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Short Communication

The impact of accelerant facilitated fire on blood detection and the efficacy of subsequent soot removal methods

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ABSTRACT

Previous literature has established that recovering heat damaged body fluids is possible, however with little investigation into the effect of accelerants used in initiating arson fires. This study therefore aimed to determine whether presumptive blood detection was affected by heat damage resulting from accelerant facilitated fires. Another objective was to examine various techniques for removing soot, which is a noted barrier to blood detection. The study focused on blood deposited on household flooring materials, one porous and one nonporous surface: carpet and tile respectively. Samples were burned with butane, petrol, and kerosene then presumptively tested using the Kastle Meyer colourimetric blood detection test. Testing was then repeated following soot removal by either wiping, scraping, or using liquid latex. The "strength" of positive detections was evaluated using a scale based on reaction speed and colour intensity. Results demonstrated that accelerants weakened detection strength, although nearly all samples tested positive overall, and the impact of each accelerant on both surface types was largely similar. It was also discovered that soot removal improved the strength of blood detection results in approximately 69% of carpet and 47% of tile samples, with wiping being the superior method on both surface types. Consequently, introducing this investigative step may be critical to maximizing blood evidence recovery in arson casework. These findings indicate the worth in recovering severely burned items, particularly for evidence as crucial as blood.

1. Introduction

Heat damage was previously believed to reduce evidence to a state unsuitable for analysis [1], making fire a useful tool in violent crimes where large volumes of evidence may be produced. Blood is a common artefact at such scenes [2] and is invaluable in many regards, from event reconstruction using bloodstain pattern analysis (BPA) to identifying victims using DNA. Its recovery and detection are therefore critical to investigation.

The visualization and detection of heat damaged blood is a seldomly studied field having little focus on the effect of accelerants. Classified as any material that assists in starting or growing a fire, accelerants most often involve ignitable liquids [2] due to their flammability and destructive capacities. Common ignitable liquids include petrol and diesel [3] due to availability, with an estimated 60 % of arson fires started with petrol [4]. These petroleum products are composed of hydrocarbons that release heat energy during combustion [5].

Fire damages evidence by altering its physical and chemical characteristics under extreme heat, for instance, accelerating the degradation of blood [3]. This process causes a shift in colour from red to black [3], relating to the oxidation of haemoglobin and affecting the properties used in spectral analysis [3]. Presumptive tests rely on the presence of haemoglobin to indicate a positive result, raising the question of whether heat affects blood detection. Hemastix testing is popular due to its capacity for onsite use, as these colourimetric test strips are directly applied to blood [1]. However, many false negatives were recorded by Tontarski *et al.* when testing blood on several surfaces after a staged arson event within a four walled structure [1]. The Kastle Meyer (KM) and Leuco Malachite Green (LMG) tests are more sensitive to diluted blood, with LMG displaying 100 % true results at 10^{-2} dilutions and KM at dilutions of 10^{-3} [6]. KM testing is more often used in casework as it has a higher specificity [6], relevant to samples potentially containing accelerants, soot, and other contaminants.

Successful DNA recovery following blood detection has been observed to varying degrees of temperature inhibition around 800 °C [1,7,8]. This is significant as domestic fires can reach temperatures over 1000 °C [9], particularly during flashover, upon which extreme heat and damage ensues [10]. Studies have examined blood on a variety of heat

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damaged household materials, several using model houses like Tontarski *et al.* [1,7,11]. Flooring warrants further investigation because it is a likely recipient of bloodstaining, with blood falling from objects or weapons with gravity and transferred around the floor via contact with other items. Its combined analysis with accelerants is significant, as ignitable liquids are often thrown onto the ground out of convenience and the amount of surface area available to facilitate a large burn.

Another investigative component is the presence of soot, as this combustion by-product has been described as a literal barrier to blood detection [1]. Klein *et al.* found that soot inhibited luminol visualization, with resulting weak or negative chemiluminescence on several different substrates [8]. In Tontarski *et al.*'s use of Hemastix, the recorded false negatives were not treated with soot removal, whereas many samples that had been consequently yielded positive results [1]. This demonstrates that if blood can be accessed, successful detection may be possible. This is significant to downstream investigation as DNA analysis is pursued only after presumptive detection [1].

Several methods of soot removal have previously been investigated including liquid latex. Case studies have reported success for this product when applying a thin coating then removing it once solidified to peel away the soot [12]. However, destruction to the underlying blood must be considered, as other publications indicate this technique damaged fragile samples [13,14]. An alternative method involves scraping soot and char away [2], as demonstrated by Vineyard *et al.* using a metal knife on wood [2]. Although this yielded positive results [2], scraping is an aggressive procedure that could also damage blood evidence. A less destructive approach was described by Tontarski *et al.* using wipes saturated in either distilled water or isopropyl alcohol [1]. Both forms produced more rapid positive detections on various household surfaces as test reagents did not have to penetrate soot before reaching blood [1].

