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A Review on Advancement Techniques in Fingerprint and Blood Evidence Retrieval from Arson Crime Scenes

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Abstract

Arson is defined as the deliberate and malicious burning of property having three main elements which includes burning of property, burning is incendiary in origin and the burning was started with the intent of destroying the property. There is a misconception that fingerprints and blood evidence cannot be retrieved when it is exposed to extremely high temperatures and hence in most of the cases, the perpetrators set up fire in the crime scenes in order to conceal a crime. This literature speaks about the methods which could be used to efficiently retrieve fingerprints and blood evidence from the scene of crime primarily using SPR and latex lifting method respectively. Infrared (780nm to 1 mm) photography can also be used to capture the blood evidence as blood undergoes oxidation when exposed to higher temperature.

SPR- Small particle reagent is an effective fingerprint developing method which is useful to collect fingerprints from wet, non-porous surfaces. Liquid latex is a material used to produce forms and moulded areas in handmade articles, latex clothing etc.., It exists in liquid form and on drying it turns out to be an elastic film which can easily pulled from a surface hence it is used as a method of preservation of dermal ridge evidence and also to retrieve DNA from the blood in the arson crime scene

Keywords: Arson, fingerprints, blood, DNA, small particle reagent, Reflected Infrared photography
Arson Arson is setting of fires to any property including vehicles, buildings, valuables, etc with intent to gain benefits like insurance facilities. Arson doesn't include fire caused by natural circumstances or by accident, one should have a proper motive to be considered as arson.

Fire

When fuel, heat, and oxygen come together in an uninhabited chain reaction, fire is the resultant chemical reaction[1]. If one of the three elements is absent the fire would stop burning. All the three elements are interdependent, and any element absent from the triangle would break the chain. Liquid fuels must be heated until they turn into vapor in order to burn; Only gases can burn solid fuels. A fuel is chemically broken down into its component gaseous forms by heat. Pyrolysis is the term for this breakdown process. The three main ways that heat energy is transferred in a fire are by radiation, convection, and conduction[1]

Elements of fire

1. Fuel

It may be a solid (wood, paper, cloth), flammable liquid (kerosene, oil, gasoline, petrol) or gaseous form (natural gas). Fuel is a substance that acts as the source of combustible material which gets ignited.

2. Oxygen

Fire requires oxygen to maintain the state of combustion. Fire also releases smoke and hazardous gases

3. Heat

Any combustible material will ignite if higher temperature is present. Heat is an essential element for the fuel to get ignited.

There are 5 main stages to a fire; Pre-heat, Early growth, Flashover, Steady state and Decay. It is important to understand these stages, as each stage will not only have a different detrimental effect on fingerprints and DNA, but also causes physical changes to the surfaces that they adhere (O'Hagan & Calder, 2020b)

Table 1.1 shows the stages of fire (O'Hagan & Calder, 2020b)

Fire stage	Heat	Smoke	Flame
Pre-heat	Low heat	Little smoke	Small flame
Early growth	Increased heat (up to 1000 OC)	Lots of smoke	Flame spread
Flashover	Mass heat ignition temperatures reached	Less smoke and soot as often consumed as fuel	Mass flame rapidly spreads as surfaces exposed to thermal radiation reach ignition temperatures
Steady state	Mass heat	Mass smoke	Extensive flame
Decay	Decreased heat	Considerable smoke	Decreased flame (Increased smouldering)

Causes of Arson

The possible motives for arson, could be

- profit;[18]
- animosity;[18]
- vandalism;[18]
- crime concealment;[18]
- political objectives;[18]
- psychopathological factors.[18]

1. Profit

A profit motive is one where the offender derives some material gain or benefit from setting a fire (Kocsis & Irwin 1997).

Profit motive can be direct or indirect. In direct profit motive the offender hold some interest in the destroyed property like burning his building for insurance claim of other benefits whereas in indirect profit motive the offender holds no interest in the destroyed property for example business rivalry.

2. Animosity

Animosity includes sentiments and feelings. It's when one's extreme sentiments like rage and anger is expressed through fire rather than assaulting an individual. This sentiment is often termed as revenge, but this doesn't describe all the psychological conditions.

3. Vandalism

Vandalism is the malicious and wanton destruction of property (Kocsis & Irwin 1997). Comprehending the proper reason of arson due to vandalism is hard because of its meaningless nature. Arson could lead due to boredom, curiosity, mischievousness, pressure from peers and family and so on.

4. Crime concealment

This suggests that the offender deliberately commits an arson in order to conceal or destroy evidence of some other crime. Here committing arson was secondary motive and its often believed that fire destroys all evidence. This misconception has led the offenders to commit arson in order to conceal their crime.

