ORIGINAL ARTICLE

Evaluation of Inkjet Ink and Substrate Degradation in Media with Varying pH Levels

Gokhale C,[1] Mali B,[2] Sood A,[3] Kaur R.[4]

Research Scholar,[1] Student,[2] Associate Professor.[3,4]
1,3,4. Department of Forensic Science, Institute of Sciences, Chandigarh University, Mohali.
2. Institute of Forensic Science Mumbai, Mumbai University, Mumbai, Maharashtra.

Abstract:

Forensic questioned document is a very important field. Forensic document expert (FDE) are generally well versed with the characteristics related to paper, ink and other writing media that helps in evaluating the case. Despite to possess great knowledge and experienced, a forensic document examiner may deals with the lot of challenges. Documents reach the forensic document examiner in different and various conditions. The documents can be torn, shredded, burnt, chemically destroy, engrave in soil or even soaked in some liquid. The document may be thrown in ponds, water tanks etc. by the criminal in order to hide the original document. During a document comes in contact with any liquid lots of destructive will happen to it. Many techniques are attempted and proposed for examination of water soaked documents and if required the restoration of content. Therefore, the present study has been attempted to evaluate the impact of soaking in different liquid medium on the different paper surfaces and printed content. The printed document soaked in liquids having different pH (Acidic, basic, neutral) were studied so as to determine the effect on printing ink and substrate. The change in characteristics of the paper and ink were noted and facilitated in estimating the age of the soaked document. The samples were examined using Olympus Stereomicroscope and under Ultra-violet light.

Keywords: Bond paper; Glossy paper; Soaked document; UV light; Stereomicroscope; Inkjet printer; Questioned documents.

Introduction:

A document is a material which contains some symbols, numbers or any other writing which gives some meaning, information to some persons or it can be considered as evidence in the course of investigation. It may be paper, wall, stone, metal, glass and wooden piece etc.[1] For the document a writing material and writing media is compulsory. Document is very important in day to day life. We almost every day come across a number of documents.[1] We write and sign daily in our personal and in professional life. In the modern age where credit cards and online purchasing are ubiquitous, identity theft are a common concern . Alteration or fabrication of the document is increasing day by day which may adversely affect the modern society. Criminals are not dim to realise the importance of documents. Modes and methods for falsification of document have been exploited to an extent by criminal class.[2] For the Forensic Document Expert, it is a very challenging task to examine different types of documents like books, wills, letters, suicidal notes, cheques and bills etc which are severely damaged by the criminals to conceal the writings or authenticity of the documents. With the changing technology in the field of forensic science, criminals are adopting new and different techniques to commit a crime. In such cases criminals destruct the documents by burning, tearing, chopping, engraving, soaking the documents. It is very important to examine the document which determines the authenticity and integrity of the document.

Researchers have used liquid nitrogen, freeze drying, vacuum freeze dehydration and stereo microscopy to attempt and successfully repair and decode various texts.[3-8] Ink feathering, lateral spreading, transference to adjacent or facing paper, change in shine and other phenomena have all been researched in saturated ballpoint pen writings and gel pen writings.[9-10] Less research on the inspection of soaked documents has been documented, according to the literature review.

The purpose of the current study was to gain a conceptual understanding of the impact of soaking inkjet printed documents on a variety of substrates in various mediums, such as acidic, neutral and basic solutions at different intervals. The printed matter on the documents were attempted to be deciphered using a Stereo microscope and UV light. The project provides a wonderful outcome for the understanding developed regarding various features of printed matter on various types of sheets soaked in various forms of liquid media.

Materials and Methods:

The current study was conducted to analyze the different brands of inkjet printer ink on Bond paper, Glossy paper and A4 sized paper soaked in three pHs of liquids at three different intervals, after the approval by Institutional ethics committee. The samples of printed documents were prepared with three different brands of inkjet printer (Table no.1) on three distinct types of paper. White normal printing paper of the JK Copier brand in an A4 size (21 cm x 29.7 cm) with a 80 GSM weight and Super White JK Excel Brand in bond paper with same size (90 GSM) and White Oddy Snap Shot inkjet ID paper brand in glossy paper with same size

Corresponding Author
Ms. Chanchal Gokhale
Email : gokhale.chanchal@gmail.com
Mobile No.: +91 79998 49915

Article History
DOR : 11.12.2022; DOA : 16.05.2023

Table 1. Brands of Printer chosen for the study.