Further research into this topic is necessary as the presented methods have yielded mixed results and behaved differently on various materials, specifically on porous versus nonporous surfaces [12–15]. The ideal method for each has not yet been comparatively identified. As discussed, another gap in literature is the impact of accelerants on blood evidence, specifically their direct application for destruction. No study has isolated these potential effects, with current studies examining ignitable liquids alongside numerous other variables [2,7].

Increasing the volume of recoverable evidence from arson scenes is highly valuable to investigation. Therefore, the aim of this study was to determine whether heat damage caused by accelerant facilitated fire affected the presumptive detection of blood deposited on flooring materials. To support this, it was also established whether various soot removal methods could assist in this detection, and if so, which was most beneficial to porous and nonporous flooring types.

2. Methods and materials

2.1. Flooring materials

Nine new 50x50cm pieces of polypropylene carpet and nine 61x30.5 cm polyvinyl chloride floor tiles were purchased from B&Q home improvement store. These were selected to represent one porous and one nonporous material and were used to examine the effects of three accelerants in combination with three soot removal methods. Each was quartered into a 2x2 grid drawn and labelled with marker to indicate which accelerant and soot removal method they would be treated with, and whether each grid area was a control or replicate of each treatment (Fig. 1). Both the control and replicates were subjected to soot removal.

2.2. Blood deposition

Defibrinated horse blood was sourced from E&O Laboratories Limited. Approximately 5 mL was applied to each sample using a 1 mL disposable Pasteur pipette, draining it onto the sample to create

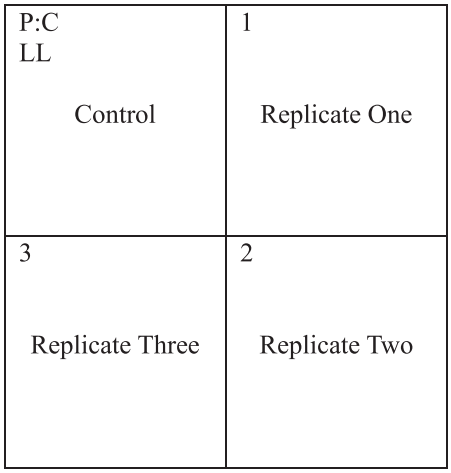


Fig. 1. Flooring sample design, with each sample subjected to a different combination of accelerant and soot removal method to be repeated for each replicate (1–3). For instance, petrol (P) paired with Liquid Latex (LL), with C representing the control not treated with accelerant.

arbitrary, "pool" patterns [16]. Samples were air dried for 24 h before individually wrapping them in greaseproof paper and packaging in paper evidence bags for transportation to the burning site.

2.3. Accelerant deposition and heat damage

Butane, kerosene, and petrol were deposited onto the samples at the Scottish Fire and Rescue Service Training Centre in Cambuslang, Glasgow. Here, burning took place in a fire safe room housing a steel box (Fig. 2), approximately 2x1x0.75 m in size and containing water in case of out of control burning. A piece of sheet metal was applied as a lid, atop which three samples were laid out at a time, each to be burned with the same accelerant to avoid contamination. Immediately before burning, approximately 5 mL of accelerant was poured onto each of the three replicate areas within each flooring sample.

Samples were burned using a propane fueled blow torch operated by a trained fire service professional. This flame burned at approximately 1600 °C and was applied to each sample for approximately five seconds as this was the duration needed for sample ignition. Kerosene samples took longer to ignite and therefore received 10 s of flame exposure. Samples were allowed to burn out completely, with carpet burning for approximately two minutes and tile for 30 s. Kerosene was again an

Fig. 2. Steel box used for burning samples.

exception, burning for approximately two minutes on tile, and for over five minutes on carpet before being extinguished with a padded smothering block to avoid excessive damage. Non-treated blood samples (the controls) did not ignite.

Samples were allowed to cool for two minutes before transferring them to the ground where they were further cooled for approximately half an hour. They were then packaged into polythene bags for transport to the laboratory, with one bag per accelerant/substrate group. Samples were fumigated overnight within either a fume hood or bio safety cabinet due to the presence of ignitable liquid residues.

2.4. Blood detection

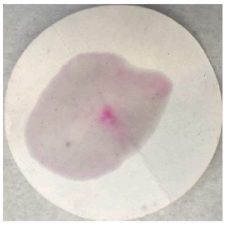
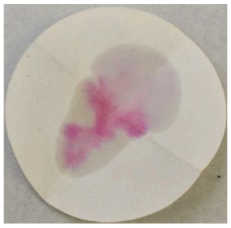
Blood was presumptively detected using the Kastle Meyer (KM) test, with testing performed by a single examiner with prior experience in its use. A circular filter paper was folded in quarters, making a triangular tip to rub across the bloodstain with light force. The paper was unfolded then treated with a drop of KM reagent in its centre. This was allowed to sit for five seconds as a first indication of false positives, as colour change should not have occurred at this time. One drop of hydrogen peroxide was then deposited in the same spot. Pink colouration within 10 s indicated a positive reaction, with a lack thereof indicating a negative. Each sample was tested prior to soot removal.

