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Differentiation of Different Blue Inks in Manipulated Documents using VSC®-8000/HS: a Comprehensive Non-Destructive Technique

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Abstract
In present scenario, ink analysis has become extremely challenging. It is crucial for a forensic document examiner to select the best non-destructive technique for analysis. Video Spectral comparators have always been used for examination of documents under question. The current advanced variant of Video spectral comparator i.e. VSC®- 8000/HS is loaded with a wide spectrum of features including database of passports and currencies, multi-spectral analysis, micro-spectrometer etc. The present study demonstrates the effectiveness and potential of multi-spectral illumination and micro-spectrometer for analysis and differentiation of blue ball point and gel inks in handwritten documents. VSC®-8000/HShaveproved to be highly effective, robust and a comprehensive non-destructive technique for visual as well as spectral analysis of handwritten documents which have been altered (additions, obliterations and overwriting) with two or more blue inks. It can efficaciously complement with the present workflow of questioned document examination to provide qualitative as well as quantitative data for the expert's opinion.

Keywords: Questioned documents; ink examination; alterations, overlapping of inks, Video Spectral Comparator

Introduction

The assessment of questioned documents hasbeen one of the crucial elementsof the forensic science investigations. In this assessment, the examination of ink segments is vital majorly while examining a back dated archive. The determination of the composition of ink helps in validating a document as back-dated. If the formulation of ink was not available as per the dating of the document, it would clearly indicate that the document is old[1,2]. Evolution of writing among humans came with the desire to communicate their thoughts with others. In earlier times, people used oral language for communication but later they devised a more effective way of communication using visible signs that could be understood by masses. The urge to write led to search for suitable writing material[3].

Writing instrument/s used to sign or write documents plays an importantrole in determining their authenticity. Such writing instruments contain ink which is made up of two basic components i.e., colorant and vehicle. The dyes or pigments which impart colour to the ink are colorants and the medium in which colorants are dissolved is known as vehicle. Sometimes, mixing of two or more colorants is also done in order to get the required colour of ink. Vehicles contain lubricants, polymers, flow control agents and various other

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components which improvise the properties of the ink according to the need. The deposition and flow of ink on paper is determined by the solvent present in inks [4,5]. A large variety of inks have been introduced in the market since decades, however, the most common type of inks used presently are ball point pen and gel pen inks. Various characteristic features of common type of inks available in the market are described in table 1.

Table 1: Characteristic features of different types of inks

S.No.	Characteristic	Ball point ink	Gel pen ink
1.	Solvent medium	Oil based	Water based
2.	Consistency	Thick	Less thick
3.	Pressure required for writing	High pressure is required for writing due to its potential of getting clumped	Low pressure is required for writing.
4.	Surface phenomenon	Get adsorbed on the surface of the paper	Get absorbed into the surface of the paper

Determination of authenticity of a document is crucial for a forensic document examiner. With advancement of technology, it has become easier to compare two or more inks in manipulated or tampered documents. Various destructive and non-destructive techniques can be used for the determination of manipulation in documents. Manipulation can be done in multiple ways such as additions, obliterations, overwriting etc. It isimportant for a forensic document examiner to use appropriate techniques for examination of such documents. Determination of composition of single or overlapped inks can prove to be effective for dating of ink as well as establishing the authenticity of the document.

Various instrumental techniques can be used todetermine the composition of ink as well as examination of altered documents. Chromatography is one of the most common method of analysis as its significance can be traced back since early 1950s[6,7]. Various studies have been conducted for examination of ink using chromatographic analysis such as TLC, HPLC, HPTLC, GC-MS etc[6,7,8,9,10,11]. Kher et al. excellently separated blue ball point pen ink samples by a HPLC method using a technique of photodiode array detection (PDA) [12]. In another study, it wasdetermined that use of Ultra-performance liquid chromatography (UPLC) is more effective than high performance liquid chromatography for analysis of ink in terms of analysis speed and sensitivity[13]. Apart from these,researchers have also examined inks using combination of techniques. Researchers have also utilized chromatographic and electrophoretic techniques for ink analysis[14].Similarly,Sharif *et.al* (2019) differentiated between fountain pen inks of blue, black, green, and red colours that are commercially used in Pakistan by UV-Vis spectroscopy, TLC, and FTIR spectroscopy[15]. However, majority of techniques used for analysis have been destructive in nature thereby it is important for a forensic document examiner to analyse the documents as well as ink using non-destructive techniques.

