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New Perspective of Calcium Oxide Nanoparticles in Forensic Science

Dr. Syeda Mona Hassan[1], Dr. Aftab Ahmad Malik[2] and Hafiza Hadia Shehzad[3]

[1] Department of Chemistry, University of Agriculture, Faisalabad

[2] Faculty of Computer Sciences and Engineering, Ghulam Ishaq Khan Institute of Science and Engineering, KPK

[3] Department of Chemistry, University of Education, Lahore.

Abstract:

Nano-technologies have wide applications in the field of forensic science. Nanotechnology is an important and powerful tool in most the areas including medicine, imaging, and forensic sciences. It has potential to make significant positive contribution in forensic science in crime detection. The present article focuses on the applications of CaO nanoparticles in developing and detecting the latent fingerprints. Fingerprint is considered noteworthy evidence in any crime scene, and nano-based techniques. An attempt was made to elucidate how nanotechnologies could be crucial in addressing current forensic investigation issues such as explosive detection, toxicological analysis, finger print analysis, forensic DNA analysis, detection of explosive residue, forensic nano trackers and drug facilitated crime.

Keywords: Nanotechnology, Forensic investigation, Nano trackers, DNA analysis, explosive detection

1. Introduction

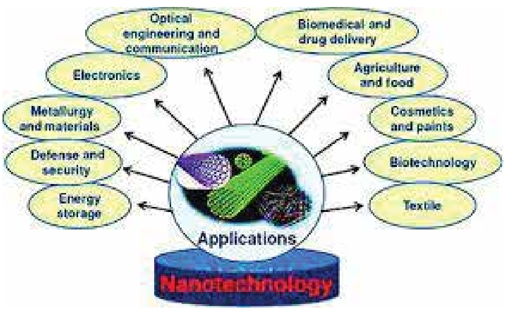
Although scientists and technologists are still being inspired by nanotechnology to investigate novel materials and human benefits (Patel *et al.*, 2008).

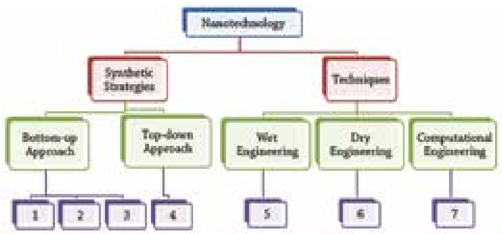
Nanotechnology is the study of the atomic or molecular processing of materials with at least one dimension in the 1–100nm range that result from controlled synthesis. Since the very first forms of life on earth, like plants and animals, were molecularly altered to create their structures, this fascinating technology is not new to nature. One can find inspiration to develop nanoscale materials by engaging in extensive observation and improving awareness of nature's fundamental design principles. This interesting field of study is made possible by the examination of nanoscale technology and how they interact with nature (Sheeparamatti, Sheeparamatti, & Kadadevaramath, 2007).

These NPs are well known for their intrinsic antimicrobial activity and have potential applications in food, climate and healthcare. CaO NPs stand out among them for their superior antibacterial power and capacity to inactivate microbial endotoxin. In photodynamic therapy, they may be utilized as a potential medication delivery system due to CaO NPs specific structural and photothermal therapy (PTT), optical properties (PDT) and synaptic distribution of chemotherapeutic agents.

Conformational changes in albumin association with NPs play a critical role in diverse biomedical applications. Thanks to its broad variety of physiological functions, BSA is a good model for studying protein conformational changes, a suitable protein for intrinsic fluorescence measurements, well characterized structure and property, and readily undergoing conformational changes, target the desired organ. When NPs enter a biological fluid there will be changes in conformation and biological activity of protein as well as modification in the properties of NPs (Gross *et al.*, 2012).

The term "nanotechnology" soon captured the imagination and curiosity of the general public as well as of various media (TV networks, the internet, etc.). Nanoparticles typically range in size from 1 to 100 nanometers. Metallic nanoparticles have various physical and chemical features from bulk metals, including as lower melting temperatures, higher special surface areas, unique optical qualities, mechanical prowess, and unique magnetization, which could be advantageous in a variety of industrial applications (Roco, 2011).





1	2	3	4
Physical *(Gas solid transformation)* 1. CVD and PVD 2. MBE 3. PLD 4. ALD 5. Ion-implantation 6. Spray pyrolysis	**Chemical** *(Liquid solid transformation)* 1. Co-precipitation 2. Sol-gel 3. Chemical reduction 4. Sono- and photochemical 5. Electrochemical 6. Microemulsion 7. Solvo-thermal (hydrothermal) 8. Template/surface derived method	**Biological** *(Bioreduction)* 1. By plants 2. By bacteria 3. By fungi 4. By yeast 5. By algae 6. By biomolecules 7. By agricultural and industrial wastes	1. Bulk nanomachining 2. Fragmentation: Nanomilling, spark erosion, etc. 3. Lithography (Optical, ultraviolet, X-ray, electron beam, laser, etc.)

