Development of Reagent Test Kit for the Enhancement of Shoeprints at Crime Scene

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ABSTRACT: Footwear marks constitute important trace evidence found in major crime scenes. Latent footwear marks require efficient treatments for possible shoe sole pattern identification in crime analysis. This study consisted of two parts: enhancement of footwear prints and development of reagent test kit for the enhancement of shoeprints at crime scene. Chemical enhancements were carried out on shoe soles subjected to muddy and bloodstained areas. The shoeprints were formed on nine different matrices including porous and non-porous surfaces. Eighteen reagents were tested for the enhancements of muddy and bloodstained shoeprints. Reagents employed on muddy prints reacted with either metal ion, amino acid or other component while reagents employed on bloodstained prints were sensitive to protein, peroxidise and amino acid. Among the eighteen reagents, leucomalachite green and patent blue were chosen as the best reagents in enhancing bloodstained shoeprints while potassium ferrocyanide and sudan black were the best enhancement technique for muddy shoeprints. All four reagents were effective on both porous and non-porous surfaces. However, the reagents were not applicable on dark background surfaces. These reagents were used for the test kit development for crime scene work. The test kit was named as SPECK (Shoeprint Enhancement Chemical Kit) and consisted of chemical reagents, instruction, safety precaution, and personal protective equipments such as gloves and masks. The reagent test kit developed was found to be reliable for screening purposes, rapid to carry out and specific as well as reasonably cost.

Keyword: shoeprint chemical enhancement, crime scene toolkit, forensic chemistry

Introduction

When one object makes physical contact with another, it may leave some of its physical characteristics on the recipient in the form of an impression [1]. Marks and impressions evidence can be generally defined as the signature (pattern) of an object that is left in another object when the two have come in contact with one another [2]. Footwear creates marks at the crime scene called as shoeprint and can be extremely informative to the forensic investigator. The sole of footwear picks up various kinds of material as a person walks, and this is readily transferred to other surfaces, creating an impression that can reveal the pattern on the sole [3].

Many footwear have soles with distinctive tread patterns, whereas others are smooth. Footwear evidence can be extremely valuable in associating perpetrators of crimes with the crime scenes. There may be shoeprints at and near the entry points to a crime scene, at the scene, and at and near the exits. In fact, there are many more shoeprints at and around crime scenes than are ever discovered or collected. It is reasonable to conclude that there are more potential footwear marks at crime scenes than there are fingerprint impressions.
Latent or unclear shoeprints are usually harder to be detected by the naked eyes and are frequently overlooked by law enforcement personnel. Moreover, most of the footwear impression or shoeprints evidences are formed on static and permanent surfaces; it is therefore not possible for crime scene officers to bring back the evidence. Hence, a means of enhancing the footwear impression must be undertaken. Bloodstained and muddy shoeprints recovered at crime scenes could be enhanced using chemical reagents specific for the detection of either blood or mud. Thus, various types of analysis on stained shoeprints must be carried out to find out the best enhancement method.

This study was therefore undertaken to develop a reagent test kit for the enhancement of shoeprints at crime scene. Chemical reagents that are specific for detection of bloodstained and muddy shoeprints were investigated for their effectiveness on various matrices for the enhancement of latent shoeprints.

Experimental

Materials: In this study, nine materials were used as surface matrices of shoeprints, which consisted of five porous surfaces and four non-porous surfaces (**Table 1**). Blood and mud were used as stained area throughout the study. Mud was obtained from an identified location around the Faculty of Science, UTM while screened, blank expired blood (group A+ and O+) in plastic packages of 300 mL were obtained from Hospital Sultanah Aminah (HSA), Johor Bahru and Hospital Tengku Ampuan Rahimah (HTAR), Klang to produce muddy and bloodstained shoeprints respectively. A Nikon D60 L11 digital camera (18-55 mm f/3.5-5.6G VR Japan) were used for the image capture of both untreated and treated shoeprints, and a ruler (inch and centimeter scale) were used to indicate the scale size in the photographic shots. A North Star size 4 patterned shoe sole was used to form the stained shoeprints on the matrices (**Fig. 1**).

