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Development and Comparison of Normal and Sun exposed Latent Fingerprint using Nanoparticles on Porous, Semi-Porous and Non-Porous Surfaces

Mr. Brinesh Pradhan

Student, M.Sc Forensic Science, Alakh Prakash Shimla University

ABSTRACT
This research explores the use of nanoparticles to develop and compare latent fingerprints left under normal and sunlight-exposed conditions on porous, semi-porous, and non-porous surfaces. Latent prints are a crucial aspect of forensic identification, but environmental factors such as sunlight can significantly degrade their quality. The study aimed to evaluate the performance of nanoparticle-based enhancement methods in revealing fingerprint details across different surface types and exposure scenarios. Due to their distinct chemical and physical characteristics, nanoparticles were utilized to improve the visibility and definition of latent ridge patterns. The results demonstrated that while nanoparticle reagents effectively developed fingerprints on all surface types, their performance varied with surface porosity and exposure. Non-porous and semi-porous surfaces produced clearer ridge patterns, whereas porous surfaces posed greater challenges. Sunlight exposure generally decreased fingerprint clarity, but some nanoparticle formulations were still able to enhance the degraded prints effectively. Overall, the study confirms the potential of nanoparticles in forensic fingerprint recovery, even under adverse conditions. Future work should focus on improving nanoparticle efficiency, validating their use across broader materials, and creating consistent application procedures for forensic field use.

Keywords: Latent fingerprints, nanoparticles, magnesium oxide nanoparticles, forensic identification, sunlight exposure, non-porous surfaces, semi-porous surfaces, porous surfaces, forensic applications.

CHAPTER 1
INTRODUCTION

Fingerprints are unique ridge patterns found on human fingertips, formed during fatal development and remaining unchanged throughout an individual’s life. These structures, made up of friction ridges and grooves, aid in grip and touch sensitivity. In forensic science, fingerprints serve as a reliable biometric identifier because the intricate ridge details are unique to every person—even identical twins do not share identical patterns. This makes fingerprints an essential tool for personal identification.

Fingerprint analysis has long been a cornerstone in forensic investigations due to its reliability and permanence. These patterns stay consistent from birth until death, with no two sets being alike. At crime scenes, the most commonly found fingerprints are latent prints—those not visible to the naked eye. These are composed of residues such as sweat, oils, amino acids, and other natural secretions. However, detecting latent prints becomes more difficult when they've been exposed to harsh environmental conditions like direct sunlight, high temperatures, or surface contamination (Ramotowski, 2012).

Prolonged exposure to sunlight, particularly ultraviolet (UV) radiation, accelerates the breakdown of amino acids and lipids in fingerprint residues, which can reduce contrast and hinder proper development using traditional methods. This type of environmental degradation is frequently encountered in outdoor crime scenes, underlining the need for advanced techniques that can still yield usable prints under such conditions (Beck et al., 2020).

The type of surface on which a fingerprint is left also plays a significant role in how effectively it can be developed. Surfaces are generally classified as porous (like paper or cardboard), semiporous (such as untreated leather or wood), and non-porous (including glass, plastic, or metal). On porous surfaces, the residue is absorbed, making development more challenging. In contrast, non-porous surfaces allow the residue to remain on the surface, simplifying detection. Semiporous materials lie somewhere in between and often require specialized techniques to retrieve clear prints (Ferguson et al., 2018).

Although traditional fingerprint development techniques—such as powder application, cyanoacrylate (superglue) fuming, and chemical reagents like ninhydrin—are widely used, their effectiveness diminishes when prints are degraded or aged. As a solution to these limitations, forensic science has increasingly turned to nanotechnology. Nanoparticles have shown significant promise due to their small size, large surface area, and unique physical and chemical characteristics that enhance fingerprint contrast and visibility (Zhou et al., 2021).

Among the various nanomaterials explored, magnesium oxide (MgO) nanoparticles have demonstrated strong potential in forensic applications. These particles are biocompatible, affordable, chemically stable, and exhibit excellent surface and optical reactivity. They can bind effectively with the lipid and sweat residues in fingerprints—even those exposed to environmental degradation—offering improved visualization. Their high surface area allows better interaction with residues, enhancing ridge detail clarity across multiple surface types (Kumar & Sharma, 2022).

This study focuses on the use of MgO nanoparticles to develop and compare normal (non-exposed) and sun-exposed latent fingerprints. It also evaluates their performance across porous, semiporous, and non-porous surfaces. The aim is to determine whether MgO nanoparticles provide reliable and improved fingerprint visualization, particularly in conditions where conventional methods are inadequate.

By examining both environmental factors (like sun exposure) and surface types, this research addresses a significant challenge in forensic science: the reliable development of latent fingerprints from compromised or outdoor scenes. The outcomes could enhance the effectiveness of evidence collection and strengthen the reliability of fingerprint-based identification in investigations.

