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Drying Stages of Blood Drops

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ABSTRACT

Blood is one of the most important & most frequently encountered evidence in criminal investigation. It can be found in almost every type of criminal activity involving physical violence like murders, robberies, rape cases, etc. Blood stain may found on location such as seen of occurrence, the culprit, the victim, the weapon, of offence, the vehicle and the route taken by the culprit. The position, size & shape of the stain often help in reconstruction of crime seen. The stain may be in the form of splashes, smears, & pools. The colour of the bloodstains varies accordingly to their age, the amount of blood present, and the nature of the material. As bloodstain increases in age, they progress through series of colour changes from red to reddish brown to green & eventually to dark brown to black. When blood is exposed to an external environment the drying process on various surfaces is initiate. Size, volume, nature of target surface, & influence of external environment such as temperature humidity, air flow affects the drying time of bloodstain. The drying of bloodstain is initially around the edges or periphery and proceeds inward to the central portion of the stain as the drying process continues. Drying time and skeletonization are both important alteration of blood. Presence of significant dried & clotted blood on surface at a scene indicates a significant time lapse between blood shade & the observation of the blood.

Keywords: Blood Drops, Drying Stages, Bloodstain

I. INTRODUCTION

Acts of extreme violence often produce a dispersion of blood volumes forced from a wound site. Gunshot and other high energy impacts, such as blunt force beatings, may disperse these blood volumes along relatively flat trajactories.

Molecular cohesion creates surface tension at the boundaries of these blood volumes. Surface tension causes the drop volumes to assume nearly spherical

shapes in free flight. These drops results in blood stain evidence being deposited on the floor, walks, ceiling, or other surface or objects within a crime scene.

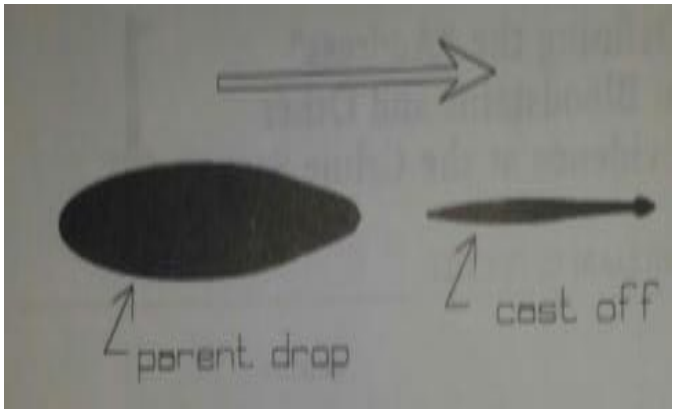
Interpretation of the resulting stain patterns may permit an analyst to approximate the three dimensional point of origin. This chapter develops an equation and a methodology for calculating that point.

t is common that, the path of a liquid drop is aligned with the long axis of the resulting stain (fig. 1). The flight direction of the drop is toward the tapered end of the stain. In a 1971 paper, MacDonell and Bialousz demonstrated that a predictable relationship exists between the lengh to width ratio of a blood stain and the angle at which it strikes a static surface. (fig 2) [2]

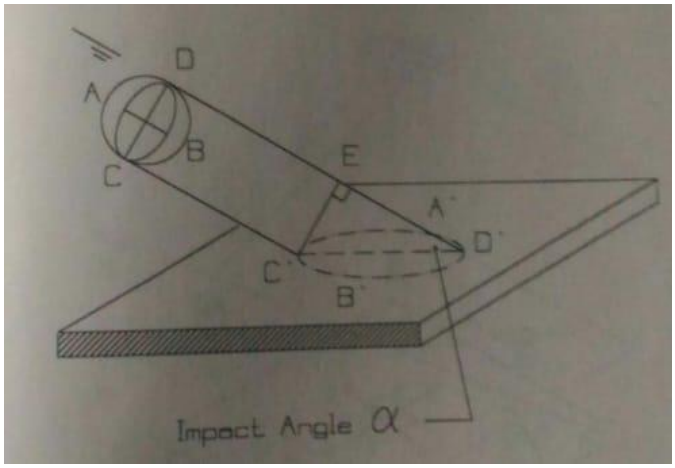
$$IMPACT\ ANGLE = arsin\ [\frac{width}{length}]$$

MacDonell further demonstrated that the approximate three dimensional point of origin can be reestablished by running several tautly stretched strings. Each string is aligned with the long axis of a particular stain and angled from the surface according to the width/length relationship of the stain.

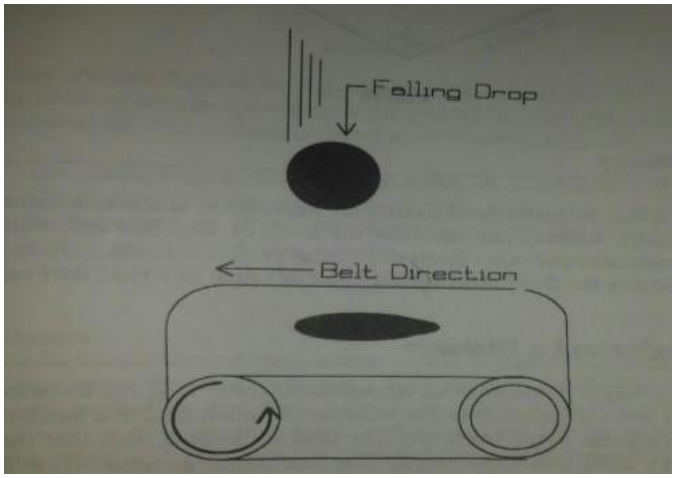
In a 1986 paper Pizzola and DeForest demonstrated that a predictable relationship exists between the length to which ratio of a stain and the velocity of a target surface moving perpendicular to the path of a falling drop (fig 3) [3].



(fig. 1)



(fig.2)



(fig.3)

Bloodstain pattern analysis is a forensic tool used by investigators to determine, among others, what, where and how a crime took place [4]. One of the most common types of bloodstains found on a crime scene following a deadly blood shedding event, is the blood pool (fig. 4). Ante- and postmortem it is often the case that a victim bleeds out, thus accumulating blood in one or multiple areas. Currently, when a blood pool is found, it is classified as such and an investigator can conclude that the blood donor was bleeding at that location for any reasonable period of time for the pool to be created, be it seconds, minutes or even hours. Previous studies have investigated if it was possible to determine what the volume of a blood pool was, to determine if such a loss of blood volume could constitute loss of life [5], or for other crime scene reconstruction purposes [6, 7, 8, 9]. However, almost no studies have been performed concerning the drying of an entire pool of blood. Such studies can

be very useful for determining, e.g., the time that the blood shedding event occurred, any actions that may have occurred during the blood shedding event or the physiological state the subject was in. For example, fig. 4) shows two crime scene pictures of the same pool, 22 hours apart. In the first (top) picture, the edges and the bottom of the pool have started drying. In the second picture the pool has completely dried. Information obtained from how fast the blood dried could be crucial to determine when the pool was created.