The "strength" of each positive was evaluated using a scale based on reaction speed and colour intensity (Table 1) once the reaction appeared to stop steadily developing. This scale was derived when varying intensities of pink (correlating to reaction speed) were observed in preliminary testing, necessitating the differentiation of positive results. Considering a few exceptions, if a reaction met the criteria for colour but not time, it was scored down. For instance, if a reaction appeared bright pink but after five seconds, it was recorded as "strong". If a reaction was barely visible but fully developed after two seconds, it was labelled 'weak". After soot removal, this process was repeated to determine if KM results differed following treatment.

2.5. Soot removal

Three methods of soot removal were applied. "Mysense SFX Makeup" liquid latex was applied using a cotton swab based on work by Klein *et al.* [15]. The swab was dipped into a beaker containing liquid latex then

Table 1
KM scale used to describe positive result "strength" using reaction time and colour intensity.

Strength	Colour	Reaction Time (sec)	Example
Weak	Pale pink (barely visible)	10	
Moderate	Light pink	>5	
Strong	Pink	<5	
Very Strong	Bright pink/purple	<1	

lightly swept across the blood sample to create a thin, even coating. After air drying for 24 h, forceps were used to remove the solid product. The inner surface of the liquid latex was also KM tested to determine if blood removed with the latex was detectable as suggested by Klein *et al.* [15], however these observations were not statistically tested.

The next method was scraping, influenced by Vineyard *et al.* [2]. A scalpel was gently scratched against the charred surface, resulting in loose powders removed by vertically tapping the substrate on the laboratory bench to catch debris on greaseproof paper.

The final method of wiping followed work by Tontarski *et al.* [1], using "Ivyone" brand wipes described as "Pure Cotton Dry Wipes" saturated with deionized water sprayed from a bottle. Wipes were folded into quarters and wrung out to remove excess water before lightly rubbing them across the burned area. Wiping stopped when the wipe ceased to turn black from the sample's surface.

2.6. Statistical analysis

KM scale scores were translated to quantitative data. Instances where removing soot was not possible (mainly due to sample fragility) were labelled "unsuccessful" and were not KM tested nor included in statistical analysis. Negatives were scored as 0, and "weak" to "very strong" positives received scores of 1 through 4 respectively. Within Excel, the percentage of each score per accelerant type, pre and post soot removal was calculated, as well as the percentage that increased, decreased, or remained the same after treatment. Paired t-tests for assessments involving two variables were also performed to compare the presence and absence of accelerants and soot removal, determining if these treatments had a significant impact on KM results overall. An average score from the three replicates within a sample was used for comparison against the control due to the 3:1 ratio of replicates to controls.

IBM SPSS software was used to perform the Kruskal Wallis test, comparing accelerant types and soot removal methods to determine whether the effects of each differed. Testing applied a pairwise comparison to identify the statistical differences with a Bonferroni adjustment to indicate which accelerant was most damaging, and which soot removal method most effective. This was repeated for carpet and tile samples separately using a significance level of 0.05.

3. Results and discussion

3.1. Effect of accelerants

Across both substrates, 15 of 18 controls resulted in high KM scores with no negatives. 88.89 % of carpet controls (n = 8) were ranked "strong" or "very strong". A paired t-test indicated that these results were significantly different from the treated sample results (p=<0.001) (Table 2), meaning accelerants had a substantial impact on blood detection by lowering the strength of KM scores. This was visually represented by treated carpet samples appearing more damaged than their controls, showing more burning to conceal underlying bloodstains (Fig. 3). Zero accelerant samples were ranked "very strong", and only 11.11 % (n = 3) "strong", with 14.81 % (n = 4) resulting in negatives (Fig. 4).

On tile, 77.78 % (n = 7) of controls were "strong" or "very strong". Both control and accelerant treated bloodstains on this substrate were blackened and fragile (Fig. 3), however there was a significant difference between the KM results of these groups (p = 0.021) (Table 2). Only 29.63 % (n = 8) of accelerant samples were ranked as "very strong" and 40.74 % (n = 11) as "strong". This indicated that accelerants also weakened KM detection results on tile.

Kerosene appeared most destructive on carpet, in multiple instances completely burning through it (Fig. 3). Petrol samples were slightly more burned than butane samples, which was consistent with testing showing more "weak" KM results (Fig. 5). Only kerosene yielded negatives for this substrate, however Kruskal Wallis testing indicated no significant difference between the scores of each treatment (p = 0.679) (Table 2). This meant that on carpet, no accelerant sufficiently weakened detection more than another, including kerosene compared to butane (p = 1.000).

On tile, kerosene appeared less damaging as only one "weak" score was recorded with zero negatives (Fig. 5). Discoloured bubbling was observed, although was located adjacent to bloodstaining therefore not affecting detection. Little evidence of burning was observed from butane with all samples yielding "strong" or "very strong" results (Fig. 5). Petrol resulted in more visibly burned samples and "moderate" scores (Fig. 5). Statistical testing indicated a meaningful difference between tile results (p = 0.006) (Table 2), with pairwise comparison revealing that kerosene more significantly weakened detection than butane (p = 0.007) on tile.