Nanoparticles are becoming an increasingly valuable tool in modern forensic practices due to their superior optical, chemical, and surface-interactive properties. Their nanoscale dimensions enable them to interact closely with the micro-details of fingerprint residues, enhancing image resolution and contrast under varied lighting conditions, including UV and fluorescent light. Materials such as titanium dioxide, zinc oxide, silver, carbon nanotubes, and quantum dots have shown promising results in these applications (Zhou et al., 2021). These particles are also resilient under extreme conditions, including high heat and intense sunlight, making them ideal for field use in forensics.

Ultimately, this research is significant for advancing forensic methodologies. By exploring how nanoparticles interact with latent fingerprints under different environmental conditions, it offers potential improvements in the accuracy and reliability of fingerprint detection. With growing advancements in the safe and economical production of nanoparticles, their integration into routine forensic work could soon become both practical and impactful (Singh & Tiwari, 2023).

Objectives of the Study

1. To synthesize and characterize magnesium oxide (MgO) nanoparticles suitable for forensic application.
2. To compare the effectiveness of MgO nanoparticles in developing latent fingerprints on porous, non-porous and semi porous substrates.

CHAPTER 2
REVIEW OF LITERATURE

2.1 History of Development of Latent Fingerprints

The use of fingerprints for identification has a rich history spanning centuries, although their formal integration into forensic science is relatively modern. While the unique and enduring nature of fingerprints has been recognized for a long time, the scientific and systematic application of fingerprints in criminal investigations only gained momentum in recent centuries.

One of the earliest recorded uses of fingerprints dates back to ancient Babylon, where they were pressed into clay tablets for purposes of personal verification in business and contractual agreements (Taylor, 2004). Similarly, in ancient China, fingerprints were utilized to authenticate documents, especially legal contracts. However, these early uses were administrative rather than investigative.

The modern scientific study of fingerprints began to take shape in the late 19th century. In 1892, Sir Francis Galton—a British scientist and cousin of Charles Darwin—published the influential book *Fingerprints*, in which he provided empirical evidence supporting the uniqueness and permanence of fingerprint patterns (Galton, 1892). His work laid the foundation for their systematic use in personal and forensic identification.

Concurrently, in Argentina, Juan Vucetich developed one of the earliest fingerprint classification systems. He based his method on the detailed analysis of ridge characteristics, including minutiae such as bifurcations and ridge endings. Vucetich's classification system not only contributed to the organization of fingerprint data but also led to a historic breakthrough in 1892 when he solved the first known criminal case using fingerprint evidence (Vucetich, 1892).

The early 20th century marked the global expansion of fingerprinting as a forensic tool. Sir Edward Henry, a British police official, developed a classification system that focused on pattern types and ridge counts, which was adopted by British law enforcement and eventually by agencies in the United States and other countries. This system became the backbone of criminal identification processes and was continually refined to improve its accuracy and usability.

Despite these advances, the detection of latent fingerprints—those not visible to the unaided eye—posed ongoing challenges. These prints are typically deposited when a person touches a surface, leaving behind traces of perspiration, oils, amino acids, and other biological secretions. Because latent prints are often faint or obscured, specialized techniques have been developed to visualize them effectively for forensic comparison and analysis.

2.2 Traditional Methods for Development of Latent Fingerprint:

Traditional methods for visualizing latent fingerprints involve both physical and chemical techniques that enhance fingerprint residues left on various surfaces. These prints, often invisible to the naked eye, consist of natural skin secretions like oils, sweat, and amino acids that are transferred during contact.

Physical methods generally involve the application of fine powders that cling to the moisture and grease in fingerprint ridges. These powders, available in a variety of colours and types (including regular, magnetic, and fluorescent), are dusted onto non-porous surfaces such as glass, metal, or plastic. Once developed, the prints can be photographed and lifted using adhesive tape for preservation and comparison. Magnetic powders are particularly useful for delicate or textured surfaces, minimizing the risk of damaging the evidence.

Chemical methods are more appropriate for porous surfaces like paper, cardboard, or unpainted wood. One of the most commonly used reagents is ninhydrin, which reacts with amino acids in the fingerprint residue to produce a purple-colored print, often used in document analysis. Other chemicals include silver nitrate, which interacts with chloride ions in sweat to form visible silver compounds under light exposure, and iodine fuming, where iodine vapours temporarily adhere to the lipid components of fingerprints, creating a brownish print that must be quickly photographed due to its instability.

The selection of a development method depends on several factors, such as the type of surface, the condition and age of the fingerprint, and environmental exposure. Often, a sequence of methods is applied, beginning with non-destructive approaches and progressing to more invasive techniques as needed.

While newer technologies like digital enhancement and alternative light sources are becoming more common, traditional fingerprint development techniques remain fundamental due to their effectiveness, accessibility, and wide applicability in field and laboratory settings. (*Champod et al., 2016; Saferstein, 2015; Rowe, 2001*).

