

A Sustainable Iron Nanomaterial Synthesis from *Saccharum officinarum* (Sugarcane): A Green Approach for Forensic Applications

Devika Arunraj^{#1}, Payal Kaveramma^{#1}, Sujith P^{#1}, Pranjali Bajrang Chole^{#2}, Amit Chauhan^{#2}

[#]Department of Life Sciences, CHRIST (Deemed to be University), Bangalore, India.

Abstract— The biosynthesis of nanomaterials is gaining importance and has been proposed as a possible surrogate for many processes involving matter and energy because of its cheap cost and environmentally benign strategy. The current study gives a summary of the green method for producing Iron oxide nanomaterials. using *Saccharum officinarum* leaf extract solution, as well as its characterization using UV-visible spectrophotometry, X-ray diffraction (XRD), dynamic light scattering (DLS), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM). The concealed fingerprint is a vital tangible proof in forensic investigations. As a promising enhancer for the latent fingerprints on porous and nonporous surfaces with distinct ridge patterns, iron oxide nanomaterial was successfully enhanced in the current work. The iron nanomaterials that were seen had a smooth texture and an irregular crystal structure. Additionally, nanomaterials produced through biosynthesis offer a wide range of benefits, such as simple application, high stability, and improved contrast.

Keywords— *Saccharum officinarum*, Iron oxide, Nanomaterial, Forensic Investigations, Latent Fingerprint

I. INTRODUCTION

A. Nanomaterial Synthesis

Nanomaterials are structures with one or more of their external dimensions in the nanoscale. Nanomaterials display distinctive characteristics and behaviors that set them apart from their bulk counterparts due to their small stature. A more extensive region of surface, improved reactivity, and, under some circumstances, quantum effects are some of the important characteristics of nanoparticles. In the past, gold and silver nanoparticles were utilized by artisans to produce vivid hues in pottery and stained glass. However, it wasn't until the late 19th and early 20th centuries that nanoparticles were subjected to scientific research and comprehension. When it comes to the study of nanoparticles, in 1857, Michael Faraday was one of the pioneers. He noticed the peculiar optical characteristics of gold colloidal solutions, which are liquid-based suspensions of gold nanoparticles. Commercial Applications in the 2000s: Electronics, cosmetics, coatings, and catalysis are just a few of the fields where nanoparticles have begun to find commercial use. Nanomaterial research is still quite active, and there have been significant advancements in the fields of materials science, nanomedicine, environmental technology, and energy-related technologies. Nanomaterials have demonstrated tremendous promise in several forensic science applications. They are useful resources for forensic research and investigation.

B. Green Synthesis

Green synthesis is a divergent strategy, comparable to chemical reduction in which it substitutes a chemical reducing agent with an extract from a natural product, like a fruit or plant material, to produce metal or metal oxide nanomaterials. The biological development of NMs makes it simple to separate the NMs present in the reaction media or concentrate them more by centrifugation. The availability, phytochemical content, and capacity to carry out reduction reactions to give the desired NM all impact the selection of the plant used to manufacture NMs. The type of plant phytochemicals, their concentration, and the presence of organic reducing agents all have an impact on the size and structure of NMs. Furthermore, the size and shape are profoundly affected by growth media variables comprising temperature, saturation of salt, and the time of exposure of NMs[1]. At room temperature, the reaction happens spontaneously, but occasionally further heating and stirring are required. Considering they are effortlessly reachable, ideal to extract NMs in large quantities. Additionally, and their waste products are helpful to the environment, plants or their extracts tend to be of the highest caliber among other living entities[2].

