

Footwear impressions visualisation

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Summary

Modern visualisation techniques offer great opportunities for visualising trace evidence, both fingerprint and footwear impression evidence. However, in the case of the latter, opportunities presented by these techniques are used only to a small extent. This article is addressed to forensic technicians and experts in the field of footwear impression evidence and fingerprints examination. It aims to present and organise information about contrasting, visualising, and collecting the most common footwear impression evidence: three-dimensional impression, impressions of dry origin (i.e. left with dust) and of wet origin (i.e. left with mud/soil, blood or urine) on various types of surfaces. The authors hope that the expertise collected in this article will help increase the number of visualised and collected footwear impression evidence.

Keywords: visualisation, footwear impression evidence, mud, blood, urine

Introduction

Modern visualisation techniques offer enormous opportunities for visualising various types of trace evidence – both fingerprints, formed during the human skin contact with the surface, as well as impressions left by gloves or footwear. Nevertheless, in the case of footwear impression evidence, opportunities presented by these techniques are used only to a small extent. This article aims to collect and summarise information about the visualisation of footwear impression evidence, but first and foremost to draw attention of forensic technicians, experts in the field of footwear impression and fingerprint studies to the possibility of cooperation, which may result in obtaining more “additional” trace evidence omitted so far due to lack of knowledge and appropriate procedures.

Types of footwear impression evidence

Footwear impressions can be divided into two- and three-dimensional (Rodowicz, 2000). Three-dimensional impressions are impressions made in the surface. In the case of two-dimensional impressions, these can be: transfer impressions on the surface – when the shoe sole was dirty or moist (e.g. with dust, mud, blood, dew, paint) and dirt was transferred to the surface, or negative impressions – when the surface was dirty and the impression was created by the shoe sole which „removes” part of the dirt. Based on the type of substance constituting the dirt, impressions can be divided into those of dry origin and wet origin (in Polish these are: *suche* and *mokre*, respectively). The English terminology indicates the impressions origin, and thus is more precise, since the Polish terms „dry” (*suche*) and „wet” (*mokre*) do not refer to the state in which the impression was found, but

rather to the moment it was left, i.e. whether it was made with a dry or wet impression-forming substance (or left as a negative impression in a dry or wet substance) (SWG-TREAD, 2009; Bodziak, 2017). This means that blood impression is classified as wet origin impression, even though it has long since dried up when found. Examples of individual impressions are presented in Fig.1-5.



Fig. 1. Transfer impression on styrofoam

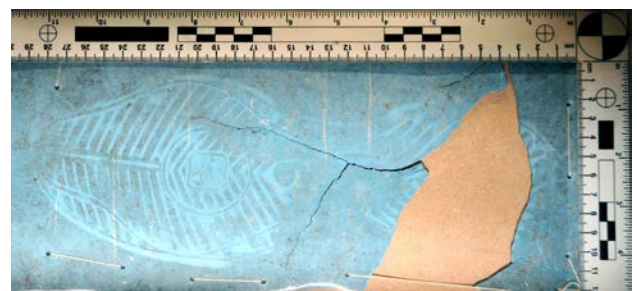


Fig. 2. Negative impression on linoleum

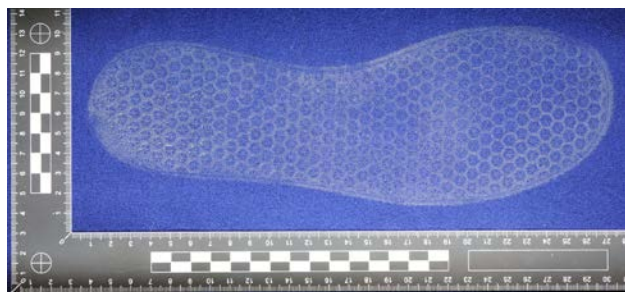


Fig. 3. Dry origin impression on a carpet

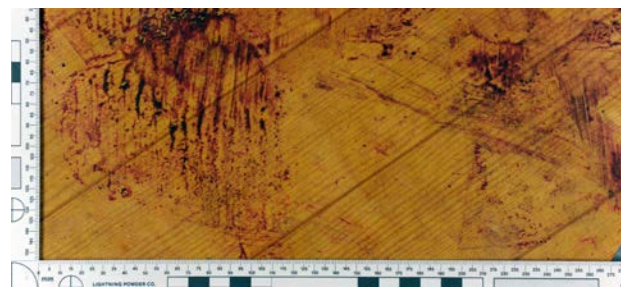


Fig. 4. Wet origin impression on wood flooring



Fig. 5. Three-dimensional impression

Proceeding with footwear impression evidence

In order to collect as much identifiable trace evidence from the crime scene as possible, it is necessary to observe certain principles and follow them (Bodziak, 2017).

To increase the chances of visualising footwear impression evidence, the crime scene should be examined both in white light using an oblique angle (flashlight) and in ultraviolet light (UV lamp). The optimal solution would be to use additional forensic flashlights (violet, blue, and blue-green light) with the forensic examination filters (yellow and orange).

If impressions are visualised, the first thing an examiner should do is photograph them. In addition to an overall photograph, they should take forensic photographs of visualised footwear impression, allowing (especially when the impression cannot be collected and delivered to the laboratory) to carry out further identification. When photographed, the scale should be placed parallel to the longitudinal axis of the impression and level with the impression (for three-dimensional impressions it is necessary to dig a depression next to the trace to place the scale). The footwear impression should be illuminated by an oblique light at an angle ensuring the best contrast. The photograph should be taken with a camera on a tripod so that the

optical axis of the lens is located perpendicularly to the surface of the impression, and passes through its centre (Rodowicz, 2000; Bodziak, 2017).

Let us not forget about the so-called „stepped-on objects” which may be an important source of footwear impression evidence. These include all objects the perpetrator could have stepped on, e.g. sheets of paper scattered on the surface, newspapers, cardboard boxes, larger glass fragments from broken windows. Such objects should be collected as a whole, delivered to the laboratory, and visualised there (Bodziak, 2017).

In the case of footwear impressions on surfaces that cannot be delivered to the laboratory, after taking the photograph, the examiner should use one of the visualisation techniques to detect impressions at the crime scene (e.g. luminol) or, if this is not possible, use a gelatin lifter to collect impressions (other types of lifters are not very efficient in the case of footwear impression evidence), alginate, silicone (transferred/negative impressions), or prepare a cast (impressions in the surface). Where the case is particularly serious and it is at all feasible (e.g. blood footwear impression on linoleum in a murder case), the examiner should consider cutting out a fragment of the surface with the impression and delivering it to the laboratory (Bodziak, 2017).

