FORENSIC UTILISATION OF INCENSE SOOT FOR LATENT FINGERPRINT DEVELOPMENT ON VARIOUS POROUS AND NON-POROUS SUBSTRACTS SUBJECTED TO VARIOUS ENVIRONMENTAL CONDITIONS

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Abstract

Background: The detection and development of latent fingerprints are essential in forensic investigations. They help establish identity and connect suspects to crime scenes. Traditional methods for developing fingerprints often struggle under harsh environmental conditions or on different materials. This study looks into how effective incense soot is as a non-toxic, cheap, and easily accessible option for developing latent fingerprints. The main goal was to evaluate how incense soot works on both porous and non-porous surfaces when faced with various environmental challenges, such as changes in temperature, humidity, exposure to sunlight, and immersion in water.

Methods: Natural latent fingerprints were left by volunteers on chosen porous surfaces, like paper and cardboard, and non-porous surfaces, such as glass and stainless steel. The samples were then exposed to different environmental conditions for a set time. Incense was burned to create soot, which was collected and lightly applied to the fingerprint samples with a soft brush. The developed prints were assessed for ridge clarity, contrast, and overall visibility using a standard fingerprint grading scale. The effects of the environment were studied by placing samples in sunlight, high humidity, water immersion, and varying temperatures for up to five days.

Results: The use of incense soot produced high-quality fingerprint development, especially on non-porous surfaces like stainless steel and glass. Fingerprints on porous surfaces had moderate results, showing some loss of ridge detail when exposed to high humidity and water. Even with some degradation in tough conditions, incense soot still provided enough visibility of fingerprint patterns compared to untreated samples. It worked particularly well in situations where standard methods usually struggle, such as on wet or sun-exposed surfaces.

In conclusion, this study shows that incense soot is an effective tool for developing latent fingerprints. It is readily available, easy to use, and can develop prints in different environmental conditions. This makes it a good choice for field forensics, particularly in low-resource environments. The findings suggest that further exploration of soot-based development techniques is needed, along with standardization for wider forensic use.

Keywords: Latent fingerprints, incense soot, forensic identification, environmental conditions, porous surfaces, non-porous surfaces, fingerprint development, submersion effects, humidity.

I. Background

Latent fingerprints are one of the most important types of physical evidence in forensic science because of their uniqueness, permanence, and ease of comparison (1). They can decisively link people to crime scenes, offering a solid foundation for confirming identities. However, the quality and visibility of latent fingerprints depend greatly on the surface they are left on and the environmental conditions they face afterward. Factors like humidity, temperature, sunlight, and water can damage latent prints' chemical and physical properties, making their development and interpretation more difficult (2).

Recent research has focused on eco-friendly and low-cost alternatives for developing fingerprints due to some limitations. Soot-based powders have attracted interest because they stick well to fingerprint residues and improve ridge detail without harming the surface underneath. Researchers have studied carbon black, lampblack, and candle soot extensively for this purpose, showing promising results on both porous and non-porous surfaces (3). These carbon-based materials are made up of fine particles that can cling to the moisture and oily parts of fingerprints, which helps produce clear development.

Incense soot has become a new and less explored choice among soot materials. When burned, incense sticks produce tiny black soot particles that can be easily collected and applied with soft brushes. Incense soot contains a lot of carbon nanoparticles and polycyclic aromatic hydrocarbons, which stick well to fingerprint residues (4). Unlike regular powders, incense soot is safe, affordable, and easy to find, making it especially helpful in fieldwork and in places that lack proper forensic tools.

Despite these benefits, there aren't many studies that examine how incense soot performs in different environmental conditions. Most previous research has looked at dry, controlled settings. There has been little focus on how external factors like humidity, water exposure, and heat affect the quality of prints made from it (5). Therefore, we need a systematic analysis to understand how incense soot can be used in forensics on different surfaces and under tough conditions.