The perimeter of each butane-treated bloodstain appeared untouched, with charring observed only outside of where this accelerant was applied (Fig. 3). This supports a proposal from Vineyard *et al.* that ignitable liquids could protect their underlying surfaces from damage [2]. However, this was not possible on carpet where accelerants were absorbed and was particularly untrue for petrol on tile. It should be considered that arson scenes are searched for characteristic areas of severe burning called "pour patterns" caused by accelerant deposition [17]. This concept indicates that certain accelerants could weaken blood detection by increasing the amount of charring and soot for test reagents to penetrate.

A potential explanation for kerosene's specific damage is that it burns at a higher temperature [18,19]. Kerosene samples also burned for a longer duration. However, because accelerant KM scores were only significantly different in one comparison, it may be more meaningful to consider their effects overall rather than separately. Burning with ignitable liquids more rapidly increases temperature [20], which would theoretically accelerate blood degradation to weaken detection. Although Abrams *et al.* found little effect on detection when burning with petrol, the resulting fires where not directly initiated on bloodstaining [7] unlike the current study. Vineyard *et al.* similarly failed to see an impact when directly applying petrol, however authors proposed this was because only 0.5 mL was used per sample [2]. It has been demonstrated that increasing accelerant volume causes housefires to reach flashover more rapidly [20], enforcing that other factors (like volume) may be more impactful than accelerant type.

Although most accelerant-treated samples were positively detected prior to soot removal, KM reaction strength relates to result confidence. "Weak" reactions took 10 s to develop. After this point, KM reagents

Table 2
Statistical analysis used to determine the significance of accelerant effect based on KM scores, applying a significance level of 0.05 to pairwise comparison results adjusted with a Bonferroni correction.

Substrate	Accelerant	t-test p-value	Kruskal-Wallis p-value	Pairwise Comparison To	Pairwise Comparison p-value	Adjusted p-value
Carpet	Butane	<0.001	0.679	Kerosene	0.414	1.000
	Petrol			Butane	0.489	1.000
	Kerosene			Petrol	0.900	1.000
Tile	Butane	0.021	0.006	Kerosene	0.469	0.007
	Petrol			Butane	0.020	0.060
	Kerosene			Petrol	0.469	1.000