It is also important to remember that the visualisation process in laboratory conditions may include not only impressions collected together with the surface but also impressions transferred to a gelatin lifter or alginates.

Impressions in the surface - contrasting

Impressions in the surface are visible impressions and, therefore, do not require visualisation. Impressions in snow are an exception to this rule: even though they are visible, if oblique lighting does not bring satisfactory results, they may need to be contrasted so that the examiner can photograph them. For this purpose, the examiner may use spray paint or Snow Print (Wax or Powder) products.

If the spray is used (Fig. 6, 7), it should be sprayed gently and from a safe distance to avoid damaging the impression. Moreover, on a sunny day, the examiner should also be careful not to cause the melting of the impression, as paints are usually dark-coloured and

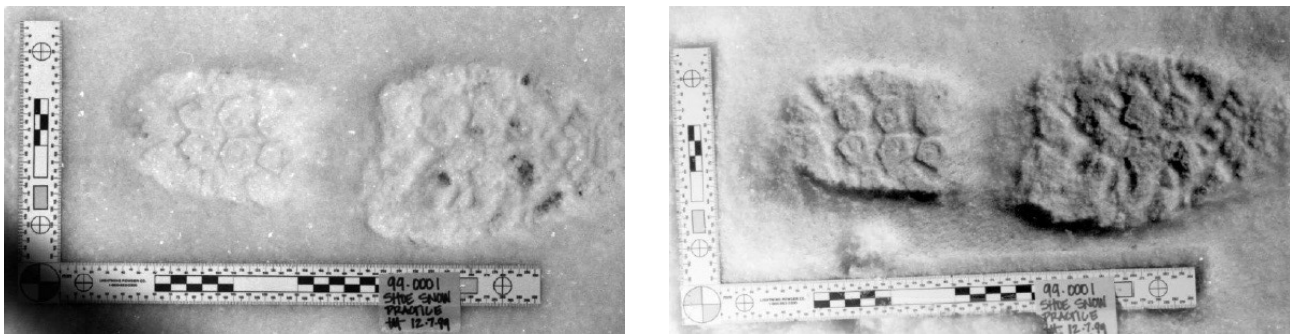


Fig. 6, 7. Snow impressions before (left) and after (right) contrasting with paint



Fig. 8, 9. Snow impressions contrasted using Snow Print Powder



Fig. 10, 11. Three-dimensional snow impression before (left) and after (right) contrasting with Snow Print Wax

absorb light faster than regular snow (Hammer and Wolfe, 2003; Bodziak, 2017).

Snow Print products are used both to contrast the impression before it is photographed, and to protect the details of the impression before a cast is made. The product type is selected depending on the ambient temperature and the type of snow. Powder (Fig. 8, 9) is recommended for hard-frozen or wet, melting snow

(it absorbs excess moisture). It is not recommended for fresh, fine/dry snow, as it can damage the impression. Wax (Fig. 10, 11) is a paraffin-based product that may be used for any type of impression. It protects the impression against „leakage” of dental stone (or gypsum, which is rarely used nowadays), used to make a cast (Rodowicz, 2000; Bodziak, 2017).

Transferred impressions - visualisation

The method of visualising transferred impressions (or negative impressions for which the same visualisation techniques can be applied, except that the background will be coloured, resulting in a negative image of the impression) depends mainly on the type of substance forming the impression left at the scene, and the type of surface. The most frequently collected footwear impressions are dust impressions (“dry origin”), and impressions left with mud/soil or blood (“wet origin”). Great possibilities of visualisation are also provided by impressions resulting from contaminating the soles of shoes with urine, although in Poland, probably due to lack of knowledge, this type of impression is hardly ever collected and does not reach the laboratory.

1. Dust impressions

Using fingerprint powders when visualising dust impressions is one of the most common basic errors made by examiners. These powders act through adhesion, i.e. sticking of powder molecules to viscous or moist components of impression-forming substance (CAST, 2014). For dust impressions, using fingerprint powders means trying to visualise dry dust with another type of dry dust. The only possible outcome is destruction of the impression, which will be „swept away” with the brush used to apply the powder. The proper

manner to isolate dust impression is to take a photograph in appropriate lighting conditions (opaque light giving the best contrast between the impression and the surface), and then transfer it to a gelatin lifter. Fingerprint powders can only be used to visualise “wet origin” impressions, e.g. left when the perpetrator moved in the rain, snow, or through damp grass, though even in this case they are not a first-choice method. Most often, it is difficult to recognise impressions of this type, so even when the examiner firmly believes that the impression is of “wet origin”, they should first check the effect of the powder on a small fragment of the footwear impression (Bodziak, 2017).

2. Blood footwear impressions

In the case of impressions left with blood or plasma, the examiner has a wide range of different reagents to choose from, rendering it possible to choose the product which works most effectively on a given surface. Dyes for visualising blood footwear impressions can be divided into (Farrugia et al., 2011a; Farrugia et al., 2011b; Farrugia et al., 2013b; CAST, 2014):

- “Acid Dyes”: Acid Yellow 7, Hungarian Red (Hungarian Red, Acid Violet 19), Amido Black (Amido Black, Acid Black 1),
- heme (peroxidase): Leuco Crystal Violet (LCV), luminol,
- amino acid: DFO, 1,2-IND, ninhydrin, DMAC.