5. Positive objectives

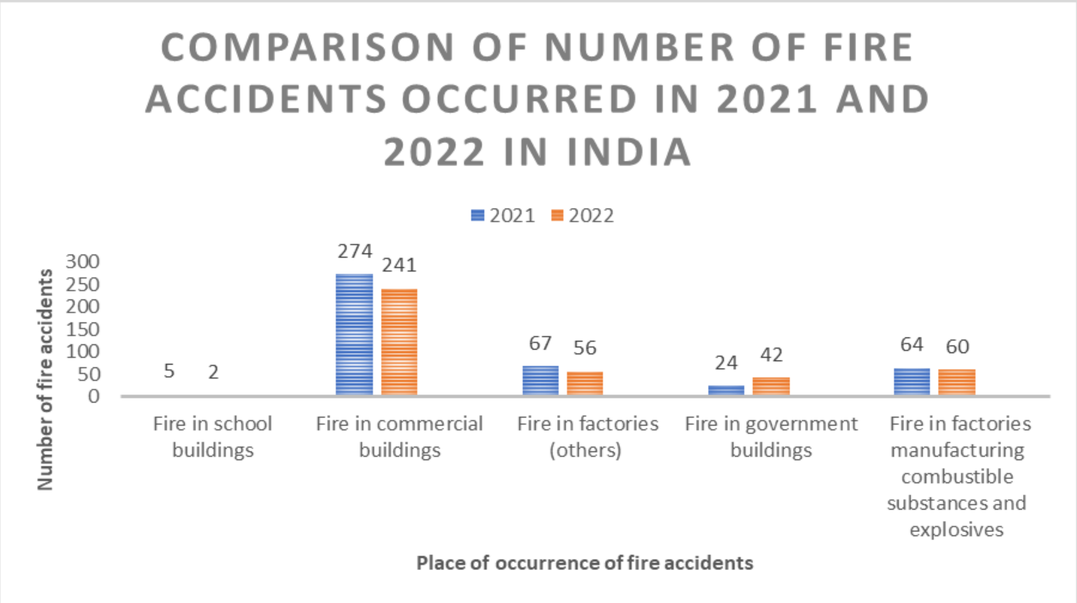
Here the arson is motivated due to political reasons. Setting fire to the public properties during the riot or protest has become common in the Indian scenario. Fires are also set because of politicians play and other serious issues

6. Psychological factors

Empirical examinations of arsonists who have been referred to psychiatric hospitals have generally found that schizophrenia, personality disorders, various forms of mental handicap, substance abuse and mood disorders are the most frequent diagnosis. (Koson & Dvoskin 1982).

Arson statistics

Graph 1 shows the number of fire accidents taken place in India (2021 and 2022) [20]



The above bar graph illustrates the number of fire accidents taken place in the year 2021 and 2022 in India. We can see that the accidents occurred in the school buildings is the least whereas the fire occurred in the commercial buildings is the highest in the both the years. It is also interpreted that the number of fire accidents has gone down in the year of 2022 comparatively.

Fingerprints

Fingerprints are impressions left on surfaces by the dermal ridges of fingers due to the sweat residues present on the skin. These fingerprints are known for their uniqueness and permanency as they are unique to each individual. Hence, they are widely used as the means for individualizing a person.

Formation

Fingerprints are formed during the embryonic developmental stage and remain throughout the life of an individual. Fingerprints can also be called as the reproductions of the friction ridges present on our fingers. These friction ridges are raised strips of skin on the palms of the hands, fingers, soles of the feet, and toes and they are formed during the 10.5 week of EGA and further mature as the embryo passes into the second trimester. These friction ridges are developed from the dermal papillae layer which is present between epidermis and dermis layer of skin.

Fingerprints are the reproductions of friction ridges on the surface. These patterns are reproduced because of the sweat particles present in our fingers.

Composition of Sweat

Sweat contains

Water: About 99%

Salt: Sweat contains electrolytes like chloride and sodium.

Urea: A nitrogenous waste.

Sweat also contains trace amounts of uric acid, ammonia, lactic acid, vitamin C, and other substances.

Types

Fingerprints have been classified into 3 basic patterns: loops, whorls, and arches which can be further classified. These patterns help in the identification process as the friction ridges consists of minutiae characters present.

Classification of fingerprints in Crime Scene

One of the most important uses for fingerprints is to help investigators connect one crime scene to the person involved in that scene. Hence it is necessary to collect fingerprints as it can play the role if major evidence.

Based on the way they are found in the crime scene fingerprints are classified into three types:

- Latent prints
- Plastic prints
- Patent prints

Latent prints: These are the type if fingerprints which are not visible to our naked eyes but require some enhancement techniques to be visible.

Plastic prints: These are the impressions or indentations left on a soft material which gives us the 3D vi-

ew of the fingerprint.
Patent prints: These are the type of fingerprints which are visible to naked eyes and do not need enhancement techniques.

Recovery and Collection of Fingerprints

Each type of fingerprint has its own recovery methods while patent and plastic prints can be recovered directly latent prints require development and enhancement techniques first and then recovery. There are some widely used fingerprint development techniques and this also depends on the type of surface the fingerprint has been imprinted.
These surfaces are of two types: porous surface and non-porous surface.

- Development methods
  Development methods for non-porous surfaces.

There are certain methods which are used to develop latent fingerprints on non-porous surface they are:

- Powder methods
- Small particle reagent
- Vacuum metal deposition method
- Cyanoacrylate fuming method and others

Development methods on porous surfaces.