5	6	7
1. Biomimetic and tissue nanotechnology 2. Bioimaging, biosensing and bioanalytics 3. Nanodiagnostics 4. Nanotherapy 5. Pharmaceuticals 6. Cosmetics 7. Environment harvesting and remediation	1. Information processing, storage and transmission 2. Electronics, optoelectronics and photonics 3. Sensors, MEMs and energy devices 4. Food packaging and storage 5. Pigments, protective glasses, textiles	1. Ab-initio and semi empirical: a. Quantum or molecular mechanics b. Quantum or molecular dynamics of: i. *Nanostructures and interfaces* ii. *Assembly and growth* iii. *Biointeractions* 2. Optimisation and predictability

Table 2.1: The use of Nanotechnology techniques in manufacture

Nanoparticles typically range in size from 1 to 100nanometers. The description of nanoparticles and nonmaterial's by different organizations is outlined in this respect. In special interest, one of the fundamental attractions and a hallmark of nanoparticles is the optical property. A 20nm gold nanoparticles, for example, has a distinctive red wine hue. The size of the nanoparticles utilized in the field of biotechnology typically ranges between 10 and 500nm. Due to their small size, these particles can interact with biomolecules inside and on the surfaces of cells in a number of ways that can be interpreted and assigned to various biochemical and physiochemical properties of these cells (Mody *et al.*, 2009).

The systems for nanoparticles must be stable, biocompatible, and selectively directed to particular places in the body following systematic delivery if they are to be used to their full potential. To recognize the targeted cells in an administration, more precise targeting systems are created. If in at least one of their lengths, nanoparticles are smaller than 100nm. In general, however, nanoparticles are materials which have nanoscale dimensions of at least two dimensions, including particles as well as fibrous materials and tubes, but excluding nanoscale materials of only one dimension, such as coatings, films and multilayer's (Holister *et al.*, 2003).

There are many types of particles under this umbrella word, which only have the resemblance of their small size. The word of "nanoparticles" is commonly used as a collective term in this study as well as in the everyday language. However, it is important to remember that it (Biswas *et al.*, 2005).

In various fields of science and technology, nanotechnology has broad applications and recent research focuses on NPs related materials and their applications. Much of the size of biological molecules is close to that NPs, because it has uses in both in vitro and in vivo biochemical studies. NPs have possible applications in drug distribution, "a wonder of nano medicine" cancer therapeutics, in antibacterial vaccinations to manage bacterial infections and to target bacteria as an alternative to antibiotics. Inorganic nano metal oxide NPs (MgO, CaO, CuO, ZnO, TiO_2) have distinct features and are safe, stable and possess multifunctional properties (Ranghar *et al.*, 2014). These NPs are well known for their intrinsic antimicrobial activity and have potential nutritional, environmental and health care applications. Among these, CaO NPs have outstanding antimicrobial potential and ability to inactivate microbial endotoxin.

Due to the unique structural and optical characteristics of CaO NPs, they have the potential to be employed as a drug delivery agent in photodynamic therapy (PDT), photo thermal therapy (PTT), and synaptic delivery of chemotherapeutic drugs. CaO nanoparticles are non-toxic to both people and animals. Conformational changes in albumin association with NPs play a critical role in diverse biomedical applications. Thanks to its broad variety of physiological functions, BSA is a good model for studying protein conformational changes, an excellent protein for intrinsic fluorescence measurements, well characterized structure and property, and easily undergoes conformational changes.

Many therapeutic nano systems, targeting the target organ, are configured for intravenous systematic administration. Changes in protein conformation and biological behavior and alternation of the properties of NPs can occur as NPs join a biological fluid (Gross *et al.*, 2012).

2. Nanoparticles

A particle with a size of at least one of the three possible dimensions between 1nm and 100nm is referred to as a "nanoparticle." In fundamental aspects, the physical, chemical, and biological characteristics of nanoparticles differ from those of all individual atoms or molecules and the associated bulk materials in this size range. Metals, non-oxide metal ions, metal oxides, ceramics, polymers, organic materials, carbon, and biomolecules the most prevalent chemical components used to make nanoparticles (Roco *et al.*, 2011).

Back in 2000, the United States initiated the almost all of the United States' states rapidly launched their own nanotechnology efforts after the National Nanotechnology Initiative(NNI) (2001). National Science Foundation departments ultimately sponsored approximately 20 research Centre (NSF), an organization that is directly accountable to the president of the United States to bring out the NNI (Moreno-Olivas *et al.*, 2014).

Recently, microbial bioprocessing has been investigated as a desirable an option to creating nanoparticles chemically and physically. Nanotechnology and microbial biotechnology are combined during the microbial synthesis of NPs. Exploration of bacteria, archaebacterial, fungus, yeast, moulds, microalgae, and viruses is being done in order to create bioactive nanostructures that have many industrial benefits (Hulkoti *et al.*, 2014).

Most of the time, microbial biosynthesis and bioprocessing results in cost-efficient, environmentally beneficial, and sustainable NPs. However, the biogenesis process takes a long time, and it is challenging to regulate the NPs' size, shape, and dispersion. To get beyond these restrictions, a number of ways have been developed, including proper strain selection, the creation of genetically modified microbes, the development of technologies for extracting and cultivating microorganisms, as well as combination techniques such photo-biological procedures (Mohammadian *et al.*, 2016).

Nanoparticles come in a variety of distinct morphologies, including spheres, tubes, platelets, and cylinders, among others. In general, nanoparticles have their surfaces modified to match the requirements of the particular applications they will be used in. the vast chemical diversity of nanoparticles that results from it. The particle's morphologies, state of particle dispersion, medium in which it is present, and, most importantly, the different potential surface alterations the nanoparticles can be exposed to, are necessary to make this an essential active area of research today (Cunill *et al.*, 2019).

3. Classification of Nanoparticles

The organic, inorganic, and carbon-based nanoparticles are the three main categories for the nanoparticles.