Fig. 12, 13, 14. Blood footwear impression visualised by Acid Yellow 7 visible in white light (left), in fluorescence (middle), and in fluorescence after being transferred from the surface to a gelatin lifter (right)

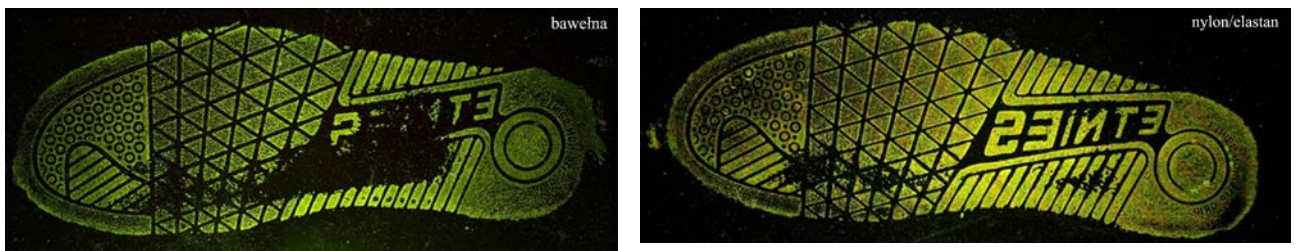


Fig. 15, 16. Blood footwear impression visualised by Acid Yellow 7 on textile surfaces



Fig. 17, 18, 19. Blood footwear impressions visualised by Hungarian Red visible in white light on the surface (left) and after being transferred from the surface to a white gelatin lifter visible in white light (middle) and fluorescence (right)

“Acid dyes” react with proteins in the blood and plasma (but also with other proteins – they act non-specifically), giving a coloured and/or fluorescent reaction product. They require a three-step visualisation process: a) fixing (it is necessary because proteins are soluble in water and other polar solvents – without this step, the print would run or be washed away from the surface), b) staining, c) rinsing. They can be used on most surfaces (Farrugia et al., 2011b; CAST, 2014).

Acid Yellow 7 (Fig. 12, 13, 14) is the most effective “acid dye” for non-absorbent surfaces (Velders, 2012; CAST, 2014). However, it should not be used on classic absorbent surfaces (e.g. paper, cardboard), because it does not rinse out and stains the background

strongly. Despite this, Acid Yellow 7 is suitable for visualising footwear impressions on fabrics and other textiles. It is the best dye to use on dark-coloured polyester, cotton, nylon, and elastane (Fig. 15, 16) (Farrugia et al., 2011b). Visualised impressions are fluorescent.

Hungarian Red (Fig. 17, 18, 19) may be used on all types of surfaces. After visualising, impressions are clearly visible in white light and are fluorescent (Velders, 2012). Red is a dye particularly recommended for visualising on light-coloured or multi-coloured textile surfaces (Fig. 20) (Farrugia et al., 2011b; Farrugia et al., 2013a).

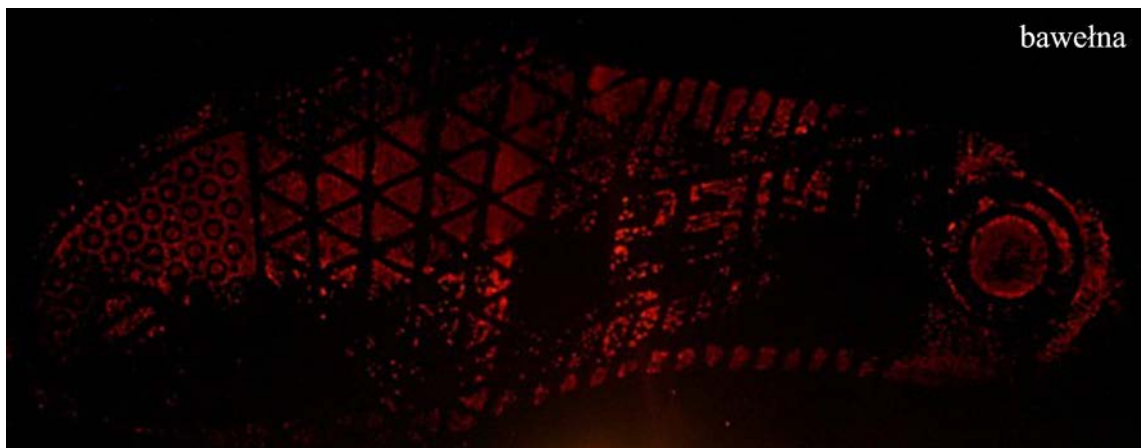


Fig. 20. Blood footwear impressions visualised by Hungarian Red on textile surface

Amido Black (Fig. 21, 22, 23, 24) is suitable for use on all types of light-coloured surfaces, including light-coloured textile substrates (Fig. 25) (Farrugia et al., 2011b). It is recommended, in particular, for visualising blood footwear impression on paper. After visualising, impressions are visible in white light (does not produce fluorescence) (Bodziak, 2017).

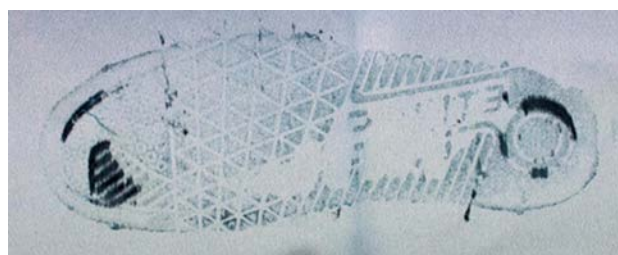


Fig. 25. Blood footwear impressions visualised by Amido Black on white cotton fabric

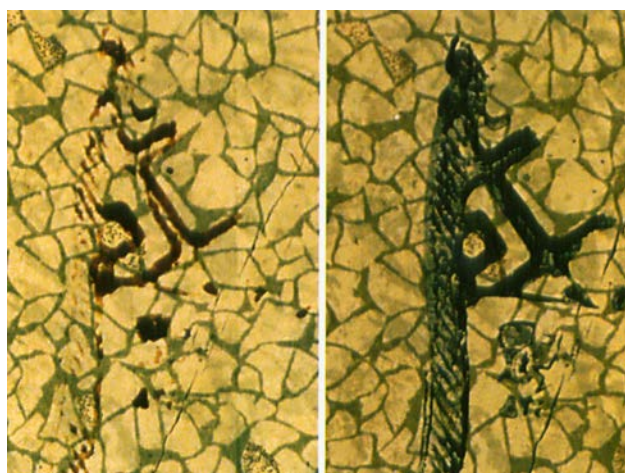


Fig. 21, 22. Blood footwear impressions on non-absorbent surface before (left) and after (right) visualising with Amido Black

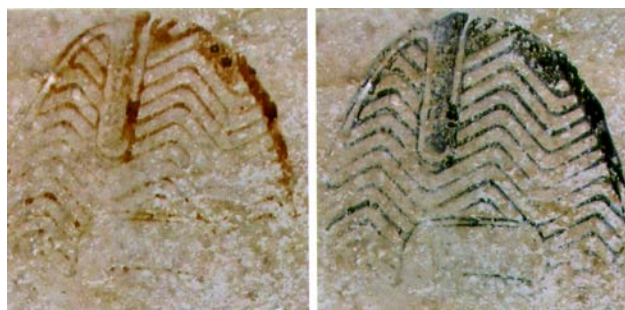


Fig. 23, 24. Blood footwear impressions on non-absorbent surface before (left) and after (right) being visualised with Amido Black

Heme dyes react with the heme group in hemoglobin (they are action-specific – they detect blood only), giving a coloured and/or luminescent reaction product. The visualising is a one-step process, and there is no need for a separate stage of fixing or using a rinsing solution (in the case of strong staining of the background, the excess reagent may be rinsed with water). They can be used on most surfaces (Farrugia et al., 2011a).

