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FORENSIC DISCRIMINATION OF MONOCHROME PRINTED DOCUMENTS OBTAINED FROM VARIOUS PHOTOCOPIER, LASER AND INKJET PRINTERS USING MULTI-MODE PLATE READER

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ABSTRACT

Aim

The objective of the present work is to examine the printed documents engendered from various photocopier machines, laser and inkjet printers, and focuses on the applicability of Multi-Mode Plate Reader for their discrimination.

Methods and Materials

For the procurement of samples, a prototype was built comprising four rectangular boxes of equal dimensions. A total of 30 monochrome printout samples (10 from each photocopier machine, laser, and inkjet printer) of varied make and models was collected from Jhansi district, Uttar Pradesh. Four punch-outs of diameter 5mm were collected from each sample and extractability of ink/toner components out of printed samples were examined in polar (Methanol) and non-polar (Hexane) solvents. Photometric scanning of each sample in both the solvents was recorded in the range of 200-800 nm. All the samples were analyzed and differentiated depending upon their absorbance spectral responses obtained from Multi-Mode Plate Reader.

Results

Based on the number of peaks observed, methanol was found to be a more suitable and versatile solvent allowing Discriminative Power of 97.7% for inkjet and 100% for photocopier and laser samples.

Conclusions

Documents are an integral part of our life and serve as a fundamental object for both public and private intents. Technological advancements have changed many aspects of human life and printed documents are one of them. As far as we know this technique is first time employed for the discrimination of printed documents and was found to be fast, eco-friendly, and cost-effective with high-throughput.

Keywords: Forensic Science, document examination, laser printer, inkjet printer, multi-mode plate reader etc.

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Introduction

Documents are the essential object of human transaction, necessary for both public and private absorption. Human interaction can be transcribed in the form of a document and has a substantial impact on both personal and professional lives. In our life, we deal with many sorts of documents that serve different purposes. Technological advancements have revolutionized every aspect of human life and its intervention has superseded the conventional way of creating a document and has given rise to a new technology called printing. In the last four decades, printing technology has made a great amount of success from manual typewriting to digital printing. Printers are the peripheral devices used in conjunction with computers to produce documents. Inkjet printers, laser printers, and photocopier machines are the most common devices used in every sector of society for the production of documents in printed form. Polychromatic printers (commonly known as color printers) are multi-cartridge printers, used in generating both color and black-and-white documents. However, monochromatic printers are also available in the market that is very commonplace and much used as compare to polychromatic printers because of their low cost and easy maintenance.

The technical expansion has led to the growth of a range of printers that are suitable with chemical modification in the ink/toner to serve the current requirement. Unlike ink, toners are the fine powder that undergoes age-related changes very slowly because of having no solvent to carry them away [1]. Ink and toners are the most essential and complex chemical systems to be used in the printing of documents that can serve as a means of source identification of printers. Whether public or private, documents of importance have always been prone to be counterfeited or misused by the wrongdoers who always stare at to serve their malign intents. With the passage of time counterfeiters are upscaling their knowledge and skills to produce counterfeit printed documents of such quality that put threats to the examiners [2]. To face such challenges, more research has to be conducted on printed document examination to overcome the counterfeiters. The present study is a novice attempt at using the Multi-Mode Plate Reader instrument for examining printed documents and has important implications for solving crimes related to the documents. Multi-Mode Plate Reader is a sophisticated instrument that works on the principle of Beer and Lambert`s Law and provides a varied range of electromagnetic radiation including UV-Vis and NIR wavelengths. The instrument provides the facility of recording UV-Vis, Fluorescence, and Luminescence spectra of the samples. The state of the art of the instrument is its high throughput and minute sample quantity.

Methods

Sample Collection

In the present study, a total of 30 monochrome printout samples (10 from each photocopier machines, laser and inkjet printers) of varied make and models were collected in the form of rectangular boxes on a standard A4 size, 75 GSM paper from Jhansi district, Uttar Pradesh. All the printout samples collected from different inkjet, photocopier, and laser printers were marked from 1 to 10 with their respective make and models listed in Table 1.