S.No.	Brands of Printer
1.	Canon G2010
2.	Epson L805
3.	Epson 3780

(180 GSM) were the substrate chosen for the investigation.

For the investigation, three distinct types of liquid mediums—acidic (pH 3), neutral (pH 7) and alkaline (pH 13)-were created by soaking the printed documents prepared on the three variety of substrates. The regular tap water, with a pH of 7,

Table 2. Showing phenomenon observed in printed document immersed in acidic medium (HCl) on A4 paper, bond paper and glossy paper at different intervals.

S. No.	Brands of Printer	Type of paper	Time Interval after a week	Time Interval after fifteen days	Time Interval after a month
1	Canon G2010	A4 Plain Paper	No Change in Ink and Paper	Ink fades away Paper turns yellow Absorbed HCl spots are seen. Ink is completely absorbed by paper	Ink is spread and slightly faded Paper turns greenish yellow Black greasy layer is seen on paper HCl spots are seen Paper is degraded
		Bond Paper	No Change in Ink and Paper	Ink starts to fade away and is spread Ink is completely absorbed by paper	Ink is completely spread and absorbed Some portion of Ink is faded away and fragmented Paper turns pale yellow Paper starts degrading HCl spots are seen on paper Ink traces and some content is are seen under UV visible light
		Glossy Paper	No Change in Ink and Paper	Ink is slightly separated No change in Paper Plastic layer separated HCl spots are seen	Ink is spread Yellowishness in Paper increases Plastic layer separated Paper degraded HCl spots are seen
2	Epson L805	A4 Plain Paper	No Change in Ink and Paper	Paper turns yellow Ink is completely absorbed by the paper Ink is spreaded HCl spots are seen	Ink is completely faded away A blackish greasy layer is deposited over Paper Paper turns greenish yellow Content is not seen on paper Paper is degraded
		Bond Paper	No Change in Ink and Paper	Blue ink completely fade away and magenta is spreaded Ink is completely absorbed by paper	HCl spots are seen Ink spreading increased Ink is completely absorbed by the paper Content is visualized under uv light Paper is slightly degraded
		Glossy Paper	No Change in Ink and Paper	Ink start to spread Plasticated layer starts separating HCl absorbed Paper are seen on paper	Ink spreading increases Plastic layer separation continous Paper degradation started Yellowishness in Paper increases HCl spots are seen.
3	Epson 3780	A4 Plain Paper	No Change in Ink and Paper	Paper turns yellow Ink is completely fragmented HCl spots are seen	Paper turns more yellow and slight green in color Ageing is increasing Ink is more fragmented HCl spots are seen Paper is more degraded Rottening is seen in paper
		Bond Paper	No Change in Ink and Paper	Ink is fragmented HCl spots are seen Paper turns pale yellow	Ink fragmentation increases Yellowness in Paper increases Paper turns more older aged HCl spots are seen Crystalline particles are observed
		Glossy Paper	No Change in Ink and Paper	Upper layer slightly separated Ink is fragmented	Upper layer separated Paper degraded Ink fragmented Paper turns pale yellow HCl spots are seen

Table3. Showing phenomenon observed in printed document immersed in alkaline medium (NaOH) on A4 paper, bond paper and glossy paper at different intervals.

