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ORIGINAL PAPER

Criminalistics

The effect of household corrosive substances on latent fingermark development in the context of deliberate corrosive substance attacks

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Abstract

Corrosive substance attacks (CSA) are a prevalent issue in the UK with 525 offenses involving a corrosive substance reported to the police in the year ending March 2022. Easy availability, low cost, and concealability in public are common reasons for choosing a corrosive substance as a weapon. The Metropolitan Police revealed that 68% of 1849 CSA cases resulted in no suspect identified or evidential difficulties. There is limited research into the effect of corrosive substances on latent fingermarks. This study aimed to determine the potential for fingermarks to be recovered from surfaces exposed to a household corrosive substance within the context of a deliberate CSA. Natural and sebaceous-loaded fingermarks were exposed to Domestos bleach, Harpic limescale remover (hydrochloric acid-based) and lemon juice. Harpic limescale remover had the most detrimental effect, with only 7.1% of fingermarks ($n=378$) exposed being identifiable (defined as sufficient clear ridge detail for identification) after enhancement, followed by bleach with only 10.3% of fingermarks ($n=378$) identifiable. Lemon juice had the least detrimental effect on fingermarks, with 40.5% fingermarks ($n=378$) identifiable compared to 53.4% for the controls (not exposed to any substance; $n=378$). Throughout the study, fewer natural fingermarks were identifiable after exposure to corrosive substances compared to sebaceous fingermarks which was as expected. Overall, this study demonstrated that there is potential to recover latent fingermarks, depending on their composition, following exposure to a household corrosive substance. This area warrants further research to establish best practice to maximize the potential to recover identifiable fingermarks.

KEYWORDS
bleach, corrosive attack, enhancement, household corrosive substance, latent fingermark, powders

Highlights

- The effect of readily available household corrosive substances on latent fingermarks was explored.
- Latent fingermarks can survive exposure to household corrosive substances.

- Domestos bleach and Harpic limescale remover had the greatest negative effect on fingermark quality.
- Lemon juice had the least impact with almost half of all fingermarks exposed still identifiable.

1 | INTRODUCTION

The recovery of latent fingermarks from exhibits is commonplace for many crime types. Fingermark examination laboratories use a range of enhancement techniques to enhance and visualize latent fingermarks to suit different circumstances. The choice of sequence of enhancement techniques depends on a number of factors including the substrate type (e.g., porous or non-porous), the fingermark type (e.g., latent or blood-contaminated) and the environment to which they have been exposed [1]. In some cases, fingermarks can be exposed to extreme conditions such as water, fire or corrosive, and hazardous substances either as a consequence of the crime being committed or in an attempt to destroy forensic evidence. These conditions can be detrimental to any latent fingermarks present. While there have been a relatively large number of studies looking at the effect of water [2, 3] and fire [4, 5], there has been very few studies examining the influence of corrosive substances [6].

Deliberate corrosive substance attacks (DCSA) have generally been considered an issue in low- and middle-income countries [7]. However, DCSA do occur in the UK. The Office for National Statistics reported 525 offenses involving a corrosive substance (violence against the person and robbery) reported to the police in the year ending March 2022, compared to 557 in the previous year ending March 2021 and 619 year ending March 2020 [8]. These figures, however, are most likely an underestimate of the true number of DCSA since not all cases result in major injury leading to the requirement for medical treatment and/or reporting to the police [7]. The motive of corrosive substance attacks can range from intent to cause grievous bodily harm (GBH), or to temporarily blind a victim with a specific purpose, for example, to rob them. There have been several attacks with sulfuric acid leaving the victims with severe injuries [9]. A high-profile case occurred in 2008, when Katie Piper had sulfuric acid thrown in her face in an attempt to ruin her modeling career, which left her partially blinded with severe scarring on her upper body [10]. In a review of 1187 reported cases involving corrosive substances, the victims were predominantly male (65%), with suspects also being predominantly male (85%) [11]. Of these cases, the most commonly encountered corrosive substance was bleach (34%), followed by ammonia (32%). Although it should be noted that information about the substance(s) used was difficult to acquire and many of the substances were reported as unknown. However, the category 'acid or alkali' accounted for 15% of cases. Substances such as bleach and ammonia are less harmful than sulfuric acid; however, they are still toxic and cause irritation to the skin and eyes [9].

When latent fingermarks are deposited, natural secretions are left behind on the surface that the fingertip has come into contact with. The chemical composition of these fingermarks is highly dependent on the individual. Secretions from the eccrine and sebaceous glands are most likely to contribute to latent fingermarks encountered at a crime scene [12]. Eccrine sweat consists mainly of water, amino acids, and inorganic ions (e.g., Na^+, K^+, Cl^-), while sebaceous secretions consist predominantly of fatty acids, triglycerides, and cholesterol. Multiple factors may affect the composition of deposited fingermarks including age, gender, diet, and medication, as well as activity shortly prior to touching a surface, for example, hand washing and touching other parts of the body such as the face and hair. Common contaminants that may also be found in fingermark residue include cosmetics (e.g., foundation), moisturizer, sunscreen, and hair products [12].

The effect of corrosive substances on the recovery of fingermarks has received limited attention to date. Masterson and Bleay carried out a preliminary study of the effects of brief exposure (5 min) of natural latent fingermarks, from a single 'good' donor, on glass, PET (polyethylene terephthalate) plastic and paper (as representative substrates expected to be encountered in an acid attack) to 4 M sulfuric acid and potassium hydroxide [6]. These substances had been previously reported in corrosive substance attacks and are relatively easily accessible by the general public [7, 13]. The authors successfully enhanced fingermarks previously exposed to sulfuric acid or potassium hydroxide on glass and PET using powder suspension, vacuum metal deposition, and black magnetic powder in decreasing order of success. Superglue fuming and solvent black 3 were unsuccessful. Marks were also successfully recovered from paper using physical developer and oil red O but not iodine fuming.