C. *Saccharum officinarum*

A significant perennial grass native to tropical South Asia and Southeast Asia, sugarcane (*Saccharum officinarum*) is a prominent member of the Poaceae family. Due to the high-yielding plants' valuable medical and economic properties, it is grown all over the world. Various fatty acids, alcohol, phytosterols, higher terpenoids, flavonoids, -O- and -C-glycosides, and phenolic acids have been found in sugarcane leaves, juice, and its products according to various phytochemical studies[3]. Sugarcane leaves also serve as a key component of sugarcane wax as a consequence of their thick coating that follows and is an

excellent source of D-003 and other policosanols. Sugarcane leaves are said to contain several phenolic substances including flavonoids in addition to policosanols and D-003[4].

D. Iron Nanoparticles

FeNPs must be produced in an effective, novel, and long-lasting manner. Recent research on FeNPs has focused on extracts from several plant components, including, green tea leaves[5], Eucalyptus leaves[6], *Lawsonia inermis* and *Gardenia jasminoides* leaves[7], and *Plantago major* leaves[8]. On the other hand, there is no scientific evidence for the research on the synthesis of FeNPs by sugarcane leaves. However, research indicates that sugarcane leaves were used as a bio-based reducing agent to produce AgNPs. As a result, we designed this work to take into account the prerequisites for the synthesis of FeNPs and the usage of sugarcane leaves.

E. Applications of Green Nanotechnology in Forensic Science

In forensic investigations, nanoparticles have demonstrated considerable promise for improving the visualization and analysis of fingerprints. A definite characteristic that sets humans apart is their fingerprints. Due to their endurance and distinctiveness, they frequently serve for identification in legal proceedings. On a range of items removed from crime scenes, they are regularly found. These are arguably the most prevalent and extensively utilized types of factual evidence that can be utilized to verify a person's legitimacy and provide an unambiguous relationship to the perpetrator. Fingerprints are the result of perspiration trails on the skin which are ridged by friction. Latent fingerprints are designated this way since the imprints are ordinarily not visible to the unaided eye. The eccrine, apocrine, and sebaceous glands create the naturally occurring secretions from the fingers [9,10]. The majority of forensic laboratories generate latent fingerprints on diverse surfaces using powder and dyes. Traditional fingerprint analysis includes uncovering latent fingerprints left behind on surfaces using methods like dusting or chemical development. Nanomaterials have created new opportunities for enhancing fingerprint detection's sensitivity and specificity[11]. Increased sensitivity, better contrast, and better visualization of latent fingerprints are just a few benefits of using nanoparticles in fingerprint analysis. When dealing with difficult surfaces, worn-out or old fingerprints, or fingerprints in intricate crime scenes, this can be quite helpful.

In this study, we have created an effective and original approach for synthesizing Fe₃O₂-Nms from sugar cane (*Saccharum officinarum*) leaf extract. Using the powder dusting approach, the powder thus prepared is used to enhance latent fingerprints on diverse surfaces. As a result of its unique attributes, which consist of durability, non-corrosiveness, affordability, and environmentally favorable protocol, for superior latent fingerprint amplification on an array of non-porous surfaces, the Fe₃O₂ nanocrystals from the sugar cane (*Saccharum officinarum*) leaf extract is perfect.

II. MATERIALS AND METHODOLOGY

A. Sample collection

Sugarcane leaves (*Saccharum officinarum*) were freshly collected from a local market in Bengaluru, Karnataka, India. Freshly washed leaves were dried in a hot air oven at 45°C for 2-3 days. Once completely dried, they are finely powdered by using an electronic blender and stored in an airtight container.

B. Preparation of crude extract

For the preparation of crude extract, 30gm of finely powdered *Saccharum officinarum* leaf samples were infused with 500 ml distilled water and placed in a hot water bath at 60°C for 45 mins. Once the solution was cooled down, it was filtered three times with Whatmann no.42 filter paper to remove any suspended particles.