2.3 Recent Advancement in Latent Fingerprint Development:

Recent advancements in latent fingerprint development have significantly enhanced the techniques used for detection and analysis, particularly in difficult conditions. One major development is the improvement of chemical reagents designed to reveal fingerprints on various surfaces. For example, Ninhydrin, a traditional reagent for detecting prints on porous surfaces, has been improved with new formulations that increase its sensitivity and effectiveness. Other reagents, like 1,2-Indanedione and DBA (Dibutyl amine), have also shown better results in visualizing prints on materials like paper and cardboard (Torrents et al., 2023). Additionally, superglue fuming (cyanoacrylate) has been refined to better bond fingerprint residues to surfaces, making prints more visible and durable (Rosa et al., 2024).

The use of laser-induced fluorescence (LIF) and alternate light sources (ALS) has become a crucial tool for visualizing fingerprints, especially on non-porous surfaces. Technologies like ALS, which include UV and IR light sources, improve contrast and sensitivity, making it easier to detect prints on smooth surfaces such as plastic or glass. Laser systems that emit specific wavelengths of light can also highlight the chemical components of latent prints, making them visible without relying on additional chemicals (Xu et al., 2024).

Nanotechnology has also contributed to the development of fingerprinting methods. The use of nanoparticles such as silver, gold, and carbon-based materials has enhanced fingerprint visibility by increasing the contrast between the print and surface. Graphene oxide nanoparticles and similar materials are especially effective in visualizing prints on porous surfaces (Kim & Jang, 2022). These innovations improve print adhesion and image resolution, even in low-contrast environments.

Digital imaging technology has seen substantial progress, with the introduction of high-resolution cameras and 3D imaging systems. These systems allow forensic experts to capture detailed images of latent prints, which can then be enhanced digitally to improve clarity. This results in better-quality images for comparison with fingerprint databases (Reimer et al., 2023).

Moreover, the integration of artificial intelligence (AI) and machine learning has revolutionized fingerprint analysis. AI can automate the comparison process between prints found at crime scenes and those in fingerprint databases, improving accuracy and speed. Machine learning algorithms also help assess the quality of prints and determine the likelihood of a successful match, enhancing the overall efficiency of forensic investigations (Smith & Zhao, 2023).

2.4 Using of Nanoparticles for Development of Latent Fingerprint:

The use of various types of nanoparticles in latent fingerprint development has significantly advanced forensic science, enhancing the detection and analysis of fingerprints, especially in difficult situations. Due to their unique properties, nanoparticles offer improved sensitivity, contrast, and resolution, making it easier to reveal prints on challenging surfaces. Different types of nanoparticles, such as silver, gold, carbon-based materials, magnetic nanoparticles, silica, and titanium dioxide, have been explored for fingerprint enhancement, each contributing in unique ways to improve print clarity.

1. Silver Nanoparticles

Silver nanoparticles (AgNPs) have gained considerable attention for fingerprint development due to their optical properties and high surface area. They interact with organic fingerprint residues like fatty acids, amino acids, and proteins, enhancing the contrast between prints and the surface. AgNPs are particularly effective in detecting prints on non-porous and textured surfaces, such as glass, plastic, and metal, where traditional methods may not yield clear results (Zhang et al., 2023).

2. Gold Nanoparticles

Gold nanoparticles (AuNPs) are widely used in latent fingerprint development because of their biocompatibility and stability. These nanoparticles form stable bonds with fingerprint residues, improving print visibility. Gold nanoparticles are particularly effective in colorimetric detection, where they change colour when binding to fingerprint residues, providing easily visible prints. Their stability and low toxicity make them ideal for use in forensic science (Nguyen et al., 2022).

3. Carbon-based Nanoparticles

Carbon-based nanoparticles, such as carbon nanotubes (CNTs) and graphene oxide, are also beneficial for fingerprint development due to their unique electrical and mechanical properties. Graphene oxide nanoparticles interact selectively with amino acids and lipids in sweat residues, enhancing fingerprint visibility, especially on porous surfaces like paper and fabric. CNTs are used to improve the adhesion of fingerprint powders, making it easier to capture prints on rough or highly textured surfaces (Xu et al., 2024).

4. Magnetic Nanoparticles

Magnetic nanoparticles, particularly iron oxide nanoparticles (Fe_3O_4), have shown promise in fingerprint development because they can be manipulated with an external magnetic field. These nanoparticles, when functionalized with specific agents, bind to fingerprint residues and enable more precise print development. Magnetic nanoparticles are used in combination with magnetic fingerprint powders to detect prints on non-porous materials and hard-to-reach areas (Li et al., 2023).

5. Silica Nanoparticles

Silica nanoparticles are versatile in fingerprint detection, often used in combination with chemical reagents like ninhydrin and 1,2-indanedione. Silica's porous nature allows it to hold reagents longer, enhancing their interaction with fingerprint residues and improving the sensitivity and resolution of prints on porous surfaces. This method is especially useful for highly textured or uneven surfaces (Torrents et al., 2023).