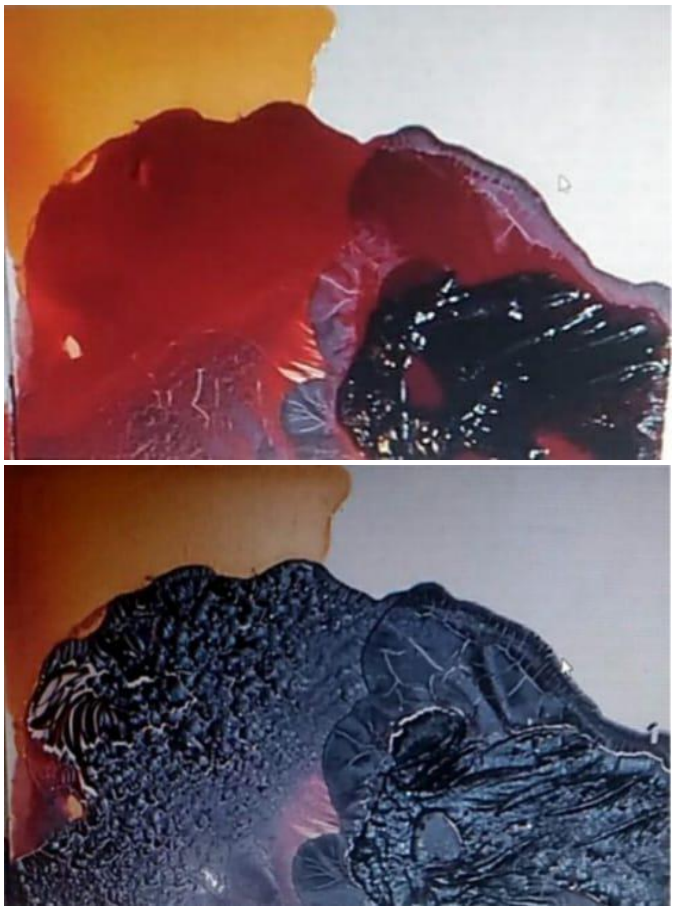


Figure 4: Picture of a real pool of blood found on a crime scene, (top) before the body was removed and (bottom) 22 hours later. The yellow liquid is serum which was separated during clotting and the black mass in the top picture is a large formed clot.

There have been several studies concerning the drying of singular blood droplets [10, 11, 12, 13, 14,]. To our knowledge only Ramsthaler et al. investigated the drying of blood pools [15]. In their study they focused on the drying and morphology of diluted blood droplets and pools to be able to distinguish between diluted and whole blood. In this paper we report on the morphology of drying blood pools. Pools of blood, obtained from healthy volunteers were deposited on linoleum surfaces. Based on our results we are able to distinguish five diff erent stages of drying. In addition, we report the universal properties of drying blood pools, but also distinguish anomalies, which can diff er between pools.

Several patterns can be observed in dried drops of a diff erent nature. Coff ee drops have been widely studied in the past by demonstrating the influence of colloids in the final pattern observed by(Deegan R. D. 2000) [16]. Regarding human blood serum (the clear portion of any liquid separated from its more solid elements), the dried drop of blood serum presents diff erent patterns depending on the individual's health condition. The specific regular pattern characteristics of a healthy individual do not appear in a dried drop of the blood serum from a person with blood disease (Martusevich, Zimin & Bochkareva 2007)[17, 18]. Experimental observations of dried drops of biological fluids (except whole human blood) have been performed and published in medical journals. The drying process is not analysed in the literature; they only focus on the final pattern in order to diff erentiate healthy people from patients with diseases. The drying technique has been used to store samples in locations, where appropriate storage conditions are not available: field studies, third world countries and desertsetc. (Zhuang et al. 1982) . The method was used to detect hepatitis B infection in serum dried on filter paper. Also, experimental observations of dried drops of serum have been performed (Yakhno 2008)[20]. The author identified the origin of the patterns observed in dried drops of serum from the phase transition (gellification) of proteins. A strong attachment of the dried serum due to a biological reaction of the protein with the glass plate of the microscope and salt crystallization were found in the dried drop, these phenomena have been explained. Whole blood is a complex colloidal suspension which

behaves like a non-Newtonian fluid. Since the colloids of blood have complicated shapes, the individual colloid behaviour is hardly predictable. Pozrikidis (2006) [21] demonstrate the existence of a molecular adhesion component to explain the flipping behaviour of a platelet over a plane wall. Besides the flow around these colloids, the biochemistry is also present, the red blood cells (RBCs) evidence repulsive behaviour near a wall as they do in the human body to avoid the vessel obstruction. When drops of blood evaporate, all the colloids are carried by the flow motion inside the drop and interact. These interactions are governed by fluid mechanics, biology and chemistry. Any modification in the drop evaporation process can reveal a given disease, either an RBC-related disease for whole blood drop evaporation or another disease for serum drop evaporation. Similar to those phenomena which we observe with whole blood are presented in the case of the desiccation of a colloidal suspension (Pauchard, Parisse & Alain 1999) [20]. Crack patterns formed by desiccation of a colloidal suspension in a sessile drop placed on a glass surface have been observed. Pauchard et al. (1999) demonstrate that the crack formation is related to the salinity of the suspension and interpreted the pattern obtained for large drops as buckling instability. The experimental observations with mica colloids in deionized water (Deegan 2000) were theoretical confirmed by Popov (2005)[23]. The biological suspension used in this study is real human whole blood from which the coagulation protein (fibrinogen) has been removed. RBCs are observed thanks to the relative transparency of a thin layer of blood (less than 500 μm). Bloodstain pattern analysis, which may be associated with the distribution, form, shape, and size of single bloodstains and the pattern itself, may substantially contribute to the reconstruction of events in the forensic setting. Although reviews of renowned experts in the field [24-31], case reports [32–34], and intensive research on the detection, molecular identification and estimation of deposition time of human traces [35-42] have considerably improved bloodstain pattern analysis, systematic research and knowledge still remain scarce concerning the physical properties of extracorporeal blood droplets [43-48]. The wipe pattern of bloodstains at a crime scene may be used to determine whether the stains were wet or dry at the time of manipulation by either victim or suspect. In some cases, the time period in which pre-existing blood stains can be altered by wiping is crucial for reconstruction purposes, e.g., to determine when a suspect had contact with a stain and then establish or eliminate an alibi. Therefore, detailed knowledge of bloodstain physical properties is of high importance. The drying process of fluids is a function of volume and surface are and mainly depends on temperature, humidity, air circulation and vapor pressure [49-50]. In addition, drying properties of viscous fluids such as blood are also affected by the target surface on which the fluid falls. Furthermore, droplet volumes may vary due to varying kinetic energy states and/ or velocities and depend on the shape of the object from which the droplet originates [24, 26, 47, 48, 51].