S. No.	Brands of Printer	Type of paper	Time Interval after a week	Time Interval after fifteen days	Time Interval after a month
1	Canon G2010	A4 Plain Paper	No Change in Ink and Paper	Ink is fragmented and start spreading Laid marks are seen Absorption spots are seen Ink is completely absorbed by the paper Paper is degraded	Laid marks are started to fade away Paper degradation continues Ink is fully absorbed by paper NaOH spots are seen Ink is spreaded and only black ink is fragmented Ink traces are seen under UV light
		Bond Paper	No Change in Ink and Paper	Laid marks are seen Ink start separating Ink is completely absorbed by paper Wet spots are seen.	Ink spreaded/ faded/ fragmented Laid marks disappeared Ink completely absorbed NaOH spots are seen on paper Paper is degraded Ink traces and some printed portion is visible under uv light
		Glossy Paper	No Change in Ink and Paper	Ink is slightly faded Laid marks are seen NaOH spots are seen on paper. Plasticated layer start separating Ink is completely absorbed by paper	Ink is spreaded Laid marks slightly fade away NaOH spots are seen Paper is degraded Plasticated layer is separating continuously Crystalline particles are observed
2	Epson L805	A4 Plain Paper	No Change in Ink and Paper	Ink is spreaded and fade away NaOH spots are seen Ink is completely absorbed by paper	Paper degradation continues Ink spreading increases Ink is faded away more NaOH spots are seen Ink is absorbed in paper too.
		Bond Paper	No Change in Ink and Paper	Ink is completely absorbed, spread and faded away	Ink is not seen as it was completely faded away from Paper NaOH spots are seen Paper is slightly degraded Ink is completely absorbed by paper Some portion of ink is visible under UV light
		Glossy Paper	No Change in Ink and Paper	Ink is slightly spreaded	Paper degradation and plastic layer separation is started Ink is slightly absorbed in paper
3	Epson 3780	A4 Plain Paper	No Change in Ink and Paper	Ink is fragmented Spots of NaOH are seen	Ink fragmentation increases NaOH spots are seen Paper starts to degrade
		Bond Paper	No Change in Ink and Paper	Ink is fragmented NaOH spots are seen on paper	Ink fragmentation increases Paper is slightly degraded NaOH spots are seen
		Glossy Paper	No Change in Ink and Paper	Plastic layer seperated Ink is fragmented	Ink fragmentation increases Plasticated layer separated Dullness in Paper increases Crystalline particles are observed

 DOI : 10.48165/jiafm.2024.46.2(Suppl).11

was chosen as the study's neutral medium. By incorporating concentrated Sodium Hydroxide (NaOH) with a pH 13.53 and concentrated Hydrogen Chloride (HCl) with a pH of 1. Before soaking the samples, the pH of each solution-acidic (pH 3), neutral (pH 7) and alkaline (pH 13.53)-was determined using a pH meter.

As the samples were prepared by using three different brands of inkjet printer on three substrates which was soaked in three different mediums made the total number of samples twenty seven. The twenty seven samples were soaked at different time interval that is one week, fifteen days and one month that made the total number of samples eighty one.

Before soaking, the samples were examined and observed under the visible light and UV radiations. One booklet from each brand

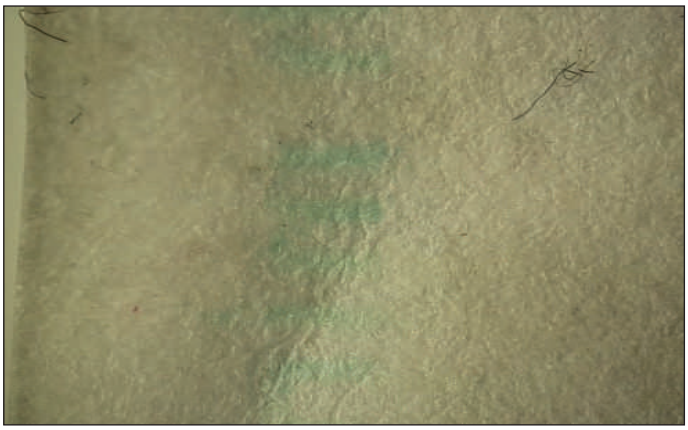

Figure 1. Change in color of inkjet printer ink and texture of paper after immersion in acidic medium for fifteen days.

Figure 2. Change in the texture of glossy paper after immersion in acidic medium for fifteen days.

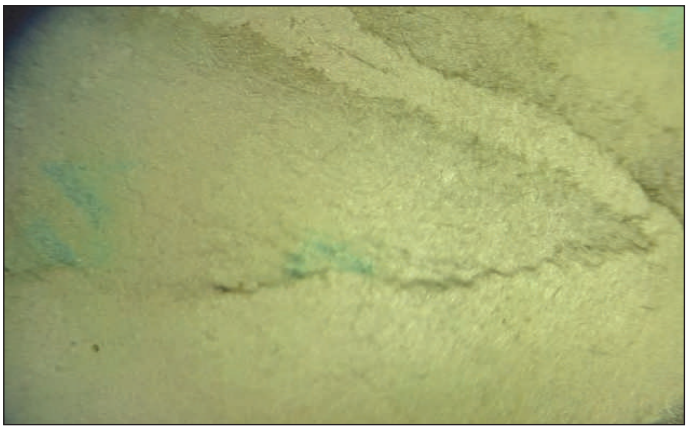

Figure 3. Change in the texture of A4 plain paper after immersion in acidic medium for one month.