Table 1. Different Types of Printing Devices Used with Varied Make and Models

Inkjet Printers			Photocopier Machines			Laser Printers		
Sample Mark	Manufac-turer	Model	Sample Mark	Manufac-turer	Model	Sample Mark	Manufac-turer	Model
I_1	Precision Core	L1455	P_1	Kyocera	Ecosys M2040dn	L_1	Konica Minolta	C652
I_2	Epson	L210	P_2	Kyocera	Task alfa 3011	L_2	Xerox	252
I_3	Epson	L805	P_3	Sindoh	N613	L_3	Xerox	SC2020
I_4	Canon	G212	P_4	Canon	2900B	L_4	Konica Minolta	C258

I_5	HP	319	P_5	Canon	iR 7095	L_5	Sindoh	D310
I_6	Canon	MP 280	P_6	Konica Minolta	Bizhub 195	L_6	Canon	C850
I_7	Canon	G 2000	P_7	Canon	iRA 6075	L_7	Ricoh	C5100s
I_8	Epson	L130	P_8	HP	M1005	L_8	HP	M226dw
I_9	Brother	L2541 DW	P_9	Toshiba	eStudio 256SE	L_9	HP	M1005
I_{10}	Brother	T710W	P_{10}	Xerox	5755	L_{10}	Canon	iR C3020

Extraction

One of the important steps in the chemical characterization and discrimination of printed documents was extracting their components out of printed material. Two different solvents methanol and hexane in terms of their polarity were chosen to serve this purpose. Eight punches of diameter 5 mm were cut from printed area of every sample and half of them were collected in two separate Eppendorf tubes each containing 1.5 ml of methanol and hexane respectively. Both the solvents were tested for their extractability of ink components out of the printed materials. To aid the process and for better extractability, all the samples were subjected to Ultra-sonicator for about 24 min. Now 0.5 ml of aliquot was pipette out and its volume was adjusted to 1.5 ml by adding distilled water (Mili Q water) to it.

Instrumentation

The Varioskan Flash Multi-Mode Reader (Thermo Fisher Scientific) with microplate format was used for the photometric scanning of the printout samples. Spectral measurements of the samples were carried out in the range of 200 to 800 nm with step size 5. All the samples were scan through 96 wells plate. The inbuilt software 'Skanlt' defined by Thermo Scientific was used for the processing of data. To record the spectral differences, 400 µL of diluted aliquots from each sample were pipette out and loaded in the 96 wells plate with their respective markings on the plate. A micro wells plate with the round bottom surface was used throughout the study. For each solvent, a blank was prepared by taking punch-outs from the non-printed area and following the same procedure as opted for the printed sample. Every time the printed samples were run with their blank (non-printed paper punch outs and the solvent) counterparts. After a photometric run, the blank subtraction option was selected to avoid any spectral interventions due to the paper and solvents used in the process.

Results and Discussion

Results of the present study provide compelling evidence for the discrimination of documents obtained from the different photocopiers, inkjets and laser printers. The Multi-Mode spectra of laser, photocopier, and inkjet printed samples analyzed without their blank subtraction in two different solvents (methanol and hexane) are shown in Figure 1.