While not liquid-based exposure, McDonald et al. investigated the effect of chlorine and hydrochloric acid (HCl) vapors on the recovery of sebaceous-loaded latent fingermarks deposited on glass and paper substrates [14]. Hydrogen chloride is most frequently encountered in the illicit production of methamphetamine in clandestine laboratories [14]. Chlorine would most likely be encountered in cases involving the tampering of water treatment and it is used in the manufacture of bleach and household cleaning products. McDonald et al. were able to enhance fingermarks with superglue fuming after exposure to 8% HCl but not 12% HCl, whereas magnetic bichromatic powder successfully enhanced fingermarks at both HCl exposure concentrations [14]. The acidification of the substrates as a result of exposure to these substances is thought to explain the lack of development in the case of chemical enhancement techniques such as superglue fuming and the lesser impact on physical enhancement techniques such as powdering [14, 15].

A number of studies have been conducted investigating the impact of CBRN (chemical, biological, radiological, and nuclear) decontamination procedures on forensic evidence including fingermarks [15–17]. Within these studies some chemical decontamination agents including bleach, chlorine-based agents and strong bases, had a negative effect on fingermark enhancement. It was also noted in one study that water rinsing steps (included in the standard protocol to remove any decontamination agent) alone also had a negative impact, albeit to a lesser extent [16].

The aim of this study was to build on the preliminary work by Masterson and Bleay to determine the survivability of latent fingermarks when exposed to commonly used and readily available household corrosive substances [6].

2 | MATERIALS AND METHODS

2.1 | Donors

A pool of eight donors (assigned codes A–H) was used aged between 19 and 49 years (five females, three males). In the main study, the same four donors (A–D) were used over subsequent weeks and fingermarks from donors E–H were collected once. Donors were asked to provide details of any cosmetics and creams they had applied on the day of donation (Table 1).

This study had ethical approval and in accordance with local ethical approval requirements informed consent was obtained from all donors. All samples were anonymized and only identifiable by an alphanumeric code to facilitate data analysis.

2.2 | Substrates

The substrates used were 25 × 75 mm glass slides (Cimed®) and used polyethylene terephthalate (PET) plastic bottles (1.5–2 L; purchased from local retail outlets), cut into smaller pieces, approximately the size of a glass slide. The plastic bottles were cleaned using deionized water and a cloth prior to deposition. Gloves were worn throughout handling of samples to prevent contamination.

2.3 | Fingermark deposition

All fingermarks were collected between December 2021 and April 2022. The donors were asked to deposit natural and sebaceous-loaded fingermarks onto the substrates, following good practice guidance recommended by Sears et al. [1].

Donors deposited a depletion series of three fingermarks with normal touch pressure on each piece of material, using a different finger for each sample. The thumb and all fingers except the little finger were used. No specified contact time was used in order to get a representation of normal handling times that could be found in practice. When collecting natural fingermarks, donors were asked to not wash or sanitize their hands for at least 30 min prior to deposition, to get a representative natural fingermark composition when completing day-to-day activities. For sebaceous-loaded fingermarks donors were asked to rub their forehead/nose/behind their ears for 10 s with all fingertips before depositing fingermarks. In addition, for both fingermark types, donors rubbed their fingertips together to evenly distribute the material immediately before depositing their fingermarks. The samples were then placed directly into the corrosive substance or aged for 1 week in the dark in small cardboard boxes at ambient humidity and temperature (approximately 15–25°C).

2.4 | Corrosive substance exposure

Three corrosive substances were chosen based on reports of substances used in attacks and ease of accessibility, that is, could be readily purchased by the public (Table 2). The substances were used as purchased from local retail outlets and not diluted.

Each corrosive substance was decanted into a 100 mL beaker ensuring the substrates were fully covered. The fingermarks were exposed to the corrosive substances for 1 min, then rinsed with water to remove excess product for approximately 10 s and left to air dry for 1–2 h before enhancement. One set of fingermarks from each donor was used as a control and not exposed to any substance or rinsed. Figure 1 summarizes the fingermark sample collection and exposure.

TABLE 1 Donor information.

Donor	Gender	Cosmetics	Facial cream	Hand cream
A	Female	Yes	Yes	No
B	Female	No	Yes	No
C	Female	No	No	Yes
D	Female	No	Yes	No
E	Male	No	No	No
F	Female	No	Yes	No
G	Male	No	No	Yes
H	Male	No	No	No

TABLE 2 Overview of corrosive substances.

Corrosive substance	Manufacturer	Ingredients	pH
Domestos Thick Bleach Original	Unilever	4.5 g sodium hypochlorite per 100 g	12.2[a]
Harpic 100% Limescale Remover Original	RB UK Hygiene Home Commercial Ltd	6.75 g hydrochloric acid per 100 g	0.5[b]
Lemon Juice	Sainsburys	Sainsburys home brand lemon juice	2.2[a]

[a]Measured using a Jenway 3510 pH meter (Bibby Scientific Ltd.).
[b]Measured using Fisherbrand™ pH Indicator paper sticks (0.0–6.0).

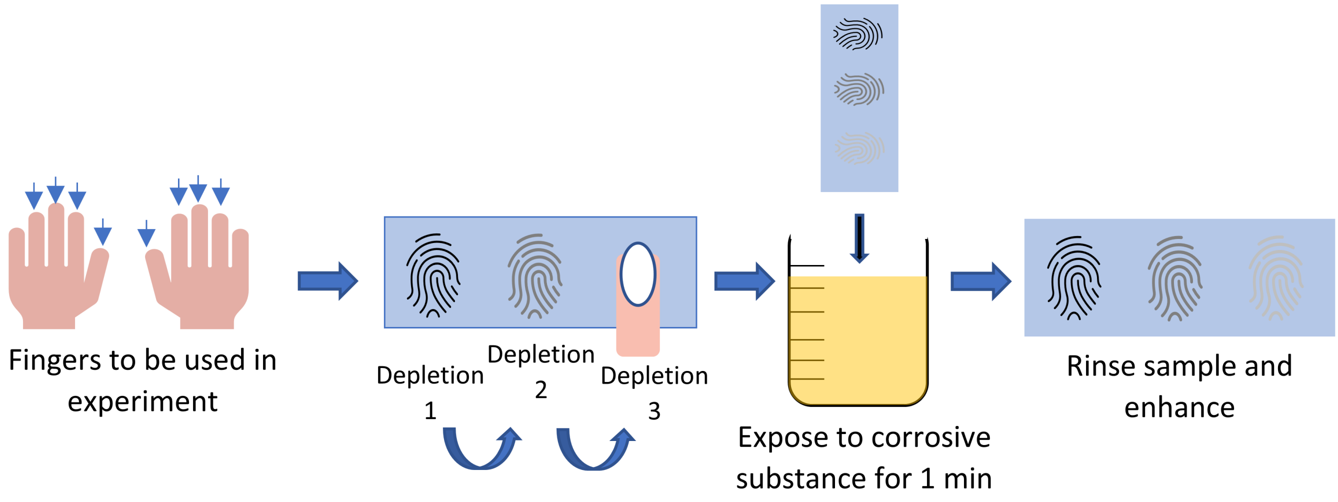

FIGURE 1 Schematic diagram of sample collection.

