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Revealing the Hidden: Deciphering the Secret Handwriting

Vanshika[1], Israa J. Hakeem[2], Ranjeet Kumar Singh[3]

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Abstract:

Secret writings are invisible writings that can be only seen after using any development technique which helps in revealing those hidden messages. The invisible inks are used for writing the secret message. These invisible inks can be any kind of colourless fluid or liquid which evaporates slowly. Earlier secret writing was used by the government mainly but nowadays the criminals also use various kinds of invisible inks for fraud purposes. Thus, the cases of fraud by secret writing are increasing day by day; but with the advancement of technology, various detecting and deciphering methods have been developed for forensic purposes which help to identify the source of those particular ink which is being used along with revealing also. These universal and common techniques for decipherment of invisible inks are development by heat and development by Iodine fuming methods. The major purpose of this term paper is to give a collective information about some of those techniques and their methodology for decipherment.

Keywords: *Secret writing, Invisible inks, Decipherment, Hidden message, Handwriting*

Authors:

1. *M. Sc. Forensic Science, Amity University Haryana, INDIA*
2. *Biochemistry Department, Faculty of Sciences, University of Jeddah, Jeddah, Saudi Arabia*
3. *Sherlock Institute of Forensic Science, INDIA*

Introduction

Secret Writing is the means of written communication that is hidden and cannot be seen by naked eyes; thus, require few developing methods. The objective of secret writing is to render the written content unreadable to anyone who comes into contact with it. Secret writing is concealed by a spy whether it is encoded or enciphered or not. But sometimes Codes and Ciphers are mistakenly placed under the heading of Secret Writing whereas the secret writing only deals with messages or texts which are handwritten with any kind of Invisible inks.

Secret writing is being used since the middle of the Twentieth century for hiding messages. Secret writing was a source of communication for Prisoners. They used their Saliva or Sweat and sometimes Urine also as invisible ink to write the message. During times of war, the government also made use of these secret writings. In that era, Magnifying glass and direct light were used to detect the hidden message, but later on, many other developing methods were introduced including both physical and chemical methods. Secret Inks are needed for writing the secret message. These secret inks are also called as Invisible ink, Sympathetic inks, Disappearing inks and Security inks. In most cases, any colourless fluids which don't evaporate immediately are used as secret inks. The writing instrument which is used for secret writing can be a paint-brush, pens with no ink, nibs, toothpicks or other any sharp-pointed object; sometimes fingers and cotton ear-bud too. Mainly plain white papers are used as a writing surface. The invisible inks dry up after a few hours when applied to papers; thus, the written content becomes invisible and cannot appear until any revealing process is used for decipherment. These inks could be used to forge documents such as agreements, cheques, property documents, and other important documents. These invisible inks are typically non-volatile.

Many destructive and non-destructive methods are available for the forensic decipherment of these secret writing **(Hemantini and Khudbudin, 2018)**.

Few of the revealing methods for invisible inks are Physical Methods like development by Heat, visualisation under Ultra-Violet light, detection under ESDA (Electrostatic Detection Apparatus), visualisation under Infra-Red light and Oblique light and Chemical Methods like Iodine fuming, treatment with Silver Nitrate, pH indicator, Precipitation reaction and some other chemical treatments **(Andharmule *et al*., 2013)**.

Some of the inks are also developed by dusting the written area with powders like Fluorescent Powder and Black Powder whereas some of the inks are developed by wetting the paper. All these developing techniques give different kinds of visualization and result with different kinds of inks due to the components present in invisible inks. These variations are also affected by the thinning of paper caused by the drying of these inks on the paper's surface when applied.