Drying processes and atmospheric changes, which bloodstains are subjected to over time, influence the evaluation of time-related processes, such as establishing alibis [52, 53, 54]. Misinterpretations may occur in distinguishing bloodstains produced in the chain of events of the original crime from bloodstains produced afterwards due to secondary dissemination, such as cleaning actions or the activities of persons involved after the crime (e.g., the police or emergency medical personnel). In some cases, specific patterns indicate diluted bloodstains, which may serve as a clue for specific actions (such as washing, cleaning, or removal of traces). Such circumstances are suspected especially when the potential bloodstains appear remarkably pale or diluted. This is a notable optical feature that may occur in pools of blood, but may also becaused by passive serum separation, which has been attributed to physiological clotting mechanisms [55]. Differentiation between these two possibilities may be

important for correct case assessment, e.g., proving cleaning attempts.

The physical properties of blood are an important factor in bloodstain pattern analysis (BPA) [56-60]. Blood is a viscous fluid consisting of approximately 45% cells in approximately 55% plasma, with an approximate water content of 90%. Thus, after blood loss, drying processes are a relevant determinant for the subsequent aspect of blood (stains) [61-63].

These drying processes are mainly affected by the time elapsed since deposition, the volume of blood making up the stain, ambient and surface temperatures, surface properties, humidity, air circulation, vapor pressure, clotting processes, and intra droplet fluid movements [64-67]. Initial macroscopic changes of extra corporal blood are affected by both evaporation and platelet activation/initiation of the coagulation cascade, which lead to constantly increasing viscosity of the blood and the formation of a mucilaginous and then gel-like entity. The subsequent external appearance of the stain is determined through further evaporation, which leads first to a varnish-like and then overall dull appearance, with partial bursts of dried blood flakes. Information on the time-dependent changes in extra corporal blood may contribute substantially to the reconstruction of a crime scene by clarifying the chain of actions leading to blood loss, since time-dependent changes are pertinent to data derived from analysis of the patterns of blood stains. The timespans during which bloodstains can be wiped before drying and the relative proportions of wiped surface areas of the droplet (i.e., thickness of skeletonization rings) are affected by the factors listed previously and might provide valuable data useful in BPA, when a prolonged chain of events is suspected. While the physical properties of extra corporal blood from healthy donors with normal blood cell counts and no anti coagulation therapy prior to blood loss have been the subject of BPA research over recent years, the drying times of blood stains composed of extra corporal blood from donors receiving anticoagulants have only been investigated for stains resulting from blood drops with low volumes. The drying times of stains resulting from low-volume blood drops were not significantly affected by anticoagulation therapy with acetylsalicylic acid (ASA), low- molecular-weight heparin (LMH), or clopidogrel (CPG) [68], despite a theoretically significant effect of those agents on drying and clotting processes.

Bloodstain pattern analysis is a forensic tool used by investigators to determine, among others, what, where and how a crime took place [4]. One of the most common types of bloodstains found on a crime scene following a deadly blood shedding event, is the blood pool (fig. 4). Ante- and postmortem it is often the case that a victim bleeds out, thus accumulating blood in one or multiple areas. Currently, when a blood pool is found, it is classified as such and an investigator can conclude that the blood donor was bleeding at that location for any reasonable period of time for the pool to be created, be it seconds, minutes or even hours. Previous studies have investigated if it was possible to determine what the volume of a blood pool was, to determine if such a loss of blood volume could constitute loss of life [5], or for other crime scene reconstruction purposes [6, 7, 8, 9]. However, almost no studies have been performed concerning the drying of an entire pool of blood. Such studies can be very useful for determining, e.g., the time that the blood shedding event occurred, any actions that may have occurred during the blood shedding event or the physiological state the subject was in. For example, fig. 4) shows two crime scene pictures of the same pool, 22 hours apart. In the first (top) picture, the edges and the bottom of the pool have started drying. In the second picture the pool has completely dried. Information obtained from how fast the blood dried could be crucial to determine when the pool was created.

II. METHODS AND MATERIAL

Materials:

1. Blood
2. Micropipette
3. Tips of Micropipettes
4. Glass Chembers
5. Tiles (White colured by "Kajaria Ceramics")
6. Glass slides
7. Soil
8. RH Meter
9. Knife
10. Camera – 3300 D
11. Vernier Calpier

III. METHODS AND MATERIAL

A sterilized vial was of around 10ml taken, after that the blood was collected from donar (healthy) as a sample of human blood, from a certified pathology laboratory. The blood was collected by a pathologist, using sterilized 10ml syringe & niddle. After taking out blood the blood was transferred & collected in sterilized vial containing EDTA in it. Which will further prevent blood from clotting. After collection the blood was kept in a refrigerator under cryogenic conditions.

After this, 4 glass chembers sterilized & cleaned with alcohol. By using white card sheet paper, covers was prepared to close the chembers from upside. Then, dry soil was taken which was heated inside the oven for 30 min. at 70 c. Then soil was spread inside the 4 chembers so that it could make leveled surface.

Here, 2 types of smooth substrates was taken one was Tiles & another one was Glass slides. This is because, most of the times on crime scenes we may found that the surfaces on which blood may found on smooth & solid surfaces like Tiles, Glass, Wood etc. Due to this tiles & glass slides were used in this.

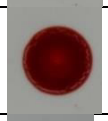
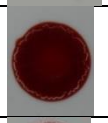
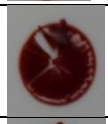
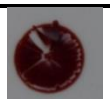
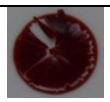
Out of 4 glass chembers, 2 tiles (white coloured by "Kajaria Ceramics") were kept into 2 chembers. 6,6 glass slides were kept in remaing 2 glass chembers respectively. After arranging the surfaces sterilized micropipette (5-50micro lit. capacity). Then, blood was taken with the help of sterilized tip adjusting micropipette at 10micro lit. and dropped on the tile from height 22.4 cm in one of the glass chamber. 3 drops were taken . Similarly by adjusting micropipette on 10micro lit. blood was taken and dropped on 3 glass slides from height 22.4cm present in another glass chamber. The same procedure was carried out for dropping the blood of volume 20 and 40micro lit. 3,3 drops were taken resp.

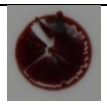
For mimicking the crime scenes, One knife was taken and dipped its sharp edge into the blood and allowed to dropped the blood on the tile of one chamber and glass slides having another chamber. 3,3 drops were taken on each substrate, from same height i.e. 22.4cm.

On first day, photographs were clicked of all drops immediate dropping. Further, photographs were clicked every 5min upto one hour. Because fast changes were observed in 1 hr. Photographs were clicked of all drops every 15 min upto 2 hr. From 3 hr. onwards photographs were clicked every half hour upto 6 hour. From 3 day onwards photographs of all drops were clicked every 2 hour form 0 hr to 6 hr. In this manner drying stages of blood were observed.

