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Latent fingerprint revealing material produced from industrial waste

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Resumo

O método do pó é uma abordagem rápida e fácil para revelar impressões digitais latentes em superfícies porosas e não porosas. Alguns materiais alternativos podem ser usados para produzir o pó revelador. O presente trabalho utilizou resíduos da indústria siderúrgica para produzir pó de impressão digital. A adição de negro de fumo intensificou a cor do material, e a adição de goma laca aumentou a adesão do pó ao resíduo de impressão. O pó obtido teve sua eficiência comparada com o material de referência internacional (Sirchie Hi-Fi Volcano) para diferentes tipos de superfícies, e sua eficiência foi comparável, tendo sido doado e aplicado por várias polícias científicas no Brasil. Ademais, o material produzido aqui apresenta a vantagem de ser produzido a partir de resíduos industriais, o que torna o método acessível e ambientalmente sustentável.

Palavras-Chave: sustentabilidade, reciclagem, impressão digital, método do pó

Abstract

The powder method is a quick and easy approach to revealing latent fingerprints on porous and non-porous surfaces. Some alternative materials may be used to produce revealing materials. This present work used waste from steel industry for producing fingerprint powder. The addition of carbon black intensified the color of the material, and the addition of shellac increased the adhesion of the powder to the print residue. The obtained powder had its efficiency compared to the international reference material (Sirchie Hi-Fi Volcano) for different types of surfaces, and they were comparable, allowing it to be donated and applied by several scientific police in Brazil. Besides, the material here produced presented the advantage of being produced from industrial waste, what makes the method affordable and environmentally sustainable.

Keywords: sustainability, recycling, digital printing, powder method

1. INTRODUCTION

Every human being is born with unique and characteristic marks on his fingertips, called distal marks. The moment the person touches an object, the chemical constituents of sweat in hand are deposited on this solid object, forming a mirror image of the distal mark. This mark is called a fingerprint, and it is usually one of the pieces of evidence most often found at crime scenes, presenting great forensic value, as it is capable of differing any individual, including twins [1],[2]

Most of the times, fingerprints are present in latent format, requiring the application of a product to transform this mark into a visible image. There are two main types of revealing materials: the physical ones, that adsorb chemical constituents fingerprints; and the chemical ones, that react with some of the chemical constituents of fingerprints, producing a colored compound [3],[4].

The chemical composition of sweat is quite varied, but it can be summarized as 99% water, 0.5% organic, and 0.5% inorganic content. The organic content is composed of fatty and amino acids, choline, creatinine, lactic acid, proteins, sugars, urea, uric acid, glycerides, squalene, sterol esters and wax esters. The inorganic is made mainly of salts and metal ions. After being settled onto a solid object, water-soluble constituents penetrate the solid if it is porous, while the non-aqueous components remain on the surface. However, some constituents may evaporate after some days, depending on the environmental conditions to which the object is exposed [5].

Several factors may influence the choice of fingerprint revealing method, such as color, condition, nature, and texture of the evidences. Because of this, there is not one single formulation generally applicable for detecting latent fingermarks on all types of surfaces [6].

In the dusting method, a thin powder is applied over the object, and part of it will be attached to moisture and greasy components of the latent fingerprint. After brushing and blowing, the excess of powder is removed, allowing a clear image to be revealed [4].

The former revealing methods date back to the end of the XIX century. At this time, the formulations were mercury-based or graphite-based powders. Today, formulations for regular revealing are mainly a mix of resinous polymers and colouring pigments: the first material is responsible for adhesion and the second one for contrasting the image.

Many studies have been published in the field of latent fingerprint exposing, including the use of different kinds of nanoparticles [7]·[8], several synthetic dyes [9,11], fluorescent materials [12,14] instrumental techniques [15,17], DNA identification [18,20], and evaluation of explosive [21,23] and drug [22,24] residues. Nevertheless, despite all these possibilities, the fingerprint powder method is the most traditional one. The main reason for that is the great efficiency it presents in non-porous materials [25]. Most of these powders are not toxic, but also not affordable for many police in the world. Then, innovative methods, presenting cheaper materials to be used as latent fingerprint revealers, are necessary.