Video spectral comparator (VSC) has been commonly used by document examiners for examination of questioned documents under various lightning conditions[3].Advanced versions of Video Spectral Comparators havemicro spectrometers which havebeen successfully used for examination of ink and paper but the use of these micro spectrometers for analysis is very limited. Very less studies have been reported in which VSC has been used for analysis of ink[16]. In a study conducted by it was found that 80% of blue and red inks and

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38% of black ink pairs could be distinguished through spectroscopy. In a study conducted on blue, black and red gel inks using hyperspectral imaging mode of VSC®-6000/HS, it was demonstrated that thehyperspectral imaging is successful for differentiation of 80% of blue and red inks whereas is effective only for 38% of black ink pairs [17]. Similarly, Silva et.al.usedVSC®-6000/HS for analysis of blue and black inks and discriminated between inks using chemometrics[18].The present study focuses on determination of efficacy and potential of VSC®-8000/HS for differentiating between ball point and gel pen inks in case of alterations including additions, obliterations and overlapping of inks.

Materials and Methods

Preparation of Samples

120 samples were prepared for analysis with different combinations of blue ball point andgel ink. Two different brands of the pens were selected from each category, Flair and Reynolds were chosen for preparing samples with ball point pen inks whereas gel ink pens from brands Rorito and Natraj were used for preparation of samples. The same pens were used to prepare samples with combination of inks as well. Ball point pen inks of brand Flair and Reynolds and gel pen inks of brand Rorito and Natraj are denoted as B1, B2, G1 and G2 respectively. 20 samples were prepared for each of following combinations: B1B2, G1G1, B1G1, B1G2, B2G1 and B2G2. All the pens were purchased in West Delhi area and were selected on the basis of their popularity and public demand. The sample for analysis were prepared on Century Star White A4 sheets cut into strips of 75 mm by 25 mm. The samples having alterations such as additions, obliterations and overlapping of ink were prepared using different combination of inks. After a 12-hour drying period, all the prepared samples were kept in plastic bags and stored in a closed container to protect them from light and to prevent degradation of ink.

Instrument Used

Video Spectral Comparator-8000 (VSC®-8000/HR) is a highly sophisticated digital system manufactured by Foster & Freeman. It is an advanced digital imaging software interface providing comprehensive examination of all forms of questioned documents. It is a workstation comprising of digital imaging system, variable light sources and multi-spectral illumination ranging from ultraviolet through visible to infrared[19].VSC®-8000/HSalso consists of a high resolution micro spectrometer**.** The micro spectrometer is a special feature of non-destructive spectral analysis for identification of distinguishing features in ink and paper formulations. Absorption, Reflectance, Fluorescence and Transmitted spectra can be obtained for the document under examination[20].

These sophisticated features offers a wide range of examination of documents including ink and paper. Analysis of ink becomes easier through advanced features like multi-spectral illumination, hyperspectral imaging and integrated micro spectrometer[19,20].

Procedure of Examination

Theprepared samples were analysed using VSC®-8000/HS accessed at Directorate of Forensic Science, Junga, Himachal Pradesh, India. All the samples were one by one kept in the main unit. The image of the sample was captured through Super Resolution Imaging (SRI) system. SRI is an optical system which uses a high precision 12 mega pixel camera for capturing the image[20]. The images of all the samples were first analysed undermulti-spectral illuminations.Followed by multi-spectral illumination, the samples were also examined using micro spectrometer. Before acquiring the spectra, the instrumental settings were optimized using a blank piece of Century Star White A4 sheet. All the absorbance spectra were obtained

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in auto focus (variable magnification as per the sample) and auto exposure mode at 50% brightness, integration at 1.3 ms, Iris at 60% and in the range of 400 to 1000 nm. In order to acquire the spectra , the samples were placed in the main unit of the VSC®-8000/HS and the area containing the ink was selected as shown in figure 1. The absorbance spectra were acquired from the samples in varied loci such that all spectra included the contributions from ink 1, ink 2 and their combination (areas with alterations). The spectrograph obtained has spectra with different colour coding. The orange coloured spectra denote ink 1, yellow spectra denotes ink 2 and red spectra denotes combination of both the inks. The colour coding was kept constant for all the samples. The spectrographs obtained were observed, analysed and interpreted.