Table 1: Nature of matrices used in this study

Type of Surface Matrix	Nature of Matrix
A4 White Paper	Porous
Cardboard	Porous
Carpet	Porous
Food Wrapper-Porous	Porous
Food Wrapper-Non-Porous	Non-Porous
Linoleum-Dark	Non-Porous
Linoleum-Light	Non-Porous
Plastic	Non-Porous
Tiles	Non-Porous

Fig. 1: Bottom shoe sole pattern Different views of North Star shoe used in the study

Chemicals: Chemicals used in this study comprised of patent blue VF, 5-sulfosalicylic acid dihydrate, leucomalachite green, and sudan black B (Sigma-Aldrich - Steinheim, Germany), and potassium hexacyanoferrate (II) from QRëC, New Zealand. All chemicals used were of analytical grade. Solvents used included analytical grade glacial acetic acid from HmbG Chemicals, hydrochloric acid from J.T. Baker (Philipsburg, USA) and ethanol from F.A.D Ltd (England, UK), 2N nitric acid (QRec, New Zealand), 30% hydrogen peroxide, and diethyl ether. Double distilled water was prepared in the laboratory.

Procedure: Muddy shoeprints were enhanced using nine different reagents which react with either metal ion, amino acid or other components while bloodstained shoeprints were treated with nine other reagents which react with either peroxidase or protein. The best enhancement reagents were identified for each muddy and bloodstained shoeprints. A crime scene toolkit was using selected reagents tested. The toolkit was named and came together with personal protective equipments as well as user manuals.

Muddy shoeprints were enhanced using potassium ferrocyanide and sudan black reagents. Two types of solutions were prepared for shoeprint enhancement using potassium ferrocyanide reagent. Solution A was prepared by mixing hydrochloric acid (10 mL) and ethanol (90 mL) and for solution B, potassium ferrocyanide (5 g) was dissolved in deionised distilled water (100 mL). The articles

bearing latent muddy shoeprints were sprayed with solution A followed with solution B [4]. Sudan black dye solution was prepared by dissolving sudan black B (3 g) in ethanol (250 mL). The matrices containing impression were sprayed with this solution and washed with distilled water [4].
Leucomalachite green and patent blue reagents were chosed to enhance bloodstained shoeprints. Leucomalachite green staining solution was prepared by mixing leucomalachite green (1 g) with diethyl ether (70 mL), glacial acetic acid (0.5 mL) and 30% hydrogen peroxide (0.3 mL). The matrices were sprayed until completely covered and the matrices were allowed to air dry. The green coloured development of impressions occured within 10 seconds [5]. Patent Blue dye solution was prepared by dissolving sulfosalicylic acid (20 g) and patent blue VF (2 g) in distilled water (1 L), resulting in a greenish-blue solution. The objects were stained by spraying the item with the dye solution for approximately 1 minute followed by rinsing it with distilled water [6].

Photographs of the enhanced prints were taken as the matrix dried up. The length, width, and patterns of the shoeprints were observed and recorded after the enhancement. In order to ensure an objective way of comparison, photographs were taken before and after treatment [1]. Besides, the purpose of taking a photograph of shoeprints is to record it for possible future comparisons with a suspect shoes. So a scale should be available in the photograph [7].

Results and Discussion

The best chemical enhancements of bloodstained and muddy shoeprint on various matrices are showed in **Table 2**. **Fig. 2** and **Fig. 3** show enhanced bloodstained shoeprints using leucomalachite green and patent blue reagents respectively. While enhanced muddy shoeprints using potassium ferrocyanide and sudan black were shown in **Fig. 4** and **Fig. 5** respectively.