2.5 | Washing study

A depletion series of three sebaceous-loaded fingermarks from each of seven donors (A and C–H) were collected on glass slides and PET per condition ($n=21$) in the same way as for the main experiment. Samples were then exposed to different conditions outlined in Table 3 and subsequently enhanced with magnetic jet black powder.

For condition 1, the control samples were left on the bench while the other samples were processed and not exposed to any corrosive substance or water. For condition 2, samples were rinsed with water for 10s and then left to air dry for approximately an hour. For conditions 3–6, samples were exposed to water or specified corrosive substances for 1 min, as used in the main experiment, before being rinsed for 10s with water and then air dried for approximately 1 h.

2.6 | Powder enhancement

Magnetic jet black powder (BVDA International, Haarlem, the Netherlands) was applied following guidance in the Fingermark Visualisation Manual [18] using a magnetic wand. The application wand was passed over the substrate, ensuring the powder was applied evenly and the ridge detail was not filled in. The enhanced marks were then visually examined against a contrasting (white) background.

Aluminum powder (Tetra Scene of Crime) was applied to the substrates using a Zephyr brush. The powder was brushed onto the substrate lightly and evenly, building the fingermark gradually [18]. The fingermarks were then visually examined against a contrasting (black) background.

2.7 | Fingermark scoring

After enhancement, fingermarks were scored on the basis of ridge quality using the Home Office grading scheme (Table 4). Fingermarks were classified as 'identifiable' if they scored 3 or 4 and therefore had sufficient clear ridge detail for an identification

TABLE 3 Conditions used in washing study.

Condition	Soaked in liquid (1 min)	Rinsed with water (10 s)
1	N/A	N/A
2	N/A	✓
3	Water	✓
4	Domestos bleach	✓
5	Harpic limescale remover	✓
6	Lemon juice	✓

TABLE 4 Enhanced fingermark grading scheme [1].

Score	Description	Evaluation
0	No evidence of mark	Not detected
1	Weak development; evidence of development but no ridge details	Detected but insufficient
2	Limited development; around $^1/_3$ of ridge details are present but probably cannot be used for identification purposes	
3	Strong development; between $^1/_3$ and $^2/_3$ of ridge details; identifiable fingermark	Identifiable
4	Very strong development; full ridge details; identifiable fingermark	

[1]. Fingermarks that scored 1 or 2 were categorized as 'detected but insufficient' to reflect their presence despite insufficient clear ridge detail for identification.

3 | RESULTS

Figures 2 and 3 show that a one-minute exposure to Domestos thick bleach original, Harpic 100% limescale remover original and to a lesser extent lemon juice, has a detrimental effect on fresh latent fingermarks, deposited on polyethylene terephthalate (PET)

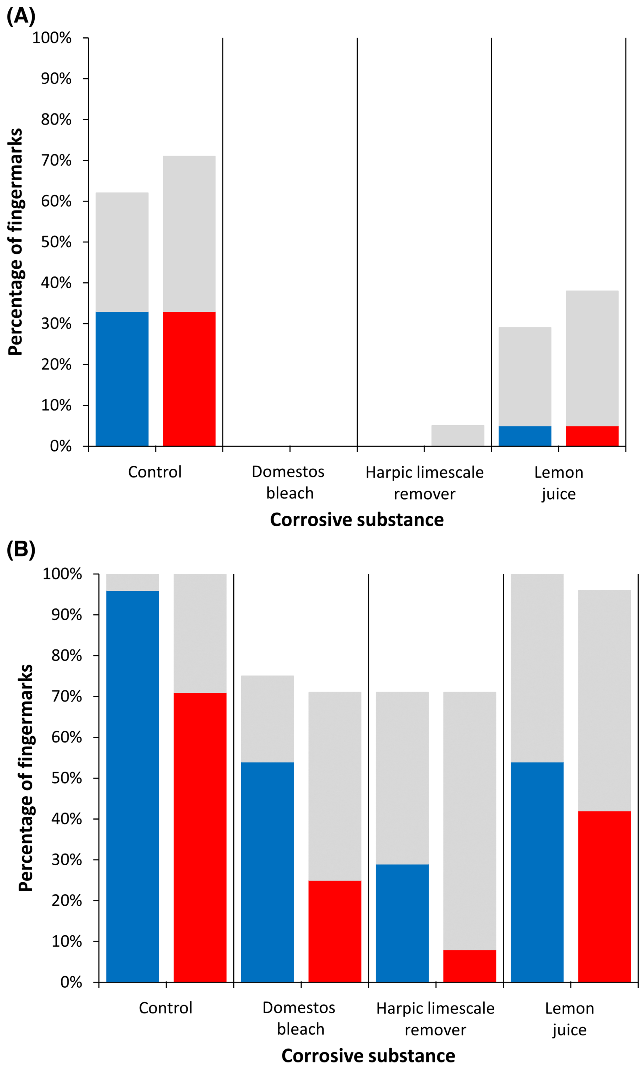

FIGURE 2 Percentage of identifiable fresh (A) natural and (B) sebaceous fingermarks enhanced on polyethylene terephthalate (PET) after 1 min exposure to corrosive substance and control (non-exposure). Fingermarks enhanced with magnetic jet black powder (blue bars; ■) and aluminum powder (red bars; ■). Additional fingermarks detected but considered insufficient for identification (score of 1 or 2) indicated by gray bars (■) (*n* = 21 [natural] and 24 [sebaceous] per category). Scored following the enhanced fingermark grading system in Table 4.