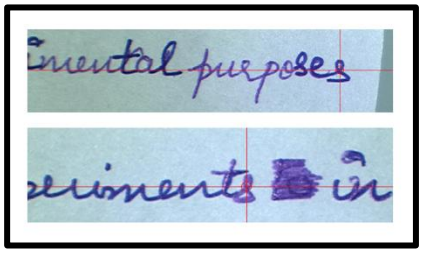

Figure 1: Selection of area of interest for absorbance spectra of ink

Observations and Results

Analysis through Multi-spectral illumination

The samples were examined under VSC®-8000/HS and the results were saved as images. The initial examination using multi-spectral illumination showed that obliterations, additions or overwriting made with two different ball point pen inkscould be observed at 665nm. On the contrary, in samples with alterations made with two gel pens, decipherment can be observed at 780nm instead of 665nm as shown in figure 2a and 2b.

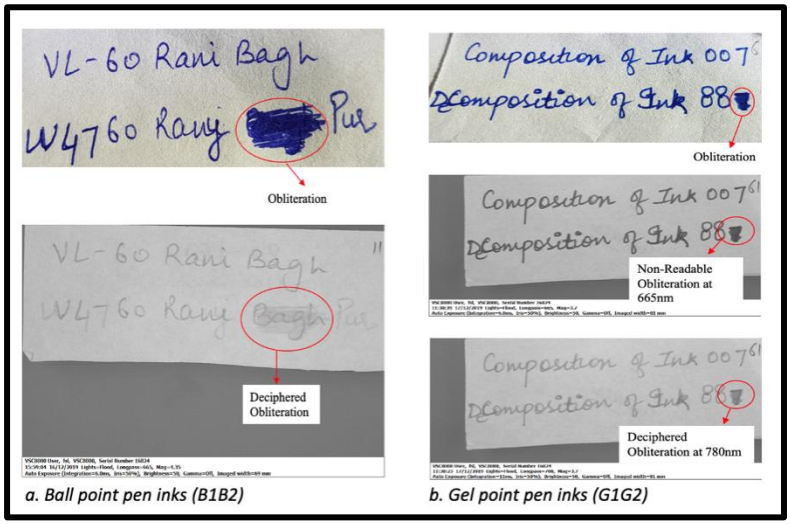

Figure 2: Multi-spectral analysis of a. ball point pen ink at 665nm; b. gel pen ink at 665nm and 780nm

The alterations in samples with combination of ball and gel pens could be deciphered at a wavelength of 665nm and 610nm (for G1B1). Thereby, the presence of two different ball point pen inks, gel pen inks or their combinations can be ascertained easily even at visible

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range of spectrum as shown in Figure 3. Therefore, it was observed that alterations in 66.7% of samples could be deciphered at 665nm successfully, 16.7% of samples could be deciphered at 610nm. The percentage of decipherment of the samples at 780nm was also found to be 16.7%.