Table 2: Results of stained shoeprint enhancement with four different reagents

Matrices/Reagents	Bloodstained Enhancement Reagents		Mud stained Enhancement Reagents	
	Leucomalachite green	Patent blue	Potassium ferrocyanide	Sudan black
A4 White Paper	+	x	x	x
Cardboard	++	+	+	+
Carpet	++	+	++	+
Food Wrapper-Porous	++	+	+	x
Food Wrapper-Non-Porous	++	++	++	+
Linoleum-Dark	x	-	+	++
Linoleum-Light	+	++	++	++
Plastic	++	++	x	+
Tiles	+	++	+	x

“-“ : Bad; “+” : Fair; “x” : Poor; “++” : Good

As a presumptive test, leucomalachite green is sensitive to the protein stain in the blood [8]. It gave a very contrast enhancement with porous and non-porous surface matrices. Subsequently patent blue solution which gave a good enhancement on non-porous matrices was also chosen as a complementary test to leucomalachite green reagent. Potassium ferrocyanide which reacts with metal ion in the soil [9] enhanced shoeprints on almost all matrices and the resulting colour of the stain was clearly visible. While sudan black stains other component of the soil which is fat [10]. A deep blue-black colour produced successfully enhanced shoeprint on non-porous matrices.

All the selected reagents were kept in room temperature for two weeks. After two weeks, the reagents were tested again and the reagents still gave positive results. Only leucomalachite green was kept in the refrigerator because hydrogen peroxide was used during the preparation of the reagent. Hydrogen peroxide was stored in the refrigerator to avoid oxidation of the reagents.

Thus, the reagents selected were used to develop the reagent test kit named SPECK (Shoeprint Enhancement Chemical Kit). The kit (**Fig. 6**) consisted of seven reagent bottles. The entire reagent bottles were labelled accordingly (**Table 3**). The test kit was also equipped with personal protective equipment like gloves and goggles, user-manual and notes regarding procedure of enhancement. Goggles were included in the kit and to be used for preventing the contact of reagent with eyes upon spraying the shoeprints. Gloves are used to avoid direct contact of hand with either the shoeprint or reagents. Mask should be worn during the enhancement to avoid the inhalation of the reagents. The kit can be placed in room temperature except for leucomalachite green, it is advised to keep the reagent in the refrigerator. It could be taken out and placed in a cooler box just before the investigators depart to the crime scene. Based on the chemicals and other apparatus to be included in the kit, the kit was estimated to cost around RM 400.00. This constituted a reasonably cost kit.

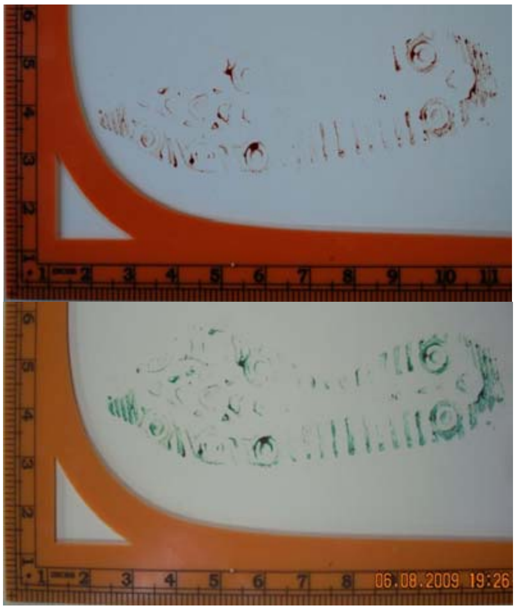

Fig. 2: The bloodstained shoeprint mark on tiles before (Top) and after (Bottom) treatment with leucomalachite green