Organic Nanoparticles

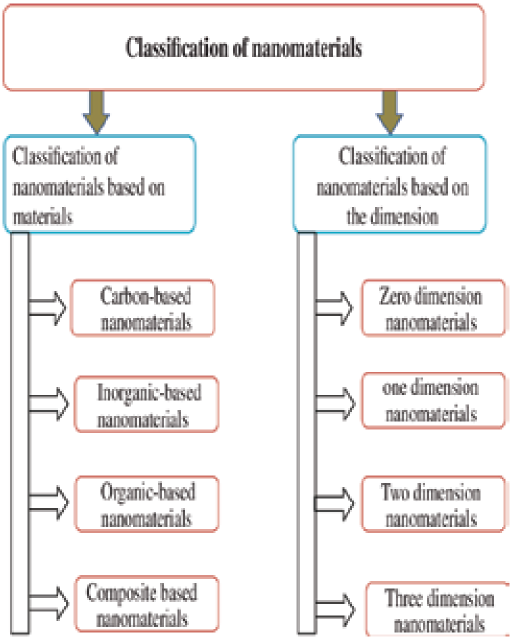
Organic nanoparticles or polymers include ferritin, liposomes, dendrimers, and micelles. Some of these nanoparticles, such as micelles and liposomes, are biodegradable and non-toxic, own hollow cores that give them the name "nanocapsules" and make them sensitive to electromagnetic and thermal radiation like heat and light. They are the perfect option for drug administration because of their distinctive qualities. In addition to their normal characteristics like size, composition, surface form, etc., the drug carrying capacity, stability, and delivery systems whether entrapped drug or adsorbed drug system determine their range of applications and efficiency. The biomedical sector uses organic nanoparticles most frequently for drug delivery systems because they are efficient and may be injected into specific physiological locations, a procedure known as targeted medicine administration.

Inorganic nanoparticles

Nanoscale metal particles Inorganic nanoparticles are those that are not made of carbon. Metallic nanoparticles are often classified as those made of metal or metal oxide.

4. Carbon based

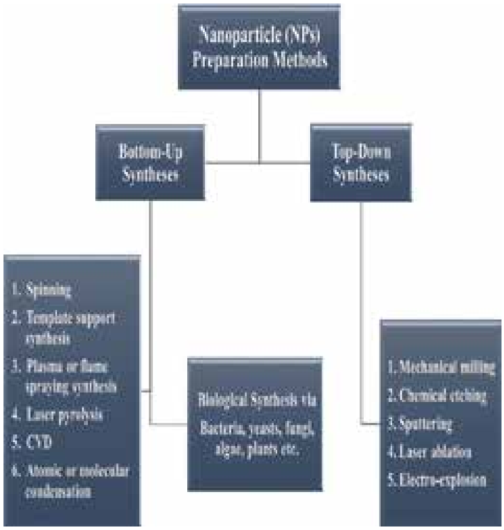
All-carbon nanoparticles are known as carbon-based nanoparticles. Fullerenes, graphene, carbon nanotubes (CNT), carbon nanofibers, carbon black, and on occasion activated carbon are used to represent them (Ealia & Saravanakumar, 2017).



5. Green Synthesis of Nanoparticles

There are many methods for the preparation of nanoparticles, but most common method we used are the

1. Top down approach
2. Bottom up approach (Iravani, 2011).



6. CaO Nanoparticles

Calcium oxide nanoparticles are used in photo thermal and photodynamic therapy and synaptic delivery as potential drug delivery agents. CaO NPs are also used in different fields with potential biomedical applications, such as electronics, environmental remediation, sensors and catalysis (Kumar *et al.*, 2019).

Calcium oxide (CaO) is the most significant substance that has been widely utilised in a variety of fields, including catalysis, cosmetics, and ceramics to control microorganisms, it is also used as an inorganic antimicrobial substance. Depending on its chemical makeup, CaO can be found in the periodic table's alkaline earth (Marquis *et al.*, 2016).

However, given the great richness of tropical plants group found in Indonesia, using tropical biomass or its extract for CaO biosynthesis would be a worthy scientific challenge due to the more efficient and environmentally friendly method of CaO biosynthesis. The ability of a metabolite chemical found in plant materials to act as a biological reducer for metal production is well established (Akhtar *et al.*, 2013). Where flavonoids compounds were found to be one of the most useful classes of plant tissue secondary metabolites added as a reducing a metal ion agent.

Depending on the type of plant, the majority of flavonoids compounds naturally contain natural colours in various shades, such as red, pink, and purple. Calcium oxide is the most significant substance that has been widely utilised in a variety of fields, including catalysis, cosmetics, and ceramics (CaO). It is also employed as an inorganic antibacterial agent to inhibit germs. Depending on its chemical makeup, CaO belongs in the periodic table's alkaline earth group. However, given the great richness of tropical plants found in Indonesia, using tropical biomass or its extracts for CaO biosynthesis would be a worthy scientific challenge due to the more efficient and environmentally friendly method of CaO biosynthesis. It is generally recognised that chemicals found in plant materials, such as biomass, can act as biological compounds on the production of metals (Mustafa *et al.*, 2013).

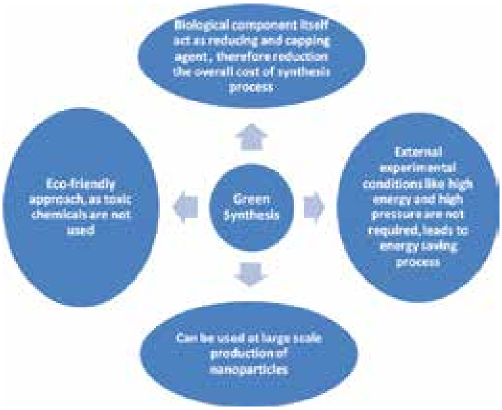
Where flavonoids compounds were found to be one of the most useful classes of plant tissue secondary metabolites added as a reducing agent for ions of metal. Depending on the shape of the plant, many flavonoids naturally create natural pigments in a variety of hues, such as red, pink, and yellow. The previous ten years, researchers have concentrated immensely on nanotechnology and intensely on nanotechnology efforts to investigate the electrical, optical and magnetic properties of nonmaterial. A number of nanoparticles-based therapeutics have increased effectiveness and decreased the toxicity of drugs, biological obstacles and selective drug delivery agents. These peculiarities can be modulated for large nano-biomedical applications (Choi & Han, 2018).