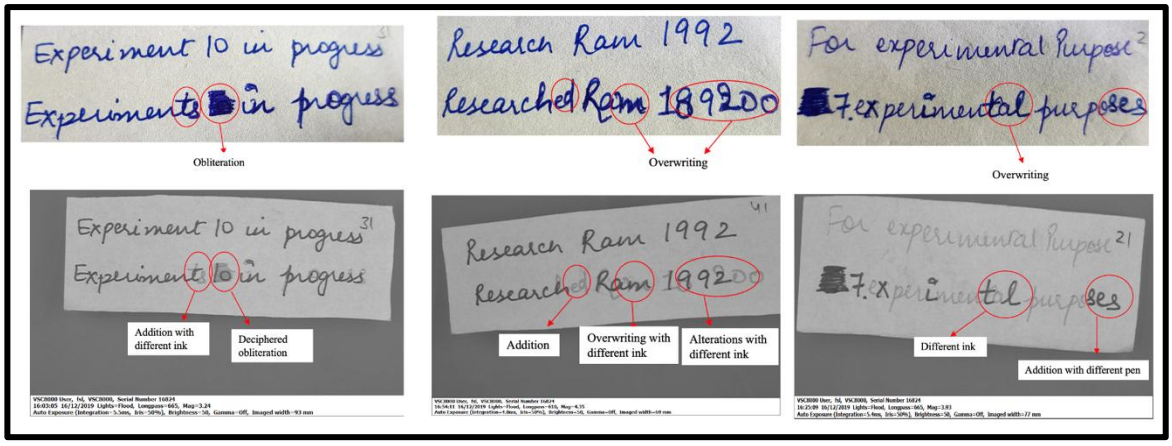
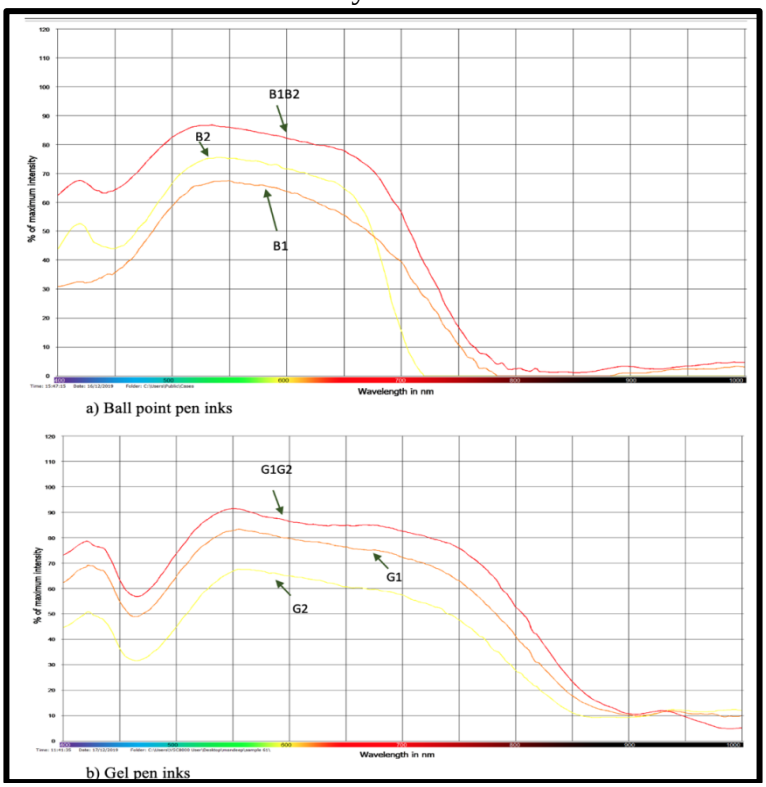


Figure 3: Multi-spectral analysis of overlapped ink (combination of ball and gel pen inks)

Analysis through micro spectrometer

Observations of samples prepared with ball point pen ink (B1B2)

As per the spectrograph shown in graph1a), the highest peaks (maximum absorbance) for B1, B2 and B1B2 has been observed in the green region (530-560nm) but showed variation in absorbance intensities. The intensity of ink B1 at the 530-560nm is 68%, the intensity of ink B2 at the same range is 75% and intensity of absorbance of combination of ink (B1B2) is 88%, far greater than the absorbance intensity of individual inks.