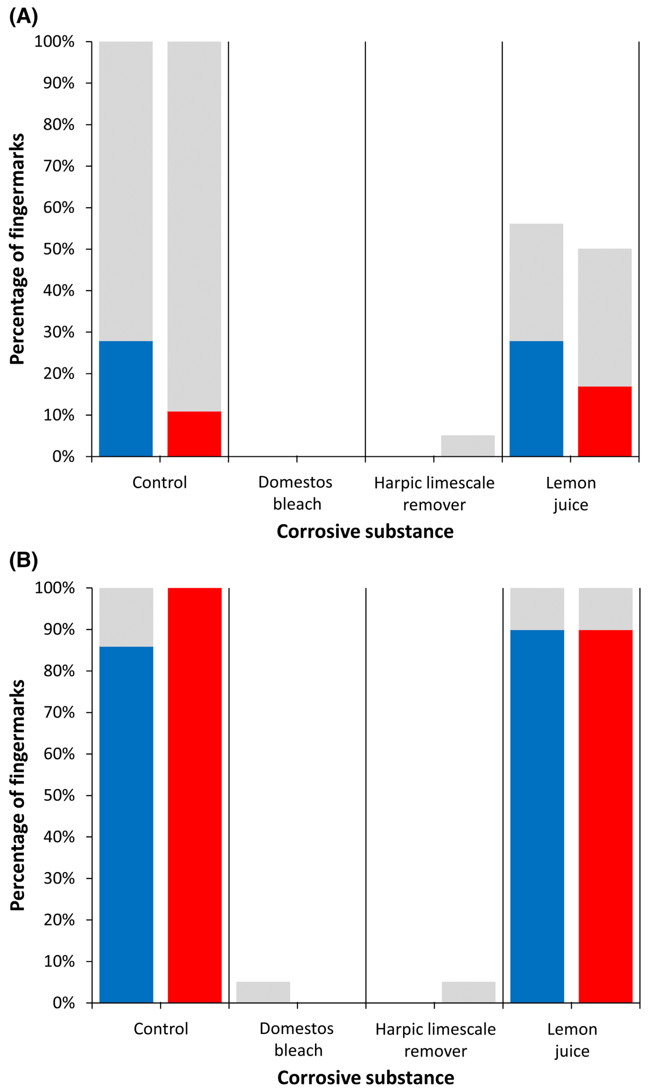

FIGURE 3 Percentage of identifiable fresh (A) natural and (B) sebaceous fingermarks enhanced on glass after 1 min exposure to corrosive substance and control (non-exposure). Fingermarks enhanced with magnetic jet black powder (blue bars; ■) and aluminum powder (red bars; ■). Additional fingermarks detected but considered insufficient for identification (score of 1 or 2) indicated by gray bars (■) (*n* = 18 [natural] and 21 [sebaceous] per category). Scored following the enhanced fingermark grading system in Table 4.

and glass, respectively, resulting in fewer identifiable fingermarks (scoring 3 or 4) compared to the control (not exposed to a corrosive substance). Three finger marks were collected from each of four donors on two separate occasions for each sample. On a small number of occasions one donor was absent and samples could not be collected. However, at least 18 fingermarks were collected in each case per condition. The effect of the household corrosive substances is greatest for natural fingermarks (Figures 2A and 3A) whereby there were no identifiable fingermarks following exposure to Domestos bleach or Harpic limescale remover on either substrate and only 13% of all fingermarks exposed to lemon juice were identifiable compared to 27% for the control fingermarks. There are some differences observed with enhancement techniques for sebaceous fingermarks (Figures 2B and 3B) with magnetic jet black powder (blue bars) producing a greater number of higher quality identifiable (score of 3 or 4) fingermarks. There is also evidence of a substrate effect with a greater detrimental effect seen for those fingermarks deposited on glass (Figure 3) compared to polyethylene terephthalate (Figure 2).

Figures 4 and 5 show that the detrimental effect of the household corrosive substances is greater for 1 week-aged natural and sebaceous fingermarks, deposited on PET and glass, respectively. Similar trends are seen as for the fresh fingermarks when comparing natural and sebaceous fingermarks and the two types of powder. It is most

