Forensic Identification and Differentiation of Different Indian Brands of Gel Pen Inks

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Abstract— Many documents are sent to the laboratory for ink analysis or for the comparison of various types of ink present on the disputed documents. Identification and differentiation of type and source (e.g. Fiber tip pen, gel pen, ball pen, fountain pen etc.) of ink used on disputed document is key priority for the forensic document examiners. Analysis of ink gives an idea about relationship between two documents in case of forgery that involves a disputed document and a standard document for its comparison. It also differentiates writing in case of alteration on the basis of comparison of the composition of their dyes. In this paper we present a simplified guide for the examination of Ink by non-destructive (observation in visible light and infrared) and destructive technique (TLC). This work is also focused to provide the Rf values of various brands of gel pen inks with three different color which may help in future to forensic document experts to compare the ink of a particular period.

Key words: Ink analysis, Disputed Document, Forgery, Alteration

I. INTRODUCTION

Ink is a writing material used in writing instrument. Basically it is liquid or semi liquid material used for drawing, painting and writing with a pen or brush. Chemically it is a colloidal system of fine pigments or dyes dispersed in solvent with resins, lubricants, fluoresces, particulate matter, solubilizers, surfactants, and other materials.

The black writing ink was developed before 2500 BC composed of carbon usually lamp black in water. In some compositions natural gum or egg albumin was added as a stabilizing agent.

Indian ink was used date back to 4th century in ancient India and known as “Masai”. This ink was composed by burnt bones, tar, pit etc. with a solvent.

A. Ink Formulation:
The basic components of ink formulation are colorants, vehicle and additives.

1) Colorants:
It is a pigment or dye that gives desired color to the ink. Basically colorants are formed in two types, natural and synthetic. The light absorption and emission characteristics of the colorants play an important role in forensic analysis under analytical examination such as observation of ink under UV and Infrared lights.

2) Vehicle:
It is also termed as carrier. Usually it is a solvent which allow colorants to flow on the surface.

3) Additives:
Additives have great forensic value because the compounds which are used as additive agents such as surface activator, fluorescence material, solubility enhancer, preservatives, and corrosion controllers are specific for each manufacturer. The quality and quantity of additives used for ink manufacturing vary for one manufacturer to other.

B. Classification of Ink:
On the basis of their nature ink falls into four categories

- Aqueous Ink
- Liquid Ink
- Paste Ink
- Powder Ink

1) Aqueous Ink:
In this type of inks pigments or dyes are dissolved only in water in other words only water is used as a solvent in these types of inks.

2) Liquid Ink:
In this type of ink organic solvent system such as propylene glycol, propyl alcohol, toluene, glycol ethers etc. is used for dissolving the pigment or dyes.

3) Paste Ink:
This type of ink is viscous and tacky like adhesive.

4) Powder Ink:
In this type of ink fine particles of pigment or dyes are in dry form.

C. Types of Ink:
There are different types of ink namely-Indian ink, Logwood ink, Iron gallotannate ink, Ballpoint pen ink, Colored dye ink, Printing ink, Stamp pad ink, Invisible ink, Gel pen ink and Type writer ribbon in which vary according to their composition. In this research we identify the gel pen inks and provide a Rf database.

Gel pen inks contain completely insoluble color pigment rather than organic dyes. It is water based ink in gel form which is completely insoluble in both water and strong organic solvents.

D. Forensic Aspect of Ink Analysis:
Ink is used for writing, painting and drawing purposes. Due to the diversity of ink formulation and writing instrument (make and model) forensic document examiner faces problem to identify the disputed ink specimen. In many cases such as forgery, alteration etc. investigating officers raised a question about the origin (from which type of pen document is prepared) and authenticity of the ink. The most common task of forensic document examiner when such type of question is raised is to analyse the ink specimen by using scientific methods and provides a scientific interpretation regarding findings. These scientific interpretations prove or disprove the authenticity of both disputed and standard inks.
II. MATERIAL AND METHODOLOGY