7. Green Chemistry

The field of "green chemistry," which was established two decades ago, represents the key efforts to address such challenges from the most fundamental level by re-examining, redesigning, and recreating the scientific tools used in the production, transformation, and use of chemical products in order to increase efficiency while reducing waste and harm. The objectives of this issue on green chemistry, which includes some of the leading professionals in the field, are to assess our needs in the area, reflect on the advancements made, and celebrate successes. This selection merely scratches the surface of the countless intriguing developments in the area (Iqbal *et al.*, 2020).

All areas of chemistry are included in "green chemistry," however there is a particular emphasis on chemical compound synthesis and chemical engineering techniques used in industrial settings using natural materials. On the other hand, laboratory investigations are also impacted by the key principles of green chemistry, creating a safer environment. According to sustainable chemistry, or "green chemistry," the use and production of hazardous compounds are reduced during reaction and synthesis. Green chemistry also involves processes for creating renewable materials. The following are the primary objectives of green chemistry, the utilization of renewable materials and energy sources, as well as the design of reactions with the highest efficiency. Using green chemistry, new nonmaterial can be created that have positive effects on the economy, society, health, and environment (Ramesh *et al.*, 2012).

Synthesis of many green nanoscale drug delivery systems this will be stressed first. The vast majority of examples for the use of green chemistry in nanoscale drug delivery systems rely on gold nanoparticles (AuNPs), polymer nanoparticles, and biological drug delivery systems based on proteins and lipids. Following each section is a quick summary of the green manufacturing companies that are currently being developed. Last but not least, a focus will be given on the future paths that the field of green nano-chemistry needs to take in order to eventually apply green chemistry in nanomedicine on a large scale to safely and successfully treat a variety of disorders (Bernardini *et al.*, 2015).



8. Parameters Effecting Green Synthesis of Metal Nanoparticles

Different parameters, such as reaction time, reactant concentrations, pH, and temperature, can be used to alter the morphological properties of nanoparticles (Table 1.1). Such factors are important for knowing the effect of environmental conditions on nanoparticles synthesis because they plays an important role in optimizing the metallic nanoparticle's synthesis through biological means (D. Zhang *et al.*, 2020).

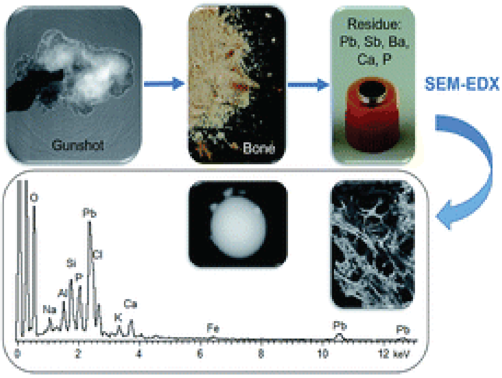
S. No.	Factors	Effect on green synthesis ofmetal NPs	References
1	pH	Shape and size of NPs	(Dubey *et al.*, 2010)
2	Reactant concentration	Shape of NPs	(Chandran *et al.*, 2006)
3	Reaction time	Shape and size of NPs	(Prathna *et al.*, 2011)
4	Reaction temperature	Yeild, shape stability and size of the NPs	(Yong Song *et al.*, 2009)

9. Application of Nanotechnology in Forensic Science

Forensic GSR Analysis

CaO nanoparticles of forensic science relies heavily on gunshot residue (GSR) to determine specific elements of crime. CaO nanoparticles is used of a gun resulted in a suicide or a murder is the major goal of GSR analysis. CaO nanoparticles is used to determine whether a shooting was unintentional, committed in self-defense or with the intent to kill a person (Sermon et al. 2012). The distance from which the weapon is fired, and how close it comes to the target, is determined by the Global System for Standardization's (GSR) Common Sense Rating (CSR) system (Schwoeble and Exline 2000). Nanotechnology is the key to overcoming the drawback faced by conventional methods for determining global temperature (GSR) and other important information. The conventional methods used for GSR determination is very time-consuming and also not accurate.

Using the ancient method, the information remains unanalyzed (Meng and Caddy 1997). This approach involves the rearrangement of GSR using high-resolution scanning electron microscopy (HR-SEM) images (Pandya and Shukla 2018). An X-ray spectrometer in conjunction with a scanning electron microscope is useful for determining the chemicals present. The most accurate GSR analysis uses several nanodevices and nanomaterials, such as gold nanoparticles (Srividya 2016). Due to the high surface-to-volume ratio, it is possible to create ultrasensitive nano sensors that can detect as little as a few micrograms of the sample (Taudte et al. 2016).