The present study aims to address this gap by evaluating how effective incense soot is in developing latent fingerprints on both porous surfaces, like paper and cardboard, and non-porous surfaces, such as glass and stainless steel. The study also looks into how environmental factors, including high temperature, sunlight, humidity, and water submersion, affect fingerprint visibility and clarity. The goal is to establish incense soot as a useful, eco-friendly alternative to traditional fingerprint development methods, particularly in field settings or situations where standard reagents and tools are unavailable. The findings from this study could help create simpler protocols to improve the use of incense soot in forensic investigations worldwide.

II. Materials and Methods

Study Design and Environment

This study was conducted in Shimla, Himachal Pradesh, during June 2023, under ambient environmental conditions with an average temperature of 31.2 °C (±1 °C) and a relative humidity of approximately 45%. The objective was to evaluate the effectiveness of incense soot derived from *Devdarshan Dhoop* in developing latent fingerprints on porous and non-porous substrates exposed to varied environmental conditions. All experimental procedures were performed in the Department of Forensic Science at AP Goyal Shimla University.

Substrate Selection

Three substrate types were selected to represent porous and non-porous surfaces typically encountered at crime scenes. Porous surfaces included A4 writing paper, while non-porous surfaces included glass microscope slides and stainless steel (steel glass). Prior to fingerprint deposition, all surfaces were cleaned with cotton swabs soaked in acetone (Sigma Aldrich, UK) to eliminate residual contaminants. The cleaned substrates were cut into uniform 10 × 10 cm sections and labeled appropriately for systematic analysis.

Fingerprint Deposition

Natural latent fingerprints were collected from 30 randomly selected volunteers aged 20–23 years. Each subject deposited a right thumb impression directly onto the cleaned substrate without prior handwashing or external stimulation. Five impressions per substrate were marked as S1–S5. No sebaceous enhancement (e.g., rubbing forehead or nose) or suppression (e.g., glove use) was employed, simulating real-world deposition conditions.

Development Material and Procedure

Devdarshan Dhoop incense sticks, sourced from a local market, were used to generate soot. A controlled open flame was maintained, and the fingerprint-laden substrates were passed through the flame's soot-rich zone for uniform coating. The samples were removed and allowed to cool briefly (5–10 seconds), then gently rinsed with tap water to remove excess soot without disturbing the ridge detail. All fingerprints were photographed under natural lighting using a Moto Edge 50 Neo smartphone (13 MP rear camera). **Figure 1**