The fluids which are used as Invisible inks for secret writing are easily available and useable with a conventional writing instrument, these are categorised as Organic Fluids including Vegetable fluids and Fruit juices, Biological Fluids and Chemical Fluids. The juices and chemicals which were used in the reviewed research papers are given below:

a) **Fruit Fluids** –
- Apple juice
- Orange juice
- Grape juice

b) **Vegetable Fluids** –
- Lemon juice
- Onion juice
- Garlic juice
- Ginger juice

c) **Biological Fluids** –
- Milk
- Saliva
- Sweat
- Blood
- Urine

d) **Chemical Fluids –**
- Vinegar
- Saline solution
- Sugar solution
- Detergent
- Baking soda
- Starch
- Dil. Acetic acid
- Iron Sulphate
- Thymolphalien

Methodology

The basic steps followed were to prepare the sample first and then analyse them. For analysing there are various decipherment methods.

A. Samples Preparation

Firstly, there is a need to prepare the samples of secret writing. The simplest way to write with invisible inks is to dip the writing instrument into the liquid invisible ink and writing on the paper **(Upadhyay and Fatima, 2017)**. Being non-volatile in nature, the ink dries up and causes disturbances in the fibres of paper; that's why it causes thinning of the paper. The thinning of the paper is the basis for the decipherment of written text when heated or treated with chemicals and also when visualised under different light sources; like UV and IR light. The variability in the surface of paper causes the colour to appear which leads to the revealing of the secret message.

B. Decipherment Methods

The decipherment techniques include both Physical and Chemical revealing methods. Most of these methods are reliable as they give good results but few of them are destructive in nature. The basic concept for the development and revealing of the hidden message is because of changed colour contrast between the marked and unmarked area of the sample, here the marked and unmarked area simply means the area of paper which contains written text (by invisible ink) and the area without written text; respectively.

1. Physical Methods

The majority of the physical methods used for deciphering invisible inks are non-destructive, but a few are destructive as well. Firstly, the physical methods are preferred for the decipherment of hidden messages but if those don't work then the decipherment process is followed by the chemical methods. Some of the physical methods are mentioned below:

a. Oblique Light

The message is revealed due to the variability in the surface of the paper when the suspected sample, which contains invisible ink, is observed under oblique light. This is due to the paper thinning, which causes translucency when viewed in oblique light. Being a non-destructive technique, it does not damage the sample, hence before any other revealing method; this method is usually opted for the decipherment.

b. Ultra-violet light

It is also a non-destructive technique. The use of a UV-lamp for the detection of secret ink is also useful as most of the invisible inks including vegetable fluids, chemical fluids give fluorescence under UV light when visualised. This fluorescence makes the impressions of writings visible. If the writings are visible then these must be photographed for further analysis **(Riordan, 1991).**

c. Infra-red light

Visualisation of the sample under an IR light source is also a non-destructive method for the detection of invisible inks. If nothing is visible under UV light then the document should be examined under IR light and if the traces of secret writings are revealed under IR light, then it must be photographed for further analysis **(Riordan, 1991)**.

d. Powder method

It is permissible to try the light dusting of fine coloured powder over the surface of the sample and if the secret writing is slightly sticky in nature or if the texture of the paper is rough; then the powder may adhere to the invisible inks on the paper. But the dusting must be done carefully; so as not to damage the document. Any highly coloured powder which has good adhering properties can be used such as Black Powder, Red Powder, Cigarettes Ash, Graphite Powder and Powdered Charcoal. **(Gardner, 71–77)**.

e. Heat

There are several methods of developing the invisible ink by heat, like –

- Set the paper on Radiator
- Place the paper in Oven
- Hold the paper unto a hot Light Bulb
- Hold the paper near the Candle Flame
- Iron the paper

All of these developing methods help in revealing the message by the changed colour. The impressions or writings which are written by the invisible ink soon changes their colour due to the thinning of paper when exposed to heat **(Upadhyay and Fatima, 2017)**.

The effect of heat should be tried over a number of small areas because it is a destructive technique. Also, the exposure time should be very less or minimum to avoid the destruction of the whole document.

f. Electrostatic Detection Apparatus

As the secret ink remains within the paper for some time before its evaporation due to which the cellulose of paper is affected i.e. the cellulose loses the fibres and also, it's sizing. Thus, even when the secret ink dries; the portion of ink which become wet due to the ink have less charge as compared to the portion which was not affected. Due to this charge variation, the impressions are developed as white impressions against the light grey background.