Some methods are used to develop latent fingerprints on porous surface they are:
Fuming methods such as ninhydrin, iodine fuming and others can be employed.
After developing these prints, we collect these prints there are many methods for collecting fingerprints as well

- The first and most widely used method is photography
- Tape lifting is also another method which is commonly used for the collection of fingerprints
- White instant lifters and many other techniques are used

There are advancements being made for the collection of these fingerprints.
Before these methods are used, we also make use of many alternating light source (ALS) to envision the latent fingerprints present on the surfaces.
And casting methods can also be employed for the collection of plastic fingerprints.
After these collection fingerprints are then compared and analysed with an already existing suspects and victims list and matched.
One of the recent advancements in the field of fingerprints is the recovery and collection of fingerprints from an arson crime scene. Many of us are in a misconception that fingerprints cannot sustain elevated temperatures and get destroyed but it is possible for fingerprints to sustain such high temperatures and remain intact.
The main reason behind this is the formation of soot in arson scenes.
Soot
Soot is a black substance which is created during the combustion process. It is a complex mixture of carbon and many other substances. This soot is the main reason for the preservation of fingerprints in such high temperature regions. Fingerprints contain sweat residues which has some chemical components which retain a little moisture on which the soot comes, and deposits and the fingerprints are preserved.

The components of sweat residues have certain temperatures at which they start degrading.

- Lactic acid degradation is believed to start at exposures of 50-100°C. (O'Hagan, 2018)
- Amino acid components of a fingerprint deposit are believed to begin to show degradation at 100°C and further degradation at 150°C. (O'Hagan, 2018)
- Thermal decomposition of Urea is initiated at 150°C. (O'Hagan, 2018)
- The most fire-resistant component of the fingerprint deposit is salt· (O'Hagan, 2018)
- Water content present in the sweat also quickly evaporates.

So, in this aspect if the soot comes and deposits on the fingerprint it prevents the print from destruction. To find those prints we need to remove the soot deposit on it and there are certain methods for the removal of soot without damaging the fingerprint. Below are certain soot removal methods given in

Table 1.2.(O'Hagan & Calder, 2020b)

Soot removal techniques	Method	Advantages	Disadvantages	Evidence type
2% Sulfo-salicylic acid	Sprayed to fix latent ridges onto their surfaces before being placed into a sonic bath.	Non-porous surfaces. - Can remove heavy soot. - Can be used alongside lifting tape. - Used in conjunction with an ultrasonic bath.	-Does not work if fuels are present.	- Fingerprints
silicone rubber casting (Mikrosil)	Mikrosil is mixed with the Mikrosil hardener, this paste is then applied to the surface and allowed to set before being removed.	-Non-porous textured surfaces -Used on 3D surfaces, or in moulded impressions. -Useful on textured surfaces, can get into the groove.	-Can only be used on very small areas. -Time consuming using a paste and waiting for it hardens. -Expensive to use.	- Fingerprints - Fingerprints in blood.
Washing with water	Lightly washing the surface to remove the soot with water and soap.	Non-porous surfaces.	-Not suitable for porous surfaces. - Wash away amino acids in fingerprint	- Fingerprints

			(so cannot use DFO or Ninhydrin). - Cannot use if fuels are present as they are hydrophilic in nature, repelling the water.	
Absorene	Sponge like material consisting of; flour, salt, water and mineral salts. Manipulated until soft and rubbed in one direction on the soot coated surface	-Porous surfaces.	N/A	-Fingerprint -DNA.
Ultrasonic bath	Contains water, gasoline, toluene, xylene, chloroform, ethanol, acetone, hexane, diluted sulfuric acid and detergent.	-Good for loosening soot not as good for removing it, better to use in conjunction with something else. -Non-porous surfaces. -Fingerprints in or previously in contact with gasoline.	-Objects must be removed from the scene for processing. -Limited with the number and size of the objects to be fingerprinted. -Good for loosening soot not as good for removing it, better to use in conjunction with something else.	-DNA. -Fingerprint
Liquid latex	Liquid latex along with a thickening agent and colorant can be sprayed through a spray gun with a suppressor onto	-Can be used to treat large areas and whole scenes if necessary. -Treatment can be	-Works best on lower porosity surfaces not porous surface. -Must be applied	-Fingerprints -DNA.

	surfaces, only dried can be peeled off, removing the soot.	carried out at the scene. - Peeled away from surface once turns opaque, only takes 5-20 mins. - Most successful technique in literature. - Method can be repeated as many times as necessary. - Some items can be dipped in liquid latex at the lab.	as a spray and has to be thinly coated. -If too much is applied 'skinning over' may occur and damage the evidence. -Sometimes blood staining adheres to the latex and therefore the latex needs to be examined before disposal	
Eraser	Light rubbing of the surface with a pencil, eraser, mostly used on metal objects for 'baked on' marks.	-Non-porous surfaces. -Heavy soot deposition. - 'Burnt on' prints. -Porous surfaces.	-Can rub away ridge detail. -Cannot enhance prints and can only be used. -Not suitable to use on a scene in its entirety.	
Light brushing	Allows carbon to adhere to the oil residue within the print using a fiberglass fingerprint brush.	-Non-porous surfaces. -No skill or training needed. -Fast, cheap and effective. -Often used primarily by CSIs as part of their daily kit. -Always used first to lightly remove excess soot.	-Cannot be used on wet surfaces. -Time consuming to use on a scene in its entirety. -Cannot remove heavy soot deposition. - Cannot enhance prints and can only be used lightly.	-DNA (blood if dry). - Fingerprint

Lifting Tape	Adhesive coated transparent tapes are placed onto the soot coated surfaces, allowing the soot to adhere before the tape and soot is removed.	-Simple and cheap to use. -Lifting tape is always carried within a CSI kit. -Porous surfaces. -Useful to lift greasy prints left in fuels.	Cannot remove heavy soot deposition.	- Fingerprints

These are the methods which are useful in the collection of soot removal without damaging the fingerprints underneath them.