Leuco Crystal Violet (LCV) is recommended for visualising blood footwear impressions on light-coloured textile surfaces and leather surfaces. The product of the LCV reaction with blood is coloured and fluorescent crystal violet (Fig. 26, 27, 28). However, the impression must be photographed as soon as possible after being visualised, since the exposure to light results in the slow staining of the entire background, which reduces the contrast between the impression and the surface (Fig. 29). An additional disadvantage is that the LCV solution is sensitive to light and temperature, therefore, it must be made anew before each use (Farrugia et al., 2011a).

Luminol is the most sensitive reagent for blood footwear impressions (Fig. 30) – it is recommended, in particular, for visualising invisible impressions (subjected to cleaning when someone tried to remove them) (Velders, 2012). According to some sources, luminol can detect blood even under four layers of paint (Bily, Maldonado, 2006). The reaction product of luminol with



Fig. 26, 27, 28. Blood footwear impressions visualised by LCV visible in white light (left), in fluorescence (middle), and in fluorescence when the light source is laser (right)

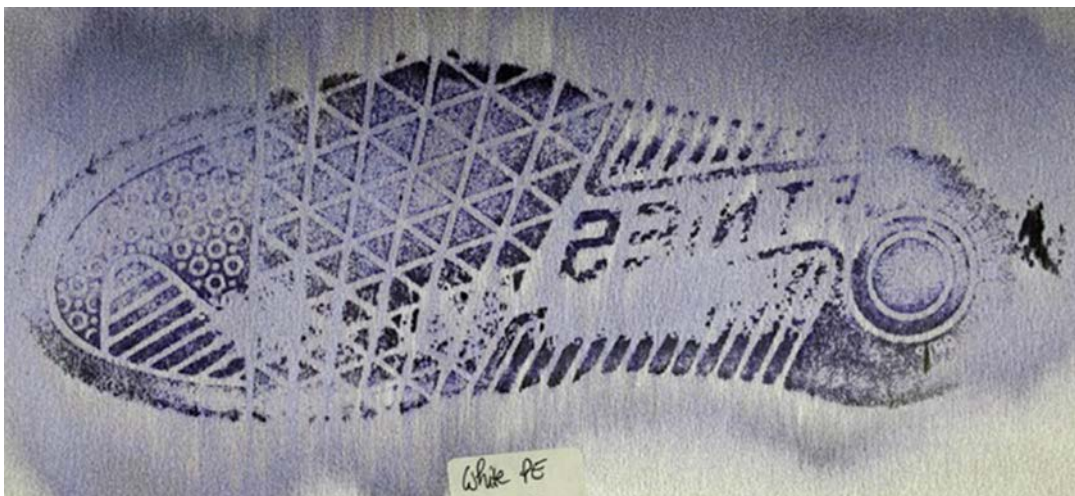


Fig. 29. Blood footwear impressions visualised by LCV – background staining following exposure to light

blood is chemiluminescence, thus no light source is required to observe the “glow” of visualised impressions. Luminol has an additional advantage in that it can be used on all types and colours of textile surfaces, including denim (Fig. 31), where other techniques are not as effective, as well as on leather surfaces (Farrugia et al., 2011a). However, the application of luminol requires a lot of attention. It should only be used with

sprayers creating a very fine, delicate mist, as otherwise the impression can be blurred (Fig. 32). Another difficulty seems to be the fact that different manufacturers provide luminols with different parameters in terms of luminescence length and intensity. This means that the application method must be revalidated with every change in the product.

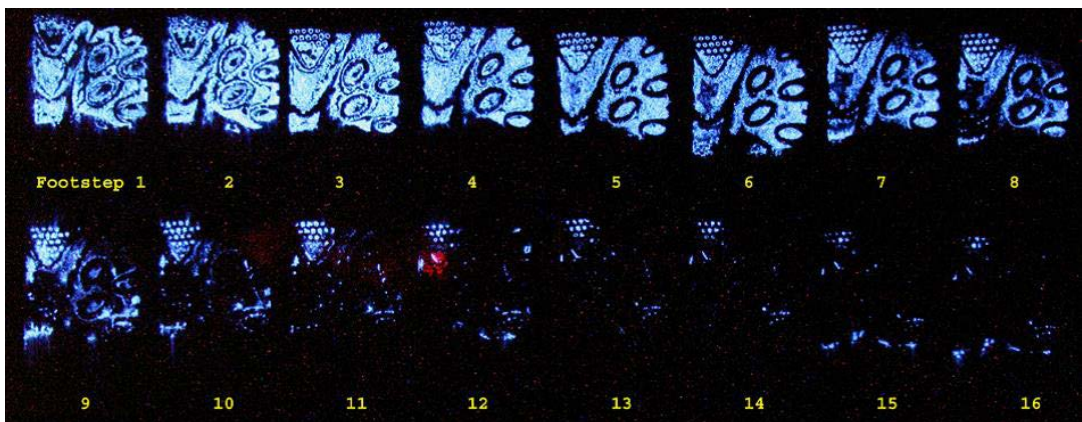


Fig. 30. A set of sixteen “fading impressions” visualised by luminol. It is clear that luminol visualises good quality impressions up to the eighth application, and detects blood impressions until the last, sixteenth application