IV. RESULTS

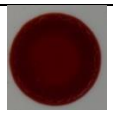
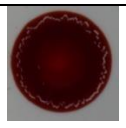
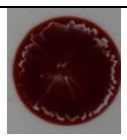
On Tile					
10µl					
Day 1					

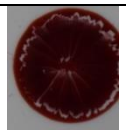
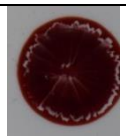
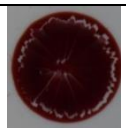
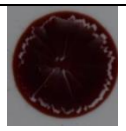
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	33.1	31	Imidiate after dropping
2		5 min	32.8	31	Cracks oberved at periphery
3		10 min	31.7	31	Cracks obsreved more clearly
4		15 min	31.4	31	Drop starting detached from surface except periphery
5		20 min	31.1	31	Apperances of radial cacks started
6		25 min	30.8	31	Colour darken, crackes observed more distinct
7		30 min	30.8	31	Colour darken, crackes observed more distinct
8		35 min	30.6	31	Colour darken, except periphery blood drop get shrunk
9		40 min	30.4	31	Gap distance between cracks increses
10		45 min	30.1	31	Gap distance between cracks increses
11		50 min	29.9	31	Colour darken, gap of radial cracks increses
12		55 min	29.9	31	Colour darken
13		60 min	29.9	31	Center part still intact to surface
14		1 Hr 15 min	29.7	31	Colour darken
15		6 hr	29.9	32	Colour darken

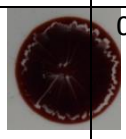
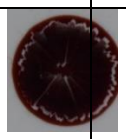
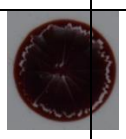
Day 3					
Sr. No.	Photo No.	Time	Temp.	Humidity	Visual observations
1		0 min	32.1	30	Gap between two cracks increases
2		2 hr	29.9	31	Some displacement of scalps occurs & colour darken
3		6 hr	31.1	31	Total detachment of blood stain except edge
Day 5					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.1	20	Only edge ring was present, small particals dispersed in surrounding to the drop
2		4 hr	30.1	22	Colour of ring darken
3		6 hr	30.3	20	Colour of ring darken
Day 7					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.8	30	Only edge ring was present, particals reamined as it was

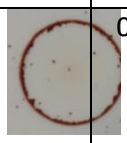
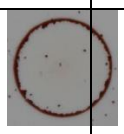
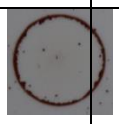
2		4 hr	30.5	30	Colour of ring darken
3		6 hr	30.7	30	Colour of ring darken
Day 8					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30.4	30	Only edge ring was present, particals reamined as it was
2		4 hr	28.9	30	Colour of ring darken
3		6 hr	29.3	30	Colour of ring darken
Day 9					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.1	20	Only edge ring was present, particals reamined as it was
2		4 hr	30.1	22	Colour of ring darken
3		6 hr	30.3	20	Colour of ring darken
Day 10					
Sr. No.	Photo No.	Time	Tem	Humidit	visual observations

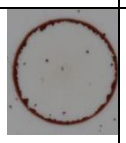
			p.	y	
1		0 min	31.5	30	Only edge ring was present, particals reamined as it was
2		4 hr	28.4	30	Colour of ring darken
3		6 hr	28.6	30	Colour of ring darken
20 µl					

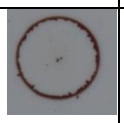
Day 1					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	33.1	31	Imidiate after dropping
2		10 min	31.7	31	Cracks starts to appear at periphery
3		15 min	31.4	31	Cracks were partially observed
4		20 min	31.1	31	Cracks got clearly observed at periphery
5		25 min	30.8	31	Crack gap increases at periphery, radial cracks initiated

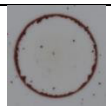
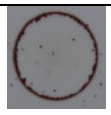
6		30 min	30.8	31	Colour darken of the drop
7		35 min	30.6	31	Radial cracks becames more clear
8		40 min	30.1	31	Colour darken of the drop
9		3 hr	29.2	31	Radial cracks started detaching from the surface
10		5 hr	29.9	31	Colour darken of the drop, crack gap increased
11		6 hr	29.7	31	Colour darken of the drop

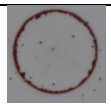
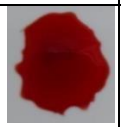
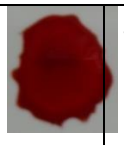
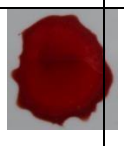
Day 3					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	31.1	30	Colour darken of the drop, radial cracks becames sharp
2		2 hr	29.9	31	Colour darken of the drop, detachment of scalps occourd
3		6 hr	31.1	33	Colour darken of the drop, center part still intacted to the surface

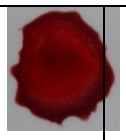
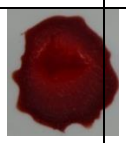
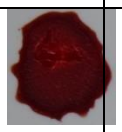
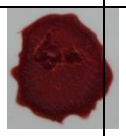
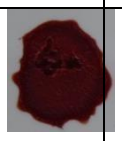
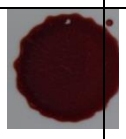
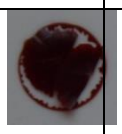
Day 5					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.1	20	Only edge ring was present, small particals were dispersed in surroundings
2		2 hr	30.3	23	Colour of ring got darken
3		6 hr	30.3	20	Colour of ring got darken

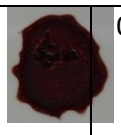
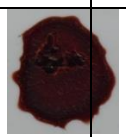
Day 7					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.8	30	Only edge ring was present, particals reamined as it was
2		2 hr	30.8	30	Colour of ring darken
3		6 hr	30.7	30	Colour of ring got darken
Day					

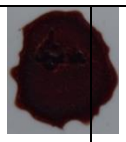
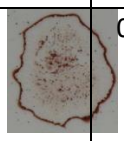
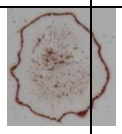
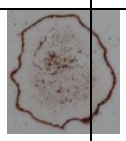
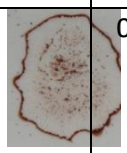
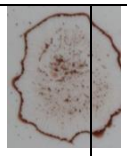
8					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30.4	30	Only edge ring was present, particals reamined as it was
2		2 hr	29.1	30	Colour of ring got darken
3		6 hr	29.3	30	Colour of ring got darken
Day 9					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations

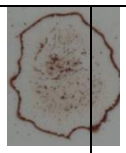
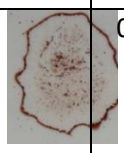
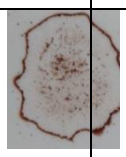
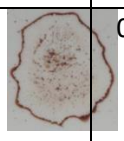
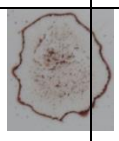
1		0 min	31.5	30	Only edge ring was present, particals reamined as it was
2		2 hr	28.8	30	Colour of ring got darken
3		6 hr	28.6	30	Colour of ring got darken
Day					

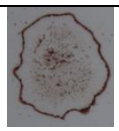
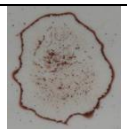
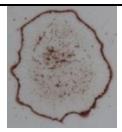
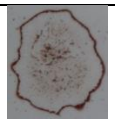
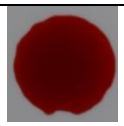
10					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30.2	30	Only edge ring was present, particals reamined as it was
2		2 hr	30.4	30	Colour of ring got darken
3		6 hr	30	30	Colour of ring got darken
40µl					
Day 1					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	29.9	31	Imidiate after dropping
2		5 min	29.7	31	Dark coloured ring like structure starts o form
3		10 min	29.6	31	Dark coloured ring like structure starts o form, black clots started appearing