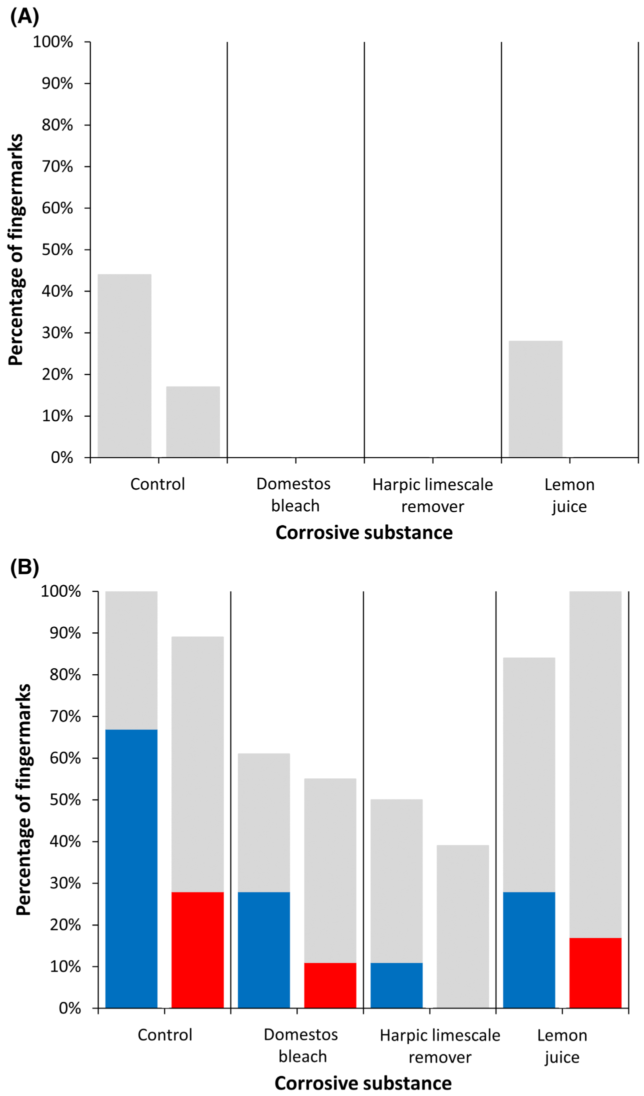

FIGURE 4 Percentage of identifiable 1-week aged (A) natural and (B) sebaceous fingermarks enhanced on polyethylene terephthalate (PET) after 1 min exposure to corrosive substance and control (non-exposure). Fingermarks enhanced with magnetic jet black powder (blue bars; ■) and aluminum powder (red bars; ■). Additional fingermarks detected but considered insufficient for identification (score of 1 or 2) indicated by gray bars (■) ($n = 18$ per category). Scored following the enhanced fingermark grading system in Table 4.

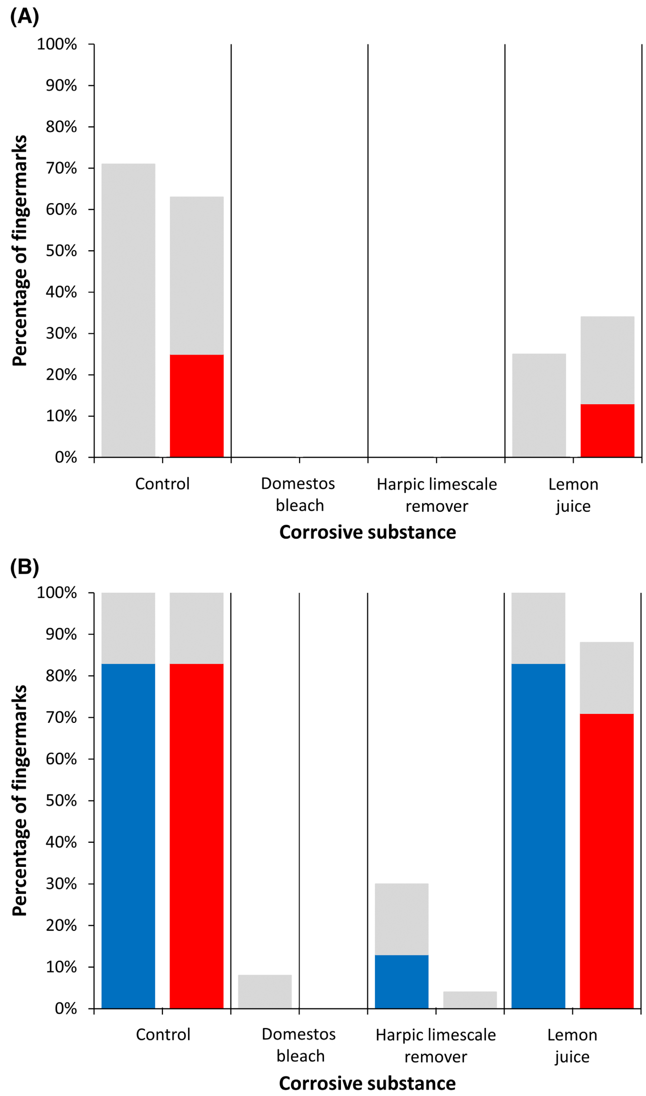

FIGURE 5 Percentage of identifiable 1-week aged (A) natural and (B) sebaceous fingermarks enhanced on glass after 1 min exposure to corrosive substance and control (non-exposure). Fingermarks enhanced with magnetic jet black powder (blue bars; ■) and aluminum powder (red bars; ■). Additional fingermarks detected but considered insufficient for identification (score of 1 or 2) indicated by gray bars (■) ($n = 24$ per category). Scored following the enhanced fingermark grading system in Table 4.

noticeable that there are very few natural fingermarks of sufficient quality for identification.

Figure 6 shows examples of fingermarks successfully enhanced with aluminum powder and magnetic jet black powder in this study on glass and PET following exposure to household corrosive substances.

Figure 7 summarizes the results from the washing study. On PET, rinsing the samples and exposing them to water or lemon juice for 1 min resulted in a 14% drop in the number of identifiable fingermarks compared to the control. Exposure to Domestos bleach and Harpic limescale remover resulted in a drop of 28% and 33%, respectively. In all cases, all marks were detected (scored at least 1) with the exception of those samples exposed to Harpic limescale remover whereby only 76% of the marks were detected.

On glass, rinsing and exposure to water and lemon juice had less of an effect compared to on PET. However, when exposed to Domestos bleach and Harpic limescale remover there were no identifiable fingermarks, that is scoring 3 or 4, compared to 95% for the control. Overall, only 5% of fingermarks were detected after exposure to Domestos bleach and 14% after exposure to Harpic limescale remover but in all cases only scoring 1 or 2.