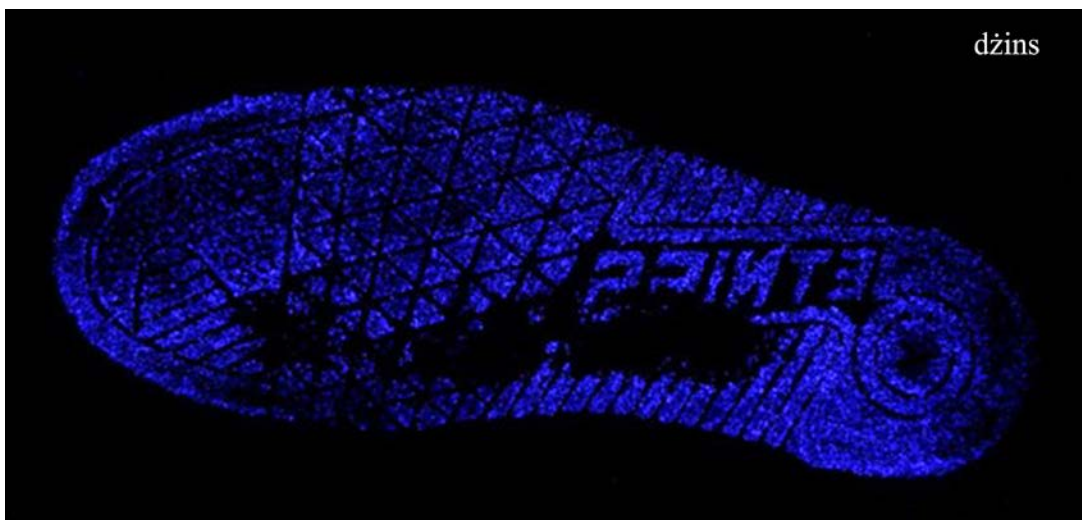


Fig. 31. Blood footwear impressions visualised by luminol on denim surface

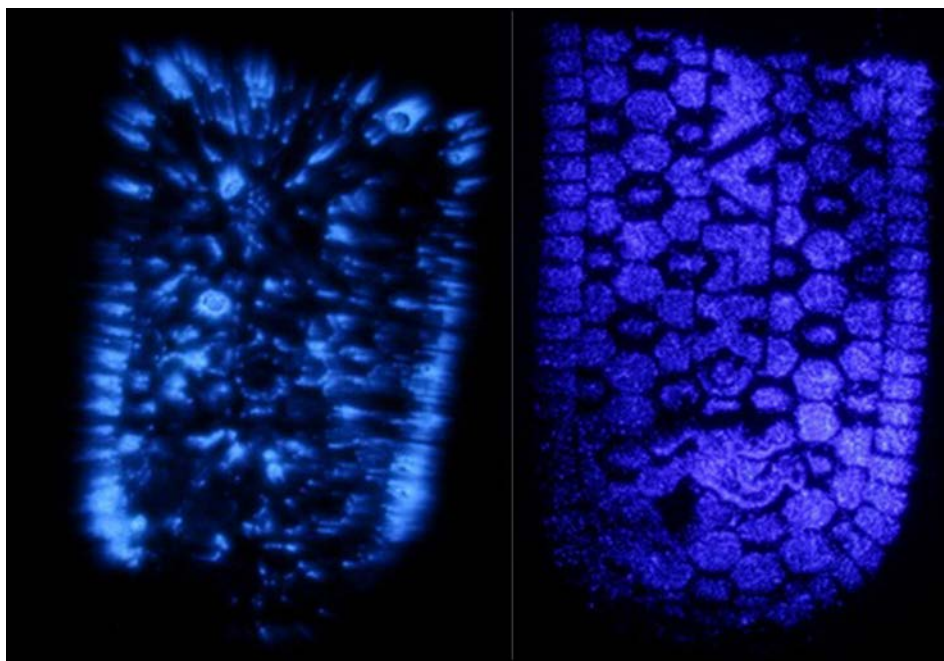


Fig. 32. A footwear impression blurred due to incorrect visualising by luminol (left) and an impression visualised with due diligence (right)

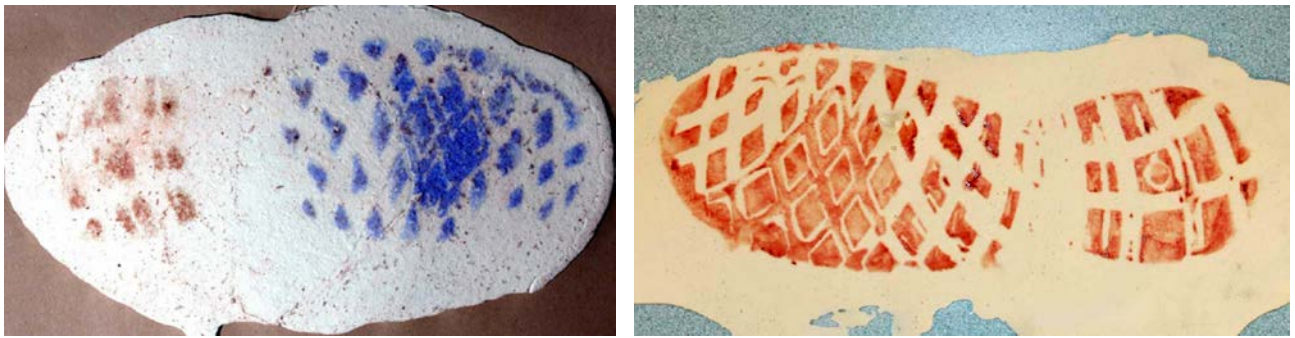


Fig. 33, 34. Blood impressions transferred to alginates from concrete (left) and leather (right)

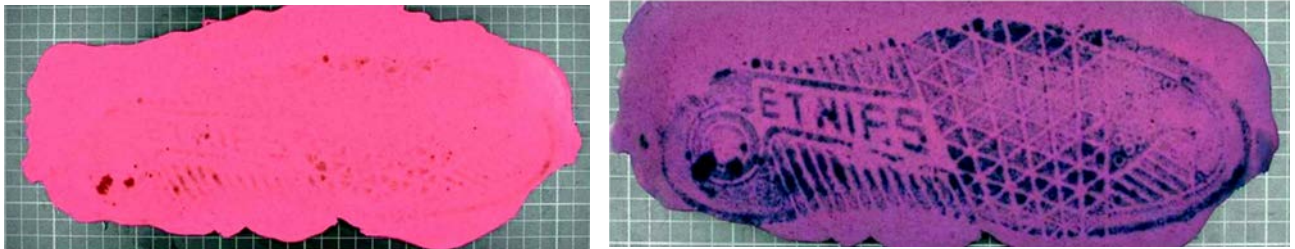


Fig. 35, 36. Blood impressions transferred to the alginate from cotton (left) and then visualised by Amido Black (right)

We should also mention two other possibilities for blood footwear impressions – amino acid dyes and alginates. Amino acid dyes react with amino acids present in body fluids, including blood and plasma (CAST, 2014). However, they can only be used on “weak” blood footwear impressions (with low saturation or left with plasma) and only on absorbent surfaces (Farrugia et al., 2013b). Since the visualisation process requires special humidity and/or temperature conditions, the use of amino acid dyes directly at the crime scene requires prior preparation and may give worse results than those obtained in the laboratory.