- Washing the surface with water is a very commonly used method but it can result in washing away fingerprints. It is only suitable for non-porous surfaces.
- Tape lifting is also another common method used for soot removal and fingerprint recovery. This method is cost effective and easily portable too it can also lift greasy fingerprints, but it cannot remove soot in case of heavy deposition.
- Light brushing method can also be employed for soot removal on non-porous surfaces. It is cheap and effective, but it can't be used on wet surfaces and time consuming in larger crime scenes.
- Liquid latex method is one of the widely used method for soot removal. This method can be used on large surfaces. if too much is used then there are chances of evidence getting destroyed.
- Absorene is a sponge like material that consists of flour, salt, water and mineral salts. This method is used for removal of soot from porous surfaces and not only fingerprints even DNA can be recovered using this method.
- Mikrosil (silicone rubber casting) is a powder material which can be bought into paste consistency using mikrosil hardener and then applied on the surface. This method is used on non-porous surfaces. This is a very time consuming and expensive method hence it is not employed commonly.
- Ultrasonic bath contains water, gasoline, toluene, xylene, chloroform, ethanol, acetone, hexane, sulfuric acid diluted and detergent. This is better suited for loosening the soot rather than completely removing it on non-porous surfaces.
- 2% sulfo-salicylic acid is sprayed to fix latent ridges onto their surfaces before being placed into the ultrasonic bath. This method can be used for the removal of heavy soot on non-porous surfaces Does not work on the surfaces where fuel is present.
- Eraser -in this method light rubbing of the surface with a pencil eraser, mostly used on metal objects for baked on marks. helps in the removal of heavy soot depositions on non-porous surfaces can possibly rub away ridge detail and destroy the fingerprint.

Collection of Fingerprints from Arson Crime Scene

There are many different methods and techniques to enhance and recover latent fingerprints. However, when substrates have been subject to arson there are many different factors that need to be considered, based on the circumstances of the fire, to assess which enhancement technique is most appropriate. These techniques are analysed and compared in the below Table 1.3 (O'Hagan & Calder, 2020b)

Fingerprint enhancement techniques	Methodology	Advantages	Disadvantages	Temperature
1.Ninhydrin	Ninhydrin crystals dissolved in solvent. Sprayed onto evidence reacting with the amino acids in the sweat to produce purple colour.	-Latent print on porous surfaces. -can be used with DFO.	-At the increased temperature the paper will turn a darker colour. -Proteins denature. -Proteins and amino acids can be removed using water.	500°C
2.DFO	DFO also reacts with amino acid secretions, to form a red coloured fluorescent product.	-Latent prints on porous surfaces. -Can be used with ninhydrin.	-Water can remove amino acids. -Cannot be used on items that have been wet. -Hazardous recommended carried out in fume hood.	500°C
3.Superglue fuming followed by 40	Superglue vapour reacts with eccrine and sebaceous secretions (moisture and salt) within a fingerprint. Polymerizing the print that turns the detail white.	-Non-porous surfaces -Applied to materials not previously possible (wood, leather, fabric) -Dyed with fluorescent stains (e.g. Basic yellow 40) to increase contrast. -portable version available.	-Easily evaporated.	200°C - 750°C
4.Iron powder suspension	Suspension of iron oxide black powder. Adhering to grease and moisture of the print.	-Detergent used to assist in soot removal.	-Not effective at extremely high temperature -Soot makes it difficult to resolve marks.	
	Evaporation of metal (silver, zinc	-Higher contrast and sensitivity	-Expensive. -Not all labs have	

5.Silver vacuum metal deposition.	or gold) and its deposition onto a latent print to form a film under vacuum.	than SPR. -Non-porous surfaces. -Works best on prints exposed to high temperatures -Useful in detecting degraded samples. -Ridge recovery in blood.	access. -Evidence must be taken to lab (size restriction). -Sebaceous secretions not found on the hands (requires contamination).	200°C 900°C
6.Physical developer	Sequence of aqueous solutions; Maleic acid, followed by redox, surfactant and silver nitrate solution. Adhere to the lipid and fatty acids in sebaceous secretions.	-Used on wet materials. -Can be used if wet with petrol. -Porous surfaces.		100-200°C

Challenges faced during the collection of fingerprints from Arson Crime Scenes:
Recovery of a fingerprint from an arson scene itself is a big challenge. we have seen many different methods used for the collection of fingerprints in the places which underwent arson but all these methods have some setbacks which makes it difficult for the recovery process.

Here are some of the challenges that we come across:

- As the temperature increases the water content present in the fingerprints start evaporating, similarly all the other particles present in the sweat residue start degrading too which can result in the deterioration of fingerprints.
- The longer the exposure to the temperature, the lower the quality of the ridge detail the fingerprint exhibits. (O'Hagan, 2018)
- The presence of volatile accelerants also affects the fingerprints, long immersion in flammable liquids destroys most part of the latent fingerprints by dissolving the fatty acid constituents. (O'Hagan & Calder, 2020b).
- The fire extinguishing methods should also be taken into consideration, because whenever water is

used on the surfaces for extinguishing fire it could possibly damage the fingerprints present on these surfaces.

After taking all these factors into consideration we have many different methods for the recovery of fingerprints, one of the most successful methods is the use of small particle reagent (SPR).