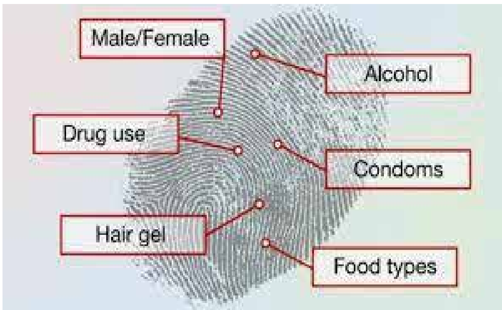


10. Forensic Fingerprint Development

The method of gathering evidence in rape crimes is frequently a simple, sensitive, and effective powder for fingerprint detection. Since the latter part of the nineteenth century, biometric identification of people has been done by using their fingerprints' distinctive patterns. One of the best systems for the safety and security of papers, gadgets (such phones, laptops, etc.), bank lockers, entrance control of workplaces, and forensic application in crime scene investigation is the development, identification, and presentation of the fingerprint (Wang et al., 2017).

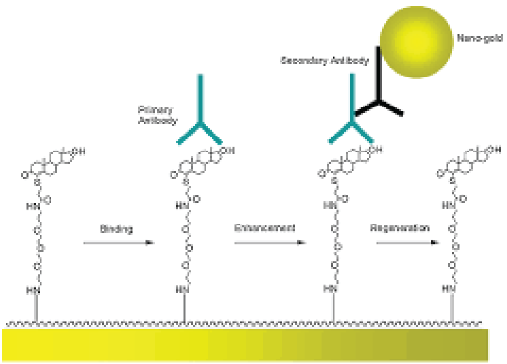
11. Traditional Methods For Fingerprint Development

Finger prints left at crime scenes are one of the tools used to incriminate or eliminate suspects. The fingerprint showed the addition of CaO nanoparticles can be classified into three classes, patent prints, plastic prints, and latent prints. The patent prints are already visible to the naked eye because of blood, or through blood-covered fingers, or in ink or dirt. Plastic prints are left on a pliable surface consisting of clay or wax. Latent prints are left on surfaces due to the natural oils and sweat secreted from the skin. Two methods can perform fingerprint detection, one is the "physical method" (powder dusting) and the "chemical method". Traditional fingerprint powder composition is complexes of regular, luminescent, metallic, and thermoplastic powders (Exline et al., 2003).



12. Biosensors

A biosensor is the most efficient and multifaceted technology that plays a very indispensable role in the province of forensic sciences. Both forensic analysis and forensic investigation are fundamental branches of the modern analytical chemistry with a social security and legal implication, according to the American Chemical Society (ACS) (Ganesh 2016). Biosensors are most extensively used in the forensic toxicological analysis of different compounds and chemicals such as poisons, alcohol, toxins, and illicit drugs. Chemical and biological weapons and explosives can also be detected with the help of these biosensors. Nanotechnology have made a tremendous change in forensic investigations of addition CaO nanoparticles in biosensors are multifunctional and thus play an important role in forensic investigations. The use of biological sensing material on the nano-wafer or nano- substrate makes the biosensors more sensitive with enhanced performance. DNA sensors having DNA attached to the electrode are used for the detection of different poisons (Frederickx, Verheggen, & Haubruge, 2011).



13. Pre-blast and Post-Blast Identification

Explosives are any solid, liquid, or gaseous object capable of conducting a spontaneous chemical reaction is an explosive. Explosive detection is crucial in forensics since most explosives are used for malicious purposes, terrorism, or mass destruction (Cowan & Koppl, 2011).

Explosives are mainly classified into two, which are as follows:

- High explosive
- Low explosive

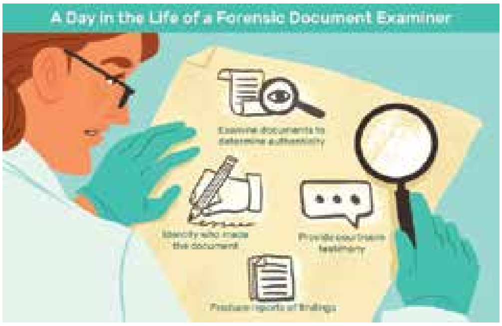
Explosives used in bombing attacks are mostly high explosives. High explosives are further classified as military, commercial, and improvised explosives. Military explosive is the chemical or mixture used in military, e.g. TNT, RDX, and PETN. Commercial explosives are chemical mixtures chemically used and produced such as ammonium nitrate/fuel oil (ANFO) (Trimpe). Micro-trace taggant technology can be used to identify and track cap-sensitive high explosives, such as cartridge-packed dynamite water gels and boosters. Pre-blast identification tags are discovered during the pre-blast recovery of an illegal explosive device. Use of explosives illicitly and the execution of criminal bombing cases can be simply understood using this technology (Seman et al. 2019). In addition of CaO nanoparticles explosives used in terrorist attacks are identified post-blast using identification taggants. Taggants are created by swapping out a hydrogen atom from a liquid or gas molecule. Isotropic technology is used for the purpose of uniquely identifying a detracted isotope. As a result, the potential of terrorism and mass destruction has decreased thanks to the widespread usage of taggants for explosive and dynamite identification (Karim et al. 2014).

14. Currency Identification

A crucial area to focus on is currency's security and distinctiveness. Numerous chemical and nano spectroscopic taggants are utilised to ensure the currency's uniqueness and prevent fraud (Natan et al. 2007). Since the spectroscopic taggants implanted in money notes are unique and cannot be duplicated, the original currency can be recognised. Additionally, invisible chemical and nanotaggants that are impossible to remove or duplicate are implanted in the currency. Therefore, taggants are widely used for the originality and security of the currency (Mead et al. 2014).

15. Document Identification

The security of anti-counterfeiting documents depends on tangential technologies as well. Important papers and documents are physically marked with taggants to monitor stolen or lost documents and to prevent duplication (Duong et al. 2014). Taggants are the unique technologies used for anti-counterfeiting and security document protection. The inks used in the printing or writing of important legal documents can be tagged with special micro-taggants. A tracker like physical taggant can be inserted on the document to save it from duplication and can be recovered when lost (Gooch et al. 2016a).