Alginates are an ideal solution for collecting blood impressions left on difficult surfaces – concrete, fabrics, human skin, etc. (Fig. 33, 34). As an additional advantage, they can be used to visualise impressions chemically before or after they were collected (Fig. 35, 36). Conversely, their disadvantage is a need to quickly take a photograph of the impression transferred to the alginate, as when the mass is drying, it begins to shrink, which distorts the actual size of the impression (Adair, 2005; Farrugia et al., 2010).

3. Mud/soil impressions

Extensive studies on visualising mud impressions on various types of surfaces were carried out in 2000 by a team from the Netherlands Forensic Institute (Theeuwen et al., 2001). This team tested several reagents, using them in various configurations on absorbent, non-absorbent, semi-porous, and textile surfaces. Since the chemical composition of mud/soil is usually unknown, and may vary significantly in the case of individual impressions (Farrugia et al., 2012b), the

researchers did not follow the way individual reagents acted, but rather tried different types of methods on various surfaces to determine which ones bring the best results. Thanks to these studies, the authors were able to indicate the most effective techniques for individual types of surfaces.

For non-absorbent surfaces, the best solution turned out to be visualising impressions by safranin (the mechanism of safranin reaction with soil/mud has not been explained), and then transferring them to a white gelatin lifter (Fig. 37, 38, 39). Equally effective method was to visualise impressions by Crystal Violet. Slightly less effective, yet still satisfactory results were obtained for the Sticky Side Powder suspension, a physical developer, and Sudan Black, which probably reacted with the soil lipid components.

For absorbent surfaces, the most effective method was to transfer the impression to a black gelatin lifter, and then visualise it using the DFO amino acid dye (amino acids from the lifter seem to be transferred to the impression-forming substance, and this allows visualising impressions with the above-mentioned method). Good results for classic absorbent surfaces were also obtained with Sticky Side Powder and safranin.

For semi-porous surfaces, the best methods were safranin (as in the case of non-absorbent surfaces), and transfer to a black gelatin lifter and visualising of the DFO impression (as in the case of absorbent surfaces).

Finally, the combination of a black gelatin lifter with visualising of DFO brought the best results for textile surfaces as well. Another team of researchers (Farrugia et al., 2012b) indicated 2,2'-bipyridine as a possible

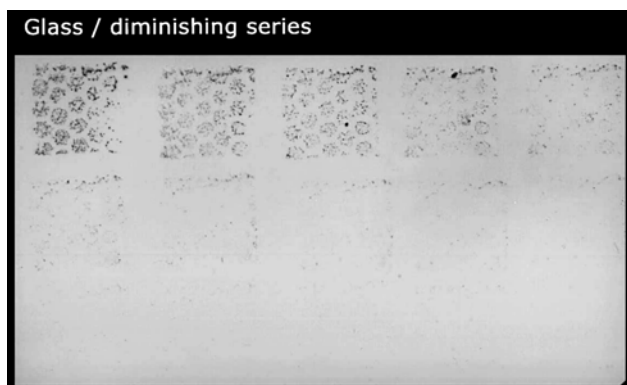


Fig. 37. A set of “fading impressions” left with mud on the glass

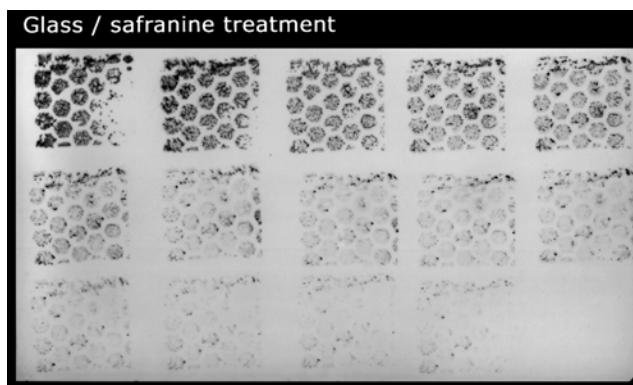


Fig. 38. A set of “fading impressions” left with mud on glass after being visualised by safranin – impressions visible in white light

method of visualising impressions left by mud on textile surfaces, however, the visualisation effects varied strongly depending on the type of surface, were less predictable and less satisfactory..

4. Urine impressions

Footwear impressions left with urine are collected very rarely, even though they occur quite frequently. They can be found in all places with public toilets – in schools, offices, restaurants, bars, pubs, discos, city toilets, etc. They are also rather easy to visualise, since undiluted human urine shows fluorescence in the so-called “short” UV light (wavelength 250-300 nm). Urine fluorescence in the remaining wavelength range is an individual trait, depending on many factors (e.g. gender, diet, medicines taken), but for most people, it does occur and is strongest when illuminated with violet light (415 nm) using a yellow forensic cut filter (Fig. 40, 41, 42, 43) (Farrugia et al., 2012a). This allows the examiner to visualise impressions at the crime scene and to take photographs. If impressions are not clearly visible, examiners can use amino acid dyes to visualise them. For impressions that may be collected along with the surface, e.g. impressions left on the so-called

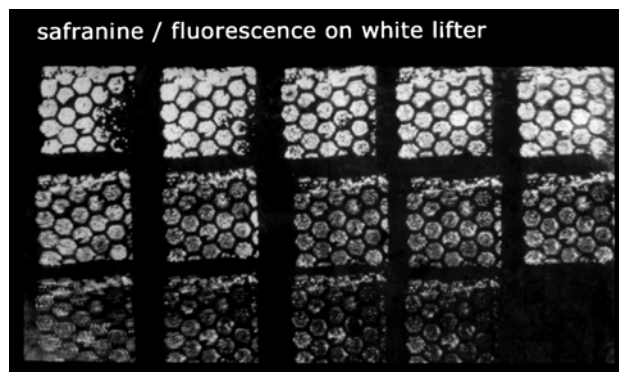


Fig. 39. A set of “fading impressions” left with mud on glass after being visualised by safranin and transferred to a gelatin lifter – impressions visible in fluorescence

„stepped-on objects”, the best solution is to deliver them to the laboratory, where they can be visualised.