Vadivel made an interesting review on everyday materials employed as non-conventional powders for the visualization of latent fingerprints [25]. This review covers different kinds of substances, such as food [26,28] , plants [29]·[30], minerals [31]·[32] and carbon based materials [26].

Iron oxides also compose a well known matrix for dusting for fingerprints. These oxides are usually mixed to dyes or resins, in order to increase adherence to the marks [1]. The use of industrial waste as a source of iron oxides for these revealing materials has not yet been explored in literature.

The steelmaking process involves reducing iron oxides in a furnace, together with charcoal, carbon monoxide and purifying agents such as limestone, silica, and dolomite, until a liquid mixture of cast iron is obtained. This cast iron still contains high levels of carbon, which causes the alloy to present low mechanical capacities for many applications. So, this liquid is transferred to a second furnace, a steel plant, where oxygen injection converts carbon into CO and CO_2, turning pig iron into steel. Together with steel, a residual dust containing a significant amount of iron, SiO_2, and other particles, is also produced at the end of this process [33]·[34].

This dust residue becomes environmental liability for the industries that produce steel, and also for the governmental organizations that inspect these companies. Then, every way to reuse this dust residue should be encouraged and explored, to make the process as sustainable as possible.

The present work proposes using this waste from steel industry to generate a fingerprint revealing powder. The addition of carbon black intensified the color of the material, and the addition of shellac increased the adhesion to the print. The developed powder had its efficiency compared to the international reference material (Sirchie Hi-Fi Volcano) in different types of surfaces, and the obtained results were statistically equivalent. Consequently, this innovative method is economically viable and environmentally correct for producing a highly efficient latent fingerprint revealer.

2. EXPERIMENTAL

2.1. Black dust production

The first step of the production of the fingerprint powder here presented, named black dust, was the transference of 7.0 g of shellac to a 250 mL beaker, and adding 50.0 mL of ethanol. This mixture was heated at 50°C in a heating plate, and stirred with a magnetic stirrer, producing solubilized shellac. After the solubilization, 30.0 g of the steel industry waste was added, followed by another stirring step, resulting in an emulsion. The new mixture was then heated in an oven for two hours at 180°C.

After this time, all solvent was evaporated, and the solid was cooled to room temperature. 30.0 g of this solid was transferred to another 250 mL beaker, and 10.0 g of carbon black was added. This new solid mixture was homogenized, ground in an analytical mill and then sieved in a 0.088 mm diameter sieve.

2.2. Pretreatment of surfaces

Naturally, there couldn't be any substances that would interfere in fingerprint revealing on the analyzed surfaces. Possible interferents would be dirt, grease, or even another fingerprint.

To guarantee this absence, a pre-treatment of surfaces of each object used as support had to be performed. Metallic surfaces were cleaned with a damp cloth containing isopropyl alcohol. Glassy and wooden objects were washed with water and soap. Cardboard surfaces were cleaned with a dry cloth, while the A4 sheets of paper used were always new ones, taken intact from their reams.

Also, the surface of each object was previously checked by applying visible light in an oblique angle: the objects were used only when no other visible print was present.

2.3 Collection and revelation of latent fingerprints

To create latent fingerprints, a single donor touched several objects, made of different materials: wood, marble, paper, ceramic, aluminum, plastic, glass, cardboard and steel. Each object was touched three times, side by side, to allow statistic evaluation. Before donating his fingerprints, this person cleaned his hands properly with soap, dried them, and passed his fingertips on the forehead to increase sebum on fingers. Each powder (the one produced from iron waste and the commercial one – Sirchie Hi-Fi Volcano) was applied on the surfaces on which fingerprints were deposited. By using a fiberglass brush, the extra powder was removed from the print, and photographs of the developed fingerprints were taken and analyzed.