6. Titanium Dioxide Nanoparticles

Titanium dioxide (TiO2) nanoparticles have photocatalytic properties, making them useful for enhancing fingerprint visibility under UV light. When exposed to UV light, TiO2 nanoparticles increase the contrast between the fingerprint and the surface, making it easier to identify the print. This property is especially helpful in forensic investigations, where UV or infrared light sources are used to reveal prints on difficult surfaces (Zhao et al., 2022).

2.5 Nanotechnology in Latent Fingerprint Enhancement:

Nanotechnology has become an influential advancement in forensic science, particularly in the development of latent fingerprints. Among various nanomaterials, magnesium oxide (MgO) nanoparticles have drawn significant interest due to their distinct characteristics, including a large surface area, chemical stability, and strong interaction with organic substances. These attributes make MgO nanoparticles well-suited for binding with components commonly present in fingerprint residues, such as oils, lipids, and proteins (Choi & Kim, 2019).

Studies have shown that MgO nanoparticles perform effectively across multiple surface types. For instance, research by Reddy and Palanisamy (2018) revealed that MgO nanoparticles significantly enhanced fingerprint visibility on both porous and non-porous surfaces. The nanoparticles worked by adsorbing the fingerprint residue and producing high-contrast images, leading to clearer and more detailed prints. This effectiveness positions them as a strong alternative to conventional fingerprint development methods, especially on difficult surfaces like porous materials.

In addition, MgO nanoparticles have proven especially useful on non-porous surfaces, where traditional techniques may not yield optimal results. Their strong adhesion to fingerprint residues results in better-defined ridge patterns and greater contrast, outperforming standard powders and chemical reagents in several cases (Reddy & Palanisamy, 2018).

2.6 Nanoparticles for Fingerprint Development on Various Surfaces:

Different surface types present distinct difficulties when it comes to developing latent fingerprints. Porous materials like paper, cardboard, and fabric tend to absorb fingerprint residues, which limits the effectiveness of traditional development techniques. In contrast, non-porous surfaces—such as glass, plastic, and metal—retain residue on the surface, allowing for better interaction with powders and chemical reagents.

Magnesium oxide (MgO) nanoparticles have demonstrated strong adhesion properties, making them effective across a broad range of surfaces. According to Reddy and Palanisamy (2018), MgO nanoparticles significantly improve the visibility of latent fingerprints on both porous and non-porous surfaces, offering more reliable results compared to conventional methods. This highlights the potential of nanoparticles—particularly MgO—as a flexible and efficient alternative for fingerprint development.

Semi-porous surfaces, such as certain fabrics and ceramics, lie between porous and non-porous materials in their ability to absorb fingerprint residues. While more complex, these surfaces have also shown improved fingerprint development when treated with MgO nanoparticles. Research by Choi and Kim (2019) supports the effectiveness of MgO in enhancing latent prints on these challenging surfaces, outperforming traditional techniques

CHAPTER 3
MATERIALS AND METHODS

3.1 Materials

In the current study, the following materials were utilized: magnesium oxide nanoparticles, soft fibre brush and the donor's fingerprint.

- **Porous:** wallpaper, packaging materials
- **Semi-porous:** varnished wood, painted metal surface
- **Non-porous:** glass, plastic

3.2 Methodology

Magnesium oxide nanoparticles, known for their fine particle size and high surface reactivity, were applied as a dry powder directly onto surfaces bearing latent fingerprints. The deposition process followed these steps:

1. **Sample Preparation**: Surfaces were first cleaned using wipes and allowed to dry to avoid contamination.
2. **Fingerprint Deposition**: Donors pressed their fingers (from the forehead and forearm) gently on each surface to leave natural latent prints.
3. **Application of MgO Nanoparticles**:
   - A soft, sterile fibre brush was dipped into a clean container holding MgO nano powder.
   - The powder was gently brushed over the area suspected of having a fingerprint using a light circular motion.

This procedure was followed for each type of surface:

- **Porous:** wallpaper, packaging materials
- **Semi-porous:** varnished wood, painted metal surface
- **Non-porous:** glass, plastic

MgO nano powder adhered selectively to the fingerprint residues, revealing ridge details for photographic and comparative analysis.

3.3 Additional Tools

Soft squirrel-hair or camel-hair brushes

3.4 Sample Collection

3.4.1 Donor Demographics

No hand washing or enhancement was done prior to fingerprint deposition to simulate real-world latent print scenarios.

3.5 Sunlight Exposure Protocol

To compare normal and sun-exposed conditions:

- The Developed latent fingerprints were photographed.
- Fingerprinted surfaces were exposed to direct sunlight for 2 hours.
- Kept it for days unless the print was disappeared.

Sunlight exposure was done between 1:00 PM and 3:00 PM, when UV radiation is typically strongest.