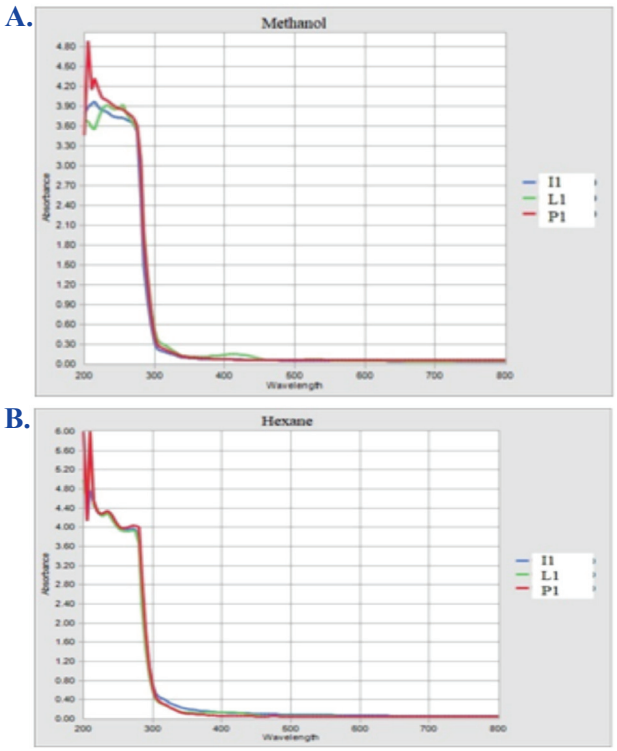


Figure 1. Spectral Absorbance of I_1, L_1 and P_1 in Methanol and Hexane

For every sample, spectral measurement with and without blank subtraction was recorded. Hexane blank giving absorbance at 200 and 215 nm is shown in Figure 2. To maintain homogeneity in the sample spectra, the impingement spectrum of paper and solvent were treated with blank subtraction. Spectral responses with their respective blank subtraction were used for the discrimination of printed samples and their records are shown in Table 2. Spectral absorbance of I_1, L_1, and P_1 with their blank subtraction in hexane is shown in Figure 3.