3. RESULTS AND DISCUSSION

Powdering is a physical process, in which particles adhere to humid, sticky, or greasy substances in latent fingerprints. Naturally, the characteristics of resinous materials employed, and their particle size directly influence this process. Also, the dye content (here employed as carbon black) significantly affects color and sharpness of the generated image. Both parameters were studied to reach the final composition of the innovative powder here proposed.

The main objective of this work was to evaluate if the fingerprint material produced from industrial waste produced images with qualities similar to the leading material on the market, presenting the same useful characteristics for dry and non-porous surfaces.

It is also important to emphasize that fingerprint revealing materials are classified based on their application. When a fingerprint is deposited on a porous surface, the emulsion forming the fingerprint gradually decomposes over time. Hydrophobic components tend to evaporate and lose mass, while hydrophilic components penetrate the substrate. As water evaporates, these hydrophilic species adhere to the pores of the material. In such cases, the fingerprint revealing material must penetrate the pores and react with these species. On non-porous surfaces, both hydrophilic and hydrophobic components remain on the surface of the solid.

To produce images that might be comparable, a sequence of 6 fingerprints was made by the same individual on a previously cleaned surface. Afterwards, half of these prints were revealed with the powder produced from industrial waste, and the other half with commercial material. In that way, three images referring to the same individual on a same surface was produced for each dactyloscopy material.

A definition for quality of a fingerprint image was settled by Austin and co-workers [35] as "the clarity of a friction ridge image, determined in terms of the confidence that the presence, absence, and details of features can be precisely detected". In that sense, the term quality can be understood as the ability of the image to produce details referring to 3 levels of a fingerprint. These levels refer to the friction ridge flow (level 1), the ridge paths and minutia (level 2), and the ones attributes to an individual ridge, such as deviations, width, shape, pores, creases, scars, edge contours, incipient ridges, and breaks (level 3) [35].

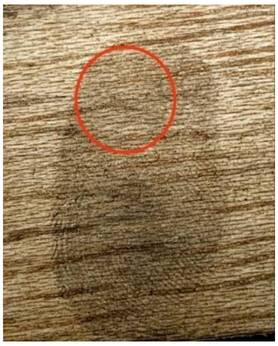
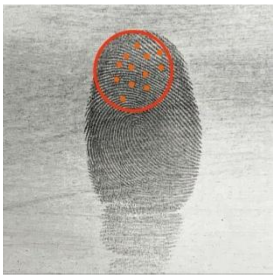
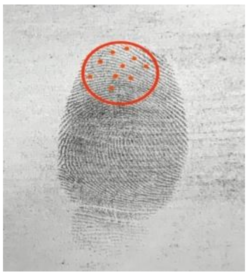
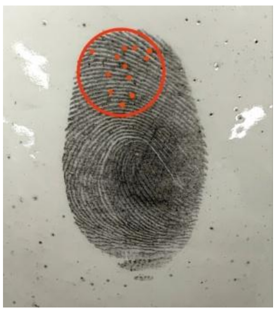
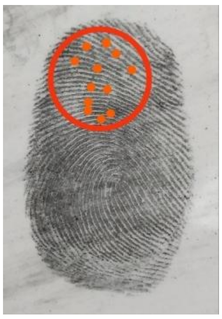
The first study of fingerprint quality assessment was proposed in the late 90s by Bolle *et al*. [36]. These researchers qualify the fingerprint image in terms of orientation of the local block. Several other later works presented different ways of making the quality assessment, but in one way or another, there are always subjective criteria inherent in this classification. Yao reviews several of them [37]. Classification based on software usage avoids subjective aspects; nevertheless, the accessibility of different police to this software is problematic since most were explicitly developed by specific law enforcement agencies and are not publicly available [38].