C. Synthesis of Nanoparticles

The clear plant extract solution, ferric chloride hexahydrate salt solution (0.1 M) in the ratio 6:4, PEG (polyethylene glycol) 5 ml were combined to create the reaction mixture. The mixture was magnetically agitated at 58 °C until the color changed. The resultant mixture was centrifuged for 10 minutes at 4°C at 10,000 rpm. The supernatant was then discarded, and each centrifuge tube containing the pellet received 2 ml of acetone before being spun again at 10,000 rpm for 10 min. Following the acetone wash, the supernatant was disposed of, and 2 millilitres of absolute ethanol was added to each centrifuge tube retaining the pellet. The tubes were then centrifuged for five minutes at 5000 rpm. There were two ethanol wash cycles.

D. Characterization of nanomaterials

Synthesized nanomaterials were characterized with UV-spectroscopy, X-ray diffraction (XRD), Dynamic light scattering (DLS), Scanning electron microscopy (SEM), Fourier-transform Infrared Spectroscopy (FTIR). UV spectroscopy was measured by using SHIMADZU, UV-1800 model with range 190 nm to 1100 nm. X-ray diffraction (XRD) pattern was performed by using RIGAKU MAKE XRD instrument (Model- miniflex 600; power- 600W, Japan). Dynamic light

scattering (DLS) was measured by using Zetasizer ZEN 3600, Malvern, Germany. For nanoparticle, Fourier-transform Infrared Spectroscopy (FTIR) analysis, SHIMADZU FTIR spectrometer (Japan) was used and spectra were recorded from 4000 to 500 cm^{-1} . For scanning electron microscopy (SEM), Apreo 2S model from Thermo scientific was used.

E. Application of nanomaterial in fingerprinting

The following steps were taken to complete the straightforward and quick process of enhancing latent fingerprints: The donors (20–24 year old volunteers) properly cleansed and dried their hands before lightly pressing them against a variety of materials, including glass, plastic, ceramic slabs, black paper, banknotes, wooden tables, doorknobs, walls, cell phones, and leather. Various methods for fingerprint development like iodine fuming for porous surfaces [12] and superglue fuming method [13] were employed to develop the latent fingerprint. Nanomaterial powder was used to enhance the quality of the developed prints, a magnetic brush was used to carefully apply about 100 mg of Iron Oxide NM powder to the surface. Any extra powder was removed. The last step included the usage of a digital camera to take pictures of latent fingerprints on various substrates.

III. RESULTS AND DISCUSSION

A. Synthesis of Nanomaterial

The reaction mixture was made up of the clear plant extract solution, ferric chloride hexahydrate salt solution (0.1 M), and 5 ml of PEG (polyethylene glycol). At 58 °C, the mixture was magnetically stirred until the color changed. After 45 minutes of reaction, the obtained solution was centrifuged at 10,000 rpm for 10 minutes. Each centrifuge tube containing the pellet was then filled with 2 ml of acetone and spun once more at 10,000 rpm for 10 min after discarding the supernatant. After the acetone wash, the supernatant was removed, and the pellet was then mixed with 2 ml of 100% ethanol in each centrifuge tube before being spun at 5000 rpm for 5 minutes. There were two cycles of the ethanol wash. After ethanol washing, the resultant solution was dried in a hot air oven overnight at 60°C. The dried iron particles were found in a dark brown powdery form.