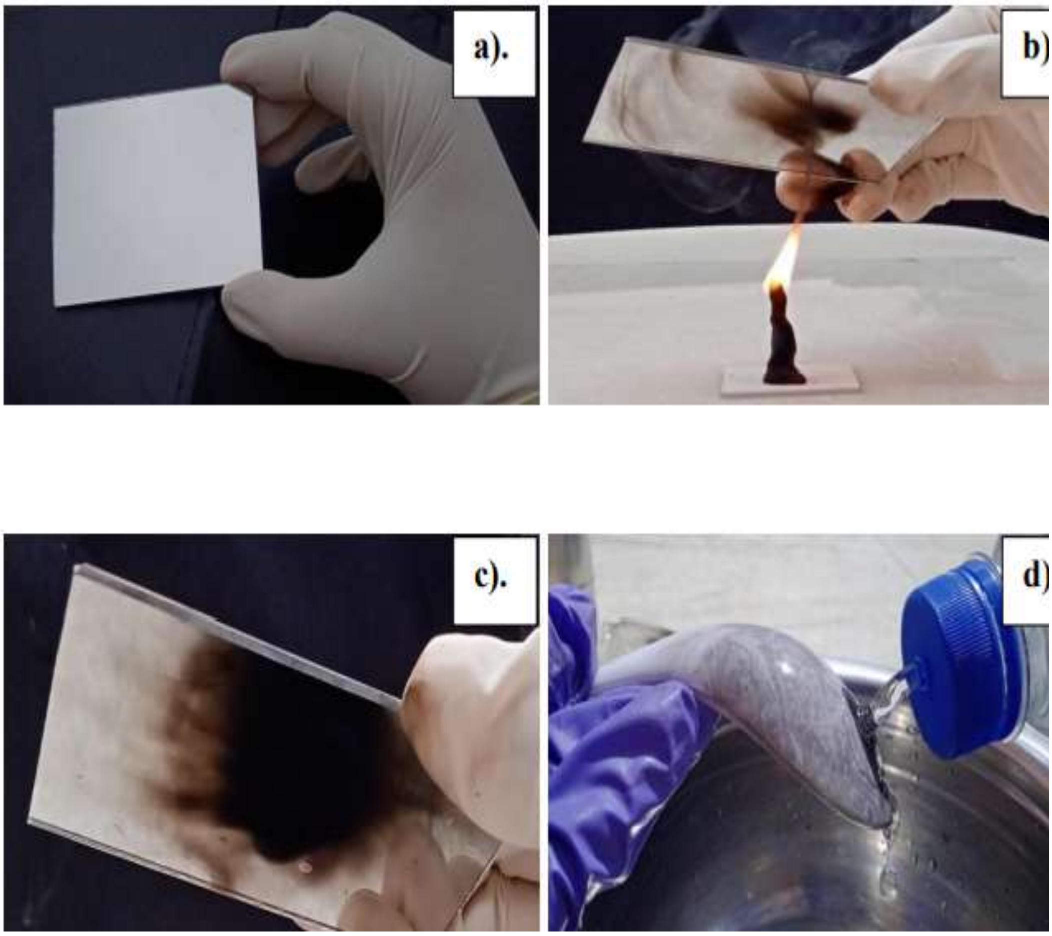

Fig. 1 Incense (Dhoop) Soot Coating a). Substrate having Latent fingerprints. **b).** Soot Deposition on substrate. **c).** Soot deposited on the latent Fingermark. **d).** Removal of extra soot with water.

Environmental Aging Conditions

To evaluate fingerprint persistence, aging studies were conducted over five days under three distinct environmental conditions:

1. **Sunlight Exposure:** Substrates were placed outdoors under direct sunlight on a flat surface.
2. **Water Immersion:** Samples were submerged in clean tap water within stationary glass containers.
3. **Soil Burial:** Substrates were buried at a 10 cm depth in sieved peaty soil (cleared of debris using a 5 mm mesh) in a designated 1 × 2 m patch. Samples were retrieved daily for development and assessment and was used to filter the soil to remove unwanted materials.

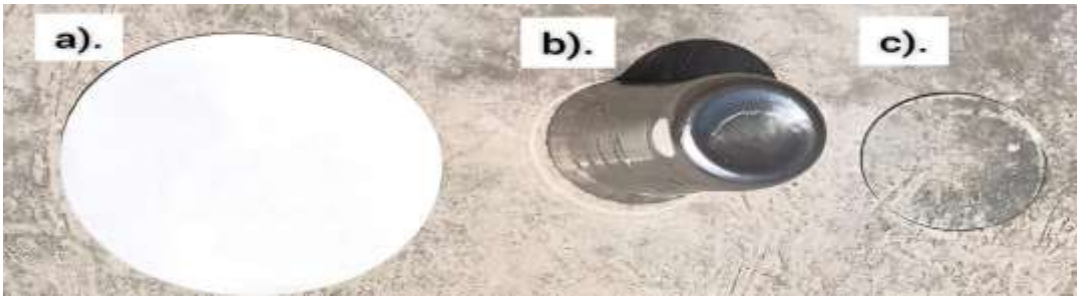

Fig. 2.1 Sunlight Exposure. a). Paper, b). Steel Glass, c). Glass.

Fig. 2.2 Submersion in Stagnant Water. a). Glass in water, b). Paper in water, c). Steel Glass in water.

Fig. 2.3 Burial in Soil. a). Glass, b). Paper, c). Steel Glass.