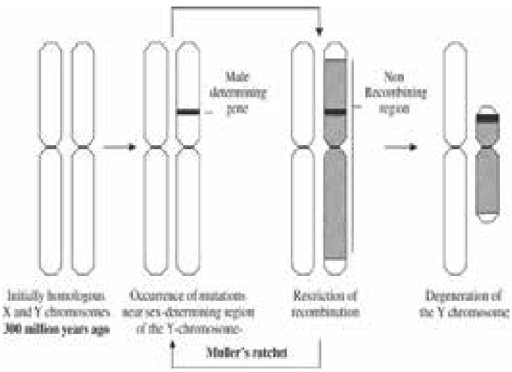


16. DNA Analysis

Nanotechnology can be an important tool for preventing crimes and for prosecuting offenders. DNA may now be extracted using magnetic nanoparticles from a variety of biological sources. One of the most crucial pieces of supporting evidence is the presence of an individual at the crime scene, regardless of whether their DNA belongs to the victim or the offender. Nowadays, magnetic CaO nanoparticles are being used to extract DNA from different biological sources like the blood, hair, skin, semen, and saliva (Eisenstein et al., 2011). Additionally, by creating nanotechnology-based instruments that can be used to directly read the DNA sequence in a molecule, more progress is made in the field of DNA analysis (McCord., 2006). Moreover, the DNA sequence can be examined using atomic force microscopy by mounting the DNA molecules on carbon nanotubes (Daniels et al., 2006).

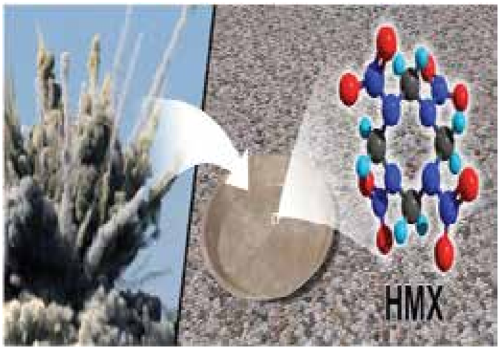
17. Y- Chromosomes Analysis

The issue of rape has been the central concern because it adversely impacts the health of exploited people by resulting in various illnesses, bodily injuries, sexual and reproductive problems, and mental clutter. It is based on four different sources of information. information obtained from the police, the general public through reviews, a legal DNA inquiry, and the judicial system. The Y chromosome is only found in men and is inherited from parents. It is passed down from a father to his child and can convey information from a male line that denotes the child to his father. In a mixture of male and female DNA samples, the study of genetic markers on the Y chromosome can specifically identify male evidence of sexual assault. Additionally, it could be applied to cases of sexual assault (Tilley & Ford, 1996).



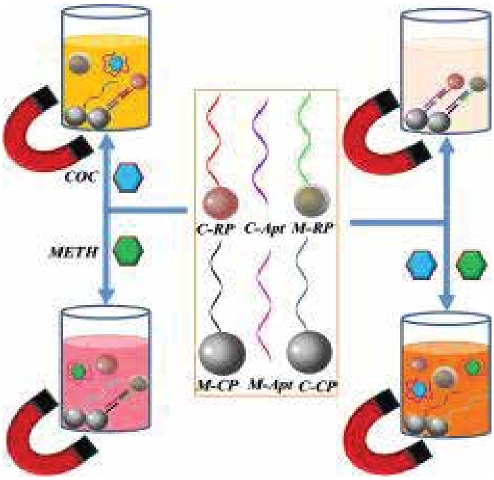
18. Explosive Residue Detection

Nanotechnology can be used to identify minute quantities of shattered explosives at the time of crime scene analysis. The detection of trace amounts of explosive is a difficult undertaking because of many issues like minuscule quantities of an unexplored substance and contaminated samples, such as contaminated soil and water. Nano-based devices can be used to detect trinitrotoluene (TNT) up to 1nm level in aqueous solution in a turmeric extracted curcumin and CaO nanoparticles-based, highly selective, and ultrasensitive fluorescent probe. For superior results, when the examiner is unable to provide enough evidence and cannot find the unregimented parts of an explosive, the nanotechnology could be used (Pandya and Shukla 2018). The trace explosive detection also involves the collection of vapor and particulate systems and detecting them using the sensitive nanomaterials. There are significant advantages of nanotechnology-based sensors such as low cost, high sensitivity and low-consumption of power. Using nanotechnology, the explosive residue detection has become an easier and effortless task (Beveridge, 1992).



19. Illicit Drug Detection

Ilicit drugs can be used to commit crimes such as sexual harassment, rape, burglary, and robbery. The main motive of this crime is to impede the behavior, interpretation capability, or commandment ability of the person under the influence of a drug. Detection of illicit drugs is an important task as DFC includes dangerous crimes like sexual harassment and rape (Zhai et al. 2014). Forensic experts have a difficult time detecting drugs because they are not present in the sample that was sent to the forensic laboratory for the inquiry in their original form. There are numerous drawbacks to the conventional method of drug testing, including cost effectiveness, instrument limitations, and instrument sensitivity, making application of nanotechnology in the pharmaceutical business vital for drug analysis. Nanotechnology and nanomaterials possess unique physicochemical properties along with the cost-effectiveness, capacity of miniaturization, and adaptability with compatibility that play a major role in the detection of illicit drugs. Research has proved that cocaine in the fingerprints can be determined using gold nanoparticles. Nanotechnology has made illicit drug detection a real-time easy job. A pin-sized gadget can be dipped in the saliva at the crime spot and can confirm the presence and absence of drugs. Also, alcohol analyzer used for drug testing can also be modified using this technology (Lad et al. 2016).