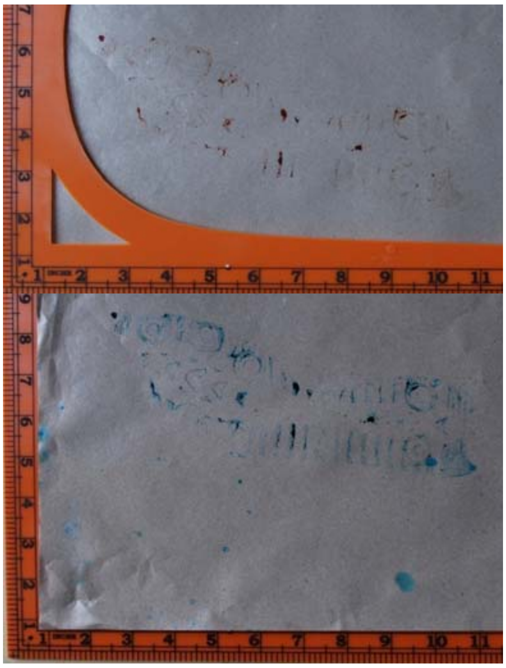

Fig. 3: The bloodstained shoeprint mark on non-porous food wrapper before (Top) and after (Bottom) treatment with patent blue

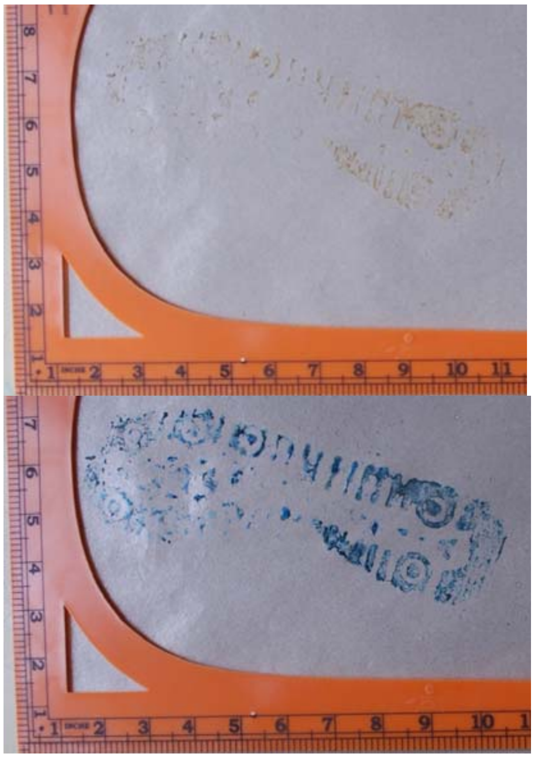

Fig. 4: The mud stained shoeprint mark on non-porous food wrapper after treatment with potassium ferrocyanide

Fig. 5: The mud stained shoeprint mark on linoleum before (Top) and after (Bottom) treatment with sudan black

Table 3: Reagents and labels

No.	Reagents	Labels
1	Leucomalachite green	A
2	Patent blue	B1
3	Deionised water	B2
4	Mixture of HCl and ethanol	C1
5	Potassium ferrocyanate	C2
6	Sudan Black	D1
7	Deionised Water	D2

Fig. 6: Shoeprint Enhancement Chemical Kit showing inside (Top) and outside (Bottom) view

For bloodstained shoeprint enhancement, reagent A or B1 and B2 could be applied. Reagent A can be straight away used to spray the shoeprint until a bluish-green colour is observed. While for reagent B, the shoeprint should be sprayed with B1 first and washed with reagent B2. The shoeprint will change to blue colour upon spraying with reagent B1. Reagent A and B could be used on both porous and non-porous surfaces.

Reagent C and D are to be applied on mud stained shoeprints. For reagent C, the user should spray the shoeprint with reagent C1 and followed with C2 until a blue colour is observed. For reagent D, D1 must be mixed with D2 before it could be sprayed onto the impression. A blue-black colour will appear upon spraying.

The reagent test kit developed was found to be reliable for screening purposes, rapid to carry out and specific as well as reasonably price.

However, the reagents are only applicable on light coloured surfaces and not suitable to be applied on dark coloured surfaces since all the enhancement colour of the reagents were not visible on dark surfaces. Morover, the reagents could only enhance blur or unclear latent shoeprints, not latent shoeprint.

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