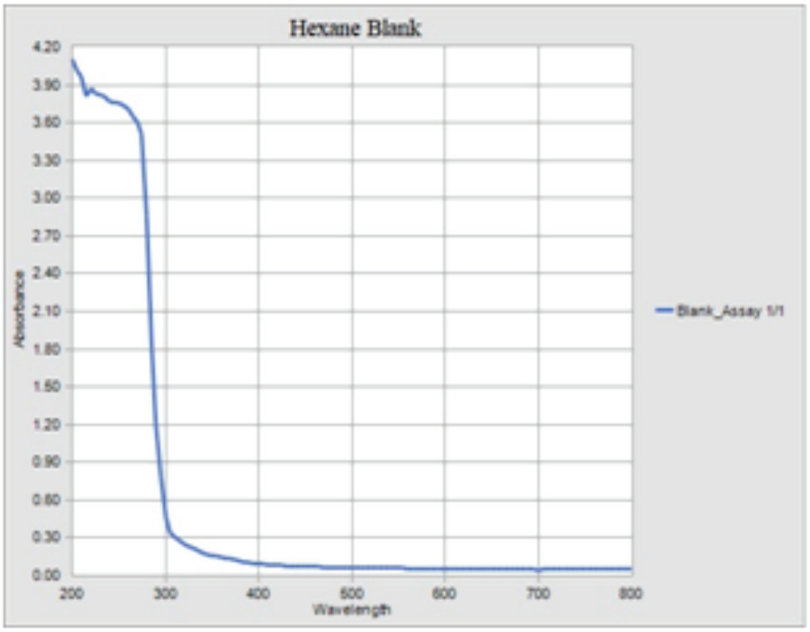


Figure 2. Spectral Absorbance of Hexane Blank

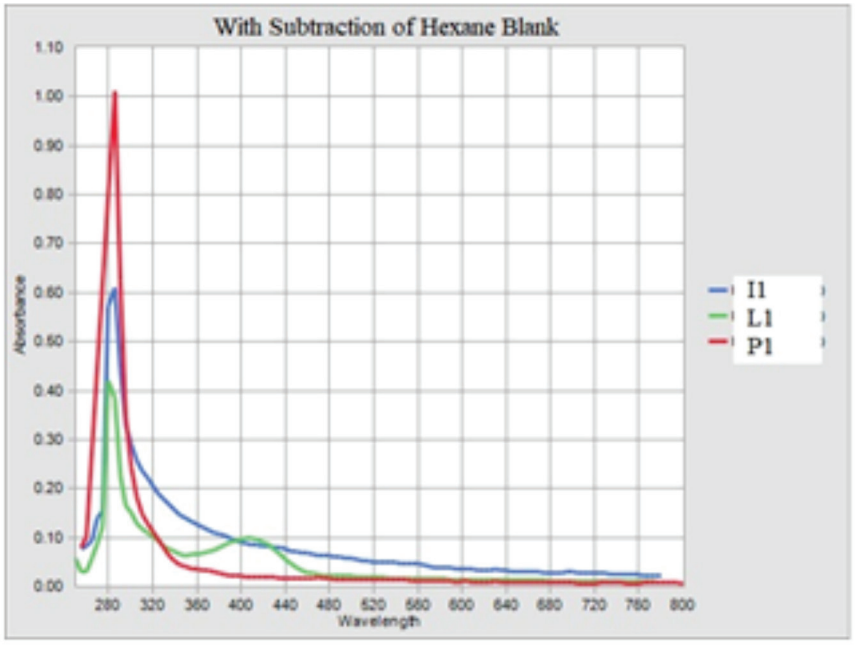


Figure 3. Spectral Absorbance of I_1, L_1 and P_1 with Subtraction of Hexane Blank

Table 2. Records of Spectral Absorbance of Different Inkjets, Photocopiers and Laser Printers with Their Blank Subtractions in Methanol and Hexane

Sl. No.	Absorbance in Methanol			Absorbance in Hexane		
	Inkjet	Laser	Photocopier	Inkjet	Laser	Photocopier
1	215,	215, 255, 280, 415,	200, 245, 280,	285	280, 405,	285, 365
2	205, 260, 280, 315, 420, 530, 580	205, 260, 275, 415	235, 280, 565	200, 285,	200, 285, 405	245, 290
3	260	205, 265, 285, 505,	200, 235, 280,	200, 285,	245, 285,	200, 285,
4	235, 250, 265, 280,	255, 280, 415	240, 280, 370, 565	285	285, 405	200, 285
5	215	210, 280, 530,	225, 255, 275,	245, 285,	260, 290,	200, 285
6	200, 255, 410, 625,	265, 280, 425, 525	265, 300, 485	285,	285, 365, 405	200, 285
7	225, 235, 260, 275	255, 280, 440	200, 280, 565	200, 285,	285	285
8	200, 280, 420, 580	240, 300, 375, 565	235, 280, 365, 570,	200, 285	285	285
9	245, 255, 265,280, 565	200, 240, 280,	210, 280	285	200, 285	285
10	210, 280, 415, 565	205, 280, 415,	240, 280, 360, 565	285	285,	285

From Table 2, it is evident that I_1 and I_5 showed similar absorbance at 215 nm in methanol. Despite being different from each other, I_1 appears to be similar to the I_5 i.e. possible only when both have identical ink composition. I_2 and I_9 giving seven and five peaks respectively and were found to be most differentiating in terms of a number of peaks observed. Thus, among all the printed samples in methanol only I_1 and I_5 showed similar absorbance, while the rest can be differentiated based on their spectral responses. In hexane five inkjets (I_1, I_4, I_6, I_9, and I_{10}), four photocopiers (P_7, P_8, P_9, and P_{10}) and three lasers (L_7, L_8, and L_9) printed samples were found giving similar absorbance at 285 nm only while four photocopiers (P_3, P_4, P_5. and P_6), three inkjets (I_2, I_3 and I_7) and one laser (L_9) printed samples were found giving similar absorbance at 200 and 285 nm. Only one inkjet (I_5), two photocopiers (P_1 and P_2) and six lasers (L_1, L_2, L_3, L_4, L_5 and L_6) printed samples were found different based on their spectral responses in hexane. In the view of the number of peaks observed, methanol was found outperforming as compared to hexane. Hexane was found down performing giving a limited number of peaks almost at similar wavelengths for a majority of printed samples irrespective of their make and models.

Photometric spectra contain information mainly related to the color agents (dyes and pigments) present in the ink formulation, especially in the UV region [3]. UV was found to be the most discriminating region, encompassing spectral features. All the samples gave characteristic peaks in this region. Furthermore, the visible region gave limited peaks but when studied with UV responses, helped in the broader classification of the samples. The Discriminative Power (DP) technique as suggested by Smalldon and Moffat [4] was employed to examine the inter and intra relationship among samples and represented as