Table 1 shows the images obtained with commercial powder and with the innovative one here produced, over porous (wood, paper, cardboard, iron), semi porous (marble) and non-porous surfaces (aluminum, plastic, glass). As it is well known, the powder technique is adequate for non-porous surfaces, since the porous ones readily absorb marks.

Analyzing Table 1, it can be observed that the material produced in this study exhibited excellent sharpness - considering all three levels of detail - along the friction ridges of fingerprints deposited on porous surfaces such as A4 paper and cardboard, as well as on non-porous surfaces including ceramic, aluminum, and plastic. Additionally, the material demonstrated sufficient sharpness for potential comparative analyses on the porous surface of wood and the non-porous surfaces of marble and glass. However, the same material did not exhibit adequate sharpness along the friction ridges of fingerprints deposited on the non-porous surface of iron. It is important to note that the iron surface employed was oxidized, what explains the poor result. According to Table 1, the results obtained with the commercial powder were comparable to those achieved with the revealer produced in this study over each analyzed surface.

To ensure that the discussion would not be based solely on the authors' assessment, which could contain subjectivity and bias, the efficiency of the produced powder was evaluated by two approaches: (i) comparing the numbers of characteristics points (minutia) in a same area of the prints (results presented in Table 2), and (ii) assessing fingerprint clarity using the evaluation scale [27] applied to the generated images. Since the fingerprints were consistently produced by the same individual, the comparison based on the number of minutiae is valid. This approach eliminates variability associated with human interpretation from the evaluation. These results are presented in Table 4.

Table 1. Latent fingerprint images obtained using the powder produced from industrial waste and the commercial one (Sirchie Hi-Fi Volcano) on different surfaces.

Surface	Type of dactyloscopy material	
	Produced powder	Sirchie Hi-Fi Volcano
Wood		
Marble		
A4 Paper		
Ceramic		

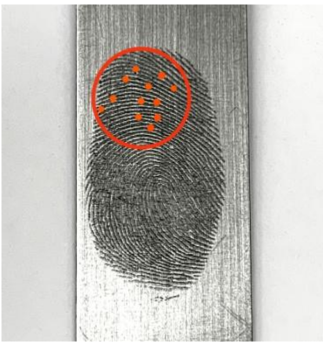
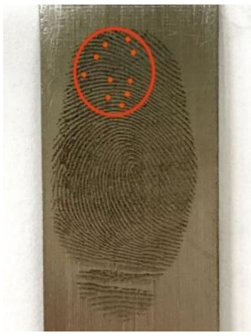
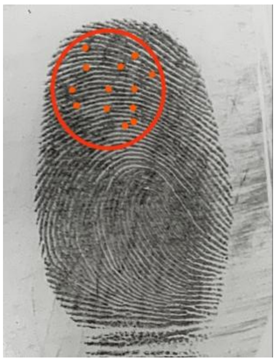
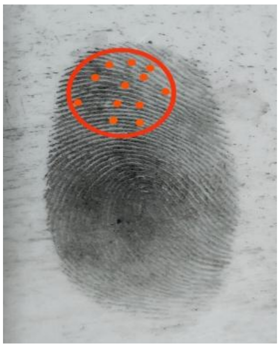
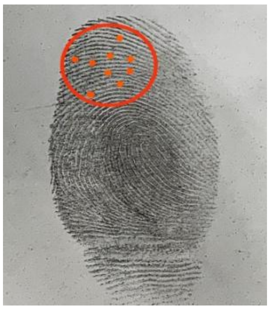
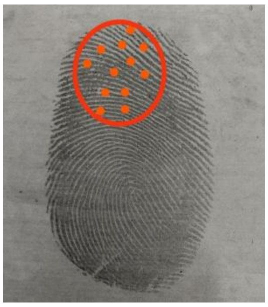
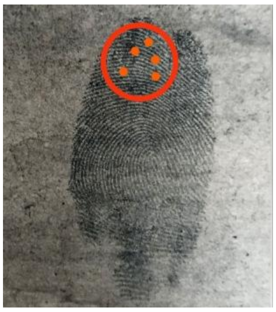
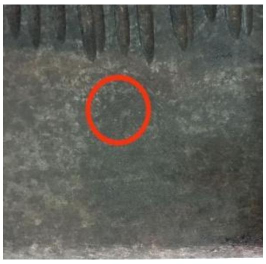
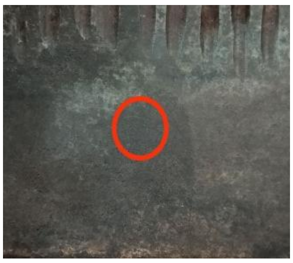
Aluminum		
Plastic		
Glass		
Cardboard		
Iron		

