*, International Forensic Research Institute, Department of Chemistry and Biochemistry, Florida International University, Miami, Florida, USA .2-3.

Musabih, O. (2014). The role of blood stains in detecting and proving crimes through nanotechnology." *The Arab Journal for Security Studies and Training*. 30(61), 41-78.2014

Pandya, A., Shukla, R.K. New perspective of nanotechnology: role in preventive forensic. *Egypt J Forensic Sci* 8, 57 https://doi.org/10.1186/s41935-018-0088-0

Pitkethly, M. (2010). Nanotechnology and forensics, mat. Today 12(6). Retrieved from: https://www.materialstoday.com/nanomaterials/articles/s1369702109701671/

Priyam, B. (2023). *Priyom holds a Ph.D. in Plant Biology and Biotechnology from the University of Madras*, India, https://www.azonano.com/authors/priyom-bose

Purasinhala, (2020). OXIDATION PROTECTION OF CARBON FIBER BY Zr3(PO4)4 – B2O3 NANOCOMPOSITE COATINGS, Conference: *International Conference on Nanoscience and Nanotechnology*, at Colombo, Sri Lanka. p1

Richa, R. (2022). Application of Nanotechnology in Forensic Science, *Journal of Forensic Research*. 13(8). 1-5.

Richa, R.(2022) .Application of Nanotechnology in Forensic Science, Journal of Forensic Research Article.

Swann L, Forbes S, Lewis S. (2010) Analytical separations of mammalian decomposition products for forensic science: a review. *Anal Chem Act*, 682:9–22

Sweta, S. (2021). Nilimamayee Samal, Nanotechnology: A Powerful Tool in Forensic Science for Solving Criminal Cases, *Arab Journal of Forensic Sciences & Forensic Medicine*; 3(2), 273-296

Vandan, P. (2016). Emerging Forensic Applications of Nanotechnology, International Journal of Medical Engineering and Science (IJEAS) Volume 2, February, Published by School of Basic and Applied Sciences, Glagotes University, Greater Noida, Uttar Pradesh, India p. 7

Worley CG, Wiltshire SS, Miller TC, Havrilla GJ, Majidi V. (2006). Detection of visible and latent fingerprints using micro-X-ray fluorescence elemental imaging. *J Forensic Sci. Jan*;51(1):57-63. doi: 10.1111/j.1556-4029.2005.00006.x. PMID: 16423224.