SPR- Small Particle Reagent

SPR is an effective and an extensively habituated system for developing fingerprints exposed to wet shells. Conventional SPR was grounded on molybdenum disulfide. Zinc carbonate, titanium dioxide and ferric oxide are some other accoutrements used in SPR. (Dhall et al., 2013)

Fluorescent SPR is better than the conventional system since the discrepancy and the visibility are largely bettered in the former. Fluorescent small flyspeck reagent composition not only detects faint and weak prints, but it also develops idle finger marks on multi-coloured shells. Small flyspeck reagent fashion is accessible, effective and cost-effective system to develop finger- marks on wide range of substrates of forensic significance. The system is grounded on the adherence of fine patches of treating result to the unctuous or adipose factors of idle finger- mark remainders. The effectiveness of fashion can be bettered by adding fluorescent colour in treating result. . .(Bumbrah, 2016). Conventionally, SPR consists of a suspension of fine molybdenum disulfide patches in a waterless medium containing soap result (as surfactant). These patches cleave to adipose factors of idle finger. .(Bumbrah, 2016). as the temperature increases the water content present in the fingerprints start sinking, also all the other patches present in the sweat patches start de mark remainders and form a slate deposit. This system is also considered as wet powdering system. Conventional SPR composition is less effective in developing idle finger- marks on multi-coloured shells due to poor discrepancy. . .(Bumbrah, 2016).Hence numerous different SPR compositions were discovered the use of tergitol- 7 soap in combination with choline chloride in molybdenum disulfide grounded SPR composition was suggested. . .(Bumbrah, 2016). It was also observed that choline chloride was not an essential element of SPR composition and use of suspense of molybdenum disulfide dispersed in Manoxol OT grounded SPR composition was suggested. . .(Bumbrah, 2016)*)*. Another study recommends the use of tergitol- 7 in zinc carbonate grounded modified SPR composition. Generally, surfactant is a synthetic soap and contains certain organic composites which can be dangerous for druggies or terrain. The use of Saponin (natural soap), in place of synthetic soap, in two SPR compositions grounded on watercolour greasepaint and introductory zinc carbonate was suggested to develop idle finger marks on a wide range of shells including compact discs due to its durable shelf life and high quality of developed prints.3 titanium dioxide grounded SPR in tergitol was also recommended for developing idle finger- marks on wet plastic bottle. . .(Bumbrah, 2016). The use of titanium dioxide grounded wet greasepaint suspense was suggested for developing crippled marks on dark, smooth non-porous shells also. Some authors used titanium dioxide grounded SPR composition to develop idle finger- marks on glass, plastic and essence shells. . .(Bumbrah, 2016). Black and Gray point greasepaint grounded SPR compositions in terizide(dish washing liquid) was also reported. .(Bumbrah, 2016). tableware- slate SPR composition was recommended to develop idle cutlet- marks on simulated vehicle- borne extemporized explosive bias order to resolve the problem of discrepancy on dark shells with conventional SPR composition, zinc carbonate- grounded composition was recommended for developing prints on dark and wet shells. Zinc carbonate grounded SPR composition was also used because zinc carbonate causes negligible effect on resulting fluorescence. .(Bumbrah, 2016) comparative study suggested the use of zinc carbonate and cyano blue dye based SPR composition over other processing techniques (iodine fuming, cyanoacrylate fuming, powder dusting) for developing latent finger-marks on both emulsion and non-emulsion sides photographic film.(Bumbrah, 2016)

Blood and its composition

Blood is a fluid connective tissue which comprises various components i.e., different cell types collectively known as blood cells, which are suspended in a watery fluid called serum. t is composed of 55% of plasma which is the fluid component of blood and 45% of blood cells which includes red blood cells, white blood cells and platelets which are the solid components of blood. Plasma itself consists of 92% of water, vital proteins involved in many functions such as blood clotting, fighting infections and transporting substances make up 7% of plasma, remaining 1% contains mineral salts, sugars, fats, hormones and vitamins. The red blood cells (also known as erythrocytes) possess the pigment molecule haemoglobin that gives blood its colour and is responsible for the transport of oxygen and carbon dioxide. The platelets are lower than the red blood cells and unlike them they're able of amoeboid-suchlike movement. Platelets are responsible for the clotting process and the output of chemical growth factors that maintain the integrity of the blood vessels. (Amendt, 2010)

White blood cells are of different sorts, all of them have amoeboid movement and are capable of providing immunity. All white blood has nuclear and mitochondrial DNA.

Deoxyribonucleic acid (DNA)

DNA is a genetic material which is made up of a polynucleotide chain twisted in a helix form made of nitrogenous bases which are of two types i.e. purines and pyrimidines. It also contains phosphate and deoxyribose sugar which forms the backbone of DNA. This molecule is the one which makes each individual unique and identifiable. Short Tandem Repeats (STR's) are sequences of DNA that are repeated typically 8-10 nucleotides and there can be thousands of them within a genome, located in the non-coding region of the chromosome33. The number of repeats at any given STR loci are largely variable with the largest amount of polymorphism (O'Hagan & Calder, 2020b)