Table 2. Number of characteristics points (minutiae) in a same area of the images using the two types of dactyloscopy material (Critical values: F = 9,28 ; T = 2,78 [39]).

Surface	Type of dactyloscopy material			
	Produced powder	Sirchie Hi-Fi Volcano	F_{value}	T_{value}
Wood	0	0	----	----
Marble	0	0	----	----
A4 Paper	11.33 ± 0.58	10.67 ± 0.58	1.00	0.943
Ceramic	10.67 ± 0.58	10.33 ± 0.58	1.00	0.471
Aluminum	10.33 ± 0.58	10.33 ± 0.58	1.00	0.471
Plastic	10.67 ± 0.58	11 ± 1.00	3.00	0.333
Glass	12.00 ± 1.00	11.33 ± 0.58	0.33	0.667
Cardboard	4.00 ± 1.00	3.33 ± 1.53	2.33	0.422
Iron	0	0		

By the application of paired t-test to the results in Table 2 at 95% confidence level, it was possible to conclude that the differences between the revealing materials in terms of minutiae is due to random errors. In other words, there is no statistical difference between the results obtained by the two methods [39]. These observations prove that the use of the powder here developed is as efficient as the most employed commercial material for fingerprint revealing.

The prints clarity assessment scale [27] presented in Table 3 was followed to fill Table 4, relating to the application of the two different revealing materials over the analyzed surfaces. Two different researchers were invited to fill Table 4, one for each material, in order to avoid any bias. Also according to these results, both powders show the same efficiency for revealing latent fingerprints.

Later, this new material was donated to various technical and scientific police in Brazil (from the States of *Rio Grande do Norte*, *Maranhão*, *Pará*, *Tocantins*, *Rio Grande do Sul*, and *Santa Catarina*), to be employed in real crime scenes. The feedback received from these forensic police leads to the conclusion that black dust may indeed be used as an alternative material to commercial powders. Also, this innovative powder presents great economical advantages, as it is produced from steel industry residues.

Table 3. Fingerprints quality assessment scale [27]

Sharpness	Description
0	No fingerprint visibility
1	Revealed fingerprint with blurred appearance
2	Only a part of the fingerprint has been revealed
3	Full reveal of the fingerprint, but only some characteristic points could be highlighted
4	Full reveal with the most minutiae visible

Table 4. Fingerprint quality assessment scale for the latent fingerprint developed imge obtained with the different powder

Surface	Type of powder	
	Produced from iron waste	Sirchie Hi-Fi Volcano
Wood	3	3
Marble	3	3
A4 Paper	4	4
Ceramic	4	4
Aluminum	4	4
Plastic	4	4
Glass	4	4
Cardboard	3	3
Iron	0	0

4. CONCLUSIONS

Black dust, the innovative fingerprint powder here developed, was attested as efficient for revealing latent fingerprints deposited on dry and non-porous surfaces. The material produced in this work showed different abilities for revealing latent fingerprints depending on the surface it was applied. However, it proved to be as useful as Sirchie's commercial material, regardless the surface on which they were applied.