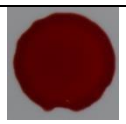
4		15 min	29.5	31	Colour darken of the ring, small cracks started appearing
5		20 min	29.5	31	Colour darken of the ring, one clot becames visible
6		25 min	29.4	31	Cracks appeared at periphery
7		30 min	29.2	31	Crackes became more clear
8		45 min	29.2	31	Crack gap increased
9		1 hr 45 min	29.2	31	One small scalp got removed
10		6 hr	29.9	32	Colour darken of the drop
Day 3					
Sr. No.	Photo No.	Time	Temp.	Humi dity	visual observations

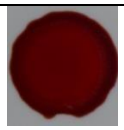
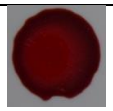
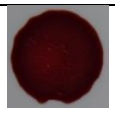
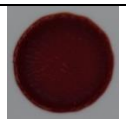
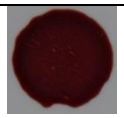
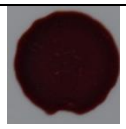
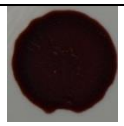
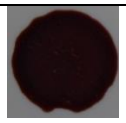
1		0 min	32.2	31	Colour darken of the drop, max clotting found at 2 points in near the center
2		2 hr	30.6	32	Colour darken of the drop, more small cracks were started to visible

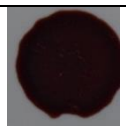
3		6 hr	31.3	33	Colour darken of the drop, at 2 clotted points small gaps were found
Day 5					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32	20	Only edge ring was present, small particals were dispersed in surroundings, more in center
2		2 hr	30.3	23	Colour of ring got darken
3		6 hr	30.4	20	Colour of ring got darken, str. of crack print found on tile surface
Day 7					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.4	30	Colour of ring got darken, particals remains as it was
2		2 hr	30.7	30	Colour of ring got darken

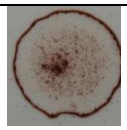
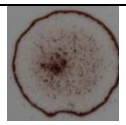
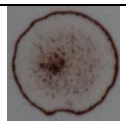
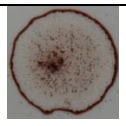
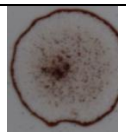
3		6 hr	30.8	30	Colour of ring got darken
Day 8					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30.2	30	Colour of ring got darken, particals remains as it was
2		2 hr	29.1	30	Colour of ring got darken
3		6 hr	29.3	30	Colour of ring got darken
Day 9					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	31.4	30	Colour of ring got darken, particals remains as it was
2		2 hr	28.5	30	Colour of ring got darken

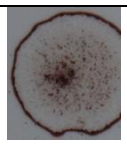
3		6 hr	28.6	30	Colour of ring got darken
Day 10					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30	30	Colour of ring got darken, particals remains as it was
2		2 hr	30.5	30	Colour of ring got darken
3		6 hr	30	30	Colour of ring got darken
Knife					
Day 1					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	29.5	31	Imidiate after dropping
2		5 min	29.5	31	Dark ring like structure started to appear

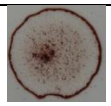
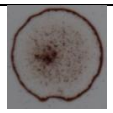
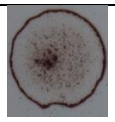
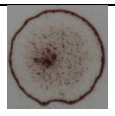
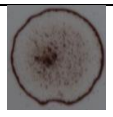
3		10 min	29.3	31	Colour darken of the ring

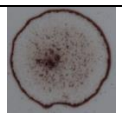
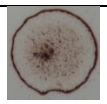
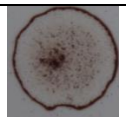
4		15 min	29.2	31	small cracks started to appear
5		20 min	29.2	31	crack no increaesed
6		25 min	29.2	31	cracks becames more clear
7		30 min	29.2	31	cracks observed at periphery
8		35 min	29.2	32	white coloured spots were observed
9		6 hr	29.9	32	Colour darken of the ring
Day 3					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	31.8	30	Dark brown coloured ring appeared at periphery, small stated to visible
2		2 hr	30	31	crack line became more distinct at periphery

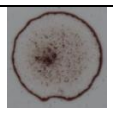
3		6 hr	31.1	33	Colour darken of the drop

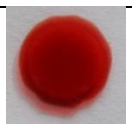
Day 5					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	31.7	20	Only edge ring was present, small particals were dispersed in surroundings
2		4 hr	30.1	21	Structure of crack print found on tile surface
3		6 hr	30.4	20	Colour darken of the drop
Day 7					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	32.3	30	Colour darken of the ring, particals remained as it was
2		4 hr	30.6	30	Colour darken of the ring

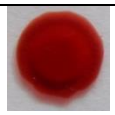
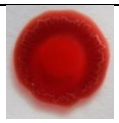
3		6 hr	30.8	30	Colour darken of the drop
Day 8					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations

1		0 min	30	30	Colour darken of the ring, particals remained as it was
2		4 hr	29	30	Colour darken of the ring
3		6 hr	29.2	30	Colour darken of the drop
Day 9					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	31.1	30	Colour darken of the ring, particals remained as it was
2		4 hr	28.5	30	Colour darken of the ring

3		6 hr	28.7	30	Colour darken of the drop
Day 10					
Sr. No.	Photo No.	Time	Temp.	Humidity	visual observations
1		0 min	30.1	30	Colour darken of the ring, particals remained as it was
2		4 hr	30.4	30	Colour darken of the ring

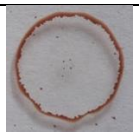
3		6 hr	30.3	30	Colour darken of the drop

Glass Slide					
10µl					
Day 1					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	33.1	31	Imidiate after dropping

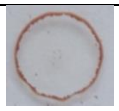
2		5 min	32.8	31	Imidiate after dropping
3		10 min	31.7	31	Cracks started appearing at dark region
4		15 min	31.4	31	Due to cracks scalps getting removed
5		20 min	31.1	31	Colour darken of the ring, crack gap increased
6		25 min	30.8	31	No. increased of the scalps removed
7		30 min	30.8	31	Center part was still intacted to the surface
8		35 min	30.6	31	Colour darken of the ring, crack gap increased

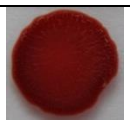
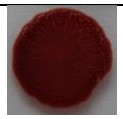
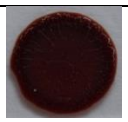
9		6 hr	29.7	32	Colour darken of the ring
Day 3					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.1	30	colour darken, scalps got detached form the suface
2		2 hr	29.9	31	Scalps detached but, center part was still intacted

3		6 hr	31.1	33	Colour darken, center & edge ring was still intacted
Day 5					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.1	20	Colour darken, More detachment of scalps occurred
2		4 hr	30.1	22	Colour darken, detachment of scalps increased
3		6 hr	30.3	20	Colour darken, detachment of scalps increased
Day 7					