20. Conclusion

A review of the scientific literature on nanotechnology has shown the importance of nanotechnology in the field of forensic science, with a focus on how it can be applied to crime scene analysis and forensics. Nanotechnology and taggant technology have many uses in forensic science inquiry and how it can advance forensic science concerns like evidence gathering and handling, sample analysis, and monitoring of products and unlawful activities are just some of the ways in which nanotechnology is used in the field. Nanotechnology is an emerging field in which nanomaterials are developed that possess unique electrical, optical, and magnetic properties that can be applied to a wide range of forensic applications. These include evidence handling, fingerprint identification, illicit drugs, GSR, and explosives detection. Taggants are used in taggant technology, which enables continuous monitoring of these technologies, which can be advantageous and productive in preventative forensic and precautions. However, the real-world outlook for the application of such technology is still dismal. This can be the result of ignorance of such techniques or reluctance to adopt new technologies. Taggant technology has the ability to prevent a crime from occurring due to their continuous monitoring, while nanotechnology is capable of handling the repercussions of a crime scene. Together, these technologies will bring a revolution in various field of forensic science such as ballistics, fingerprint analysis, DNA analysis, Illicit Drug Detection and toxicology.

21. Reference

1. Abraham, S., & Sarathy, V. J. I. J. P. S. R. R. (2018). Biomedical applications of calcium oxide nanoparticles-a spectroscopic study. *49*(1), 121.

2. Akhtar, M. S., Panwar, J., Yun, Y.-S. J. A. S. C., & Engineering. (2013). Biogenic synthesis of metallic nanoparticles by plant extracts. *1*(6), 591-602.

3. Bernardini, J., Cinelli, P., Anguillesi, I., Coltelli, M.-B., & Lazzeri, A. J. E. P. J. (2015). Flexible polyurethane foams green production employing lignin or oxypropylated lignin. *64*, 147-156.

4. Biswas, P., Wu, C.-Y. J. J. o. t. a., & association, w. m. (2005). Nanoparticles and the environment. *55*(6), 708-746.

5. Brito, J. O., Silva, F., Leão, M., & Almeida, G. J. B. t. (2008). Chemical composition changes in eucalyptus and pinus woods submitted to heat treatment. *99*(18), 8545-8548.

6. Choi, Y. H., & Han, H.-K. J. J. o. P. I. (2018). Nanomedicines: current status and future perspectives in aspect of drug delivery and pharmacokinetics. *48*(1), 43-60.

7. Cunill, O. M., Salvá, A. S., Gonzalez, L. O., & Mulet-Forteza, C. J. I. J. o. H. M. (2019). Thirty-fifth anniversary of the International Journal of Hospitality Management: A bibliometric overview. *78*, 89-101.

8. Ealia, S. A. M., & Saravanakumar, M. (2017). *A review on the classification, characterisation, synthesis of nanoparticles and their application.* Paper presented at the IOP conference series: materials science and engineering.

9. Eram, R., Kumari, P., Panda, P. K., Singh, S., Sarkar, B., Mallick, M. A., & Verma, S. K. J. J. o. N. (2021). Cellular investigations on mechanistic biocompatibility of green synthesized calcium oxide nanoparticles with Danio rerio. *2*(1), 51-62.

10. Gross, L., Mohn, F., Moll, N., Schuler, B., Criado, A., Guitián, E., Peña, D., Gourdon, A., & Meyer, G. J. S. (2012). Bond-order discrimination by atomic force microscopy. *337*(6100), 1326-1329.

11. Halim, S., Mohamed, S., Azhan, H., Khawaldeh, S., & Sidek, H. J. P. C. S. (1999). Effect of barium doping in Bi–Pb–Sr–Ca–Cu–O ceramics superconductors. *312*(1-2), 78-84.

12. Holister, P., Weener, J.-W., Roman, C., & Harper, T. J. T. w. p. (2003). Nanoparticles. *3*, 1-11.

13. Hulkoti, N. I., Taranath, T. J. C., & Biointerfaces, s. B. (2014). Biosynthesis of nanoparticles using microbes—a review. *121*, 474-483.

14. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry, 13*(10), 2638-2650.

15. Kumar, V., Kumar, S., Chauhan, P., Verma, M., Bahuguna, V., Joshi, H. C., Ahmad, W., Negi, P., Sharma, N., & Ramola, B. J. S. r. (2019). Low-tempera-

ture catalyst based hydrothermal liquefaction of harmful macroalgal blooms, and aqueous phase nutrient recycling by microalgae. *9*(1), 1-9.

16. Marquis, G., Ramasamy, B., Banwarilal, S., Munusamy, A. P. J. J. o. P., & Biology, P. B. (2016). Evaluation of antibacterial activity of plant mediated CaO nanoparticles using Cissus quadrangularis extract. *155*, 28-33.

17. Mody, V. V., Nounou, M. I., & Bikram, M. J. A. d. d. r. (2009). Novel nanomedicine-based MRI contrast agents for gynecological malignancies. *61*(10), 795-807.

18. Mohammadian, M., Abasi, E., Akbarzadeh, A. J. A. c., nanomedicine,, & biotechnology. (2016). Mesenchymal stem cell-based gene therapy: A promising therapeutic strategy. *44*(5), 1206-1211.