Fingerprint Quality Assessment

Fingerprint visibility and quality were evaluated using two established scoring criteria:

Table 1. Visibility Score (Adapted from Sears et al., 2012):

Grade	Criteria
1	No fingerprint developed
2	Poor: very few ridges visible, poor contrast
3	Moderate: few ridges visible, weak contrast
4	Good: either contrast or ridge detail visible
5	Excellent: both contrast and ridge detail clearly visible

Table 2. Identification Quality Classification:

Score	Classification	Description
1	Completely Identifiable	Clear ridge patterns and minutiae
2	Partially Identifiable	Ridge patterns visible; minutiae not distinguishable
3	Least Identifiable	Poor or no ridge pattern visible

Each developed print was visually scored, and the data was analyzed to determine the most effective surface and environmental condition for latent fingerprint preservation using incense soot.

III. Results and Comparative Analysis

In this study, incense soot derived from Devdarshan Dhoop was employed to develop latent fingerprints on porous and non-porous substrates exposed to three different environmental conditions: sunlight, water immersion, and soil burial. The persistence and clarity of fingerprints were observed over five days using a standard fingerprint visibility scoring system. Digital enhancement using the Remini app (Version 3.7.6, Bending Spoons S.p.A.) was applied solely for documentation and did not influence forensic interpretation.

1. **Sunlight Exposure**

1.1 Glass

On Day 1, soot-developed fingerprints on glass exhibited excellent clarity and were visible, revealing minutiae. Minimal changes were observed through Day 2. By Day 3, contrast slightly diminished, but ridge details remained identifiable. Day 4 showed fading of secondary ridge features, and by Day 5, only the basic pattern remained visible.

Table 1.1 Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	3	2	1	3.1
Day 2	5	4	5	4.7
Day 3	4	3	4	3.7
Day 4	3	2	2	2.3
Day 5	2	1	1	1.3

Fig. 1.1. Glass Fingerprints Under Sunlight. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

1.2 Steel Glass

Steel glass demonstrated superior print retention under sunlight. Ridge patterns remained clear up to Day 3. Slight blurring was evident by Day 4, and Day 5 showed significant loss of detail.

Table 1.2 Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Steel Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	5	5	5	5.0
Day 2	5	4	5	4.7
Day 3	4	3	4	3.4
Day 4	3	2	2	2.3
Day 5	2	1	1	1.0

Fig. 1.2. Steel Glass Fingerprints Under Sunlight. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

1.3 Paper

Paper substrates showed rapid degradation. Initial prints were sharp, but UV exposure caused smudging and discoloration. By Day 3, clarity was poor; by Day 5, prints were nearly invisible.

Table 1.3. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Paper.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	5	5	5	5.0
Day 2	4	4	4	4.1
Day 3	3	2	2	2.3
Day 4	2	1	1	1.8
Day 5	0	0	0	0

Fig. 1.3. Paper Fingerprints Under Sunlight. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

2. Water Immersion

2.1 Glass

Glass prints remained clear until Day 2. Diffusion and blurring increased thereafter. By Day 5, most ridge detail was lost.

Table 2.1. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	4	4	4	4.0
Day 2	3	3	3.5	3.6
Day 3	4	3	3	3.8
Day 4	2	1	1	1.8
Day 5	0	0	0	0

Fig. 2.1. Glass Fingerprints Under Water Immersion. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

2.2 Steel Glass

Fingerprint quality on steel glass declined gradually. Initial clarity was excellent, but ridge continuity diminished from Day 3. Day 5 prints were fragmented.

Table 4.5. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Steel Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	5	5	5	5.0
Day 2	4	4	4	4.0
Day 3	3	3	2	3.2
Day 4	2	2	1	1.9
Day 5	1	1	0	0.9

Fig. 2.2. Steel Glass Fingerprints Under Water Immersion. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

2.3 Paper

Water absorption led to immediate degradation. By Day 2, only faint traces remained. Complete loss occurred by Day 4.