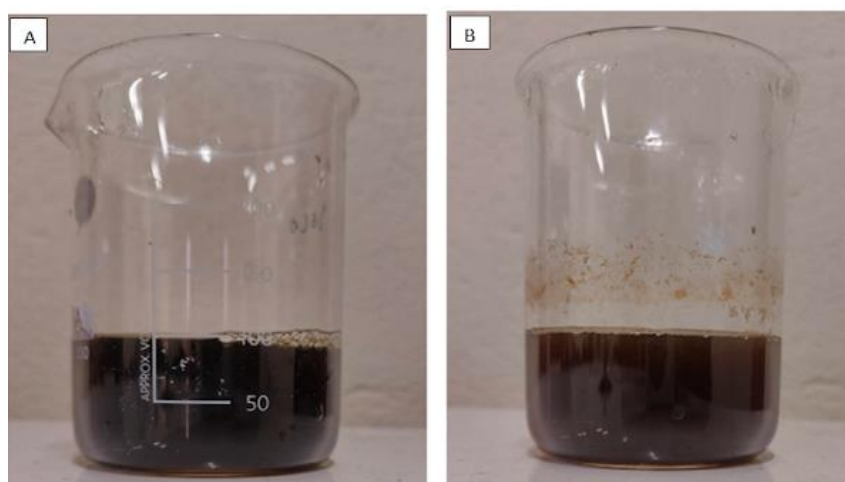


Fig. 1 Synthesis of Nanomaterials **A-** The reaction mixture before synthesis, **B-** The reaction mixture after synthesis.

Iron particles were dissolved in deionized water for the analysis of UV-visible spectrophotometry. The absorbance of the UV-visible spectrum of the reaction mixture and iron particles is shown in given figure- 2. The analyzed value of λ_{max} of Iron particles was 326 nm. The reaction mixture with precursor salt i.e., Ferric chloride hexahydrate salt has recorded λ_{max} 530 nm. This study helps to prove that, in iron, the particle of ferric chloride had reduced. A surface plasmon resonance has shown a complete change between the resultant product and the precursor salt. Hence, it is proved that the synthesis of iron particles has been done successfully with the reduction of ferric chloride hexahydrate salt.

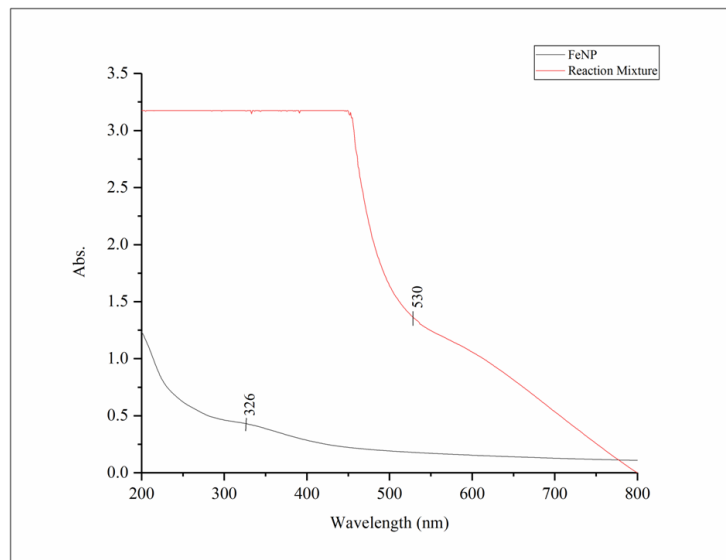


Fig. 2 Representation of UV-visible spectrometric analysis of Iron particles

B. Characterization of Nanomaterials

1) *X-ray Diffraction*: The XRD report of the synthesized iron oxide reveals peaks at (30.7, 33.16, 35.76, 43.28, 44.62, 54.24, 57.44, 62.8, 69.68, and 76.84) which are characteristic of iron oxide structure [14]. The synthesized nanomaterials are in the nanoscale range based on observable line broadening of the diffraction peaks.