Figure 4. Change in the texture of bond paper and spreading ink after immersion in neutral medium for fifteen days.

Figure 5. Fading of ink on bond paper after immersion in neutral medium for one month.

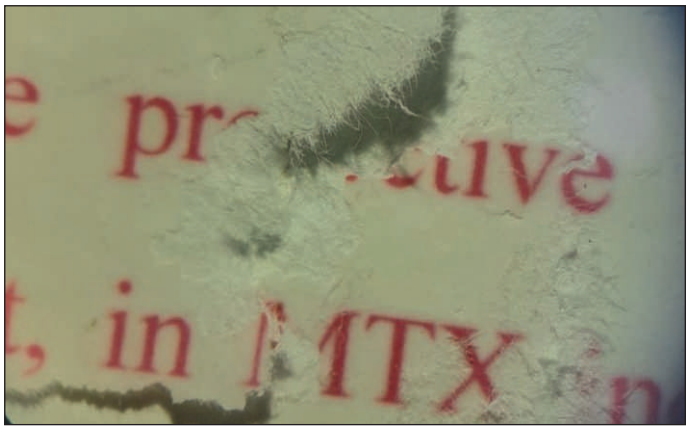

Figure 6. Plastic layer of the glossy paper separated after immersion in neutral medium for one month.

of printer, prepared on three different substrates selected for the study and preserved as control samples. After one week, fifteen days and a month, one booklet from each medium-acidic (pH 1), neutral (pH 7) and alkaline (pH 13)-was removed, observed in visible light and examined under a stereomicroscope and UV radiation. The outcomes of printed documents soaked in varied pH liquids at different time intervals were noted (Table 2-4). Blank samples were also prepared and analyzed in the same way and preserve as standard samples.

Results and Discussion:

The findings of printed document samples prepared on three different substrates that is A4 size plain paper, glossy paper and bond paper soaked in different liquids having varied pH that is acidic, neutral and basic for three different intervals have been evaluated (Table 2-4) and has following characteristic features.

Printed Documents in acidic medium at different time intervals: The outcomes of printed documents soaked in acidic medium that is in hydrochloric acid after one week, fifteen days and one month were analyzed (Table no.2). It was observed that no spreading of ink, fading of ink, transfer of ink on subsequent paper or facing paper or no changes seen in the texture of A4 plain paper, bond paper and glossy paper soaked in acidic medium after one week. While spreading, changing and fading of inkjet ink, spots of HCl and transfer of ink seen after fifteen days of soaking on A4 plain paper (Figure 1), bond paper and glossy paper whereas changes in color and texture of A4 plain and degradation of transparent film on the glossy paper seen after fifteen days (Figure 2). Similarly after one month, change in the texture of A4 plain paper and glossy paper was clearer this shows the aging of the document. So, as the time interval increases more prominent characteristics were observed.

Printed documents in neutral medium at different time intervals:

The outcomes of printed documents soaked in neutral medium that is in tap water (pH 7) after one week, fifteen days and one month were analyzed (Table no.4). It was observed that no spreading of ink, fading of ink, transfer of ink on subsequent paper or facing paper or no changes seen in the texture of A4 plain paper, bond papers and glossy paper soaked in neutral medium

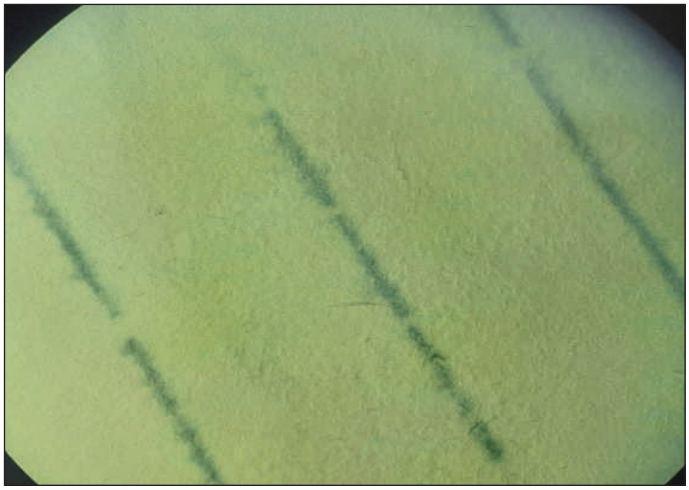

Figure 7. Line marks are present on paper after immersion in alkaline medium for fifteen days.