3.6 Development and Visualization Procedure

Each surface with a deposited fingerprint underwent independent powder treatment using:

- MgO nano powder

Steps followed:
1. **Dusting with brush** as described in 3.2.
2. **Photographic documentation** under natural light and ALS.
- **Ridge clarity**
- **Contrast with surface**

This study investigated the development and comparison of latent fingerprints under normal and sun-exposed conditions using magnesium oxide (MgO) nanoparticles on different surface types: porous, semi-porous, and non-porous. The primary objective was to assess the effectiveness of MgO nanoparticles in revealing latent prints under varying environmental conditions and surface types.

The quality of latent fingerprints developed using magnesium oxide (MgO) nanoparticles on various surfaces under different conditions.

Rating 5 Very high clarity. Full ridge detail is clearly developed, with excellent visibility of both class characteristics and minutiae. No absorption occurs; residue remains on the surface, allowing maximum nanoparticle interaction. Rating 4 Slight fading in ridge detail due to environmental exposure, but overall pattern remains sharp and identifiable. Minor loss in contrast, but sufficient for forensic comparison. Rating 4Good development of ridge patterns with some minutiae visible. Partial absorption occurs, but enough residue remains for effective nanoparticle adherence. Rating 3Ridge flow is still visible, but clarity is reduced due to exposure and partial degradation. Rating 3 Basic class characteristics can be observed (ridge flow), but prints lack sharpness. Rapid absorption of residue into the surface limits nanoparticle binding, reducing detail. Rating 2 Very poor development; prints are either faint or entirely absent after Day 2 of sunlight exposure. Ridge detail is mostly lost, and prints are unusable for identification.

Materials: Magnesium oxide nanoparticles were purchased from a reliable supplier. The surfaces selected for fingerprint development included (porous), wallpaper and packaging material (semi-porous), varnished wood and painted surface (non-porous) glass and plastic. Latent fingerprints were collected from volunteers by pressing their fingers gently onto these surfaces. Latent fingerprints were prepared: after clicking photo in normal temperature, and another exposed to direct sunlight for days. Other materials used included soft camel hair brushes for applying the MgO nanoparticles, mobile camera (Infinix GT 20 Pro) for documenting the developed prints.

The MgO nanoparticles were applied to the latent fingerprints using a soft camel hair brush, ensuring a uniform distribution without disturbing the fingerprint details. Any excess powder was carefully removed by tapping or light brushing to avoid smearing the prints. The developed fingerprints were then photographed under controlled lighting conditions with a mobile camera. The quality of the prints, including ridge clarity, contrast, and overall visibility, was observed. A comparison was made between the effectiveness of MgO nanoparticles in revealing latent prints under normal versus sun-exposed conditions on various surfaces. The impact of sunlight exposure on the preservation of fingerprint details and the overall development process was also analysed. The results were then analysed to determine the influence of MgO nanoparticles and environmental factors, like sun exposure, on the development of latent prints across different surfaces.

CHAPTER 4
RESULTS

In the present study, observations and outcomes obtained from developing latent fingerprints using magnesium oxide (MgO) nanoparticles on porous, semiporous, and non-porous surfaces. Both normal (fresh) and sun-exposed fingerprints were analysed and compared based on clarity, ridge visibility, and pattern recognition. The results were evaluated using visual scoring and photographic documentation.

Nanoparticles Used: Magnesium Oxide (MgO)

Surfaces Tested:

- **Porous:** wallpaper, packaging materials
- **Semi-porous:** varnished wood, painted metal surface
- **Non-porous:** glass, plastic

Fingerprint Types:

- Normal (fresh) latent prints
- Sun-exposed latent prints

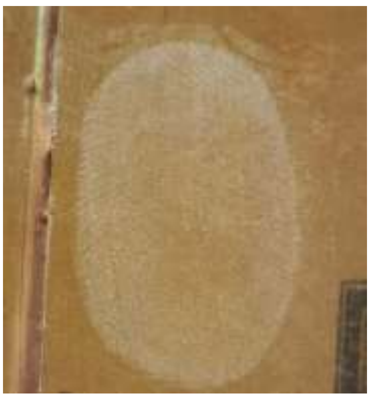
Normal print

Sun exposed print (day 1)

Sun exposed print (day 2)

Fig .4.1 Development on Porous Surfaces Using MgO Nanoparticles on wallpapers

Normal print



Sun exposed print (day1)

Sun exposed (print day 2)

Fig.4.2 Development on Porous Surfaces Using MgO Nanoparticles on Packaging material

In contrast, porous surfaces like paper and cardboard posed greater challenges. While class characteristics could be identified shortly after deposition, the rapid absorption and degradation of residue often hindered the development of minutiae, resulting in faint or incomplete prints.

Normal (3/5): On materials like wallpaper, packaging material fingerprints were visible but lacked precision. The porous nature of these surfaces caused rapid absorption of the fingerprint residue, limiting nanoparticle attachment. As a result, only primary ridge patterns were generally discernible.