Degradation of DNA

There are many different forms of DNA degradation that can occur when samples are exposed to higher temperatures. The extreme temperatures that are produced can cause hydrolytic cleavage of phosphodiester bonds. Phosphodiester bonds link the 3' carbon of one sugar molecule to the 5' of another; Producing the strands of nucleic acid that make up DNA. The longer the strand of DNA the higher the chances of cleaving to occur. As blood is exposed to the ambient environment outside the body, the process of degradation occurs, where the haemoglobin present within the blood undergoes an oxidisation process and becomes oxyhaemoglobin. The extreme conditions of fire exposure may increase the rate of degradation and the oxygenation process of haemoglobin. (Bastide et al., 2021)

General techniques to retrieve DNA from Crime Scenes

The basic methods to collect blood evidence found in the crime scene is mentioned in the tabular column below:

Table 1.4 shows the different methods to retrieve blood from crime scene (O'Hagan & Calder, 2020b)

DNA enhancement techniques	Methods	Advantages	Disadvantages	DNA type
Bluestar	Uses modified luminol reagent molecules to produce chemiluminescence (blue light emission). Luminol reacts with hematin; produced when bloodstains age	- Detect severely burnt blood stains -Highest light intensity (but decreases rapidly) Very good with aged samples - Can be re-sprayed	Short shelf life Scene must be darkened to see emission (not always possible) - False positives in presence of copper salts Luminescence only lasts few minutes	Blood - 800°C
Kastle Meyer	First phenolphthalein reagent is dropped onto cotton bud containing sample, followed by hydrogen peroxide. In the presence of blood, the swab turns pink. The ion in the blood and the presence of hydrogen peroxidase oxidises phenolphthalin into phenolphthalein	-Presumptive blood test Effective and reduces the amount of evidence recovered - Non – destructive - Colour change is instant, less than 30 seconds	Selective, cannot use over the whole scene - results harder to obtain if presumptive chemicals used Only presumptive not conclusive False positives; saliva, metals and malt extract -All swabs turn pink eventually as they oxidise on their own in air	
Hemascein	Fluorescein based product, emits	Long shelf life	- low light	Blood

	green when excited with blue light	Detect severely burnt blood stains Outperforms Bluestar	intensity emission	904℃
Benzidine	Benzidine base solution is made in acetic acid, dropped onto filter paper containing a sample, followed by drop of hydrogen peroxidase; the colour change of blue is apparent in the presence of blood. Can be carried out by officers Benzidine paper has a shelf life of a year but can be revitalized by again being soaked in benzidine solution	Quick and easy technique carried out at the scene	Carcinogenic hazardous to man False positives can be produced e.g. vegetable peroxidases Specific to peroxidases but not blood itself	Blood
PCR	Amplification of DNA samples to create DNA profile	- Creates DNA profiles for comparison Create multiple copies of DNA over short period of time Can be used on any sample type	Will not work if the DNA is too degraded or fragmented Expensive Samples recovered from scene Knowledge of DNA sequence to produce primers	Blood Semen Saliva
Real time PCR	Fluorescence probes bind to targeted DNA sequence, once synthesised light is emitted. The higher the wavelength the more binding, the more DNA present, the less degradation.	Multiple sequences can be analysed at once Can analyse	Designed primers have to have similar annealing temperatures Only quantitative	Blood Saliva Semen

		mixed DNA samples Only takes 90 minutes Can save time if DNA is too degraded no further analysis carried out	- Will not identify suspect	
Amido black	Protein stain that will react with the proteins present in blood, but not specific to just blood. Turns proteins dark blue/black colour, increasing contrast for identification	Enhances patterns in blood, fingerprints and footwear Porous and non-porous surfaces Used at the scene but mostly at the lab	Only used to enhance patterns in blood such as fingerprints and footwear Blood must be on light coloured surface to create effective contrast Corrosive	Blood Fingerprints in blood
Leucocrystal violet	Reacts with the heme- group in blood to form dark blue/purple product.	Applied as a wash spray Presumptive blood test Typically used on porous surfaces	Contains hydrogen peroxide, if used on heavy blood stains foaming can occur and detail can be lost Not appropriate for nonporous surface	Blood Fingerprints in blood
Luminol	Luminol is sprayed onto suspected surface, giving blue fluorescence under UV light, blood catalyses oxidation reaction in luminol	Detects blood at high temperatures 1000℃	Not specific to blood, bleach, metals and plant peroxidases can cause luminol to	Blood 1000℃

			fluoresce	
ABA card Hema Trace test strip	If haemoglobin is present a mobile antigen-antibody complex is formed with a monoclonal antibody. This complex migrates to test area T where the polyclonal complex is immobilized forming an antibody-antigen antibody sandwich and a purple band is formed.	Applied at the scene and in the lab - Results in 10 minutes Positive results even after being treated with luminol Tests with animal blood gave negative results	Detection limit of 0.05 ug/ ml blood Less sufficient when sample subject to heat negative results to human saliva and urine, only works with blood	Blood

Challenges in collecting blood evidence and retrieving DNA in Crime Scenes

In cases of crimes involving blood, perpetrators set fire in the scene of crime to deteriorate the evidence present there. Especially when the blood evidence is exposed to higher temperatures, the probability of retrieving DNA evidence from it becomes very difficult and that becomes a major problem for the crime scene investigators. As blood is exposed to the ambient environment outside the body, the process of degradation occurs, where the haemoglobin present within the blood undergoes an oxidisation process. (Bastide et al., 2021)

These chemical changes to the haemoglobin occur in two stages, i) Hb-O2 to MetHb and ii) MetHb to Hemichrome (HC). As this chemical change takes place, physical changes occur respectively, where the blood transforms from a rich dark red colour to black in appearance and the viscosity changes from liquid, to solid as a result of coagulation. The extreme conditions of fire exposure may increase the rate of degradation and the oxygenation process of haemoglobin.[2] High environmental temperature affects the quantity of extracted DNA from different stain but less effect on the quality of extracted DNA. (Bastide et al., 2021)

But recent research reveals that blood even after exposure to temperatures greater than 1000℃, we can retrieve from those.