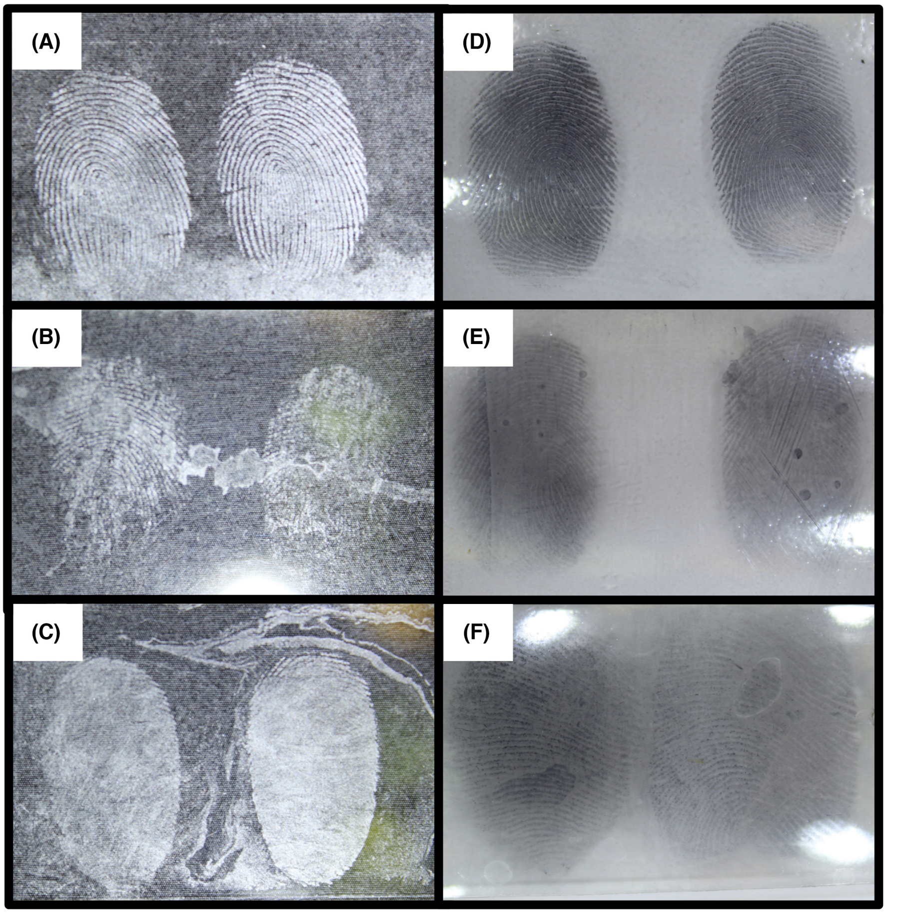

FIGURE 6 Examples of sebaceous-loaded fingermarks on (A–C) glass enhanced with aluminum powder and (D–F) on polyethylene terephthalate (PET) enhanced with magnetic jet black powder following 1 min exposure to household substance where applicable. (A) and (D) control fingermarks and not exposed to any corrosive household substance; (B) exposed to Harpic limescale remover; (C) and (F) exposed to lemon juice; (E) exposed to Domestos bleach.

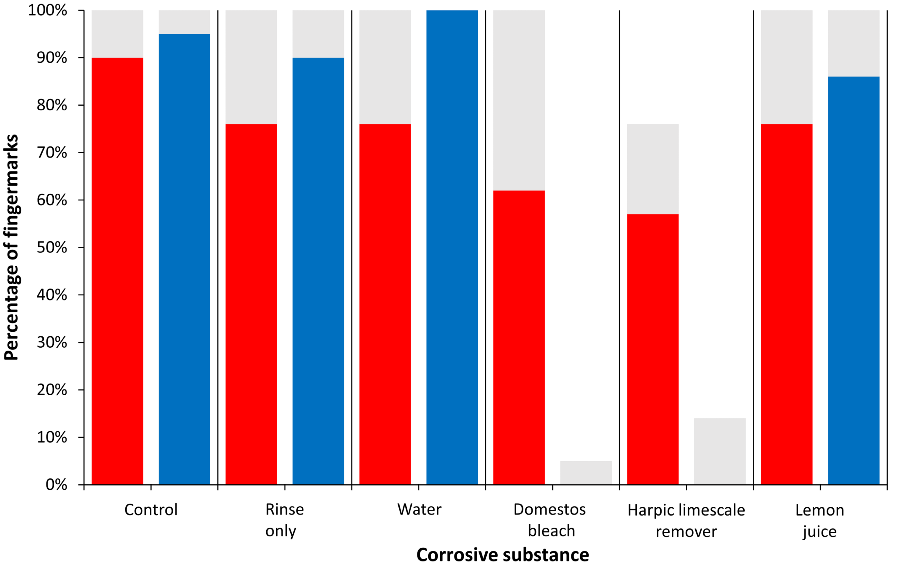

FIGURE 7 Percentage of fingermarks deposited on polyethylene terephthalate (PET) (red; ■) and glass slides (blue; ■) that were identifiable (score of 3 or 4). Additional fingermarks detected but considered insufficient for identification (score of 1 or 2) indicated by gray bars (■). Fingermarks enhanced using magnetic jet black powder ($n=21$ per category). Scored following the enhanced fingermark grading system in Table 4.

4 | DISCUSSION

Glass and polyethylene terephthalate (PET) were selected to represent the commonly encountered vessels used to carry and use corrosive substances in a DCSA, such as glass perfume bottles (with a spray nozzle) and plastic squeezy bottles, respectively [6, 11]. Domestos bleach was chosen as bleach is commonly used in reported attacks [11]. In addition, lemon juice has been reported to have been used in similar types of attacks [19]. Harpic limescale remover was also chosen as this product is irritating to the skin and eyes and therefore could potentially be used in an attack. The selected corrosive household products also range in pH, from acid to alkali, similar to previous work [6].

Preliminary work trialed superglue fuming with basic yellow 40 enhancement and solvent black 3 alongside the two powder techniques (aluminum and magnetic jet black) [18]. Natural and sebaceous fingermarks were collected on glass and PET from four donors and exposed to each of the three corrosive substances as described for the main study. There was, however, heavy background staining with superglue and basic yellow 40 on both substrate types following exposure to corrosive substances, which concurs with Masterson and Bleay who similarly had no success with superglue on any wetted samples, including water [6]. While this also concurs with the recommendations made in the Fingermark Visualisation Manual [18], the results are contrary to other previous work [2, 20]. Solvent black 3 was included in the preliminary work since it targets the endogenous lipid component of fingermarks and external contaminants such as grease and cosmetics [21, 22]. However, no marks were enhanced using Solvent black 3, including the control samples. Aluminum powder and magnetic jet black powder performed well in the preliminary work and consequently were selected for the main study.

