

A Comparative Study Between Infrared Photography and Luminol in Bloodstain Detection Under Varying Conditions and Time Periods

Kumaraguru M¹, Sankarasubramanian V², Aparna A P³

^{1,2}III B.Sc Forensic Science, Department of Criminology and Forensic Science, Nehru Arts and Science College, Coimbatore, India

³Assistant Professor, Department of Criminology and Forensic Science, Nehru Arts and Science College, Coimbatore, India

Abstract—Bloodstain detection plays a crucial role in forensic investigations, particularly when biological evidence is concealed, degraded, or invisible to the naked eye. This study presents a comparative analysis of infrared (IR) photography and luminol chemiluminescence for detecting bloodstains across different environmental conditions, fabric types, and time intervals. Blood samples were deposited on cotton, polyester, denim, and nylon fabrics and exposed to conditions such as submerged, buried, outdoor, washed, and indoor environments. Observations were conducted over a five-day period to evaluate the impact of ageing on detection efficiency. Infrared photography demonstrated strong performance on dry and indoor samples, offering a non-destructive and reliable method for visualizing stains through spectral absorption properties of hemoglobin. In contrast, luminol exhibited high sensitivity across all conditions, successfully detecting blood even in washed and submerged samples, though with variations in luminescence intensity. However, luminol presented limitations such as potential false positives and temporary visualization. The findings suggest that both techniques possess complementary strengths. Infrared photography ensures preservation of evidence and documentation quality, while luminol enhances detection sensitivity. The combined use of both methods significantly improves forensic accuracy, making them essential tools in modern crime scene investigation.

Index Terms—Infrared photography, Luminol, Bloodstain detection, Forensic science.

I. BLOOD AS EVIDENCE: IMPORTANCE AND DETECTION TECHNIQUES

Blood evidence is one of the most significant forms of physical evidence in forensic science due to its ability to reconstruct events, establish timelines, and link individuals to crime scenes. Even minute traces of blood can provide valuable information about the nature of a crime, including directionality, force, and sequence of actions. However, criminals often attempt to conceal such evidence through washing, painting, or environmental exposure, making detection increasingly complex.

Traditional detection methods relied heavily on visible inspection, which is insufficient when stains are latent or degraded. This limitation led to the development of advanced techniques such as luminol testing and infrared photography. Luminol operates through a chemiluminescent reaction with hemoglobin, producing a visible blue glow in dark conditions. This method is highly sensitive and capable of detecting extremely diluted bloodstains.

Infrared photography, on the other hand, functions through optical principles. Hemoglobin absorbs infrared radiation, causing bloodstains to appear darker under IR imaging. Unlike luminol, this method is non-destructive and does not require chemical interaction with the evidence.

The growing complexity of crime scenes necessitates the integration of both methods. While luminol excels in sensitivity, infrared photography offers stability and preservation. Understanding their roles is essential for effective forensic investigation.

II. SPECIFICITY AND FALSE POSITIVES IN BLOOD DETECTION

One of the major challenges in forensic detection is ensuring that the observed results genuinely indicate the presence of blood. Luminol, although highly sensitive, is susceptible to false positives. Substances such as bleach, certain metals, and cleaning agents can trigger similar chemiluminescent reactions, leading to potential misinterpretation.

Researchers have attempted to improve luminol specificity by analyzing reaction patterns rather than just intensity. True blood reactions tend to produce sustained luminescence, whereas false positives often appear as brief flashes. Despite these improvements, the possibility of misinterpretation remains.

Infrared photography provides a different approach by relying on physical properties rather than chemical reactions. Blood absorbs infrared radiation distinctly compared to most substances, allowing for differentiation. However, some materials like rust or dark pigments may also absorb infrared light, requiring careful interpretation.

Therefore, neither technique is entirely free from limitations. Luminol may over-detect, while infrared imaging may occasionally misidentify. This highlights the importance of combining methods and confirming results through additional forensic tests.

III. INFLUENCE OF SUBSTRATE AND MATERIAL COMPOSITION

The effectiveness of blood detection techniques is significantly influenced by the type of surface or material on which the blood is deposited. Porous materials such as cotton and denim tend to absorb blood, making detection more stable over time. Non-porous or synthetic materials like polyester and nylon may show different detection patterns due to lower absorption.

Luminol's performance depends on its ability to interact with hemoglobin on the surface. On porous materials, the reagent penetrates deeper, producing stronger luminescence. However, surface coatings or multiple layers (such as paint) can reduce effectiveness.

Infrared photography relies on contrast between the stain and the background. Textiles generally provide better contrast, while patterned or reflective surfaces

may interfere with detection. Environmental factors such as moisture, dirt, and exposure also affect results. This study confirms that cotton and denim exhibited higher detection rates, while synthetic fabrics showed variability. Thus, substrate composition plays a critical role in determining which method is more effective.

IV. IMPACT OF ENVIRONMENTAL CONDITIONS AND TIME

Environmental exposure significantly affects the detectability of bloodstains. Conditions such as washing, burial, water immersion, and outdoor exposure lead to degradation, dilution, or chemical alteration of blood components.

Infrared photography showed reduced effectiveness in submerged and washed conditions due to diffusion of hemoglobin. However, it performed consistently in indoor and dry environments, where stains remained stable.

Luminol demonstrated superior performance under challenging conditions. Even after washing or prolonged exposure, luminol was able to detect blood through chemiluminescent reactions. However, the intensity of the glow decreased over time, indicating gradual degradation.

Ageing also influenced detection. While infrared imaging depended on preserved optical contrast, luminol could detect even aged samples due to chemical sensitivity.

These findings highlight that environmental context must be considered when selecting detection methods.