Advancements in detecting blood from arson crime scenes

The assumption that blood on exposure to temperatures of or exceeding 1000℃ cannot be retrieved from scene of crime with DNA has already been disproved. It is shown that Klein et al. verified complete DNA profiles on almost all test objects exposed to temperatures up to 700 °C and in 60% of the cases exposed to 1000 °C. Tontarsky et al. (O'Hagan & Calder, 2020b)

also attained complete DNA profiles after exposure to temperatures up to 800 °C. Prerequisite for carrying out these forensic and legally relevant serological examinations was of course the prior localization of the bloodstains (Klein et al., 2019).

There are significant studies which shows that DNA in the blood remains intact even after exposure to high temperatures of 800°C. This could be because of the double helix structure of DNA but then detecting the same using presumptive tests is not possible as it shows negative results for the same. In such cases in order to extract DNA from the degraded blood liquid latex method could be used.

Latex lifting method

Liquid latex lifting method is a fast, simple, inexpensive, and gentle way to preserve traces; as both soot and bloodstained surface may adhere to the pulled off latex film, a joint examination of the object and latex used is recommended.

In the experiment conducted by Anke Klein, Oliver Krebs, Axel Gehl, Judith Morgner, Louisa Reeger, Christa Augustin and Carolin Edler to understand the effectiveness of liquid latex lifting method of blood, they exposed 11 different objects with three sets each where first and second was stained with human blood and third was unstained sample such as hammer, screwdriver, jackknife, roof tile, porcelain, smooth tile, stone tile, glass bottle, cast iron pipe, copper pipe, and leather shoe to three different temperatures such as 300°C , 700°C and 1000°C observed the results as follows:

On the basis of intensity and dissemination of objects results were formulated, it was found out while comparing the results before and after the application of liquid latex on the test objects, that the reference samples from test series 1 (without bloodstains, before using latex) displayed chemiluminescence in 25 of the 33 cases; however, following a latex application, chemiluminescence could only be verified on 13 of the 33 reference samples. There were thus fewer false positive results detected. Aside from the reference samples, two of the 66 objects with bloodstains also showed (only) faint chemiluminescence after the luminol and liquid latex application—the shoe (side view or perspective 2, respectively), from the 300 °C test, each in the first and second test series. An intense luminescence could be observed in the second test series on 58 (88%) of altogether 66 objects which had been covered with blood. Only 22 (66%) from a total of 33 objects from the first test series emitted an intense chemiluminescence. The application of liquid latex thus showed more intense visualization of the luminescent reaction.

Hence, they concluded that, using luminol, traces of blood can be detected even after exposure up to a temperature of 1,000 °C. The additional use of liquid latex is advantageous. Traces of blood can be localized and often more clearly depicted through the combined application of luminol and the liquid latex lifting method—the examination of the latex lift tends to produce better results with fewer artifacts. This should be taken into consideration when investigating crime scenes involving fire. (Klein et al., 2019)

Another study by Larkin, Marsh, and Larrigan (New Scotland Yard, GB) in 2006 speaks about using liquid latex for lifting bloodstains from larger surface area as described by Hans Gross where he used gum arabic solution to lift the bloodstains from glass articles or special paper once it has been dried.

Small items can be dipped into latex. This is useful for items that are collected and taken to the laboratory. The time taken for the drying of liquid latex depends on the liquid used and the thickness of the layer. Sometimes the bloodstain can be found on the latex, depending on the adhesion of the blood to the surface and the latex. Therefore, the latex should be examined before it is disposed. If stains are on the latex, it is important to know that the storage time of the dried latex is limited. Such samples should be examined right away. If latex lifts are to be stored, it is best to place them individually on a non-latex surface. Otherwise, layers of lifted latex will adhere to one another.[16]

For large areas such as walls it is helpful to use a compressor system in order to deposit the latex in a thin layer. Hence, it usually dries quickly. Compressor systems are also used forensically for the application of chemicals in searching techniques (Luminol, Fluorescin) and enhancement techniques (Amido Black, Fuchsine, Titanium Dioxide). The costs are reasonable for a regular compressor. The advantage of spraying is the application to large areas and the shortened drying times due to the thinner layers. Because of the gentleness of the latex, this procedure can be repeated as often as needed. This method is also very inexpensive. [16]

Reflected Infrared Photography

The absorption of infrared radiation by haemoglobin and its derivatives was first examined in 1935 by Merkelbach. It was found that oxyhaemoglobin (Hb-O2) and methaemoglobin (MetHb) can absorb a broad range of wavelengths including infrared radiation, while carboxyhemoglobin (COHb) is unable to absorb infrared. One erythrocyte consists of approximately one million haemoglobin molecules where these erythrocytes are held tightly with haemoglobin. The formation of MetHb indicates the decomposition of blood components via an aging process. In a fresh bloodstain, haemoglobin predominantly exists as oxyhaemoglobin (Hb-O2). In this state, blood can absorb light in the visible spectrum with three main peaks: 415 nm, 540 nm and 575 nm. As the blood ages, its ability to absorb light changes most rapidly within the 540–575 nm bandwidth due to the oxidation of Hb-O2 to MetHb, and then to hemichrome (HC*)*. (Bastide et al., 2019)