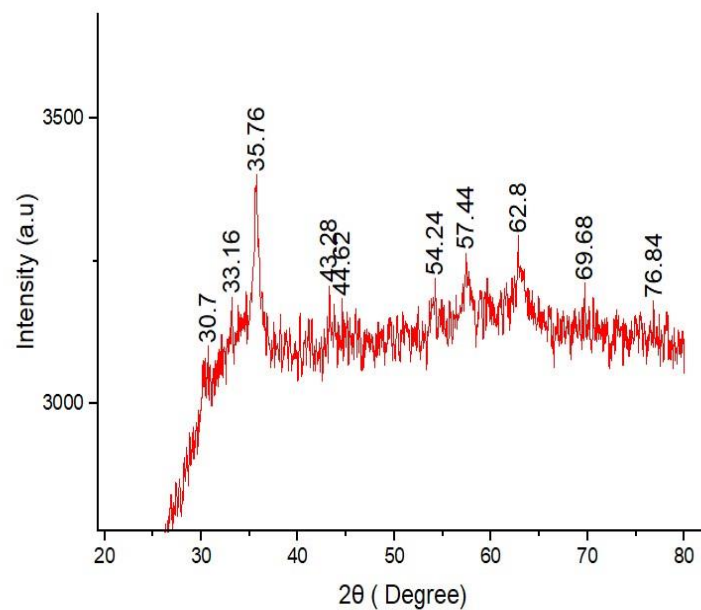


Fig. 3 Illustrates the XRD analysis of Iron Oxide

2) *Dynamic Light Scattering*: Dynamic Light Scattering (DLS) measurements were employed to track the size of Iron nanoparticles. DLS measures the rate at which the laser light intensity varies as particles diffuse through the solvent. According to the report, the average particle size of iron oxide nanoparticles is 697.5 nm.

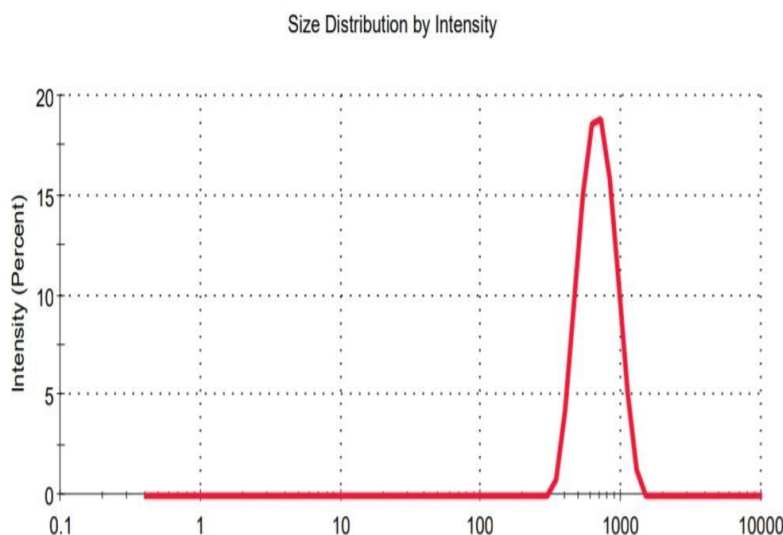


Fig. 4 shows the particle size of the Iron Oxide nanomaterials

3) *Fourier Transform Infrared Spectroscopy*: To understand the functional groups present in the nanomaterials, Fourier Transform Infrared Spectroscopy analysis was conducted. The absorption bands were observed at (3350.14092), (2172.02231), (2026.36401), (1633.65781), (1258.08787), (1031.03229), (843.96133), (602.62552), and (489.81174). (3350.14092) the band corresponds to the functional group OH, (2172.02231) the band correlates to alkynes, (2026.36401) the band matches to N-H functional group which is an amine salt, (1633.65781) the band is equivalent to C=O, (1258.08787) the band is complementary to a C-F, (1031.03229) the band equal to C-F bond, (843.96133) the band depicts to alkenes and aromatic C-H bond, (602.62552) The band similar to the Fe-O bond. (489.81174) the band indicates C-I stretch.