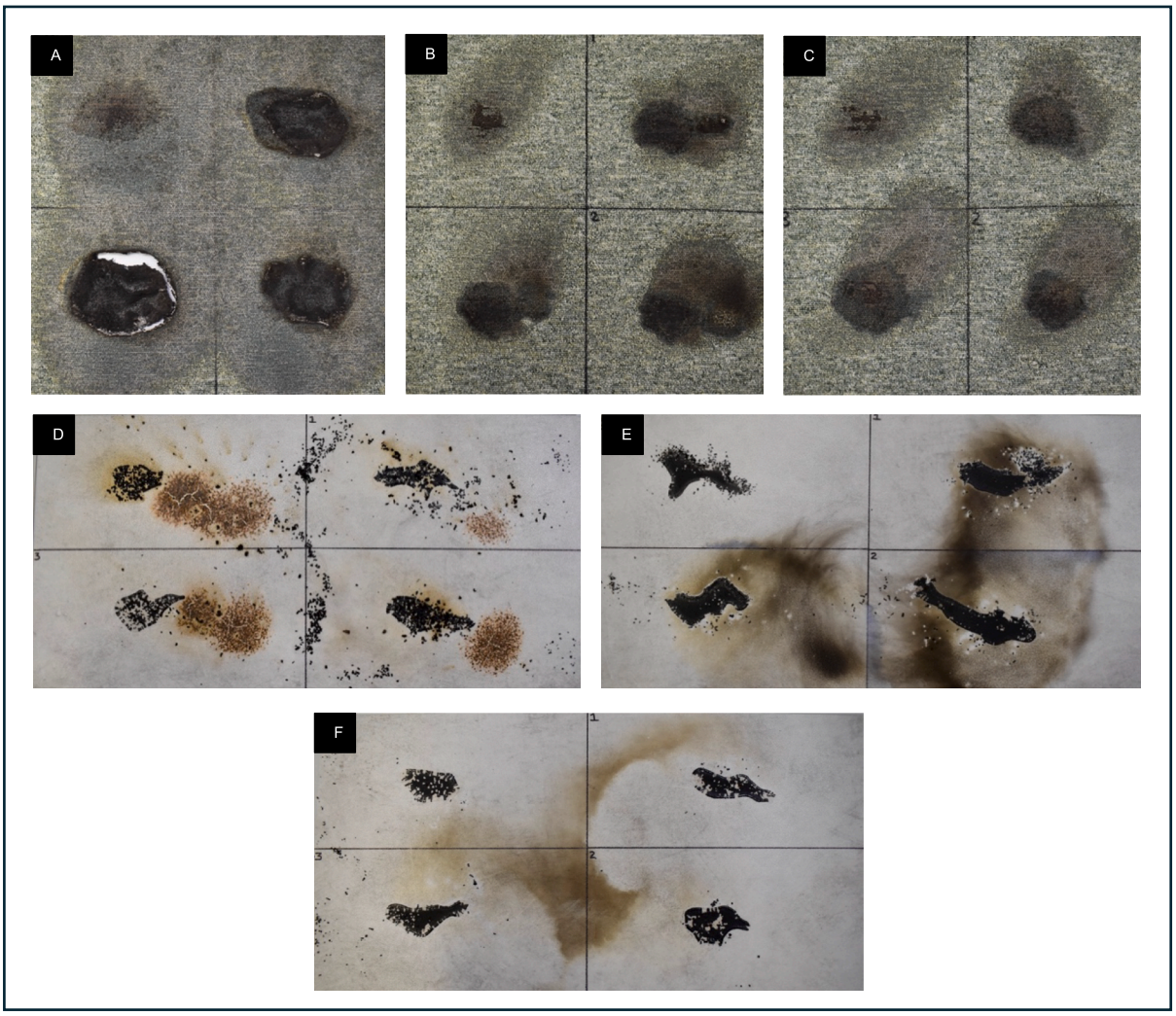


Fig. 3. Samples post-burning, with controls located in each top left grid. A-C represent carpet treated with A) kerosene B) petrol and C) butane. D-F represent tile treated with D) kerosene E) petrol F) butane.

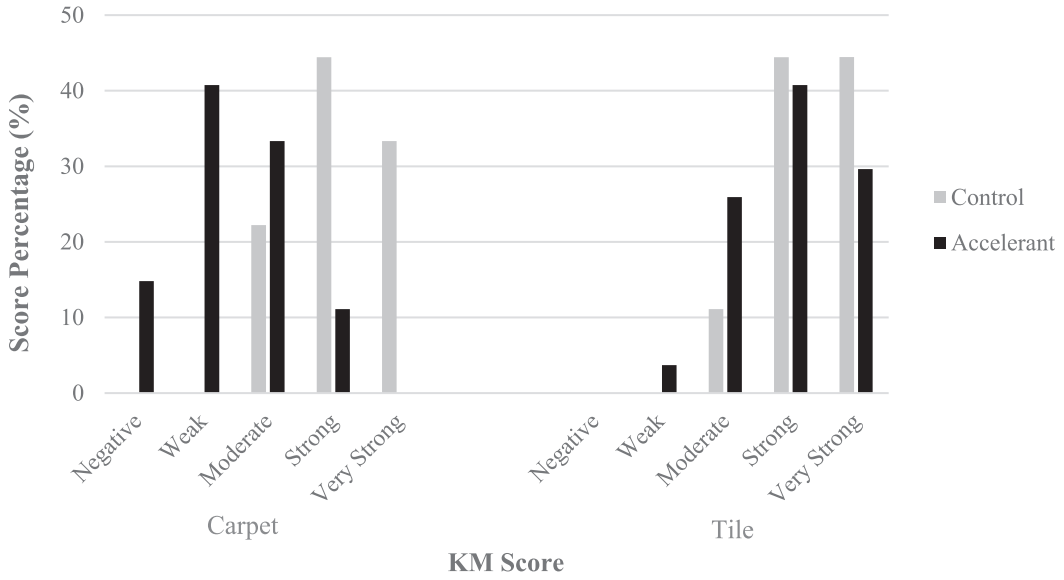


Fig. 4. Comparison of KM scores from control and accelerant-treated samples after burning.

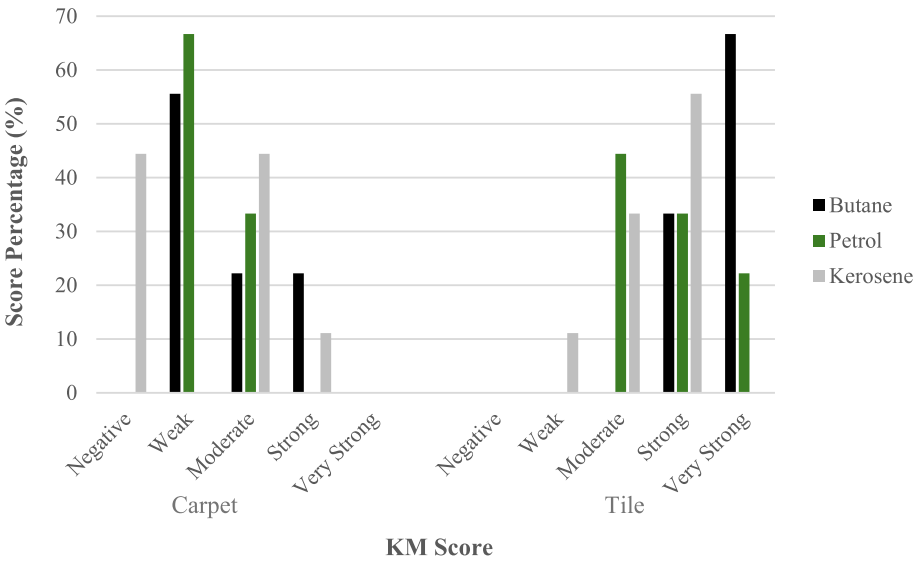


Fig. 5. Comparison of KM scores after burning with each accelerant.

begin to turn pink from oxidation in open air even in the absence of blood [6], making these samples easily mistakable for negatives. Rapid results therefore provide assurance of true positives, particularly for inexperienced examiners. Weak reactions were also described as hardly visible. Filter paper applied to burned samples turned black and brown with soot, making it difficult to identify faint colour changes (Fig. 6). Because colour subjectivity is a universal issue, vivid results reduce uncertainty surrounding interpretation and emphasize the need for soot removal.