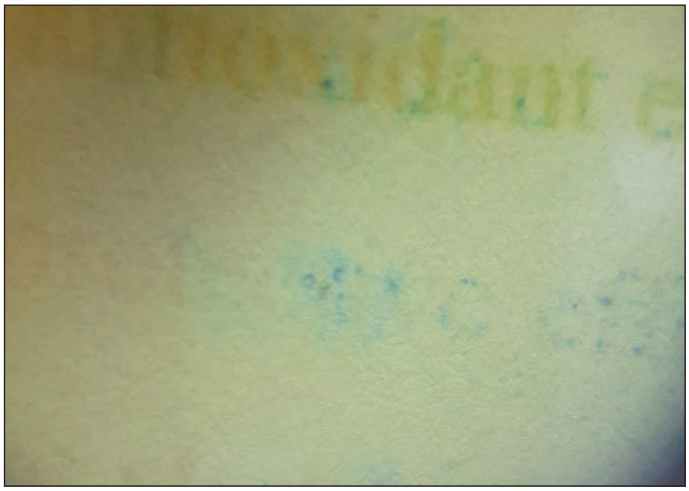

Figure 8. Spreading and transferring of ink after immersion in alkaline medium for one month.

Figure 9. Ink completed fade after immersion in alkaline medium for one month.

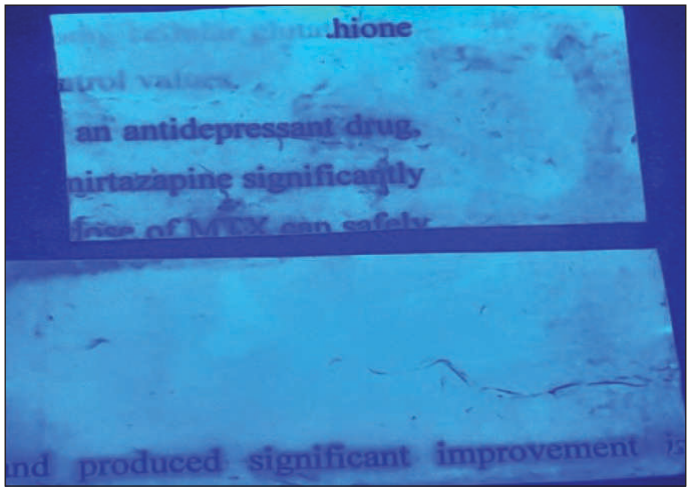

Figure 10. Change in texture of glossy paper and spreading of ink after immersion in acidic medium for one month under UV radiations.

Table 4. Showing phenomenon observed in printed document immersed in neutral medium (tap water) on A4 paper, bond paper and glossy paper at different intervals.

S. No.	Brands of Printer	Type of paper	Time Interval after a week	Time Interval after fifteen days	Time Interval after a month
1	Canon G2010	A4 Plain Paper	No Change in Ink and Paper	Ink is spreaded and destroyed Wet spots are seen Ink is completely absorbed by paper	Ink is spreaded and faded Ink is completely absorbed by the paper Water spots are seen Crystalline particles are observed Ink is slightly fragmented too
		Bond Paper	No Change in Ink and Paper	Ink is fragmented Water spots are seen	Paper turns slight yellow Ink is slightly fragmented, slightly spread and slightly faded away on paper Paper is degraded Some content is seen under UV light Ink is completely absorbed by paper Water spots are seen Ink traces are also observed under UV Light
		Glossy Paper	No Change in Ink and Paper	Plastic layer starts separating No change in ink	Plastic layer separated Ink fade away Paper degraded Ink is slightly spread
2	Epson L805	A4 Plain Paper	No Change in Ink and Paper	Ink is faded, spreaded and completely absorbed by the paper Water spots are seen	Ink is completely faded and spreaded away from Paper Paper is slightly degraded Water spots are seen Ink traces can be visualized under UV light
		Bond Paper	No Change in Ink and Paper	Paper turns yellow Ink is completely absorbed by the paper Ink is spreaded HCl spots are seen	Ink is completely faded away A blackish greasy layer is deposited over Paper Paper turns greenish yellow Content is not seen on paper Paper is degraded
		Glossy Paper	No Change in Ink and Paper	Spreading of ink increases Paper absorbed Water Plastic layer starts separating	Ink spreading continous Water spots are seen Paper degradation and plastic layer separation continues
3	Epson 3780	A4 Plain Paper	No Change in Ink and Paper	Ink is fragmented	Ink fragmentation increases Paper is degraded Crystalline particles are observed
		Bond Paper	No Change in Ink and Paper	Ink is fragmented Ink starts to separate in spots Water spots are seen on paper	Paper is slightly degraded Ink fragmentation increases Water spots are seen on paper Crystalline particles are observed over the paper
		Glossy Paper	No Change in Ink and Paper	Upper plastic layer separated Ink is fragmented	Plasticated layer completely separated Ink more fragmented Paper is degraded