Black dust was developed from residual material produced by steel industry, in a very simple and affordable method, assessing the economical viability and environmental sustainability of the proposed procedure.

It is also important to mention that this new material was developed at a Brazilian University at the State of Rio de Janeiro (*Universidade Federal Fluminense*), and it was donated and effectively applied in real crime scenes by various technical and scientific police in Brazil (from the States of *Rio Grande do Norte*, *Maranhão*, *Pará*, *Tocantins*, *Rio Grande do Sul*, and *Santa Catarina*).

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6. REFERENCES

[1] C. CHAMPOD, C. LENNARD, P. MARGOT, M. STOILOVIC, Fingerprints and Other Ridge Skin Impressions. Christophe Champod,Chris J., CRC Press, New York, 2004.

[2] P. Hazarika, D.A. Russell, Advances in fingerprint analysis, Angew. Chemie - Int. Ed. 51 (2012) 3524–3531. https://doi.org/10.1002/anie.201104313.

[3] D.E. Newton, Forensic Chemistry, Facts On File, Inc., 2007.

[4] J.A. Siegel, Forensic Chemistry, John Wiley & Sons, 2015.

[5] S. Cadd, M. Islam, P. Manson, S. Bleay, Fingerprint composition and aging: A literature review, Sci. Justice 55 (2015) 219–238. https://doi.org/10.1016/j.scijus.2015.02.004.

[6] G.S. Sodhi, J. Kaur, Powder method for detecting latent fingerprints: A review, Forensic Sci. Int. 120 (2001) 172–176. https://doi.org/10.1016/S0379-0738(00)00465-5.

[7] A. Abdollahi, A. Dashti, M. Rahmanidoust, N. Hanaei, Metal-free and ecofriendly photoluminescent nanoparticles for visualization of latent fingerprints, anticounterfeiting, and information encryption, Sensors Actuators B Chem. 372 (2022) 132649. https://doi.org/10.1016/j.snb.2022.132649.

[8] H. Zhou, H. Chen, R. Ma, X. Li, X. Du, M. Zhang, Use of conductive Ti2O3 nanoparticles for optical and electrochemical imaging of latent fingerprints on various substrates, J. Electroanal. Chem. 936 (2023) 117387. https://doi.org/10.1016/j.jelechem.2023.117387.

[9] C. Yuan, M. Li, M. Wang, L. Zhang, Cationic dye-diatomite composites: Novel dusting powders for developing latent fingerprints, Dye. Pigment. 153 (2018) 18–25. https://doi.org/10.1016/j.dyepig.2018.01.055.

[10] D.S. Bhagat, P.B. Chavan, W.B. Gurnule, S.K. Shejul, I. V. Suryawanshi, Efficacy of synthesized azo dye for development of latent fingerprints on Non-porous and wet surfaces, Mater. Today Proc. 29 (2020) 1223–1228. https://doi.org/10.1016/j.matpr.2020.05.480.

[11] R. Fouad, M. Saif, M.M. Mashaly, M. Zekrallah, Synthesis and spectroscopic characterization of fluorescent 3-acetyl-4-hydroxy coumarin for biomedical and latent fingerprint applications, J. Mol. Struct. 1284 (2023) 135421. https://doi.org/10.1016/j.molstruc.2023.135421.

[12] S. Li, L. Wang, Y. Ma, L. Zhu, W. Lin, A multifunctional fluorescent molecule with AIE characteristics for SO2 derivatives detection, fluorescence ink and latent fingerprint imaging, Sensors Actuators B Chem. 371 (2022) 132595. https://doi.org/10.1016/j.snb.2022.132595.

[13] P. Zhang, M. Xue, Z. Lin, H. Yang, C. Zhang, J. Cui, J. Chen, Aptamer functionalization and high-contrast reversible dual-color photoswitching fluorescence of polymeric nanoparticles for latent fingerprints imaging, Sensors Actuators B Chem. 367 (2022) 132049. https://doi.org/10.1016/j.snb.2022.132049.