Kuenstner and Norris discovered the peak absorption for MetHb and Hb-O2 occurs at approximately 630 nm and 930 nm respectively, with MetHb absorbing approximately 10 times more infrared radiation than Hb-O2. Horecker examined the differences in wavelength absorption for different isolated haemoglobin states in hemolyzed human blood throughout the visible and infrared spectrum. The results indicated that MetHb has a greater absorption rate of radiation than Hb-O2 in the infrared region (≈900 nm) with MetHb absorbing at 0.794 and Hb-O2 absorbing at 0.296 respectively, at neutral pH levels. (Bastide et al., 2019)

A comparison between the absorption properties of blood between the visible and infrared spectrum at heat exposure of 200 °C temperature profile indicated that there is an increase in relative absorption in the infrared region than in the visible light range (≈0.58 in the infrared region, in comparison with ≈0.41 in the visible spectrum). This result correlates with the results achieved by Horecker , where MetHb can absorb a greater amount of infrared light than Hb-O2, indicating the increased presence of MetHb within whole blood at higher temperatures. (Bastide et al., 2019)

The affinity of fire-exposed blood to absorb infrared radiation may be related to the biochemical changes that occur when blood is exposed to heat. This study found that an increased rate of degradation of blood emerges through the ionisation process of Hb-O2 to MetHb enabled by heat exposure. As MetHb prevalence is increased during the process of degradation and has an affinity to absorb infrared radiation greater than Hb-O2, the application of reflected infrared photography becomes a suitable method of bloodstain evidence recovery in fire scenarios. (Bastide et al., 2019)

From a practical perspective, when photographing blood that has been heat affected >200 °C, long pass optical filters equivalent to a Wratten 87C would provide a suitable transmission range, but also dependant on the spectral sensitivity of a modified digital camera and sensor. Understanding the infrared absorption properties of blood when exposed to heat from fire sources, aids in the development of more effective forensic photography and crime scene investigation work. (Bastide et al., 2019)

Conclusion

From this literature the recovery of fingerprints from elevated temperatures is possible and this has been adapted in real life crime scenes too, this is because the dermal ridges can sustain high temperatures. Despite this, recovery of fingerprint from arson crime scenes is not the primary approach of the forensic investigators because it appears there is no soot removal techniques or fingerprint development techniques that will have a one solution to fix all approaches. But still to date there have been an extensive range of studies about the new methodologies to recover fingerprints from arson crime scenes and the SPR method is one such technique which is proven to show more success rate compared to others.

Also, retrieval of DNA from blood exposed to extreme conditions could be successfully done using liquid latex lifting method as it helps in removing the soot deposition from the blood. We could also observe that blood that has been exposed to temperatures above 800°C shows negative results for the preliminary tests but still efficiently could be extracted using soot removal techniques. As blood degrades and undergoes oxidation process on exposure to high temperatures, it can be captured using reflected infrared photography and could be used for understanding the characteristics of blood, also for documentation and courtroom presentation.

Discussion

Small particle reagent is one of the advanced versions for the recovery of fingerprint from arson scene. While molybdenum sulphide is a traditional SPR method there have been many new SPR techniques based on zinc carbonate and titanium oxide. SPR method is especially convenient for the collection of fingerprints found on the wet surfaces which is advantageous in those arson places where the fire extinguishing method is liquid (water) and also on the surfaces which contains liquid accelerants. Powder dusting method one of the most widely used methods for developing fingerprints was found to be least effective on these surfaces because this technique is useful for collecting uncontaminated fingerprint marks. This was found in the study conducted by the *department of chemistry, university teknologi Malaysia* collaboration with *PDRM forensic laboratory,* which after a ground experiment concluded that spr was better compared to other developing methods.

While this was for the fingerprint developing, we also see many methods for the removal of soot from the surfaces underneath which the fingerprints are preserved. we have common methods like tape lifting, erasing, silicone rubber casting which can be used but use of absorene on porous surfaces is an easy process without any disadvantages. Liquid latex is also a recommended method for soot removal, but it has limitations one of which is if liquid latex is heavily coated on surface, it can damage the fingerprint ridges.

In arson crime scenes, although recovery of fingerprints and blood evidence is a difficult task, understanding the stages of fire and having a knowledge on various soot removal techniques makes it much easier. When we consider retrieving blood from the scene of crime and extracting DNA from the same, we could clearly see that using luminol can easily detect the traces of blood exposed to temperatures above 1000°C and further extracting blood could be efficiently performed using latex lifting method as it is very simple and inexpensive method for removal of soot. Once the blood has been retrieved using latex lifting method, success rate of extracting DNA from those samples are high.

Reflected Infrared Photography can be used in arson crime scene to visualise the blood and capture the same as it provides higher contrast and also it is a better method compared to the visible light photography. There are numerous experiments and studies that reveals using infrared photography over visible light photography would be successful in capturing the traces of blood exposed to high temperatures.

From the above discussions, we could say that implementing advanced techniques in crime scene investigations especially in arson cases could help in solving a larger number of criminal cases where the evidence collection poses a major difficulty to the crime scene investigators.

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