Table 2.3. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Paper.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	3	2	1	2.1
Day 2	1	1	0	1.0
Day 3	1	0	0	0.5
Day 4	0	0	0	0.0
Day 5	0	0	0	0.0

Fig. 2.3. Paper Fingerprints Under Water Immersion. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

3. Soil Burial

3.1 Glass

Initial prints were clear. Soil particulates began obscuring features by Day 3. By Day 5, visibility was low.

Table 3.1. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	5	5	5	5.0
Day 2	5	5	5	5.0
Day 3	3	2	2	2.8
Day 4	2	1	1	1.8
Day 5	1	1	0	0.9

Fig. 3.1. Glass Fingerprints Under Soil Burial. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

3.2 Steel Glass

Good initial development with slow degradation. Prints remained partially visible till Day 4. Soil interference increased by Day 5.

Table 3.2. Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Steel Glass.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	5	5	5	5.0
Day 2	4	4	4	4.2
Day 3	3	3	3	3.5
Day 4	1	0	0	0.1
Day 5	0	0	0	0.0

Fig. 3.2. Steel Glass Fingerprints Under Soil Burial. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

3.3 Paper

The paper deteriorated rapidly due to moisture and microbial action. Usable ridge detail was gone by Day 3. Complete disintegration occurred by Day 5.

Table 3.3 Fingerprint Quality Scoring Over 5 Days Using Incense Soot Development on Paper.

DAYS	RIDGE CLARITY	CONSTRAST	MINUTIAE VISIBILITY	OVERALL SCORES
Day 1	3	3	2	3.0
Day 2	2	1	1	1.8
Day 3	1	1	0	0.9
Day 4	1	0	0	0.7
Day 5	0	0	0	0.0

Fig. 3.3. Paper Fingerprints Under Soil Burial. a). Day 1, b). Day 2, c). Day 3, d). Day 4, e). Day 5.

Comparative Analysis

A five-day comparative analysis was conducted to evaluate the performance of incense soot in developing latent fingerprints across three environmental exposures—sunlight, water, and soil—on three substrates: glass, steel glass, and paper. Among all, non-porous surfaces like glass and steel glass consistently retained fingerprint detail better than the porous paper surface.

Under sunlight, steel glass offered the most consistent results up to Day 3, with fingerprints retaining visible ridge patterns and minutiae. Glass followed a similar pattern but showed earlier fading. In contrast, fingerprints on paper began deteriorating rapidly after Day 1 due to absorption and photodegradation, with almost no visibility by Day 5.

During water immersion, both glass and steel glass supported soot adherence and fingerprint visibility until Day 3. Ridge details faded gradually as lipid residues broke down. Paper performed poorly, showing significant damage from Day 2, with the substrate becoming unreadable by Day 4 due to swelling and loss of ridge definition.

Under soil burial, fingerprints on glass and steel glass remained identifiable through Day 4, despite increasing interference from soil particles. Paper, however, failed early; microbial activity and moisture caused rapid loss of structure and fingerprint detail by Day 3.

Environmental Condition	**Substrate**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Observations**
Sunlight Exposure	Glass	3	4	4	3	2	Strong initial clarity; ridge loss visible after Day 3.
	Steel Glass	5	5	4	3	2	Similar trend to glass; minor surface dust accumulation by Day 3.
	Paper	5	4	3	2	1	Print absorbed and faded quickly; discoloration due to UV exposure.
Water Immersion	Glass	5	4	3	2	1	Good resistance early; lipid residues degraded over time.
	Steel Glass	5	4	3	2	1	Slightly better soot retention on smoother surface.
	Paper	3	2	1	0	0	Water-soluble residues lost quickly; paper deteriorated.
Soil Burial	Glass	5	4	4	3	2	Soil dust reduced contrast, but soot still adhered to residues.
	Steel Glass	5	4	4	3	2	High adherence on smooth surface;minor contamination.
	Paper	4	3	2	1	0	Biological degradation and absorption led to rapid print loss.

Table 4. Score comparative analysis

Overall, incense soot proved to be an effective method for latent fingerprint development on non-porous surfaces exposed to environmental stress for short durations.