3.2. *Efficacy of soot removal*

Paired t-testing implied a meaningful difference between pre and post treatment results for carpet ($p = 0.0015$) (Table 3), with 69.44 % ($n = 25$) of samples showing an increase in detection strength following soot removal (Fig. 7). Meaning they more rapidly turned a brighter pink, four false negatives turned to positives and four "weak" results to "strong". Scores were unchanged in 25 % of cases ($n = 9$), meaning treatment neither improved nor inhibited KM strength. Only two samples showed a decrease in strength following treatment, therefore, in most cases soot removal efforts improved detection strength on carpet.

On tile, less than half of scores improved after soot removal (47.22 %, $n = 17$) and 19.44 % ($n = 8$) were unchanged (Fig. 7). However, unlike carpet, most tile results were already "strong" or "very strong" (Fig. 4). Nonetheless, the only "weak" sample turned "very strong", as did five of the seven "moderate" scores. These results were largely impacted by unsuccessful scraping efforts comprising 25 % ($n = 9$) of tile samples (Fig. 7). Bloodstains on this material were very smooth and material could not be scraped without destroying the already fragile blood. Scraping was somewhat applicable to kerosene samples, as areas of textured char were identified, scraped, then successfully tested. Disregarding the unsuccessful samples, paired t-testing showed that on tile, pre and post soot removal results were significantly different ($p = >0.001$) (Table 3), meaning that scores were overall improved following these efforts.

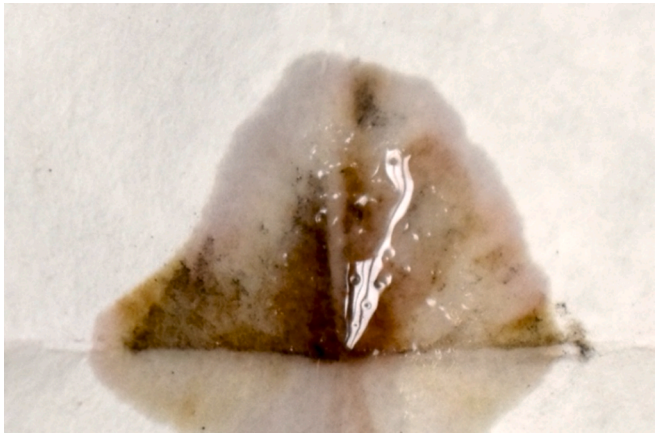


Fig. 6. "Weak" KM test result where the positive pink colour reaction was obstructed by soot.

To evaluate each soot removal method, Kruskal Wallis testing showed no significant difference in KM scores on carpet ($p = 0.795$) (Table 3) to suggest that no method outperformed another, as supported by pairwise comparison. On carpet, the highest level of increase was observed in wiped samples (75 %, $n = 9$), however Fig. 8 illustrates that this percentage was similar between methods. Because 75 % ($n = 9$) of scraping tile was unsuccessful, scraping was deemed unsuitable for this substrate. Kruskal Wallis testing found no statistical difference between the results of liquid latex application and wiping on tile ($p = 0.l812$) (Table 3).

Success was therefore further evaluated based on sample destruction. Peeling liquid latex removed almost entire bloodstains from tile samples (Fig. 9), an effect that Luche *et al.* witnessed on multiple nonporous surfaces (however not to the same extent) [14]. Klein *et al.* did not describe lifting the blood as damage, instead finding that peeled latex fluoresced as strongly as remaining substrate blood when using luminol [16]. Because the present study's focus was detection rather than BPA, it was unnecessary for the entire bloodstain to remain intact. Liquid latex behaviour on tile was potentially advantageous, as blood was preserved on the inner surface of the latex, exposing a side untouched by soot (Fig. 9). When tested, these peels exhibited "strong" or "very strong" positives. However, the application swab tended to remove very large flakes of blood (Fig. 9).

Meanwhile, liquid latex application on carpet was highly variable, and was difficult to peel from many samples. This resulted in areas of unremovable latex that obstructed blood and yielded small, shrivelled peels that were unsuitable for testing. Luche *et al.* proposed that spraying a thin, even layer could keep it from damaging samples and prevent the liquid from soaking into porous materials and adhering too strongly [14]. This could explain the described shortcomings, however effective spraying would only be possible using expensive equipment [14].

Table 3
Statistical analysis used to determine the significance of soot removal effect based on KM scores, applying a significance level of 0.05 to pairwise comparison results adjusted with a Bonferroni correction.