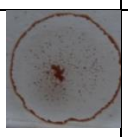
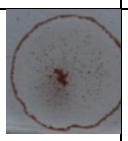
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.8	30	Only edge ring was present, small particals were dispersed in surroundings
2		4 hr	30.5	30	Colour of ring got darken
3		6 hr	30.7	30	Colour of ring got darken
Day 8					

Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	30.4	30	Only edge ring was present, particals remains as it was
2		4 hr	28.9	30	Colour of ring got darken
3		6 hr	29.3	30	Colour of ring got darken
Day 9					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	31.5	30	Only edge ring was present, particals remains as it was
2		4 hr	28.4	30	Colour of ring got darken
3		6 hr	28.6	30	Colour of ring got darken
Day 10					
Sr. No.	Photo No	Time	Tem	Humidity	Visual observations

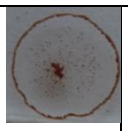
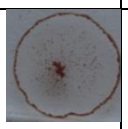
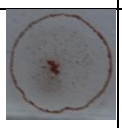
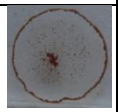
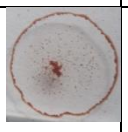
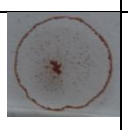
			p.		
1		0 min	30.2	29	Only edge ring was present, particals remains as it was
2		4 hr	30.2	29	Colour of ring got darken
3		6 hr	30	29	Colour of ring got darken
20µl					
Day 1					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	33.1	31	Imidiate after dropping
2		5 min	32.8	31	Dark coloured ring like structure started to form
3		10 min	31.7	31	colour darken of the ring
4		15 min	31.4	31	Small cracks found at dark region of the ring
5		20 min	31.1	31	Colour darken, cracks no. increased

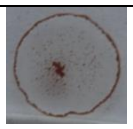
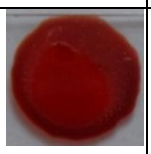
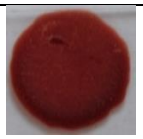
6		25 min	30.8	31	Colour darken, crack gap increased
7		30 min	30.8	31	Colour darken, cracks no increased
8		35 min	30.6	31	Colour darken, crack gap increased
9		6 hr	29.7	32	Colour darken of the ring
Day 3					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		2 hr	32.1	30	Colour darken of the ring, cracks became more clear
2		4 hr	29.7	29	Colour darken of the ring,
3		6 hr	31.1	33	Some parts of the cracks got detached

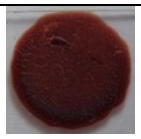
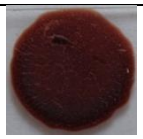
Day 5					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations

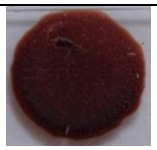
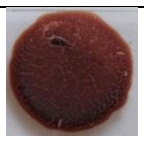
1		2 hr	31.1	20	Detachment of the scalps increased
2		4 hr	30.1	22	Cracks became more clear
3		6 hr	30.1	20	Colour darken
Day 7					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		2 hr	32.8	30	Only edge ring was present, small particals were dispersed in surroundings
2		4 hr	30.5	30	Colour of ring got darken
3		6 hr	30.7	30	Colour of ring got darken
Day 8					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations

1		2 hr	30.4	30	Only edge ring was present, particals remains as it was

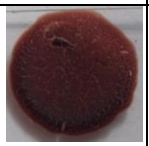
2		4 hr	28.9	30	Colour of ring got darken
3		6 hr	29.3	30	Colour of ring got darken
Day 9					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		2 hr	31.5	30	Only edge ring was present, particals remains as it was
2		4 hr	28.4	30	Colour of ring got darken
3		6 hr	28.6	30	Colour of ring got darken
Day 10					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		2 hr	30.2	29	Only edge ring was present, particals remains as it was
2		4 hr	30.2	29	Colour of ring got darken

3		6 hr	30	29	Colour of ring got darken
40µl					
Day 1					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	29.4	31	Imidiate after dropping
2		5 min	29.7	31	Dark coloured ring like structure started to form
3		10 min	29.6	31	colour darken of the ring
4		15 min	29.5	31	Small cracks found at dark region of the ring
5		20 min	29.5	31	Small cracks no. increased, 2-3 white spots were found
6		25 min	29.4	31	Cracks became clear, at one place blood clot found
7		30 min	29.2	31	Colour darken of the ring

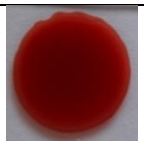
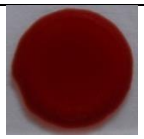
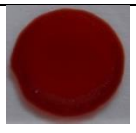
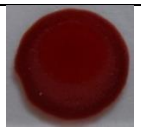
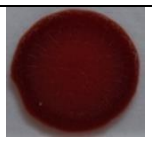
8		35 min	29.2	31	Cracks became more clearly visible
9		6 hr	29.9	32	colour darken of the ring
Day 3					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.2	31	Colour darken, more clotting occoured at one point
2		2 hr	30.6	32	One small scalp got removed
3		6 hr	31.3	33	Two more scalps got removed
Day 5					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32	20	Colour darken, dark coloured part started to detach from surface
2		4 hr	30.1	22	Colour darken, again one small scalp got removed

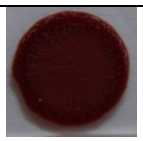
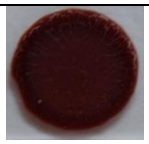
3		6 hr	30.4	20	Colour darken of the drop
Day 7					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.2	30	Colour darken, detachment increased
2		4 hr	30.5	30	Colour darken of the drop, cracks became more clear
3		6 hr	30.8	30	Colour darken of the drop
Day 8					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	30.2	30	Colour darken, detachment increased
2		4 hr	29	30	Colour darken of the drop

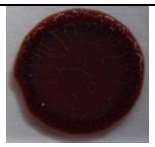
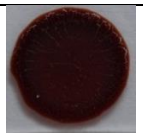
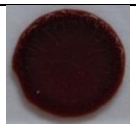
3		6 hr	29.3	30	Colour darken of the drop

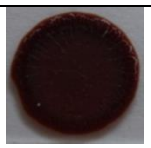
Day 9					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	31.4	30	Colour darken of the drop
2		4 hr	28.4	30	Colour darken of the drop
3		6 hr	28.4	30	Colour darken of the drop
Day 10					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	30	29	Colour darken of the drop
2		4 hr	30.4	29	Colour darken of the drop

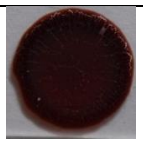
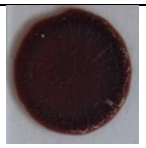
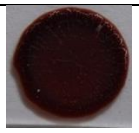
3		6 hr	30	29	Colour darken of the drop