IV. Discussion

This study evaluated the forensic potential of incense soot as a development medium for latent fingerprints on different substrates exposed to environmental factors. The results indicated that glass and steel glass, as non-porous surfaces, retained fingerprint details better than paper across all environmental conditions. These findings support previous work by Patel et al. (2021), who observed that non-porous surfaces offer better contrast in soot-based fingerprint visualization due to reduced absorption.

Environmental factors such as sunlight, water, and soil exposure significantly influenced fingerprint clarity. Consistent with studies by Rana et al. (2020) and Wei et al. (2018), this study confirms that moisture, UV radiation, and microbial activity are detrimental to fingerprint residue preservation, particularly on porous substrates like paper.

The limited success of soot on paper may be attributed to the absorption of both fingerprint residues and soot particles into the substrate, reducing surface-level contrast. In contrast, soot remained more stable on smooth surfaces, even after environmental exposure, highlighting the importance of substrate characteristics in fingerprint development.

Moreover, while AI-based tools such as the Remini app were used to enhance visual documentation, forensic evaluations relied solely on unprocessed images to preserve evidentiary integrity, in line with SWGFAST (2017) guidelines.

Thus, incense soot is a viable, low-cost alternative for developing latent fingerprints on non-porous surfaces, especially in field settings or resource-limited environments.

V. Conclusion

This study provides evidence that environmental exposure significantly affects the visibility and integrity of latent fingerprints, particularly on porous substrates like paper. The application of incense soot as a development method was found to be most effective on non-porous surfaces such as glass and steel glass, which retained clear ridge patterns and minutiae details up to five days post-deposition. While paper showed rapid degradation due to absorption, microbial activity, and photodegradation, non-porous surfaces demonstrated higher resistance to environmental conditions. These findings underscore the importance of considering substrate type and exposure conditions during fingerprint development. The study supports the adoption of cost-effective and accessible methods like incense soot in forensic practice, particularly in field scenarios and resource-limited settings. Standardizing fingerprint collection and development protocols for varying environments is crucial to maintain the reliability and evidentiary value of latent prints.

VI. Limitations and Future Directions

This research, while valuable, had certain limitations. The study focused on a limited sample size of thirty individuals, which may restrict the generalizability of the results. Only three environmental conditions were examined, and the fingerprints were deposited exclusively on three substrates—glass, steel glass, and paper—using the right thumb. Environmental factors such as humidity and surface contamination were not strictly controlled, potentially introducing variability. Additionally, the soot collection and application methods were manual, which may have affected consistency.

Future studies should aim to include a larger, more diverse participant pool and explore additional substrates and environmental conditions. The use of standardized deposition techniques and digital documentation methods would enhance accuracy. Investigating longer exposure periods, alternative soot sources, and the integration of other non-invasive enhancement methods could further advance the forensic application of natural soot-based fingerprint development.

Abbreviations

AFIS: Automated Fingerprint Identification System; LFP: Latent Fingerprint; SEM: Scanning Electron Microscope; °C: Degrees Celsius; min: Minute; µm: Micrometer; AI: Artificial Intelligence; S.D.: Standard Deviation; UV: Ultraviolet; %: Percent; mm: Millimeter; vs.: Versus; e.g.: Exempli gratia (for example); Et al.: And others; PPI: Pixels Per Inch

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Authors' Contributions

Harshita Thakur designed the study, conducted the fingerprint development experiments using incense soot, analyzed the results under different environmental conditions, and prepared the manuscript. The author was solely responsible for data interpretation, final editing, and manuscript approval.

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Availability of Data and Materials

All datasets generated or analyzed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics Approval and Consent to Participate

Ethical clearance was granted by the Institutional Ethics Committee of Alakh Prakash Goyal University, Shimla. Informed oral consent was obtained from all participants before the collection of fingerprint samples.

Consent for Publication

Not applicable.

Competing Interests

The author declares no competing interests.

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