Natural and sebaceous fingermarks were collected from a range of donors on multiple occasions to increase the range of fingermark compositions collected as it is well-established that a range of factors affect fingermark composition and consequently enhancement quality [23]. Natural fingermarks collected from donors on glass and PET were generally of poor quality throughout this work, with only 17% of all enhanced natural control marks (i.e., not exposed to any substance) considered identifiable (scoring 3 or 4) and a further 49% considered detected but insufficient (scoring 1 or 2) ($n=162$). Natural fingermarks predominantly consist of eccrine sweat and eccrine gland activity varies with temperature amongst other things [24]. As the fingermarks were collected between December 2021 and April 2022 in colder weather conditions, it is expected that less eccrine sweat was deposited onto the substrates in the first instance, resulting in poor enhancement. It is also expected, based on previous work, that natural fingermarks will be more susceptible to the detrimental effects of water due to their higher content of eccrine sweat and consequently higher content of water-soluble constituents [25]. Sebaceous fingermarks were of better quality with 81% of all control marks collected throughout this study considered identifiable and a further 18% considered detected but insufficient ($n=216$). Natural fingermarks were included in this study as the preferred sample type in accordance with best practice in fingermark research to better mimic fingermarks likely to be encountered in operational circumstances [1, 26].

Domestos bleach and Harpic limescale remover had a detrimental effect on fresh natural fingermarks on glass and PET, with no or very few fingermarks detected (score ≥1; Figures 2 and 3). Given the function of bleach and limescale remover to clean and remove material from surfaces, this destructive effect is to be expected, although the samples were only placed in the substances for 1 min and there was no wiping of the surface. Both substances were similarly destructive for fresh natural and sebaceous fingermarks on glass with no identifiable fingermarks recovered with the exception of Harpic limescale remover on sebaceous fingermarks enhanced with aluminum powder. However, in the case of fresh sebaceous fingermarks on PET, 25/54% (aluminum powder/magnetic jet black powder) and 8/29% of fingermarks were identifiable after exposure to Domestos bleach and Harpic limescale remover, respectively. Lemon juice had less of an impact on the fresh fingermarks although only a low percentage of natural fingermarks were identifiable on PET (5% with aluminum powder and 5% with magnetic jet black powder) and glass (17% with aluminum powder and 28% with magnetic jet black powder). Sebaceous fingermarks survived better in lemon juice with 90% identifiable fingermarks on glass and 48% on PET.

The greater survivability of sebaceous-loaded fingermarks (also referred to as 'groomed' fingermarks) is not unexpected given the sample pre-treatment loads the fingermarks with predominantly hydrophobic sebaceous material including triglycerides, wax esters, and free fatty acids [27, 28]. There is more material for enhancement techniques, such as powders in this case, to adhere to. Fingermark powders such as those used in this study do not target specific constituents and adhere to sticky residue, which is consistent with the better quality enhanced sebaceous fingermarks observed in this study [29]. Some of the donors reported using cosmetics or creams at least 1 h prior to each sample collection (Table 1). The presence of facial creams or cosmetics could contribute to greater survivability. Further work would be required to explore this.

Masterson and Bleay observed a greater detrimental effect of potassium hydroxide, a strong alkali, compared to sulfuric acid and suggested that this was a consequence of saponification of the sebaceous components of the fingermark combined with dissolution of eccrine components [6]. The results observed here for the Domestos bleach, also a strong alkali, are consistent with this and with previous work on chemical warfare agent decontamination procedures including bleach [16]. Domestos bleach contains hypochlorite ions which have been reported to react with double bonds in unsaturated lipids such as those found in sebum (e.g., fatty acids, triglycerides, and squalene), as well as the side chains of proteins and the amino acid backbone [17]. The reaction of Domestos bleach with the fingermark constituents is expected therefore to have removed material for the powders to adhere to and resulted in the observed reduction in enhancement quality.

Harpic limescale remover was, overall, as detrimental to both types of fingermark as Domestos bleach. This differs from the observations of Masterson and Bleay who found that overall the strong alkaline conditions of potassium hydroxide were more detrimental than the strong acidic conditions of sulfuric acid. The results also differ from the work of McDonald et al. using chlorine and hydrochloric acid vapors [14]. However, this may be expected since Harpic limescale remover contains a plethora of other constituents in addition to hydrochloric acid (6.75% w/w) which may also impact fingermark residue. In addition, it is liquid based with the consistency of a thick gel which adheres to surfaces and therefore behaves differently to an aqueous solution of sulfuric acid as used in Masterson and Bleay [6]. Further work would be needed to explore this and determine the basis of the different actions.

When considering the one-week-aged natural fingermarks, similar trends are seen to those for the fresh fingermarks. Comparing the control samples and samples exposed to lemon juice, there is lower quality ridge detail in the aged fingermarks than the fresh fingermarks. For the controls, only 7% of one-week-aged natural fingermarks were considered identifiable and a further 44% detected but of insufficient quality for identification, compared to 27% and 51% of fresh natural fingermarks, respectively. A similar reduction in quality is seen for those fingermarks exposed to lemon juice: 13% of fresh natural fingermarks considered identifiable drops to 4% of 1-week-aged and 29% of fresh natural fingermarks considered detected but insufficient drops to 19% of 1-week-aged fingermarks. The decrease in ridge detail after leaving the natural marks to age for 1 week could be explained by the loss of moisture as water evaporates and degradation of fingermark residue constituents resulting in reduced material on the substrate which is less receptive to powder enhancement [28, 30]. In the case of the sebaceous-loaded fingermarks, overall fingermark enhancement quality was higher but again decreased with aging. For the control samples, 68% of 1-week-aged fingermarks were identifiable and a further 30% detected but insufficient compared to 88% and 12%, respectively, for the fresh fingermarks. Of those samples exposed to lemon juice, 54% of 1-week-aged fingermarks were identifiable and a further 39% detected but insufficient compared to better results for the fresh fingermarks: 68% and 31%, respectively. The good quality enhancement of 1-week-aged sebaceous loaded fingermarks is consistent with previous observations and that some constituents generally remain stable over time and do not degrade [27, 28, 30, 31].

Domestos bleach and Harpic limescale remover have a similarly destructive effect on 1-week-aged fingermarks. Combining both powder techniques, only 8% and 6% of aged sebaceous marks on PET were considered identifiable after exposure to Domestos bleach and Harpic limescale remover, respectively. In addition, 19% and 23% of marks were considered detected but insufficient after exposure to Domestos bleach and Harpic limescale remover, respectively. The effect was greater on glass, with no fingermarks identifiable after bleach and 6% after limescale remover and a further 4% and 10% detected but insufficient, respectively. Again these results are consistent with expectations in terms of the activity of the two cleaning products.