V. NON-DESTRUCTIVE ANALYSIS AND DNA INTEGRITY

Preservation of biological evidence is essential in forensic investigations, especially for DNA analysis. Infrared photography offers a major advantage as a completely non-destructive technique. It does not alter the sample, allowing for repeated analysis and further laboratory testing.

Luminol, although generally safe, introduces moisture and oxidative conditions. Repeated application may dilute or alter the sample, potentially affecting DNA quality. Therefore, it is often used as a preliminary detection method rather than a final analytical tool.

This distinction is crucial in modern forensic workflows. Infrared imaging is ideal for initial

documentation, while luminol is used for locating hidden evidence. The sequence of application plays a significant role in preserving evidence integrity.

VI. DOCUMENTATION, PHOTOGRAPHY, AND LEGAL ADMISSIBILITY

Forensic evidence must be documented in a manner that is admissible in court. Photography serves as a primary method of recording crime scenes, and accuracy is essential.

Infrared photography produces permanent images that can be stored, analyzed, and presented as evidence. It aligns well with standard forensic documentation procedures.

Luminol, however, produces temporary luminescence that must be photographed immediately in dark conditions. Failure to capture the reaction can result in loss of evidence.

Thus, from a legal perspective, infrared photography provides stronger documentation reliability. It ensures reproducibility and clarity, which are essential in judicial proceedings.

VII. EXPANDING APPLICATIONS OF INFRARED IMAGING

Infrared photography has expanded beyond traditional bloodstain detection. It is now used in forensic pathology to detect bruises, internal injuries, and subcutaneous hemorrhages. It also assists in detecting evidence on dark skin tones, where visible light examination may fail.

Additionally, IR imaging can reveal concealed evidence beneath surfaces and assist in post-mortem examinations. Its versatility makes it a valuable tool across multiple forensic domains.

Luminol, while highly effective, remains largely limited to surface detection. This difference highlights the broader potential of infrared imaging in forensic science.

VIII. COMPARATIVE EFFECTIVENESS AND INTEGRATED APPROACH

The comparative analysis demonstrates that both infrared photography and luminol have distinct advantages. Infrared imaging provides stable, non-

destructive visualization, while luminol offers unmatched sensitivity.

Infrared performed best in indoor and dry conditions, whereas luminol excelled in detecting washed, buried, and submerged samples. Fabric type also influenced performance, with natural fibers showing better results.

The key finding is that neither method is sufficient alone. Their combined use provides a comprehensive detection strategy. Infrared imaging can be used first to preserve evidence, followed by luminol for enhanced detection.

IX. CONCLUSION

This study highlights the importance of integrating multiple forensic techniques to achieve reliable and accurate bloodstain detection. Infrared photography and luminol represent two fundamentally different yet complementary approaches. Infrared imaging operates through optical absorption, offering a non-invasive and stable method for detecting and documenting bloodstains without altering the evidence. Its ability to preserve biological material makes it particularly valuable for subsequent DNA analysis and forensic examination.

Luminol, in contrast, functions through a chemical reaction that produces visible light, enabling the detection of extremely small or degraded blood traces. Its sensitivity allows investigators to uncover evidence that would otherwise remain undetected, especially in cases involving attempts to clean or conceal bloodstains. However, this sensitivity also introduces limitations, including the potential for false positives and the temporary nature of the luminescent reaction. The experimental findings demonstrate that environmental conditions, substrate type, and ageing significantly influence detection outcomes. Infrared photography performs best under stable conditions, while luminol remains effective even in adverse environments such as washing and submersion. These differences reinforce the need for a strategic approach rather than reliance on a single method.

Ultimately, the combined application of infrared photography and luminol provides the most effective solution. By using infrared imaging for initial detection and documentation, followed by luminol for enhanced sensitivity, forensic investigators can maximize accuracy while preserving evidence

integrity. This integrated approach not only improves crime scene analysis but also strengthens the reliability of forensic conclusions presented in court.

REFERENCES

- [1] V. Barrera and M. Bohnert, "Reconstruction of crimes by infrared photography," 2016.
- [2] N. A. Dilkie, *Documenting Bloodstain Patterns Concealed Beneath Architectural Paint Layers*, 2016.
- [3] P. Massey and M. T. Miller, *Crime Scene Photography*, 2016.
- [4] S. Ghosh and D. Nagesh, "Efficiency of luminol in detection of bloodstains," 2017.
- [5] C. Wang *et al.*, "Artemisinin-luminol chemiluminescence for blood detection," 2017.
- [6] B. M. Cassidy *et al.*, "Quantitative method for luminol detection limits," 2017.
- [7] L. E. Joyce, "Infrared photography in bloodstain detection," 2017.
- [8] Jerkovic, "Application of infrared photography in forensic science," 2020.
- [9] K. Ito *et al.*, "Luminol chemiluminescence and image analysis," 2020.
- [10] J. Hart *et al.*, "Infrared imaging for blood detection," 2021.
- [11] T. Telyatitskaya, "Digital photography in forensic examination," 2021.
- [12] Dubey *et al.*, "Near-infrared photography in post-mortem analysis," 2022.
- [13] E. Verhoeven *et al.*, "Evaluation of infrared photography for bloodstains," 2022.
- [14] M. Airlie *et al.*, "Infrared detection on floor coverings," 2022.
- [15] C. D. Duncan, *Advanced Crime Scene Photography*, 2023.
- [16] M. A. Saucier *et al.*, "Near-infrared dye systems for blood detection," 2024.
- [17] C. Ellis *et al.*, "Specificity of infrared photography in blood detection," 2025.
- [18] S. Supalaknari, "Detection of bloodstains in water using luminol," 2025.
- [19] T. Suzuki *et al.*, "Repeatable chemiluminescence of luminol," 2025.
- [20] L. Perold *et al.*, "Infrared imaging in forensic pathology," 2025.