For absorbent surfaces, the recommended reagent is DFO, which gives the best visualisation results (Fig. 44, 45, 46), it also works on “old” impressions and impressions on textile (light-coloured) surfaces. 1,2-IND and ninhydrin produce poorer results, and ninhydrin is in addition limited by the fact that it can only be used on

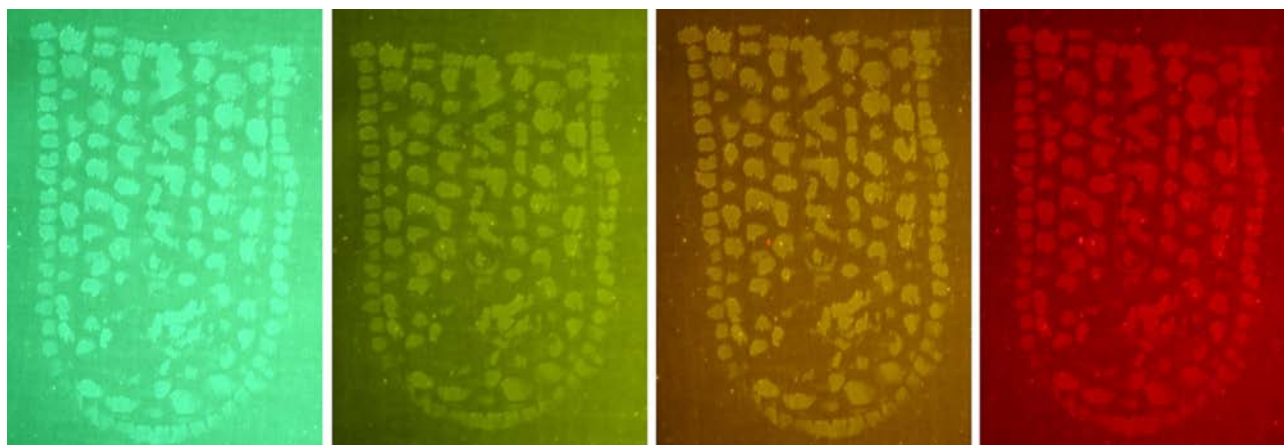


Fig. 40, 41, 42, 43. Self- fluorescence of undiluted human urine



Fig. 44, 45, 46. Urine footwear impressions on cotton surfaces visualised by DFO, visible in white light (left) and in fluorescence (middle and right)

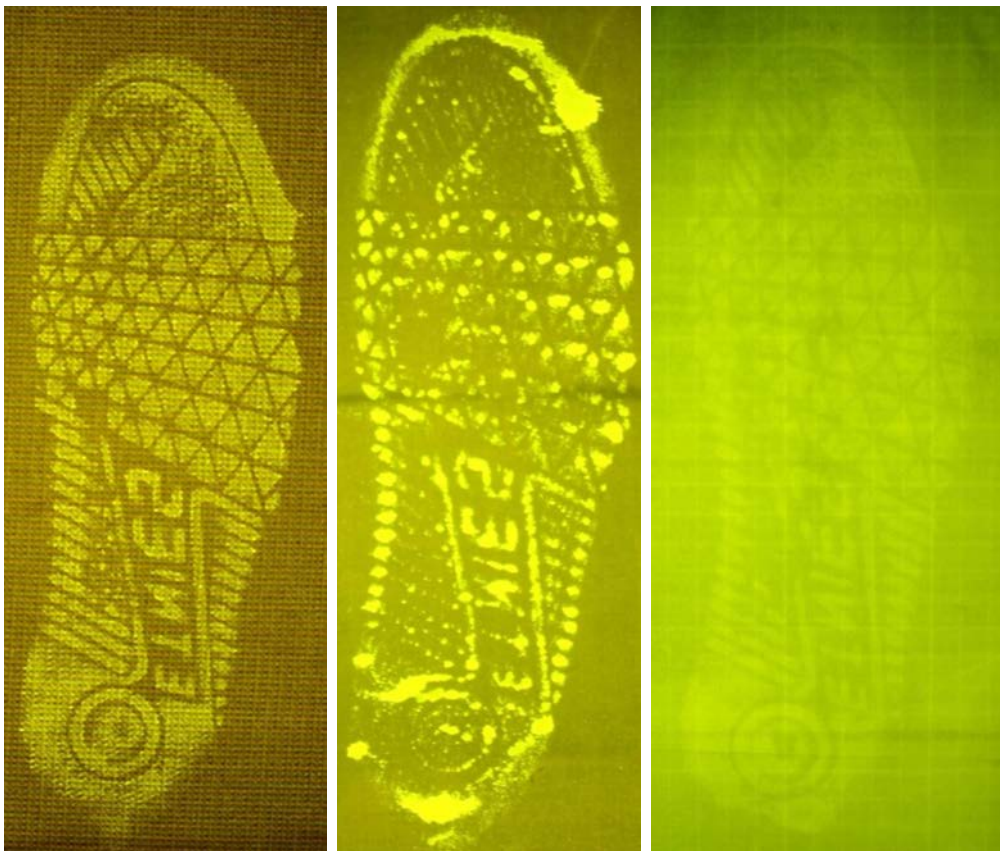


Fig. 47, 48, 49. Examples of footwear impressions left by urine on textile surfaces, visualised by DMAC