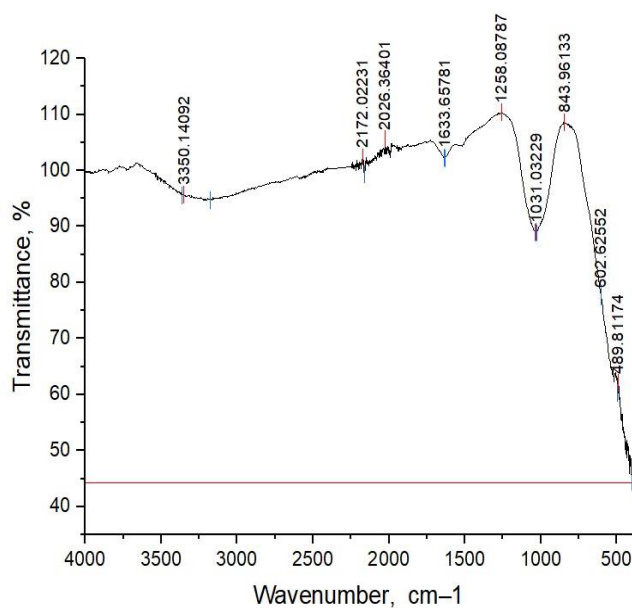


Fig. 5 Depicts the functional group present in the Iron Oxide nanomaterials

4) *Scanning Electron Microscopy*: For the confirmation of the texture and morphological characters of these Iron nanomaterials, further analysis was done with the help of a scanning electron microscope. The observed Iron nanomaterials were in crystalline, uneven shape, with smooth texture as shown in fig. 6. The size of each Iron nanoparticle was ranging below the size of 100 nm.

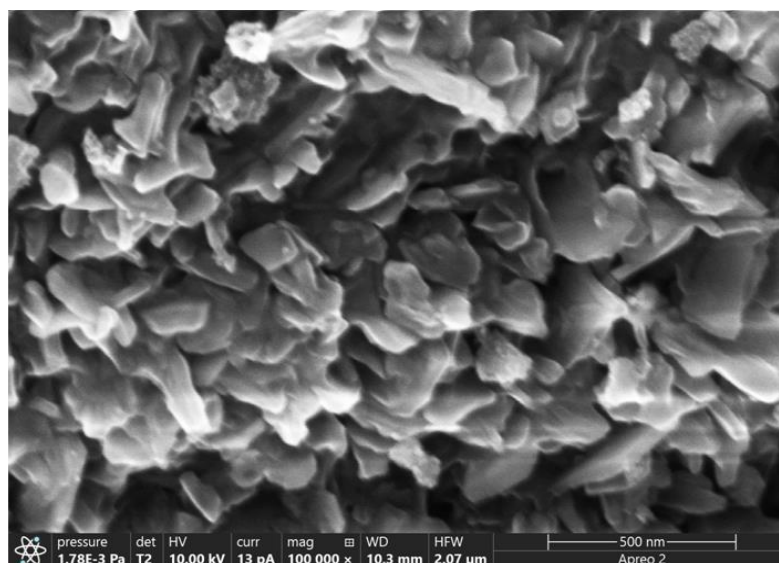


Fig. 6 Represents the morphological structure of Iron Oxide nanomaterials

C. Application of Iron Nanomaterials

The powder developed by the synthesis of nanomaterials from the leaf extract adheres to the sweat residue produced by the finger when in contact with a surface. These sweat residues help the powder to stick onto the substrate and help create a contrast between the two surfaces. The powder developed by the scientific protocol was found to be effective in developing latent fingerprints from both porous and non-porous surfaces. Even and uneven surfaces also tend to provide effective results in the development of latent fingerprints. Metallic and steel surfaces were found to produce the best result among the many other surfaces tested. Paper also was observed to give a good image after the application of the powder immediately after the print was placed. The performance of the powder on other surfaces like concrete, plastic, etc along with the effect of time of exposure of the prints to the atmosphere is yet to be determined.