Substrate	Soot Removal Method	t-test p-value	Kruskal-Wallis p-value	Pairwise Comparison To	Pairwise Comparison p-value	Adjusted p-value
Carpet	Liquid Latex	0.0015	0.795	Wipe	0.501	1.000
	Wipe			Scrape	0.683	1.000
	Scrape			Liquid Latex	0.791	1.000
Tile	Liquid Latex	>0.001	0.812			
	Wipe					
	Scrape					

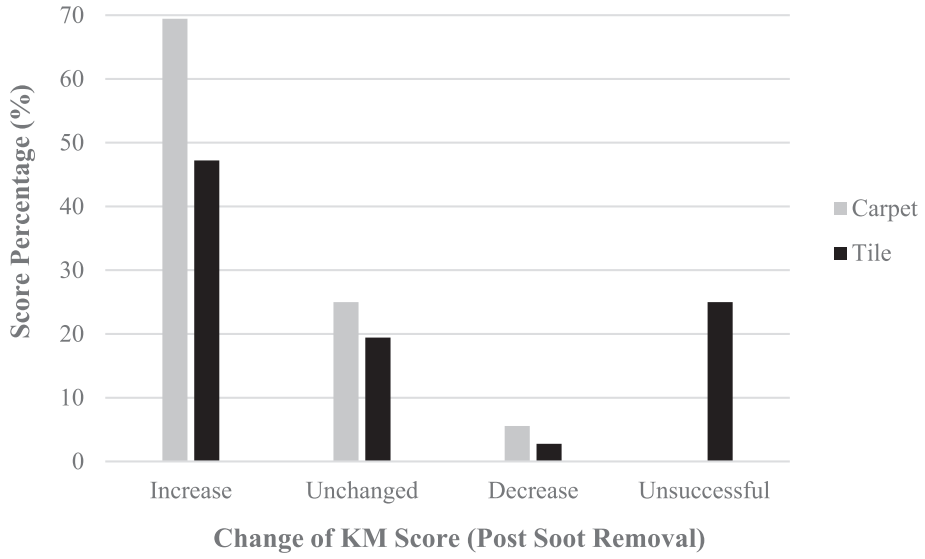


Fig. 7. Changes in KM score after attempted soot removal.

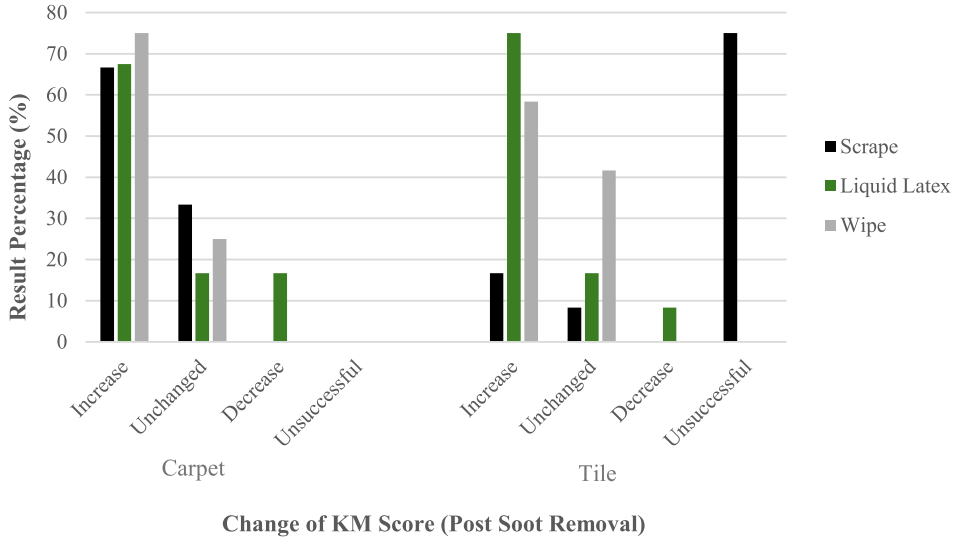


Fig. 8. Comparison of KM score changes after each attempted soot removal method.

Although this may be worthwhile, the consistency, convenience, and low cost of other methods may outweigh this possibility. Based on these factors, disregarding liquid latex as a method may be best overall.

Scraping and wiping carpet was nonproblematic due to its porous, absorbent nature that preserved detectable blood even after aggressive treatment. On tile, even gentle wiping removed flakes of blood (Fig. 9), however, this method was still effective as demonstrated by the wipe turning black with soot and the high percentage of increased KM scores (Fig. 8). Less blood was damaged when wiping tile compared to scraping. Considering sample preservation for downstream analysis, results suggested wiping was best for nonporous materials.

Comparing these methods on carpet, wiping revealed underlying blood slightly more. This indicated that wiping porous surfaces may be marginally superior, as visible blood facilitates targeted KM testing, a more efficient approach. Improved visualization supports the need for soot removal regardless of samples already testing positive. Tontarski