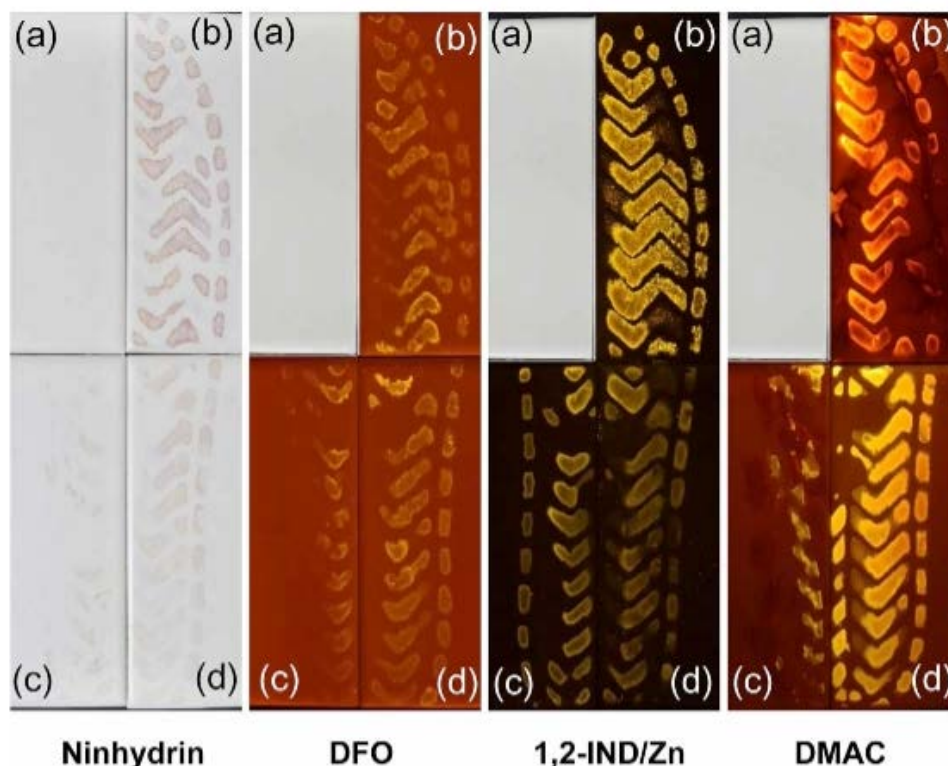


Fig. 50. Comparison of the spraying method, using tissues and the dry method for visualising urine footwear impressions on white floor tiles: (a) control, (b) spraying method, (c) use of a tissue, (d) dry method.

light-coloured surfaces. The effects of DMAC visualisation are strongly dependent on the type of surface – for certain surfaces, DMAC visualises impressions of quality comparable to DFO (Fig. 47), for others it blurs impressions or strongly stains the background (Fig. 48, 49). Thus, the examiner should be particularly careful when visualising impressions by this reagent, and it is best to carry out a test beforehand (Farrugia et al., 2012a).

Amino acid dyes are intended for impressions on absorbent surfaces and produce the best visualisation results when the visualisation process is carried out under appropriate humidity and/or temperature conditions. Nonetheless, in 2019, the Korean team of researchers managed to obtain good results in visualising by these dyes on non-absorbent surfaces - floor tiles in toilets (Kim, Hong, 2019). The reagents were applied in three manners: spraying, covering the impression with a tissue which was then soaked with a reagent, or dry method - by covering the impression with a sheet of office paper, previously soaked in the concentrated reagent and dried, and then heating the sheet with an iron heated to the temperature of approx. 100°C. These experiments demonstrated that the best visualisation results are achieved by applying ninhydrin and 1,2-IND on the impression by spraying, and using the dry method in the case of DFO and DMAC (Fig. 50).

Conclusion

Despite the numerous possibilities of choosing the appropriate method or sequence of visualising methods, the examiner should not forget about the two most important principles of visualisation. Since the exact composition of the impression-forming substance is unknown (the perpetrator could have walked on many different surfaces and created a unique mixture of dirt on the soles), or – in the case of absorbent surfaces, particularly textile ones – how the surface will “behave” (which chemical compounds, optical brighteners or dyes are contained therein, and how will they react with the reagent used for visualising, e.g. whether it will be possible to rinse the reagent off from the surface, whether there will be no unexpected reaction), before starting the visualisation process the examiner should:

- take photographs of the footwear impression in the proper manner, i.e. one that makes it possible to carry out a subsequent identification,
- test the result of the selected visualising method on the surface (it is best to carry out the test on a small fragment of the surface far away from the footwear impression).

Having regard to the above-mentioned principles, a wide range of available visualisation techniques can be freely used.

Table 1. List of the most effective methods for visualising footwear impression evidence depending on the type of surface and impression-forming substance

		Surface type			
		Non-absorbent surfaces	Absorbent surfaces	Semiporous surfaces	Textile surfaces
Impression-forming substance type	Blood	Acid Yellow 7	Amido Black/ Hungarian Red	Amido Black/ Hungarian Red	Acid Yellow 7 (dark-coloured) Amido Black /Hungarian Red/LCV (dark-coloured) Luminol (denim, leather)
	Urine	DFO, DMAC (dry method) 1,2-IND, ninhydrina (spray)	DFO	DFO, DMAC * (dry method)	DFO (light-coloured)
	Mud	Safranin + White gelatin lifter Crystal Violet	Black gelatin lifter + DFO	Black gelatin lifter + DFO Safranina	Black gelatin lifter + DFO

*No literature data on semiporous surfaces but based on the results obtained for non-absorbent and absorbent surfaces it may be presumed that the indicated visualisation methods will be most effective

Table 1 presents a summary of the most effective visualising methods depending on the type of surface and impression-forming substance.

The above-mentioned list shows how many possibilities there are for effective visualisation of footwear impression evidence. However, in order to use this list, technicians and experts in the field of footwear impression and fingerprint examination need to have basic knowledge of the visualisation of footwear impression evidence, and be willing to cooperate with each other. This article has been drawn up to facilitate, at least in part, the acquisition of this information, and to encourage cooperation, with an end-result of visualising many new – so far omitted – footwear impression evidence.

Sources of photos and tables:

- Fig. 33, 34: Adair, T.W. (2005).
 Fig. 8-11, 21-24: Bodziak, W.J. (2017).
 Fig. 35, 36: Farrugia, K.J. et al. (2010).
 Fig. 26-29, 31, 32: Farrugia, K.J. et al. (2011a).
 Fig. 15, 16, 20: Farrugia, K.J. et al. (2011b).
 Fig. 40-49: Farrugia, K.J. et al. (2012a).

- Fig. 25: Farrugia, K.J. et al. (2013b).
 Fig. 6, 7: Hammer, L., Wolfe, J. (2003).
 Fig. 50: Kim, S.J., Hong, S. (2019).
 Fig. 37-39: Theeuwen, A. et al. (2001).
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 Table 1: own study

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