The number of possible sample pairs (within group) was calculated (n*(n-1))/2 i.e. (10*9)/2=45, each for inkjets, photocopiers and laser samples. Spectra of samples in methanol were examined for the

discrimination study. Within group, qualitative comparative analysis of Inkjet samples showed 97.7%, while photocopiers and laser samples showed 100% variations in their spectral responses. Again, discrimination between groups was also analyzed for the three subsets (between inkjet-and-photocopiers, photocopier-and-laser, and laser-and-inkjets). The number of possible sample pairs (between two distinct groups) was calculated as (n_1*n_2) i.e. 10*10 = 100 each for three subsets. Between groups, the qualitative comparative analysis showed 100% variation in all three subsets. Saini and Saroa [5] analyzed 28 printed samples obtained from photocopier and laser printers using a UV spectrophotometer and were successful in classifying them in 10 different classes depending upon peaks observed. Verma *et al.*. [6] used Diffuse Reflectance UV-Visible Spectroscopy for the discrimination and comparison of printed documents obtained from 50 laser and 50 photocopier machines and observed discriminating power of 95.03% for laser printer and 89.55% for photocopier machines. Despite the number of samples observed, the most striking result to emerge from the current study is that 100% DP was observed in the case of laser and photocopier printed samples. The results of the present study correlate favorably well with the previous findings [5,6] and further support the concept of using Multi-Mode Plate Reader as a substantial tool for the discrimination of printed documents.

$$DP = \frac{(\text{Number of discriminated sample pairs})/(\text{Total number of sample pairs})}{\text{Total number of sample pairs}}$$

Conclusions

The present research work provides a cutting-edge solution to the printed document examination that can play a significant role in their classification and discrimination. The most striking remarkable result that comes out from the study is that 100% DP is observed in the case of photocopier and laser printed documents along with 97.7% for inkjet printed samples. Methanol (a polar solvent) was found to be the most versatile and suitable solvent, dissolving most of the components out of the printed samples and giving a majority of peaks over hexane. Multi-Mode Plate Reader was found to be an indispensable tool as it requires only a micro amount of sample and is capable of handling multiple samples at a time. To the best of our knowledge, no other authors have employed Multi-Mode Plate Reader for the discrimination of printed documents. This technique was found to be fast, sensitive, and eco-friendly (requires less amount of chemicals) with high-throughput that could be used for the analysis of printed documents.

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HUMANITARIAN FORENSICS: A PROSPECTIVE ENTITY OF FORENSIC SCIENCES WITH CONTEMPORARY RELEVANCE-GENIAL APPROACH OF COMPASSION, SOLACE AND EMPATHY IS NECESSARY IN EVERY UNFORSEEN SITUATIONS

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ABSTRACT

Forensic Science is popularly known to be associated with the criminal justice delivery system and is defined as the application of scientific knowledge to aid in the administration of justice. In contrast to such a perception humanitarian forensics is associated with the genial component of humanity with the virtues of empathy, compassion and solace for the needy society. It is defined as the application of forensic knowledge for the humanitarian purposes. In general, forensic sciences play a vital role in the justice delivery in any kind of crimes whether it is against property or against the individual / humanity. Whereas the humanitarian forensics finds its application in the cases of humanity which is deprived, depressed and distressed or the society which is under the perils due to unforeseen situation or crisis due to war, conflicts, disasters and abuses on account of race, gender and age and other associated factors. It envisages the importance of the humanitarian forensic action in any crisis situations of manmade or natural origin.

Keywords: Humanitarian Forensics, Disasters, Crisis, Forensic action, etc.

Introduction

For more than a century, forensic science has been in the lime light in the criminal justice system across the globe. This is mainly due its advantages of accuracy, precision and reliability, non duplicity, robustness and so on. So naturally forensics sciences have always been associated with the criminal investigations and identification of criminals. Any kind of crimes is possibly resolved based on the scientific facts that are forensic science. There is hardly anything that is insulated with the forensic applications [1]. The concept of societal welfare is always associated with it but it is indirectly done through the justice delivery. So the concept of humanitarian forensics got into being by encompassing the important elements of humanity such as compassion, solace and empathy. This is necessitated during the crisis situation where in the scientific approaches are mandated for getting the basic normalcy. The scientific approaches are found to be associated with the forensic element for the humanitarian considerations. In any case of unforeseen situations there is a need for the approach of humanitarian action with the forensic element [2].