[14] Z. Wang, J. Huo, X. Luan, S. Sun, G. Ma, Excitation-wavelength-dependent luminescence of Sr3P4O13:Eu3+ amber-emitting microphosphor for fluorescence latent fingerprint visualization, Opt. Laser Technol. 149 (2022) 107763. https://doi.org/10.1016/j.optlastec.2021.107763.

[15] D.K. Williams, C.J. Brown, J. Bruker, Characterization of children’s latent fingerprint residues by infrared microspectroscopy: Forensic implications, Forensic Sci. Int. 206 (2011) 161–165. https://doi.org/10.1016/j.forsciint.2010.07.033.

[16] M.R. Strąkowski, P. Strąkowska, J. Pluciński, Latent fingerprint imaging by spectroscopic optical coherence tomography, Opt. Lasers Eng. 167 (2023). https://doi.org/10.1016/j.optlaseng.2023.107622.

[17] J.N. Pollitt, G. Christofidis, J. Morrissey, J.W. Birkett, Vacuum metal deposition enhancement of friction ridge detail on ballistic materials, Forensic Sci. Int. 316 (2020). https://doi.org/10.1016/j.forsciint.2020.110551.

[18] K.Q. Schulte, F.C. Hewitt, T.E. Manley, A.J. Reed, M. Baniasad, N.C. Albright, M.E. Powals, D.S. LeSassier, A.R. Smith, L. Zhang, L.W. Allen, B.C. Ludolph, K.L. Weber, A.E. Woerner, M.A. Freitas, M.W. Gardner, Fractionation of DNA and protein from individual latent fingerprints for forensic analysis, Forensic Sci.