Table 5 shows the percentage of identifiable fingermarks throughout the study (natural and sebaceous fingermarks combined and both fresh and aged) scoring a 3 or 4 on the two types of substrate after exposure to the different substances. It is apparent from Table 5 that

TABLE 5 Percentage of identifiable fingermarks (natural and sebaceous) deposited on glass and polyethylene terephthalate (PET) in main study.

	Control		Domestos bleach		Harpic limescale remover		Lemon juice	
Powder	Glass	PET	Glass	PET	Glass	PET	Glass	PET
Magnetic jet black	49	52	0	22	3	11	51	23
Aluminum powder	56	36	0	10	1	2	48	17

Note: Number of fingermarks in each category: $n = 87$ for glass with magnetic jet black powder and glass with aluminum powder; $n = 81$ for PET with magnetic jet black and PET with aluminum powder.

there is a difference between substrates in the impact of Domestos bleach and Harpic limescale remover on the survivability of the fingermarks. When compared to the results for the control samples, this is not due to differences in performance of the two powders. In general, Domestos bleach and Harpic limescale remover have the greatest detrimental effect on those fingermarks deposited on glass. The reverse is observed for lemon juice.

As previously addressed, the quality of an enhanced fingermark is influenced by a large number of different variables including fingermark composition, time since deposition, the substrate, and environmental conditions, as well as how these variables interact and influence one another [27, 28]. PET and glass are both non-porous substrates whereby the fingermark residue sits on the surface [27]. Moret et al. conducted a study on the microscopic examination of sebaceous fingermark residue on glass, polyvinyl chloride (PVC), polyethylene, and polypropylene. Differences in behavior of the fingermarks over time were observed on the different substrates [32]. The ridge detail on glass was clearly defined, with droplets within the mark remaining. However, the droplets within marks deposited on PVC and polypropylene seemed to disappear. In a further study comparing the two plastics, fingermarks had almost completely disappeared after 4 days. The cause of this was unclear but it was hypothesized to be due to the surface tension of the plastics, or the marks dissolving into any coatings on the plastic, such as plasticizers. While this may explain the difference in performance after exposure to lemon juice, there are clearly other factors involved when considering the results for Domestos bleach and Harpic limescale remover. It is important to note that Moret et al. did not explore enhancement quality in their study.

As the fingermarks are exposed to liquids during the initial recovery of the item, an experiment was conducted to understand whether the observed decrease or loss of ridge detail was due to the ingredients within the corrosive substances used, or because the fingermarks were being exposed to liquid including the water rinse. As most natural control marks were very poor, only sebaceous fingermarks were used with magnetic jet black powder which had outperformed aluminum powder in the previous experiment. The donor pool was increased slightly to seven donors (A and C–H), resulting in a sample size of 21 per condition (1–6 in Table 3).

On glass, all marks following exposure to water were identifiable but 95% and 86% of fingermarks following exposure to Domestos bleach and Harpic limescale remover, respectively, were not detected at all (scoring 0). This is in contrast with marks deposited on PET whereby all marks were at least detectable following exposure to bleach and 76% following exposure to Harpic limescale remover. These results contrast with those of the main study. This could be due to the use of additional different donors and the collection of samples on different days to those of the main study. These results highlight the importance of using as many donors as possible and recognizing the potentially high variability between individuals (inter-donor variability) and different sampling times (intra-donor variability). For the purposes of this discussion, the results of the water study have been kept separate from those of the main study to ensure a fair comparison.

In comparison to the control samples, rinsing (condition 2) and soaking in water (condition 3) have relatively little impact on the fingermarks on glass (5% reduction at most) compared to 14% drop in identifiable fingermarks on PET. However, consistent with the main study Domestos bleach and Harpic limescale remover exposure results in no identifiable fingermarks and only 5% and 14% considered detected but insufficient, respectively. Results for lemon juice were comparable to water exposure and rinsing only. Consequently, these results indicate that the exposure to water and liquid in general has little detrimental effect on the fingermarks and the decrease in ridge detail following exposure to corrosive substances is most likely due to the ingredients within the corrosive substances.

Overall, this study builds on the pilot study by Masterson and Bleay [6], demonstrating that fingermarks can be enhanced from a corrosive substance attack, following exposure to acidic/alkaline conditions. Similarly to Masterson and Bleay, this study observed alkaline conditions in the form of Domestos bleach to have a detrimental effect on fingermarks. In contrast to the previous study where little or no effect on the quality of the ridge detail was observed after exposing the fingermarks to sulfuric acid for 5 minutes, this study observed the acidic Harpic limescale remover to be more detrimental to the fingermarks, with 11.1% scoring a 3 or 4. The differences in observations could be due to differences in experimental design including number of donors and the choice of acidic corrosive substance used.

This study focused on PET and glass, as these substrates may be forensically significant in a corrosive substance attack case and were also used in Masterson and Bleay [6]. However, there may be other substrates in the vicinity of a corrosive substance attack that fingermarks may have also been deposited on. The substances used in this study may also be forensically significant as bleach and limescale remover are cleaning products and may be used to clean items such as weapons, following use in a crime. If a weapon, for example, a knife with a plastic handle, was to be submerged in an acidic or alkaline substance, it may still be possible, based on the findings of this study, to recover fingermarks from it.

5 | CONCLUSIONS

This study has shown that it is possible to recover latent fingermarks following relatively short exposure to acidic and alkaline household corrosive substances, namely Domestos bleach, Harpic limescale remover and lemon juice. It has also been shown that the substrate may affect the success of this, as well as the choice of enhancement technique and the composition of the latent fingermark (natural or sebaceous, fresh or aged). A larger scale experiment is currently being undertaken by the authors to further explore this using multiple substrates, household corrosive substances and fingermark donors under different conditions to continue to improve our understanding of what may be possible to recover from an exhibit in a DCSA and strengthen cases brought against offenders.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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