Sun-Exposed (2/5): Prolonged sunlight exposure led to significant degradation. Within two days, many prints became very faint or completely disappeared, making them difficult to analyse or interpret accurately

On porous surfaces such as wallpaper and packaging materials, fingerprints developed using MgO nanoparticles were clearly visible on Day 0 and Day 1. However, by Day 2, the prints began to fade and became increasingly difficult to detect. After Day 2, especially by Day 3 and beyond, the fingerprints were nearly invisible or completely absent.

The comparison between normal and sun-exposed prints on porous surfaces:

When comparing fresh (normal) prints with those exposed to sunlight on porous surfaces, the fingerprint ridge details were initially clear. The MgO nanoparticles effectively adhered to the sweat and oil in the prints during the first two days. However, when the prints were exposed to sunlight, the residue from sweat and oil began to dry or get absorbed into the surface. As a result, by Day 2, the fingerprints were faint or unclear, and by Day 3, they were almost entirely gone. This highlights the significant impact of sun exposure on the visibility of fingerprints on porous materials. The longer the exposure, the more difficult it becomes to develop clear prints, even with the use of MgO nanoparticles.


Normal print


Sun exposed print (day 1)


Sun exposed print (day 2)

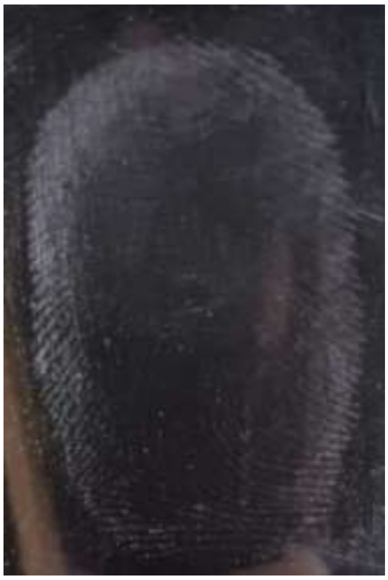

Sun exposed print (day 3)


Sun exposed print (day 4)

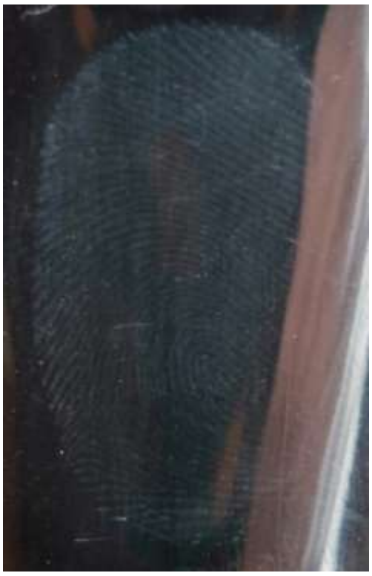
Fig. 4.3 Development on Non-Porous Surface using MgO Nanoparticles on Glass

On non-porous surfaces such as glass and plastic, the nanoparticles effectively adhered to the fingerprint residue, resulting in clear visualization of ridge flow patterns and the successful enhancement of finer minutiae points, including ridge endings and bifurcations. These surfaces offered minimal absorption of residue, preserving both the clarity and definition of the prints.

Normal print



Sun exposed print (day 1)



Sun exposed print (day 2)

Sun exposed print (day 3)

Fig.4.4 Development on non-porous surfaces using MgO Nanoparticles on Plastic

On non-porous surfaces like glass and plastic, fingerprints developed with MgO nanoparticles produced excellent results. In fresh (normal) prints, the ridge patterns were sharp, clear, and well-defined. The MgO nanoparticles effectively adhered to the fingerprint residues, such as sweat and oil, making the prints highly visible.

Even after exposure to sunlight, the fingerprints on non-porous surfaces remained largely visible and identifiable for several days. Although some fading occurred after a few days of sun exposure, the overall ridge details were still discernible and could be effectively developed using MgO nanoparticles.

This demonstrates that non-porous surfaces are the most suitable for fingerprint development with MgO nanoparticles, as the fingerprint residues remain intact on these surfaces and are less influenced by sunlight compared to porous materials.

Normal (5/5): On smooth, non-porous surfaces such as glass and plastic, fingerprints developed under standard conditions appeared extremely clear, with well-defined ridge patterns. Because the fingerprint residue remained on the surface and did not absorb, MgO nanoparticles bonded effectively, producing high-contrast prints suitable for identifying both general ridge flow and detailed minutiae.

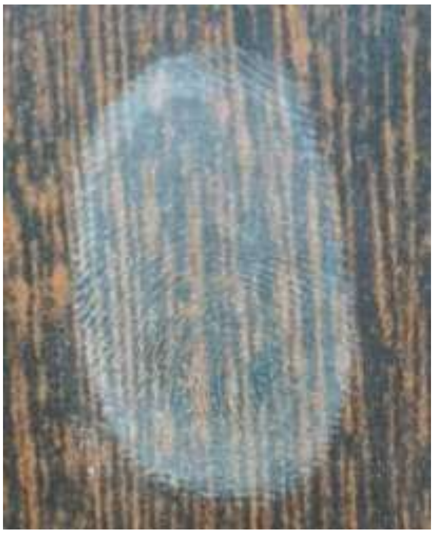
Sun-Exposed (4/5): Although some minor fading occurred due to exposure, the prints remained legible and usable, with most ridge details still intact.