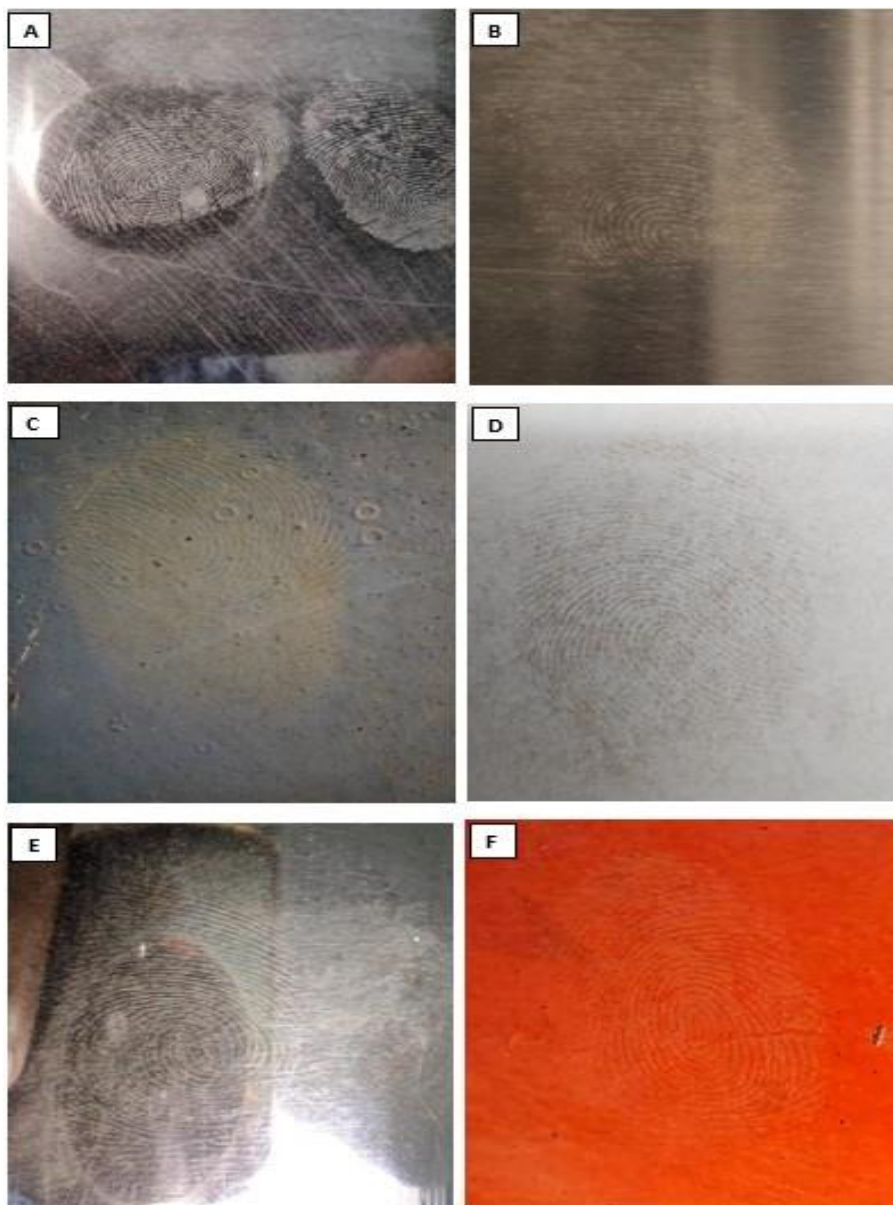


Fig.7 Latent fingerprint developed from different surfaces. A- Steel chair, B- Steel lock, C- Paper, D- Uneven painted surfaces, E- Steel railings, F- Fire extinguisher

IV. CONCLUSION

To reduce the environmental impact of the manufacture and use of chemicals, the green synthesis of iron nanoparticles uses safe reaction media for long-term applications and environmental cleanup. Utilizing sugarcane leaf extract, new modified Fe_3O_2 nanoparticles were created and applied to identify recent latent fingerprints on numerous surfaces. The amino acids found in human sweat are susceptible to and selective for these particles. These discoveries have made it possible to create a technique for latent fingerprint enhancement on smooth, porous, and nonporous objects. The novel powder may have many uses, which are now being looked into.

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