Graph1a): Spectrographs of ball point pen inks (B1B2)
Graph 1b): Spectrographs of gel pen inks (G1G2)

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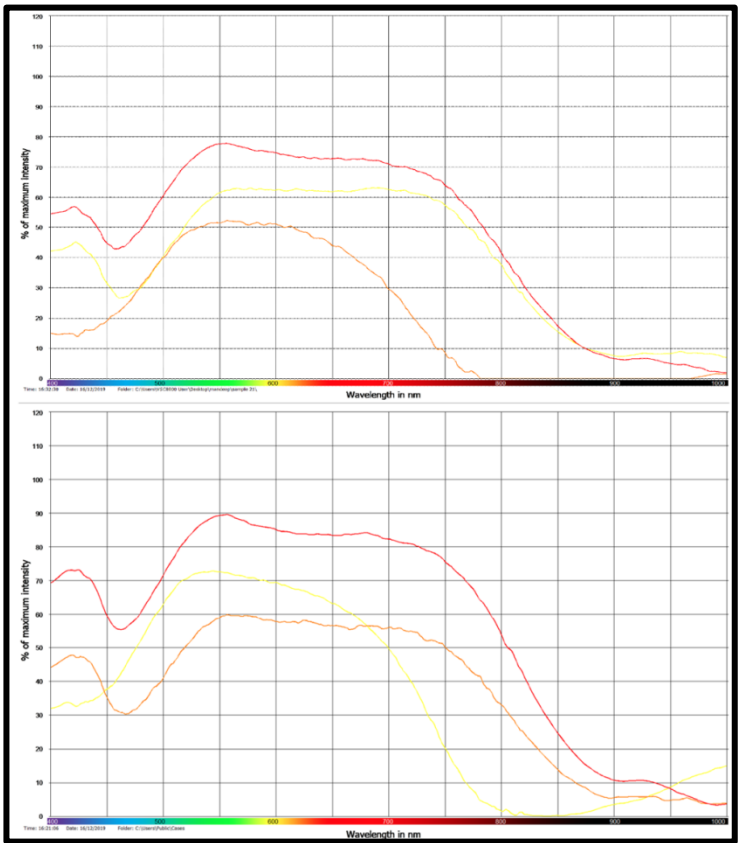
Observations of samples prepared with gel pen inks (G1G2)

As per the spectrograph shown in graph 1b), the spectra for G1, G2 and G1G2 is almost similar with varying intensities of absorption. A sharp dip in absorption can be seen in blue region (460-480nm) in all the three spectra. The highest peaks or maximum absorption can be observed in green region (550-560nm). The absorption intensity of ink G1 at 550-560nm is 82%, the absorption intensity of G2 at same wavelength range is 68% and absorption intensity of combination of inks (G1G2) is 91%, far greater than the absorbance intensity of individual inks.

Observation of samples prepared with combination of ball and gel pen inks

As per the spectrographs shown in graph2, the highest peaks or maximum absorption for gel pen inks (G1 or G2) and combination of gel and ball (G1B1, G1B2, G2B1,G2B2) has been observed in the green region (550-560nm) whereas the maximum absorption region of ball ink is broader in the green region (530-570nm). Similar to the results obtained for ball point pen inks, the spectra for gel, ball and their combination also showed variation in absorbance intensities. The intensity of gel inks at the maximum absorbance peak (550-560nm) is 59%-62%, the intensity of ball point pen inks at 530-570 nm is between 51%-59% and intensity of absorbance of combination of inks is 78-89%, far greater than the range of absorbance intensity of individual inks. This indicates that the involvement of gel ink in writing or overlapping of gel and ball ink result in the formation of new compounds with higher absorbance intensity.



Graph2: Spectrographs of overlapped regions of inks (combination of ball and gel pen inks)

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Conclusion

VSC®-8000/HS has been demonstrated to be a sophisticated and powerful tool for comparison of similar appearing ball point and gel pen inks on handwritten documents. The analysis with multi-spectral illumination as well as micro-spectrometer have proved to be successful in identification of presence of multiple blue inks in altered documents. Being a rapid, effective and non-destructive, approach VSC®-8000/HS could be readily integrated into existing analysis workflow. The concrete and comprehensive results obtained from it can successfully support the decision making capability of the forensic document examiners. Therefore, it can be concluded that VSC®-8000/HS is a robust tool for differentiation of overlapped blue inks and can serve as an important step towards corroborating and homogenizing feature-comparison methods in questioned document examination. It will also enable the examiners to select non-destructive technique over destructive ones for ink analysis. However, further study using chemometrics can be done to strongly validate the results. Along with chemometrics, future work might include how age and quality of ink can affect the result.

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