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Scope and need

The situations wherever there is a need for humanitarian assistance the humanitarian forensics plays a vital role. In India, this concept is having vast scope, more relevant and is also vital as there is a substantial number of vulnerable populations. The people affected in various circumstances use to be among the different age groups and gender such as children, women and elderly. The scope of Humanitarian Forensic Action is mandated to serve the people affected by disasters, war and conflicts, violence/ abuses due to the gender and age and persecutions due to race and religion etc.

The affected people are always in need of assistance of medical, social, psychological, cultural, socio-economical aspects. There is need for an exclusive core group that is required to meet the needs of such people is being taken care of, by the experts of humanitarian forensic action.

Starting from the immediate need for the maintenance of physical and mental wellbeing, the socio-cultural and socio-economic, medico-legal, and obligations are being taken care of by the humanitarian forensics expertise.

People affected people are to be responded with more compassion, solace and empathy as they are in physical and emotional distress, deprived, depressed with the loss of life of relatives, loss of property and belongings and are forced to be in grief and despair. These people are to be taken care of with systematic scientific approaches so that they retain their normalcy in every aspect. In addition to this there is a mandate for the dignified management of the dead. This includes the socio cultural approach towards the departed souls . This requires a comprehensive protocol with dedicated and well coordinated efforts of the humanitarian forensics.

Indian perspectives

India is a very vast country in terms of population and geographical area. It is characterized by the multi-lingual, multi-cultural with distinct demography. Disasters are quite common phenomena in India due to its varied geographical profile. Thereby the population affected is also of huge numbers in any given scenario. Government of India and all other states rush swiftly to carry out the relief and rescue operations with an umpteen number of instantaneous relief measures. Even in every such scenario government announces the ex gratia for the nearest kin of the deceased. In certain conditions, they are offered with the employment by the government on compassionate grounds. All these duties / responsibilities would require the humanitarian forensics action either directly or through a facilitating mechanism. The affected populations are always taken care of with the immediate necessities with the coordinated efforts of the stakeholder such as the disaster management authorities, disaster response forces, Police organizations, armed forces, medical officers, paramedical/ nursing staff, forensic scientists, social welfare organizations etc.

Humanitarian Forensic Action, the hall mark of the victim management

The coordination needs to be done with a comprehensive and composite effort from humanitarian perspective. This is the hall mark of the victim management. The dedicated efforts are to be done in a well calibrated manner. The first and foremost is to impart the emergency medical attention to the victim who is in danger for life. The dead victims are to be identified and to be handed over to the relatives for the last rites to be performed according to their religious beliefs. The facilitating approaches are the psycho social aspects. The victims who are in despair and depressed would be treated with compassion and solace. The socio- economic, socio cultural, psycho social factors are the specific features associated with this.

Well set protocols in the global perspective

There are well set protocols to deal with the scenario of disasters as far as the victim management is concerned. The INTERPOL protocol mentions about the identification of victims through the fingerprints, DNA, dentistry and the anthropological traits. This ultimately leads to the absolute identification. After the victims are identified, there is also systematic protocol for the disposal of the body in a dignified manner. This would be done with the due dignity to the dead.

Victim management in the Indian scenario

In the Indian scenario, the socio cultural approaches are well organized and coordinated as there is a large cross cultural groups to deal with in the case of mass disasters. The socio cultural aspects are well facilitated. This implies that the religious beliefs are respected and the same are applied for the disposal of the dead. The socio economic perspective is also facilitated through the respective organizations of the

government. The systematic approaches ensure that the victims are able to retain normalcy of livelihood with the assistance from the government. The psycho social factors are taken care of by facilitating them to receive the respective relief. The legal perspectives are also well coordinated with the collective measures through the coordinated groups with the valid documentation for the obligations accordingly.

In case of victim of abuses such as women, children and elderly, this is kmore pertinent. In the course of human trafficking also, the stakes are high for the humanitarian forensic action. The humanitarian forensic action is always boundless irrespective of the unforeseen situation of any origin. Humanitarian Forensics is Swift in action when the humanity is at stake.

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