19. Moreno-Olivas, F., Gant, V. U., Johnson, K. L., Peralta-Videa, J. R., & Gardea-Torresdey, J. L. J. J. o. Z. U. S. A. (2014). Random amplified polymorphic DNA reveals that TiO2 nanoparticles are genotoxic to Cucurbita pepo. *15*(8), 618-623.

20. Mustafa, G., Tahir, H., Sultan, M., & Akhtar, N. J. A. J. o. B. (2013). Synthesis and characterization of cupric oxide (CuO) nanoparticles and their application for the removal of dyes. *12*(47), 6650-6660.

21. Nunthavarawong, P., Sanjay, M., Siengchin, S., & Thoppil-Mathew, M. (2022). Introduction to Antimicrobial and Antiviral Materials *Antimicrobial and Antiviral Materials* (pp. 1-4): CRC Press.

22. Patel, K., Szabo, S., & Hemandez, V. J. H. p. (2008). protuberans COL1A1-PDGFB fusion is identified in virtually all protuberans cases when investigated by newly developed multiplex reverse transcription polymerase chain reaction and fluorescence in situ hybridization assays. *39*(2), 184.

23. Ranghar, S., Sirohi, P., Verma, P., Agarwal, V. J. B. A. o. B., & Technology. (2014). Nanoparticle-based drug delivery systems: promising approaches against infections. *57*, 209-222.

24. Roco, M. C. (2011). The long view of nanotechnology development: the National Nanotechnology Initiative at 10 years *Nanotechnology research directions for societal needs in 2020* (pp. 1-28): Springer.

25. Roco, M. C., Mirkin, C. A., & Hersam, M. C. (2011). Nanotechnology research directions for societal needs in 2020: retrospective and outlook.

26. Salari, M., Amine, G., Shirazi, M., Hafezi, R., Mohammadypour, M. J. C. M., & Infection. (2006). Antibacterial effects of Eucalyptus globulus leaf extract on pathogenic bacteria isolated from specimens of patients with respiratory tract disorders. *12*(2), 194-196.

27. Sinha, S., Aman, A. K., Singh, R. K., Kr, N., & Shivani, K. J. M. T. P. (2021).

Calcium oxide (CaO) nanomaterial (Kukutanda twak Bhasma) from egg shell: Green synthesis, physical properties and antimicrobial behaviour. *43*, 3414-3419.

28. Vecchio, M. G., Loganes, C., & Minto, C. J. T. O. A. J. (2016). Beneficial and healthy properties of Eucalyptus plants: A great potential use. *10*(1).

29. Daniels, L. B., Clopton, P., Bhalla, V., Krishnaswamy, P., Nowak, R. M., McCord, J., . . . Storrow, A. B. J. A. h. j. (2006). How obesity affects the cut-points for B-type natriuretic peptide in the diagnosis of acute heart failure: results from the Breathing Not Properly Multinational Study. *151*(5), 999-1005.

30. Eisenstein, D. J., Weinberg, D. H., Agol, E., Aihara, H., Prieto, C. A., Anderson, S. F., . . . Balbinot, E. J. T. A. J. (2011). SDSS-III: Massive spectroscopic surveys of the distant universe, the Milky Way, and extra-solar planetary systems. *142*(3), 72.

31. Le, M., Raxworthy, C. J., McCord, W. P., Mertz, L. J. M. p., & evolution. (2006). A molecular phylogeny of tortoises (Testudines: Testudinidae) based on mitochondrial and nuclear genes. *40*(2), 517-531.

32. Tilley, N., & Ford, A. (1996). *Forensic science and crime investigation*: Home Office, Police Research Group London.

33. Beveridge, A. J. F. s. r. (1992). Development in the Detection and Identification of Explosive Residues. *4*(1), 17-49.

34. Beveridge, A. J. F. s. r. (1992). Development in the Detection and Identification of Explosive Residues. *4*(1), 17-49.

35. Cowan, E. J., & Koppl, R. J. T. R. o. A. E. (2011). An experimental study of blind proficiency tests in forensic science. *24*(3), 251-271.

36. Daniels, L. B., Clopton, P., Bhalla, V., Krishnaswamy, P., Nowak, R. M., McCord, J., . . . Storrow, A. B. J. A. h. j. (2006). How obesity affects the cut-points for B-type natriuretic peptide in the diagnosis of acute heart failure: results from the Breathing Not Properly Multinational Study. *151*(5), 999-1005.

37. Eisenstein, D. J., Weinberg, D. H., Agol, E., Aihara, H., Prieto, C. A., Anderson, S. F., . . . Balbinot, E. J. T. A. J. (2011). SDSS-III: Massive spectroscopic surveys of the distant universe, the Milky Way, and extra-solar planetary systems. *142*(3), 72.

38. Exline, D. L., Wallace, C., Roux, C., Lennard, C., Nelson, M. P., & Treado, P. J. J. J. o. f. s. (2003). Forensic applications of chemical imaging: latent fingerprint detection using visible absorption and luminescence. *48*(5), 1047-1053.

39. Frederickx, C., Verheggen, F., & Haubruge, E. J. B., Agronomie, Société et Environnement. (2011). Biosensors in forensic sciences. *15*(3).

40. Tilley, N., & Ford, A. (1996). *Forensic science and crime investigation*: Home Office, Police Research Group London.

41. Trimpe, M. The Current Status of GSR Examinations| FBI: Law Enforcement Bulletin (2022).

42. Wang, M., Li, M., Yu, A., Zhu, Y., Yang, M., & Mao, C. J. A. f. m. (2017). Fluorescent nanomaterials for the development of latent fingerprints in forensic sciences. *27*(14), 1606243.