The comparison between normal and sun-exposed prints on non-porous surfaces:

On non-porous surfaces such as glass, plastic, or metal, both normal and sun-exposed fingerprints developed well with MgO nanoparticles, though there were some noticeable differences. Fresh (normal) fingerprints displayed clear, defined ridge details. The sweat and oil from the finger adhered well to the surface, allowing the MgO nanoparticles to bond easily. As a result, the prints were sharp, bright, and showed good contrast against the background.

In contrast, sun-exposed fingerprints still revealed visible ridge patterns but appeared slightly faded compared to fresh prints. This fading occurred because sunlight caused some of the fingerprint residue to dry out or degrade. However, since the surface is non-porous and doesn't absorb the fingerprint material, most of the residue remained on the surface and could still be developed effectively.

Normal print



Sun exposed print (day 1)

(day 3)

Fig.4.5 Development on Semi Porous Surfaces Using MgO Nanoparticles on Varnished Wood

Normal print

Sun exposed print (day 1)

Sun exposed print (day 2)

Sun exposed print (day 3)

Fig.4.6 Development on Semi Porous Surfaces Using MgO Nanoparticles on Metal Surface

Semi-porous surfaces, such as painted metal and varnished wood, allowed for the consistent identification of Level 1 ridge patterns, though Level 2 minutiae were occasionally diminished due to partial absorption of fingerprint components.

On semi-porous surfaces like glossy varnished wood and metal, fingerprint development using MgO nanoparticles showed moderate results.

For fresh (normal) fingerprints, the ridge patterns were clear and visible. The surface retained some of the fingerprint residue on top, allowing the MgO nanoparticles to adhere and highlight the ridge details effectively.

However, for sun-exposed fingerprints, there was a noticeable decrease in clarity after 2–3 days. The heat and sunlight caused some of the fingerprint residue to dry out and break down. Since semi-porous surfaces can partially absorb fingerprint material, some of the residue was lost, making it more difficult to develop the remaining print.

Normal (4/5): Surfaces such as painted metal or varnished wood showed good fingerprint visibility under normal conditions. Some degree of residue absorption occurred, but sufficient material remained for effective development. Basic ridge patterns were clearly identifiable, and some finer details could also be observed.

Sun-Exposed (3/5): Sunlight exposure reduced the clarity of the prints. While ridge patterns were still visible, they appeared fainter, and minutiae points were less prominent due to partial degradation or absorption of the residue.

The comparison between normal and sun-exposed prints on semi-porous surfaces:

On semi-porous surfaces like varnished wood and metal, the development of latent fingerprints using MgO nanoparticles produced moderate results, with clear differences between normal and sun-exposed prints.

Normal fingerprints exhibited good ridge clarity. The fingerprint residue largely stayed on the surface, allowing the MgO nanoparticles to adhere effectively and reveal clear, visible ridge patterns.
However, sun-exposed fingerprints showed reduced visibility. After being exposed to sunlight for 2 to 3 days, the fingerprint residue began to dry out or partially absorb into the surface. As a result, the developed prints appeared fainter and less detailed, with some loss of ridge pattern definition.

Table 4.1 Fingerprint Development Results and Ratings

Surface type	Condition	Development Quality	Rating (Out of 5)
Non-Porous	Normal	Very clear, full ridge details	(5/5)
	Sun-Exposed	Slightly faded but still clear	(4/5)
Semi-Porous	Normal	Good ridge visibility	(4/5)
	Sun-Exposed	Faint, partial ridge visibility	(3/5)
Porous	Normal	Visible but not sharp	(3/5)
	Sun-Exposed	Poor or no visible print after Day 2	(2/5)

CHAPTER 5
DISCUSSION

This study investigated the development and comparison of normal and sun-exposed latent fingerprints using magnesium oxide (MgO) nanoparticles on porous, semi-porous, and non-porous surfaces. The findings revealed significant differences in fingerprint visibility based on the type of surface and the effects of sunlight exposure.
Non-porous surfaces provided the best results for fingerprint development. Under normal conditions, the prints were sharp, detailed, and easily visible. Even after sun exposure, the fingerprints remained relatively clear, although there was a slight decrease in contrast. This is because the fingerprint residue stays on the surface and doesn't absorb into it, allowing MgO nanoparticles to adhere effectively. These surfaces proved to be the most suitable for fingerprint recovery, even after several days of sunlight exposure.
Fingerprint development on semi-porous surfaces yielded moderate results. Normal prints displayed good ridge detail, but sun-exposed prints began to fade after 2–3 days. This fading occurred because some of the fingerprint residue was absorbed into the surface and partially degraded under sunlight. While MgO nanoparticles were still somewhat effective, the clarity of the prints decreased compared to those on non-porous surfaces.
On porous surfaces, the results were the weakest, particularly for sun-exposed fingerprints. Normal prints could be developed when fresh, but the fingerprint residue quickly absorbed into the surface or evaporated upon sunlight exposure. After just 2 days, most prints became faint or completely invisible, even with MgO nanoparticles. This suggests that porous materials are unsuitable for long-term or outdoor fingerprint collection.

