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Evaluation of the solvent black 3 fingermark enhancement reagent: Part 2 — Investigation of the optimum formulation and application parameters

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ABSTRACT

A comparison is reported of the relative effectiveness to two formulations of the solvent black 3 (Sudan Black) reagent used to enhance grease contaminated fingermarks. These experiments compared the currently recommended ethanol-based formulation with a lower flammability system based on 1-methoxy-2-propanol (PGME) using natural, deliberately sebaceous and grease contaminated marks across a range of surfaces. It is shown that overall the PGME-based formulation was significantly better at producing good ridge detail on most surfaces for both natural and deliberately sebaceous prints, and for contaminated prints the ridge detail obtained with the PGME-based formulation was as good or better than that obtained with the ethanol formulation.

Several smaller experiments were also carried out in order to provide additional information on the solvent black 3 process. These showed that solutions of age up to 2 years can still develop good ridge detail, but the colour of the stained mark may vary. It was also demonstrated that the currently recommended 2 minute treatment time often resulted in very heavy background staining and in practice significantly reduced treatment times can be recommended according to the nature of the surface present.

1. Introduction

Solvent black 3, alternatively known as Sudan Black B, is currently recommended as a fingermark enhancement reagent for use on grease contaminated surfaces. Although the process is a simple one, it is probably the least researched and reported of all widely recommended enhancement processes.

Solvent black 3 is a diazo dye composed of two naphthalene rings bound by an azo bond (N═N) as shown in Fig. 1. One naphthalene ring is coupled to a phenyl ring by a second azo bond and the other to two secondary amino groups, which are bound to a quaternary carbon holding two methyl groups. Solvent black 3 consists of a mixture of two isomers (para- and ortho-), the para isomer being more strongly basic than the ortho- form because the ortho-isomer can form intramolecular hydrogen bonds. Para-ortho isomerisation can be initiated by visible light, giving the molecule strong absorption across in the visible region of the spectrum. In its solid form solvent black is a dark brown-black powder with a maximum absorption of 596–605 nm [1], when dissolved in solvents it is a deep blue-black colour.

Although related compounds such as Sudan III (solvent red 23) and Sudan IV (solvent red 24) were synthesised and commercially available in the late 1800s/early 1900s, solvent black 3 was not introduced until the mid-1930s. Industrially, the dye is used for the colouration of organic solvents, printing inks, laquers and a range of fats and wax substances [1].

Soon after its introduction the dye was proposed as a stain for fats and various other microbiological applications and has been successfully utilised in this role to this date. The use of the dye as a biological stain results in fatty matter being stained a deep blue/black colour. When used as a stain, solvent black 3 is applied from a solvent in which it is sparingly soluble. As solvent black 3 comes into contact with materials in which it is strongly soluble (such as fats), the lipophilic dye molecules preferentially transfer into the fat from the solution. Although the primary action of solvent black 3 is to stain lipids by dissolving in them, it can also stain materials ionically. This may result in some background staining.

The first published use of solvent black 3 for the development of latent fingermarks was by Mitsui et al. in 1980 [2], who used solvent black 3 in a mixture of ethylene glycol, ethanol and water to develop marks on water-soaked paper items. The performance of solvent black 3 was found to be superior to ninhydrin on this type of article. A further study by Stone and Metzger [3] compared solvent black 3 with black magna powder to develop marks on wetted porous items. In this comparison magna powder was found to give the best results.

In the early 1980s the Home Office Central Research Establishment (HO CRE) conducted an evaluation of over 60 biological dyes for their ability to develop latent fingermarks on both paper and thin polythene surfaces such as carrier bags [4]. These studies identified solvent black 3 as having particular potential for the development of fingermarks, in

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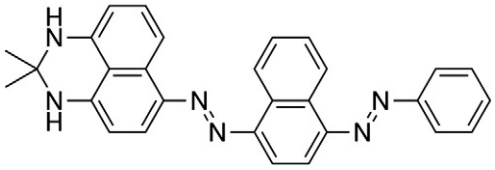

Fig. 1. Solvent black 3 structure.

this case the promising results were obtained on polythene. An operational trial was conducted to compare the effectiveness of solvent black 3 with the two existing techniques recommended for polythene at the time, vacuum metal deposition (VMD) and small particle reagent (SPR) [5]. An initial phase of the work suggested that solvent black 3 could give superior results to VMD on polythene bags and the study was extended to a full operational trial. In these more detailed studies both VMD and SPR were found to be significantly more effective than solvent black 3 and the reagent was not considered further for these applications.