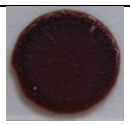
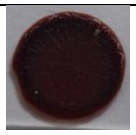
Knife					
Day 1					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	29.5	31	Imidiate after dropping
2		5 min	29.5	31	Dark coloured ring like structure started to form
3		10 min	29.3	31	colour darken of the ring
4		15 min	29.2	31	Small cracks found at dark region of the ring
5		20 min	29.2	31	Small cracks no. increased, one small scalp got removed
6		25 min	29.2	31	Cracks became clear, at one place blood clot found
7		30 min	29.2	32	Colour darken, more cracks found at periphery, one small salp got removed

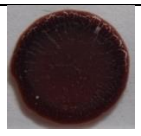
8		35 min	29.2	32	Colour darken, cracks no. increased
9		6 hr	29.9	32	Colour darken of the drop

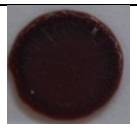
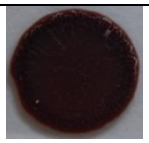
Day 3					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	32.8	30	Dark coloured ring appeared,
2		2 hr	30	31	Cracks became more clear
3		6 hr	31.1	33	Cracks became clearly visible
Day 5					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	31.7	20	Colour darken, dark part started detaching from the surface

2		4 hr	30.1	21	One small scalp got removed
3		6 hr	30.4	20	Colour darken of the drop
Day 7					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations

1		0 min	32.3	30	Colour darken of the drop, detachment increased from the surface
2		4 hr	30.6	30	Colour darken of the drop
3		6 hr	30.8	30	Colour darken of the drop
Day 8					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	30	30	Colour darken of the drop, detachment increased from the surface

2		4 hr	29	30	Colour darken of the drop
3		6 hr	29.2	30	Colour darken of the drop
Day 9					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	31.1	30	Colour darken of the drop, detachment increased from the surface
2		4 hr	28.5	30	Colour darken of the drop

3		6 hr	28.7	30	Colour darken of the drop
Day 10					
Sr. No.	Photo No	Time	Temp.	Humidity	Visual observations
1		0 min	30.1	29	Colour darken of the drop, detachment increased from the surface

2		4 hr	30.4	29	Colour darken of the drop
3		6 hr	30.3	29	Colour darken of the drop

V. CONCLUSION

Here we can concluded that, drying time of drop-stain on glass slide is little bit more than drying time of drop-stain on tiles.

Drying time of greater volume bloodstain is always greater than smaller volume bloodstains.

We can estimate the average time of bloodstain deposition on surface.

VI. REFERENCES

[1] S. H. James, P. E. Kish, T.P. Sutton, A. L. Carter, W.L. Fisher, C. Henderson, Scientific & Legal Application of Bloodstain pattern 1999.

[2] MacDonell, H. L. and Bialousz, L. F. Flight Characteristics and stain Patterns of Human Blood, Washington, D. C., U. S. Dept. of Justice, Law Enforcement Assistance, National Institute of Law Enforcement and Criminal Justice, 1971.

[3] Pizzola, P. A. and Deforest, P. R., Blood Droplet Dynamics 2, Journal of Forensic Science, JFSCA, Vol. 31, No. 1, Jan 1986, pp. 50-54.

[4] S. H. James, P. E. Kish, Sutton, Principles of Bloodstain Pattern Analysis, Theory and Practice, CRC, 2005.

[5] H. F. Bartz, Estimating original bloodstain volume: the development of a new technique relating volume and surface area, Ph.D. thesis, Department of Biology, Laurentian University, Sudbury, Ontario (2003).

[6] H. Lee, Estimation of original volume of bloodstains, Identification News 9 (1986) 4.

[7] S. P. Sant, S. I. Fair grieve, Exsanguinated blood volume estimation using fractal analysis of digital images*, Journal of forensic sciences 57 (3) (2012) 610–617.

[8] N. Laan, R. H. Bremmer, M. C. G. Aalders, K. G. de Bruin, Volume determination of fresh and dried bloodstains by means of optical coherence tomography, J. Forensic Sci. 59 (1) (2014) 34–41.

[9] N. Laan, K. G. de Bruin, D. Slenter, J. Wilhelm, M. Jermy, D. Bonn, Bloodstain pattern analysis: implementation of a fluid dynamic model for position determination of victims, Scientific reports 5.

[10] D. Brutin, B. Sobac, B. Loquet, J. Sampol, Pattern formation in drying drops of blood, Journal of fluid mechanics 667 (2011) 85–95.

[11] B. Sobac, D. Brutin, Structural and evaporative evolutions in desiccating sessile drops of blood, Physical Review E 84 (1) (2011) 011603.

[12] W. Bouzeid, D. Brutin, Influence of relative humidity on spreading, pattern formation and adhesion of a drying drop of whole blood, Colloids and Surfaces A: Physicochemical and Engineering Aspects 430 (2013) 1–7.

[13] W. B. Zeid, J. Vicente, D. Brutin, Influence of evaporation rate on cracks formation of a drying drop of whole blood, Colloids and Surfaces A: Physicochemical and Engineering Aspects 432 (2013) 139–146.

[14] B. Sobac, D. Brutin, Desiccation of a sessile drop of blood: cracks, folds formation and delamination, Colloids and Surfaces A:

Physicochemical and Engineering Aspects 448 (2014) 34–44.

[15] F. Ramsthaler, J. Schlote, C. Wagner, J. Fiscina, M. Kettner, The ring phenomenon of diluted blood droplets, International journal of legal medicine 130 (3) (2016) 731–736.

[16] Deegan, R. D. 2000 Pattern formation in drying drops. Phys. Rev. E 61, 475–485.

[17] Martusevich, A. K., Zimin, Y. & Bochkareva, A.2007 Morphology of dried blood serum specimens of viral hepatitis. Hepatitis Mon. 7, 207–210.

[18] Shabalin, V. N. & Shatokhina, S. N.2007 Diagnostic markers in the structures of human biological liquids. Singap. Med. J. 48, 440–446.

[19] Zhuang, H., Coulepis, A. G., Locarnini, S. A. & Gust, I. D. 1982 Detection of markers of hepatitis B infection in serum dried on to filter-paper: an application to field studies. Bull. World Health Organ. 60, 783–787.

[20] Yakhno, T. 2008 Salt-induced protein phase transitions in drying drops. J. Colloid Interface Sci. 318, 225–230.

[21] Pozrikidis, C. 2006 Flipping of an adherent blood platelet over a substrate. J. Fluid Mech. 568, 161–172.

[22] Pauchard, L., Parisse, F. & Alain, C. 1999 Influence of salt content on crack patterns formed through colloidal suspension desiccation. Phys. Rev. E 59, 3737–3740.

[23] Popov, Y. O. 2005 Evaporative deposition patterns: spatial dimensions of the deposit. Phys. Rev. E 71, 036313.

[24] Peschel O, Kunz SN, Rothschild MA, Mützel E (2011) Blood stain pattern analysis. Forensic Sci Med Pathol 7(3):257–270.

[25] White RB (1986) Bloodstain pattern of fabrics—the effect of drop volume, dropping height and impact angle. J Canadian Society Forensic Sci 19(1):3–36.