This study serves as an initial exploration, as no prior research has compared the development of normal and sun-exposed latent fingerprints using MgO nanoparticles on porous, semi-porous, and non-porous surfaces.

CHAPTER 6
SUMMARY

This study examines the effectiveness of magnesium oxide (MgO) nanoparticles in developing latent fingerprints on three surface types: porous, semi-porous, and non-porous. The fingerprints were tested under two conditions: fresh (normal) and sun-exposed, to assess how environmental exposure impacts the quality of fingerprint development.

The findings revealed that non-porous surfaces, such as glass and plastic, provided the best results, with clear ridge details in both normal and sun-exposed conditions. Semi-porous surfaces, like glossy paper, yielded moderate results, where normal fingerprints were visible, but sun exposure caused a decrease in clarity after a few days. Porous surfaces, such as paper and cardboard, produced the weakest results, particularly after sun exposure, as the fingerprint residues were either absorbed or degraded, making them difficult to develop after two days.

In conclusion, the study demonstrates that MgO nanoparticles are effective for developing fingerprints, particularly on non-porous surfaces, and that sun exposure significantly reduces fingerprint visibility, especially on porous materials. For optimal results, timely fingerprint collection is recommended.

Limitations of the Study

Despite the promising results obtained in this study, several limitations must be acknowledged:

1. Limited Range of Nanoparticles

Only magnesium oxide (MgO) nanoparticles were used in this study. Other nanoparticles such as silver, gold, titanium dioxide, or graphene oxide, which may offer different enhancement capabilities, were not explored. This limits the comparative scope of the findings

2. Restricted Environmental Conditions

Sunlight exposure was tested for a limited duration and during a fixed time period (1:00 PM to 3:00 PM). Other environmental factors like humidity, rain, dust, or extreme temperatures were not evaluated, which may affect fingerprint degradation differently in real-life crime scenes.

3. Short Observation Duration

The prints were not observed beyond a few days. Long-term durability and the effect of prolonged exposure were not assessed, which is important for outdoor crime scene analysis.

4.Surface Type Generalization:

Only selected materials (e.g., wallpaper, varnished wood, glass) were tested as representatives of porous, semi-porous, and non-porous surfaces. Other common surfaces like ceramic tiles, leather, or untreated fabric were not included, limiting the generalizability of surface-type findings.

5. Manual Scoring of Ridge Clarity

The evaluation of fingerprint quality was done visually and rated manually. More objective or digital methods (e.g., AFIS-compatible image scoring) could have improved accuracy and reduced observer bias.

Forensic Significance

This study holds practical importance in forensic science, particularly in the recovery and enhancement of latent fingerprints under challenging conditions. By demonstrating that magnesium oxide (MgO) nanoparticles can enhance latent prints even after exposure to sunlight, this research provides a viable solution for crime scenes located in outdoor or uncontrolled environments.

The findings suggest that non-porous and semi-porous surfaces retain usable prints for a longer duration, even under environmental stress, reinforcing the relevance of surface type during evidence collection. The successful application of MgO nanoparticles further supports the integration of nanotechnology into standard forensic protocols for latent print development.

Moreover, this study contributes to the growing body of research advocating for cost-effective and accessible materials (like MgO) that can be used in routine forensic investigations. The simplicity of the application method also makes it suitable for field-level operations, aiding in real-time evidence collection at crime scenes.

Future Directions

To build upon the findings of this study, future research should consider the following directions:

1. Use of Multiple Nanoparticles:

Compare MgO with other nanoparticles (e.g., silver, gold, titanium dioxide, graphene oxide) to identify the most effective agents across varied environmental and surface conditions.

2. Long-Term Exposure Studies:

Extend the duration of sunlight and environmental exposure (e.g., 7–30 days) to assess the resilience of latent prints over time.

3. Environmental Variables:

Examine the effect of additional environmental factors such as humidity, rainfall, dust, and wind on the degradation and development of latent fingerprints.

4. Larger Sample Size and Diversity:

Use a more diverse pool of donors with different skin types, ages, and health backgrounds to evaluate the consistency and reliability of fingerprint development across individuals.

5. Integration with Digital Tools:

Employ automated digital imaging and analysis software for objective evaluation of ridge clarity, pattern quality, and statistical fingerprint comparison.

6. Field Application Testing:

Conduct real-world simulations or collaborate with law enforcement agencies to validate the practical utility of MgO nanoparticle-based fingerprint development methods.

7. Standardization of Protocols:

Develop and test standardized protocols for MgO nanoparticle application in forensic labs and field kits to ensure reproducibility and consistency.

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