A. Material Required:

1) VSC (Video Spectral Comparator)
2) UV Chamber
3) Developing Jar
4) Pre-coated silica gel - G TLC plates
5) Scale
6) Chemical -
   - Ethanol
   - Solvent system -
     - Butanol 50ml + Ethanol 10ml + Water 15ml
     - Ethyl acetate 75ml + Ethanol 35ml + Water 30ml
     - n-butanol 5ml + acetic acid 1ml + water 5ml
     - Methanol 6ml + acetic acid 2ml + water 3ml
     - Ethanol 4ml + acetic acid 1ml + water 5ml
     - Ethanol 5ml + pyridine 1ml + water 4ml
7) Specimen - Total No. of samples were used 15 gel pen inks of different color (red, green and black) is used. Brand name, their color and designations are mentioned below in table.1.

<table>
<thead>
<tr>
<th>Make</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uni-ball eye fine (water proof) (B1)</td>
<td>Black</td>
</tr>
<tr>
<td>Uni-ball eye fine (water proof) (B2)</td>
<td>Red</td>
</tr>
<tr>
<td>Uni-ball eye fine (water proof) (B3)</td>
<td>Green</td>
</tr>
<tr>
<td>Add gel Achiever (A1)</td>
<td>Black</td>
</tr>
<tr>
<td>Add gel Achiever (A2)</td>
<td>Red</td>
</tr>
<tr>
<td>Add gel Achiever (A3)</td>
<td>Green</td>
</tr>
<tr>
<td>Cello Pointec Gel (C1)</td>
<td>Black</td>
</tr>
<tr>
<td>Cello Pointec Gel (C2)</td>
<td>Red</td>
</tr>
<tr>
<td>Cello Pointec Gel (C3)</td>
<td>Green</td>
</tr>
<tr>
<td>Elkosvelo (E1)</td>
<td>Black</td>
</tr>
<tr>
<td>Elkosvelo (E2)</td>
<td>Red</td>
</tr>
<tr>
<td>Elkosvelo (E3)</td>
<td>Green</td>
</tr>
<tr>
<td>MontexHy speed gel (M1)</td>
<td>Black</td>
</tr>
<tr>
<td>MontexHy speed gel (M2)</td>
<td>Red</td>
</tr>
<tr>
<td>MontexHy speed gel (M3)</td>
<td>Green</td>
</tr>
</tbody>
</table>

Table 1: Brand and Color of the specimen

B. Experimental Procedure:

Ink analysis was done with various methods and it accessed help to ascertain that whether there was any addition or alteration done to the contents of the ink. The methods for ink analysis are as follows:

1) Non-destructive techniques were used in the analysis of inks which involves microscopic examination and the use of various wavelengths of radiation (e.g., visible light, infrared and ultraviolet radiation, filters, etc.) for the determination of its contents. Although, it was useful in the elimination of some inks but these techniques were not as definitive as destructive techniques, in which small discs were removed from the ink lines.
2) Destructive techniques were useful for the determination of two inks on the same or different documents which were of the same formulation or if the ink present on a document and the ink in a seized pen were of the same formulation. By comparing with an ink standard it is possible to determine the manufacturer of the ink as well as the date it was introduced (useful in detecting backdated documents). Various methods such as thin layer chromatography, HPLC, GC are used. In this research we used Thin Layer Chromatography for analysis.

C. Optical Examination:

For this test we write few paragraphs from each pen and examine their optical property under Video Spectral Comparator Fig:1. Possibility of differentiation of ink on the basis of light source is depends upon the emission and absorption properties of the light. The entire ink specimen was examined under IR radiation (.78 µm-500 µm).

III. THIN LAYER CHROMATOGRAPHY

A. Sample Preparation:

Take 5 µl of concentrated ink sample from each pen and dilute it by adding 50 µl of ethanol solution.