A subsequent re-evaluation of the reagent found that solvent black 3 had potential for developing fingermarks in cases where surfaces were contaminated and powdering was not possible. Examples of this type of surface included takeaway food containers and carbonated drinks cans. The process, in the form of solvent black 3 dissolved in a water/ethanol mix, was subsequently included in the Home Office Manual of Fingerprint Development Techniques [6] and recommended for these applications.

Another re-evaluation of a range of lipid reagents for use on non-porous surfaces was conducted in 1999–2000 [7]. This study investigated several other lysochromes including Oil Red O (solvent red 27) and Sudan III (solvent red 23). These studies confirmed solvent black 3 to be the best performing of this type of lipid dye on non-porous surfaces and it was not considered worthwhile initiating development of formulations based on other dyes. Instead, research was initiated to develop a formulation based on a less flammable solvent than ethanol that could allow the reagent to be safely used at scenes. From this research 1-methoxy-2-propanol (PGME) was identified as an appropriate solvent. Further laboratory trials indicated that there was no discernible difference between this and the ethanol-based formulation. This formulation was subsequently published for operational use [8].

The trials resulting in the publication of the PGME-based formulation of solvent black 3 primarily considered natural fingermarks, although attempts were made to identify a means of providing consistent levels of 'realistic' surface contamination. In a more recent study [9], several scenarios involving the presence of contaminants were considered, including fingermarks in contaminant on an otherwise clean surface and natural fingermarks being deposited onto a contaminated surface. The results of this confirmed that solvent black 3 was generally the best performing reagent of its type on light coloured, grease contaminated non-porous surfaces, although this study did not include comparisons of the PGME-based formulation against the ethanol-based formulation.

Other than research by the UK Home Office, there has been very little published work on the use of solvent black 3 for fingermark enhancement. One independent study assessed the effectiveness of solvent black 3 in both powder and solution form, with the solution treatment found to be more effective. Marks up to 75 days old were successfully detected on porous surfaces using this approach [10]. The authors also recommended the reagent for development of lipstick marks.

In preparation for the new edition of the Home Office Manual of Fingerprint Development Techniques, solvent black 3 was further re-evaluated to fill gaps in the knowledge relating to the operational use of the process. The first part of this study [11] investigated the fundamental interactions of the ethanol- and PGME-based solvent black 3 formulations with fingermark constituents and with real fingermarks at a microscopic level to see if any differences in behaviour could be identified. The outcome of this initial phase was that both solvent black 3 formulations appeared very similar in the way that they interacted with both fingermark constituents and with real fingermarks and could not be distinguished in this respect.

Table 1
A summary of the variables investigated in the main experiment.

15 donors	6 surfaces	3 ages	3 types of mark	
	WMCC	1 day	Natural	
	WCT	1 week	Sebaceous	
	GLA	1 month	Contaminated	Olive oil
	HGEP			Butter
	LBLW			Vegetable fat spread
	GPW			Hand cream

The study reported in this paper considers whether the lower flammability PGME-based solvent black 3 formulation could replace the ethanol-based solvent black 3 formulation for all currently recommended operational purposes as well as use at scenes of crime, thus reducing the overall number of formulations required.

Two secondary experiments examining specific aspects of the operational application of the process are also reported:

1. An investigation to establish if the age of solution has an effect on the ability of the solvent black to stain the fingerprints.
2. An investigation to identify the optimum staining time for different types of surface, so as to minimise background staining and maximise the ridge detail of the fingermarks.

2. Materials and methods

2.1. Summary

In the main experiment the ethanol- and PGME-based formulations of solvent black 3 were directly compared through their ability to enhance fingermarks:

- From 15 donors of mixed age, background and gender
- On 6 different surfaces
- Across 3 different ages: 1 day, 1 week and 1 month
- Using 3 different kinds of fingermark: natural, deliberately sebaceous and contaminated
- Using four different contaminants: Olive oil, butter, vegetable fat spread and hand cream (Table 1).

2.2. Fingermarks

Natural fingermarks were obtained from 15 donors of varying ages, genders and backgrounds. The marks deposited in this study are intended to model those encountered during casework. Each donor deposited fingermarks at least 30 min after last washing their hands,

Table 2
Six surfaces selected for comparison of solvent black 3 formulations.

Surface	Acronym
White melamine coated chipboard	WMCC
White ceramic tile	WCT
Glass (toughened)	GLA
Hard grey engineering plastic (PVC)	HGEP
Light brown laminated wood	LBLW
Gloss painted wood (white)	GPW