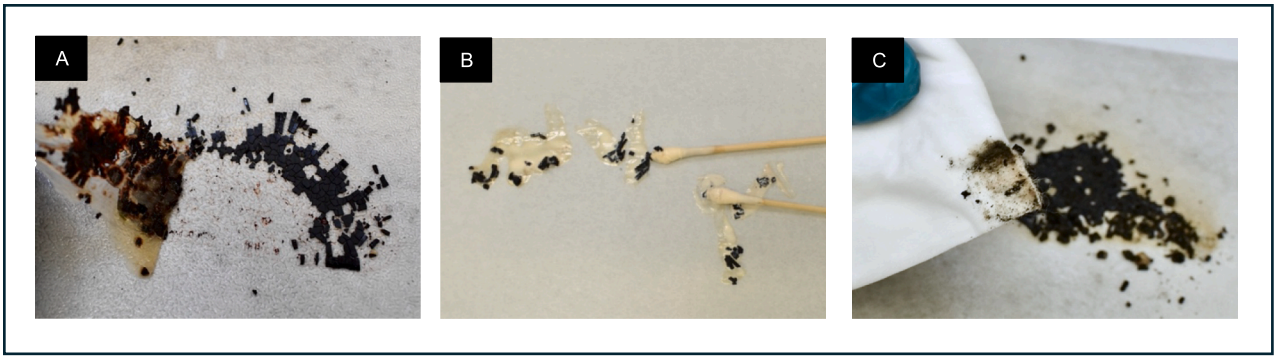


Fig. 9. Destruction to fragile tile samples caused by attempted soot removal including peeling liquid latex (A), liquid latex application via swab (B) and wiping (C).

et al. also noted that wiping increased the rate of positive reactions [1]. This again relates to subjectivity, as a test immediately turning bright pink provides more certainty than a slow, faint one. Furthermore, when soot and char were sufficiently removed, KM filter papers were cleaner. This allowed even "weak" reactions to be clearly observed, demonstrating added worth to this procedure. The simplistic and inexpensive nature of wiping gives it the potential to be easily integrated into arson investigations.

3.3. Strengths and Limitations

Disadvantages of this work relate to authenticity. For instance, the volume of blood used. In real casework, often only minute drops are recovered. Here, heat and accelerant damage could potentially be more impactful and soot removal more destructive. The blowtorch used to ignite samples helped to accurately represent a realistic temperature, but unlike other studies constructing model homes [7,11], certain elements were lacking. For instance, higher levels of soot are likely to build up on flooring as other household materials burn [8], and larger fires with greater burn times should be expected.

Another limitation was that the examiner was aware blood was present and where it was deposited. This potentially led to confirmation bias, therefore further study should involve multiple blind examiners. This could also assist in assessing reproducibility. As mentioned, colour perception is objective, therefore may be interpreted differently between individuals or when lighting conditions vary. For this reason, another significant limitation was that the quantitative results obtained from the derived scale were founded on subjective determinations. This was combatted somewhat by coupling colour determination with reaction development time under consistent lighting, although soot challenged colour interpretation in some instances.

Above all, it should be noted that in many ways this work serves as a proof-of-concept piece. The methodology could be improved, for instance by applying computer software to generate an absorbance value for positive scores, removing the subjectivity associated with the human eye's observation of colour. However, the current scale successfully indicated general trends in accelerant behaviour and KM results. Overall, it increased the amount of numerical data obtained from testing to help explain findings and inform future studies.

Another strength was the simplicity in isolating only two variables. As well, this study's comparative nature was able to identify wiping as the most suitable soot removal method. Therefore, future work could also examine its efficacy on other porous and non-porous flooring materials to determine if this method can be generalized. By extension, assessing samples subjected to more realistic conditions could be valuable to implementation in future casework.

4. Conclusion

This study aimed to determine whether heat damage from accelerant facilitated fires impacts blood detection. This was accomplished by burning household flooring materials with common ignitable liquids and developing a scale to rank the strength of positive KM detection results. Results demonstrated that directly burning with accelerants weakened blood detection strength by causing KM reactions to develop more slowly with fainter colouring. This effect was largely similar between different accelerants on carpet; however, kerosene was found to be more detrimental than butane on tile. Although most accelerant treated samples still tested positive, weak KM results are more likely to be labelled false negatives due to colour subjectivity.

This supported the secondary aim of soot removal, which overall proved to strengthen KM results affected by accelerants. Various methods behaved differently on porous and nonporous surfaces regarding the number of improved detection results and the resulting damage to underlying blood. Scraping soot off tile was unsuccessful, and although liquid latex improved detection, it almost completely removed bloodstains from their substrate. Because liquid latex application on carpet was extremely variable, using this product is discouraged. KM results from wiping and scraping carpet were similar, with neither method significantly damaging. Wiping was deemed superior for its ability to visualise underlying blood slightly more, suggesting this method is best for porous and nonporous surfaces.

Improving the speed and colour intensity of a positive reaction improves result confidence, which is particularly important to the examination of damaged evidence. These findings therefore supported the need for recovering severely burned samples even when accelerants have been used. Future work is necessary to establish the robustness of these results and whether they can be replicated for other materials within a more realistic setting. However, this work encourages the examination of arson scenes by helping to widen the scope of investigative information possibly gathered from them.

Ethics statement

Ethical approval was deemed not required for this project.

CRediT authorship contribution statement

Anna Kozbor: Investigation, Methodology, Data curation, Formal analysis, Writing – original draft. **Katie Davidson:** Project administration, Conceptualization, Resources, Supervision, Writing – review & editing. **Felicity Carlysle-Davies:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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