after one week. Whereas after fifteen days ink starts to fade and spreading of ink takes place while the paper turns yellow in A4 plain paper and bond paper, plastic layer starts separating in glossy paper shows significant feature of aging. Similarly after one month plastic layer of the glossy paper gets completely fading of ink can be observed (Figure 3-6).

Printed documents in basic medium at different time intervals: The outcomes of printed documents soaked in neutral medium that is in tap water (pH 13.5) after one week, fifteen days and one month were analyzed (Table no.3). It was observed that no spreading of ink, fading of ink, transfer of ink on subsequent paper or facing paper or no changes seen in the texture of A4 plain paper, bond paper and glossy paper soaked in neutral medium after one week. After fifteen days line marks are seen on the A4 plain paper, bond paper and glossy paper while spreading of ink and fading of ink started. Similarly, ink got completely faded and visible under UV light (Figure 7-9).

Development of the disappeared content under UV light: It was observed that more prominent feature of spreading of inkjet printer ink and changes in the texture were studied under UV light but ink does not produce fluorescence under UV light.

Similarly the blind samples were examined to estimate the changing effect on the three types of substrates in three liquid aqueous medium with varied pHs. 100% accurate results were obtained under different phenomena in different time intervals with three different substrates and matched with the preserved samples.

Conclusion:

It was concluded that study on inkjet printer ink on three different types of substrates soaked in three liquid mediums with varied pHs produced highly consistent results. The study can be successfully applied for the forensic analysis where printed documents are found in soaked condition. The current study has a one-month time limit, but it can be extended to a longer period of time and it can also explore different written or printed materials with a comparable study.

Conflict of Interest: None

Financial Assistance: None

References:

1. Sharma, B.R. “Forensic Science in Criminal Investigation and Trials” 5th edition, 672-673.
2. Nabar, B.S. “Forensic Science In Criminal Investigation” 3rd edition, 156.
3. Waters, P. (1975). Procedures for Salvage of Water-Damaged Library Materials. L.C. Publications on Conservation of Library materials Washington D.C.Library of Congress 2nd edition. p-30.
4. Mc Cleary, J.M. (1987) Vacuum Freeze drying a method used to salvage water damaged archival and library material: A ramp study with guidelines United National Educational, Scientific and Cultural Organization PGI 87/WS/7,Paris.
5. Tremain, D and Grattan, D (1989) Air craft log books and document recovered from Air Ontario Dryden Crash for the Canadian Aviation Safety Board. A treatment Report by Canadian Conservation Institute the Canadian Aviation Safety Board Communication Canada. Pp 1-8.
6. Steggal, JHA (1992) Case Study in the use of freeze drying techniques to restore water submerged documents presented at 21st annual meeting of the Midwestern Association of forensic Scientist in Grand Rapid, [Jasuja O.P. The Effect Of Water Soaking On Ball Point Pen Writings. The American Society of Questioned Document Examiners, Inc 2007 p- 47-100].

7. Horton, RN Freeze Drying Paper Documents: A Case Report [Jasuja O.P. The Effect Of Water Soaking On Ball Point Pen Writings. The American Society of Questioned Document Examiners, Inc 2007 p- 47-100].
8. Santcroche, G (1999) The Forensic Examination Of Fire And Water Damaged Documents. International Journal of Document Examiners 5 p-76-82.
9. Jasuja, O.P. The Effect Of Water Soaking On Ball Point Pen Writings. The American Society of Questioned Document Examiners, Inc 2007 p- 47-100.
10. Kaur, R. (2018) The Effect Of Water Soaking On Gel Point Pen Writings. Journal of Indian Academy of Forensic Medicine 40 (4) p- 342- 348.