[26] Stuart H J ,Kish P E, Sutton TP (2005) Principles of bloodstain pattern analysis. Theory and Practice. Taylor & Francis, Boca Raton

[27] Karger B, Rand S P, Brinkmann B(1998)Experimental bloodstains on fabric from contact and from droplets. Int J Legal Med 111(1):17–21.

[28] Rothschild MA (2008) Analyse des Blutspurenverteilungsmusters. In: Kneubuehl BP, Coupland RM, Rothschild MA, Thali MJ (eds) Wundballistik, 3. Aufl. Springer, Berlin.

[29] Rand S, Madea B, Brinkmann B (1985) Zur Morphologie von Blutspuren. Beitr Gerichtl Med XLIII:259–264.

[30] MacDonell HL (1993) Bloodstain patterns. Golas, NY.

[31] Bevel T, Gardener RM (1997) Bloodstain pattern analysis with an introduction to crime scene reconstruction. CRC, Boca Eaton.

[32] Karger B, Rand S, Fracasso T, Pfeiffer H (2008) Bloodstain pattern analysis—casework experience. Forensic Sci Int 181:15–20.

[33] Kettner M, Ramsthaler F, Schnabel A (2010) “Bubbles” a spot diagnosis. J Forensic Sci 55(3):842–844.

[34] Sauvageau A, Schellenberg M, Racette S, Julien F (2007) Bloodstain pattern analysis in a case of fatal varicose vein rupture. Am J Forensic Med Pathol 28:35–37.

[35] Wilson CI, Altschul S, Mead A, Flannagan LM (2004) Bloodstain pattern analysis in a case of suicide with a compound bow and arrow. Am J Forensic Med Pathol 25:80–82.

[36] Barni F, Lewis SW, Berti A, Miskelly GM, Lago G (2007) Forensic application of the luminol reaction as a presumptive test for latent blood detection. Talanta 72:896–913.

[37] Laux DL (1991) Effects on luminol on the subsequent analysis of bloodstains. J Forensic Sci 36:1512.

[38] Laux DL (2005) The detection of blood using luminol. In: James S, Kish PE, Sutton TP (eds)

Principles of bloodstain pattern analysis: theory and practice. CRC, Boca Raton, pp 369–389.

[39] Lytle LT, Hedgecock DG (1978) Chemiluminescence in the visualization of forensic bloodstains. J Forensic Sci 23:550–555.

[40] Weber K (1966) Die Anwendung der Chemilumineszenz des Luminols. Z Gerichtl Med 57:410.

[41] Quickenden TI, Creamer JI (2001) A study of common interferences with the forensic luminol test for blood. Luminescence 16:295–298.

[42] Ackermann K, Ballantyne KN, Kayser M (2010) Estimating trace deposition time with circadian biomarkers: a prospective and versatile tool for crime scene reconstruction.

[43] Anderson S, Howard B, Hobbs GR, Bishop CP (2005) A method for determining the age of a bloodstain. Forensic Sci Int 148:37–45.

[44] Donaldson A, Walker NK, Cordiner SJ, Taylor MC (2010) Using oral microbial DNA analysis to identify expirated blood spatter. Int J Legal Med 124(6):569–576.

[45] Gardener RM (2002) Directionality in swipe patterns. J Forensic Ident 52(5):579.

[46] Pizzola P A ,Roth S ,DeForest PR(1986)Blood droplet dynamics—I. JFSCA 31(1):36–49.

[47] Pizzola PA, Roth S, De Forest PR (1986) Blood droplet dynamics— II. JFSCA 31(1):50–64.

[48] Buck U, Kneubuehl B, Näther S, Albertini N, Schmidt L, Thali M (2011) 3D bloodstain pattern analysis: ballistic reconstruction of the trajectories of blood drops and determination of the centres of origin of the bloodstains. Forensic Sci Int 206:22–28.

[49] Donaldson AE, Walker NK, Lamont IL, Cordiner SJ, Taylor MC (2011) Characterising the dynamics of expirated bloodstain pattern formation using high-speed digital video imaging. Int J Legal Med 125:757–762.

[50] Laber TL (1985) Diameter of a bloodstain as a function of origin. Distance fallen and volume of drop. IABPA News 2(1):12–16.

[51] Laber TL, Epstein BP (1983) Bloodstain pattern analysis. Callen, Minneapolis.

[52] Ramsthaler F, Schmidt P, Bux R, Potente S, Kaiser C, Kettner M (2012) Drying properties of bloodstains on common indoor surfaces. Int J Legal Med 126(5):739–746.

[53] James SH, Kish PE, Sutton TP (2005) Principles of bloodstain pattern analysis: theory and practice. Taylor and Francis – CRC Press, Boca Raton.

[54] Laber TL, Epstein BP (2001) Substrate effects on the clotting time of human blood. J Can Soc Forensic Sci 34(4):209–214.

[55] Stuart HJ, Kish PE, Sutton TP (2005) Principles of bloodstain pattern analysis: theory and practice. Taylor & Francis, Boca Raton.

[56] Bevel T, Gardener RM (1997) Bloodstain pattern analysis with an introduction to crime scene reconstruction. CRC, Boca Raton.

[57] Gardener RM (2002) Directionality in swipe patterns. J Forensic Ident 52(5):579.

[58] Kettner M, Schmidt A, Windgassen M, Schmidt P, Wagner C, Ramsthaler F (2015) Impact height and wall distance in bloodstain pattern analysis—what patterns of round bloodstains can tell us. Int J Legal Med 129(1):133–140.

[59] Peschel O, Kunz S N, Rothschild MA, Mützel E (2011)Blood stain pattern analysis. Forensic Sci Med Pathol 7(3):257–270.

[60] Stuart HJ, Kish PE, Sutton TP (2005) Principles of bloodstain pattern analysis. Theory and practice. Taylor & Francis, Boca Raton.

[61] Anderson S, Howard B, Hobbs GR, Bishop CP (2005) A method for determining the age of a bloodstain. Forensic Sci Int 148:37–45.

[62] Pizzola PA, Roth S, De Forest PR (1986) Blood droplet dynamics—I. JFSCA 31(1):36–49.

[63] Pizzola PA, Roth S, De Forest PR (1986) Blood droplet dynamics—II. JFSCA 31(1):50–64.

[64] Ramsthaler F, Schmidt P, Bux R, Potente S, Kaiser C, Kettner M (2012) Drying properties of bloodstains on common indoor surfaces. Int J Legal Med 126(5):739–746.

[65] Ramsthaler F, Schlote J, Wagner C, Fiscina J, Kettner M(2016)The ring phenomenon of diluted blood droplets. Int J Legal Med 30(3): 731–736.

[66] Raymond MA, Smith ER, Liesegang J (1996) The physical properties of blood—forensic considerations. Sci Justice 36:153–160.

[67] White RB (1986) Bloodstain pattern of fabrics—the effect of drop volume, dropping height and impact angle. J Canadian Society Forensic Sci 19(1):3–36.

[68] Ramsthaler F, Schmidt P, Bux R, Potente S, Kaiser C, Kettner M (2012) Drying properties of bloodstains on common indoor surfaces. Int J Legal Med 126(5):739–746.