B. Sample Application:

On TLC plate a parallel line (origin line) is drawn with the help of a pencil from 2cm bottom of the plate and another line was also drawn at about 10cm from origin known as solvent front. A small spot of sample solution was put on this line with the help of a capillary tube. The plate was then left for drying at room temperature for 10 min. (Fig: 1)

C. Developing:

The prepared solvent systems was poured in a developing tank and the prepared spotted TLC plate was kept in the chromatographic chamber for development of the chromatograms (Fig. 2). Observe all the plates under UV chamber at 365 nm and calculate the Rf value (Fig 3). The sample was then identified with their respective Rf values.
Fig. 2: Sample Application

D. Rf Value:
When the solvent runs to a suitable height the plate was removed from the tank and allowed to air dry. Rf value was calculated for each section and recorded.

\[ \text{Rf formula} - \text{Rf} = \frac{\text{distance travelled by the solute}}{\text{distance travelled by the solvent}} \]

Fig. 3: Developed Plate

Fig. 4: Visualization of plate under UV Chamber

IV. RESULT AND DISCUSSION
A. Optical Examination:
Optical examination comes under non-destructive methods but it is not confirmatory test for ink analysis. All the observation which was observed under IR light source are presented in table no. 2.

<table>
<thead>
<tr>
<th>Color</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>All brand B1, A1, C1, E1 and M1 are possible to differentiate under IR light.</td>
</tr>
<tr>
<td>Red</td>
<td>A2, C2, and M2 are possible to differentiate under IR light but B2 and M2 shows similarity and little confusion in differentiation.</td>
</tr>
<tr>
<td>Green</td>
<td>B3 and C3 possibly differentiate by this light source but A3, E3 and M3 give similar appearance and seems difficult to differentiate from each other.</td>
</tr>
</tbody>
</table>

Table 2: Optical Differentiation Table

As mentioned in above table black pen inks are easy to differentiate under IR light but in Red color Add gel pen (A2), Cello pointec gel pen (C2) and Montex Hyspeed gel pen (M2) give different appearance under this light source but Uniball gel pen (B2) and Elcosvelo gel pen (E2) give same appearance under the same light and therefore it is difficult to differentiate between these two brands of ink from each other. When we further observe all the green pen inks under the IR light it gives different appearance for Uniball gel pen (B3) and Cello pointec gel pen (C3) and hence quite easy to differentiate but the three brands green ink Add gel pen (A3), MontexH speed gel pen (M3) and Elcosvelo gel pen (E3) give similar appearance and difficult to differentiate.

B. Thin Layer Chromatography Examination:
After the development of the plate each plate is individually visualized under UV chamber and Rf value is calculated by using following formula.

\[ \text{Rf formula} - \text{Rf} = \frac{\text{distance travelled by the solute}}{\text{distance travelled by the solvent}} \]

Calculated Rf value for Black, Red and Green gel pen are individually presented in Table no. 3, 4 and 5.

<table>
<thead>
<tr>
<th>Pen Brand</th>
<th>Color of Chromatogram</th>
<th>Rf value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniball gel pen (B1)</td>
<td>Orange/Brown/Black</td>
<td>0.81/0.71/0.31</td>
</tr>
<tr>
<td>Add gel pen (A1)</td>
<td>Yellow/Brown/Gray/Black</td>
<td>0.85/0.74/0.66/0.37</td>
</tr>
<tr>
<td>Cello pointec gel pen (C1)</td>
<td>-----------------</td>
<td>-----</td>
</tr>
<tr>
<td>Elcosvelo gel pen (E1)</td>
<td>-----------------</td>
<td>-----</td>
</tr>
<tr>
<td>Montex Hyspeed gel pen (M1)</td>
<td>Orange/Purple/Gray</td>
<td>0.78/0.59/0.25</td>
</tr>
</tbody>
</table>

Table 3: Black Gel pen Rf values

As mentioned in Table 3. B1, A1 and M1 gives different color chromatogram respectively Orange/Brown/Black, Yellow/Brown/Gray/Black and Orange/Purple/Gray with Rf value 0.81/0.71/0.31, 0.85/0.74/0.66/0.37 and 0.78/0.59/0.25 respectively. Other two gel pen inks named as C1 and E1 showed no chromatogram. These two inks were analyzed in all the solvent systems which were mentioned in this paper but there is no development of any chromatogram.
D. Red Ink:

<table>
<thead>
<tr>
<th>Pen Brand</th>
<th>Color of Chromatogram</th>
<th>RF value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniball gel pen (B2)</td>
<td>Orange/Yellow</td>
<td>0.62/0.55</td>
</tr>
<tr>
<td>Add gel pen (A2)</td>
<td>Pink/Yellow</td>
<td>0.65/0.47</td>
</tr>
<tr>
<td>Cello pointec gel pen (C2)</td>
<td>Pink/Orange</td>
<td>0.67/0.43</td>
</tr>
<tr>
<td>Elcosvelo gel pen (E2)</td>
<td>Pink/Orange</td>
<td>0.65/0.45</td>
</tr>
<tr>
<td>MontexHy speed gel pen (M2)</td>
<td>Pink/Yellow</td>
<td>0.75/0.53</td>
</tr>
</tbody>
</table>

Table 4: Red pen RF value

As mentioned in Table 4. All the inks show different color of chromatogram in decreasing order with their individual RF values.

E. Green Ink:

<table>
<thead>
<tr>
<th>Pen Brand</th>
<th>Color of Chromatogram</th>
<th>RF value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniball gel pen (B3)</td>
<td>Blue/Yellow</td>
<td>0.55/0.38</td>
</tr>
<tr>
<td>Add gel pen (A3)</td>
<td>Blue/Green/Yellow</td>
<td>0.65/0.39/0.31</td>
</tr>
<tr>
<td>Cello pointec gel pen (C3)</td>
<td>Blue/Yellow</td>
<td>0.58/0.43</td>
</tr>
<tr>
<td>Elcosvelo gel pen (E3)</td>
<td>-------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>MontexHy speed gel pen (M3)</td>
<td>Blue/yellow</td>
<td>0.56/0.33</td>
</tr>
</tbody>
</table>

Table 5: Green Ink RF value

Ink B3, A3, C3 and M3 give different chromatogram Blue/Yellow, Blue/Green/Yellow, Blue/Yellow and Blue/yellow and the RF of these inks are 0.55/0.38, 0.65/0.39/0.31, 0.58/0.43 and 0.56/0.33 respectively. Here E3 inks showed no chromatogram. This ink is analyzed by using all the solvent systems which were mentioned in this paper but there is no development.

V. Conclusion

In India there is various kinds of gel pens are available in the market. Identification and differentiation of type of source of the inks used in these pens is key priority for the document examiners. Hence, many documents are sent to the laboratory for ink analysis of the various type of ink present on the disputed documents.

In the present study an attempt has been made to provide the RF values of various brands of gel pen inks with three different color pens. During the analysis we examine three different color of gel pen inks namely, black, green and red of five different brands of gel pens. We analyze the optical properties by non-destructive technique using UV-visible and infrared light in which we observe that black pen inks of different brands are easy to differentiate under IR light but in red color some brand’s ink are distinguishable under IR light whereas some showed similar optical properties under IR light, hence, it is quite difficult to differentiate between these brands of inks from each other. On contrary, on observing the ink of green color under IR some showed the different optical property whereas some of them gave similar appearance and hence, difficult to differentiate.

On analyzing through destructive technique using TLC we developed different chromatograms and also studied there RF value which can be used in future by the forensic document experts to compare the ink of particular brand and period.

Hence, it is concluded that through this a standard data can be set for different brands of gel pens which would be helpful in future for the experts in establishing a relationship between two documents in case of forgery or ink analysis that includes a standard and a disputed document for its comparison.

Therefore, further increasing the no. of specimens and by performing more experiments (both destructive and non-destructive), better results can be drawn and hence, helpful in the analysis of different inks and their dye constituents.

REFERENCES

[4] Ralph Hodgson, questioned document examination “the handwriting on the wall may be a forgery”, 1.