Int. Genet. 50 (2021) 102405. https://doi.org/10.1016/j.fsigen.2020.102405.
[19] K. Nontiapirom, W. Bunakkharasawat, P. Sojikul, N. Panvisavas, Assessment and prevention of forensic DNA contamination in DNA profiling from latent fingerprint, Forensic Sci. Int. Genet. Suppl. Ser. 7 (2019) 546–548. https://doi.org/10.1016/j.fsigss.2019.10.085.
[20] A. al Oleiwi, I. Hussain, A. McWhorter, R. Sutton, R.S.P. King, DNA recovery from latent fingermarks treated with an infrared fluorescent fingerprint powder, Forensic Sci. Int. 277 (2017) e39–e43. https://doi.org/10.1016/j.forsciint.2017.05.008.
[21] C.M. Longo, R.A. Musah, MALDI-mass spectrometry imaging for touch chemistry biometric analysis: Establishment of exposure to nitroaromatic explosives through chemical imaging of latent fingermarks, Forensic Chem. 20 (2020) 100269. https://doi.org/10.1016/j.forc.2020.100269.
[22] K.L. Fowble, R.A. Musah, Simultaneous imaging of latent fingermarks and detection of analytes of forensic relevance by laser ablation direct analysis in real time imaging-mass spectrometry (LADI-MS), Forensic Chem. 15 (2019) 100173. https://doi.org/10.1016/j.forc.2019.100173.
[23] K. Kaplan-Sandquist, M.A. LeBeau, M.L. Miller, Chemical analysis of pharmaceuticals and explosives in fingermarks using matrix-assisted laser desorption ionization/time-of-flight mass spectrometry, Forensic Sci. Int. 235 (2014) 68–77. https://doi.org/10.1016/j.forsciint.2013.11.016.
[24] J.S. Day, H.G.M. Edwards, S.A. Dobrowski, A.M. Voice, The detection of drugs of abuse in fingerprints using Raman spectroscopy I: Latent fingerprints, Spectrochim. Acta - Part A Mol. Biomol. Spectrosc. 60 (2004) 563–568. https://doi.org/10.1016/S1386-1425(03)00263-4.
[25] R. Vadivel, M. Nirmala, K. Anbukumaran, Commonly available, everyday materials as non-conventional powders for the visualization of latent fingerprints, Forensic Chem. 24 (2021) 100339. https://doi.org/10.1016/j.forc.2021.100339.
[26] Richa Rohatgi, A.K. Kapoor, New Visualizing Agents for Developing Latent Fingerprints on Various Porous and Non-Porous Surfaces Using Differ... richa rohatgi, Asian J. Sci. Appl. Technol. 3 (2014) 33–38.
[27] V. Saran, L. Kesharwani, A.K. Gupta, M. Kumar Mishra, COMPARATIVE STUDY OF DIFFERENT NATURAL PRODUCTS FOR THE DEVELOPMENT OF LATENT FINGERPRINTS ON NON POROUS SURFACES Study of Diatom Flora of Kaalesar Ghat of Rapti River at Gorakhpur for Forensic Consideration View project PhD research View project 39 PUBLI, 3 (2015) 9–12. https://www.researchgate.net/publication/306286127.
[28] A. Dhunna, S. Anand, A. Aggarwal, A. Agarwal, P. Verma, U. Singh, New visualization agents to reveal the hidden secrets of latent fingerprints, Egypt. J. Forensic Sci. 8 (2018) 4–9. https://doi.org/10.1186/s41935-018-0063-9.
[29] Z. Shirani, C. Santhosh, J. Iqbal, A. Bhatnagar, Waste Moringa oleifera seed pods as green sorbent for efficient removal of toxic aquatic pollutants, J. Environ. Manage. 227 (2018) 95–106. https://doi.org/10.1016/j.jenvman.2018.08.077.
[30] R.S.P. King, P.M. Hallett, D. Foster, Seeing into the infrared: A novel IR fluorescent fingerprint powder, Forensic Sci. Int. 249 (2015) e21–e26. https://doi.org/10.1016/j.forsciint.2015.01.020.
[31] D. Li, J. Yu, AIEgens-Functionalized Inorganic-Organic Hybrid Materials: Fabrications and Applications, Small 12 (2016) 6478–6494. https://doi.org/10.1002/smll.201601484.
[32] A. Badiye, N. Kapoor, Efficacy of Robin® powder blue for latent fingerprint development on various surfaces, Egypt. J. Forensic Sci. 5 (2015) 166–173. https://doi.org/10.1016/j.ejfs.2015.01.001.
[33] M.P. de C. Filho, Introduçãoà Metalurgia Extrativa e Siderurgia, LTC - Livros Técnicos e Científicos Ltda., 1981.
[34] C.N.R. Amaral, F.N. Feiteira, R.C. Cruz, V.O. Cravo, R.J. Cassella, W.F. Pacheco, Removal of basic violet 3 dye from aqueous media using a steel industry residue as solid phase, J. Environ. Chem. Eng. 4 (2016) 4184–4193. https://doi.org/10.1016/j.jece.2016.09.023.
[35] R. Austin, M. Antonia, B. Stephen, Latent Fingerprint Quality : A Survey of Examiners, J. FORENSIC Identif. 61 (2011) 385–419.
[36] Rudolf Maarten Bolle;, Pankanti;Sharathchandra Umapatirao;, Y.-S. Yao, United States Patent (19), 1999.
[37] Z. Yao, J. Le Bars, C. Charrier, C. Rosenberger, Literature review of fingerprint quality assessment and its evaluation, IET Biometrics 5 (2016) 243–251. https://doi.org/10.1049/iet-bmt.2015.0027.
[38] T. Oblak, R. Haraksim, P. Peer, L. Beslay, Fingermark quality assessment framework with classic and deep learning ensemble models, Knowledge-Based Syst. 250 (2022) 109148. https://doi.org/10.1016/j.knosys.2022.109148.
[39] J.N. Miller, J. C., Miller, Statistics for Analytical Chemistry, 3rd ed., Prentice Hall, 1993.