When the document is placed between the metal plate and thin transparent polymer film with the help of suction; then on passing electric current of 5kV, any variations on the surface of the document causes fluctuation in potential. These fluctuations help in the detection of the indentations with the help of toner powder. In such a way the visible image is formed over the surface of the paper. Adhesive tapes are used for more transparency, in the case of indentations. For the development of impressions ESDA's Powder Cloud Development technique was also tried, but for secret writing inks; Cascade Developing Method gave the best results **(Gupta *et al.*, 1989)**.

2. Chemical Methods

If the decipherment of secret writing fails by Physical methods; then few chemical methods can be used for development. Most of the Chemical developing methods are destructive in nature. Some of the chemical methods for development are mentioned below:

a. pH Indicator

The majority of invisible inks are revealed by pH indicators, which reveal any changes in pH caused by the presence of the hidden inks by analysing the indicator's solution. When exposed to an acidic or basic solution, the colour of the material changes. An indicator has two species: Ind_1 and Ind_2, out of which one can be observed by protonation of another.

$$Ind_1 \rightleftharpoons Ind_2^- + H^+$$

And these both species have a different colours due to their different bonds and electric structures, thus resulting in their different absorption spectra in the visible frequencies of lights. When Ind_1 is exposed to an acidic or basic environment, the colour of the mixture depends upon their equilibrium concentrations.

For the development of hidden messages by pH indicator, the aqueous solution of pH solution is applied to both marked and unmarked regions of the document or sample. The choices of the indicator must be in such a way that both marked writing and unmarked area gives a different colour.

b. Precipitation Reaction

Development by precipitation reaction is preferred for water-soluble salts, these colourless salt solution gives coloured precipitates. The ink applied on paper contains ion in an aqueous form, thus when the aqueous solution of another Ion is applied on the ink, both combine and forms coloured precipitate.

$$Ion_I + Ion_D \rightarrow Salt_P \downarrow$$

These coloured precipitates of salt, on the paper surface, makes writings visible **(Artin and Brandl, 2011)**.

c. Iodine Fuming

Iodine Fuming is a non-destructive technique and sometimes it may be used to reveal the secret writing. As when the fumes of Iodine pass through the sample containing writings, the writings on the surface of paper are revealed. This is due to the presence of starch in the paper; as a result, the colour of the paper changes while the printed text remains unchanged **(Sahu and Hussain, 2017)**.

d. Phenolphthalein

It is a destructive technique in which some of the invisible ink changes its colour when treated with Phenolphthalein solution. The reason behind the change in colour is that the affected area or marked area of paper on which writing is made with invisible inks are slightly acidic in nature and the Phenolphthalein does not change its colour in an acidic medium. Thus, the unmarked or unaffected area of paper changes its colour; and the variability in the colour of the sample makes writing visible **(Upadhyay and Fatima, 2017)**.

e. Silver Nitrate

Various invisible inks react with Silver Nitrate when treated because of the presence of some specific salts. These salts react with silver nitrate which results in the formation of the Silver salts. These silver salts decompose into Silver metal when exposed to light and this silver metal gives colour which makes the text visible **(Sahu and Hussain, 2017).**

f. Other Chemicals

Few more chemicals are used according to the invisible ink as few specific inks having different components react with different chemicals which results in changes of colour. These colour changes are helpful in the decipherment of secret writings or secret messages. Some of the chemicals can also be revealed by treating them with Vinegar **(Andharmule *et al.*, 2013)**.

Results and Discussion

For Physical Developing Methods, the development by Heat and UV gives better results as compared to all other physical developing methods, even when observed for 30 days continuously. Detection of ESDA also gave good results on the sample even after a lapse of 1 week, 1 month and 4 months. With the help of ESDA, even the sample written with water also gave good results after this much interval of time. Even highly volatile chemical, Benzene could also be developed with the use of ESDA **(Gupta *et al.*, 1989)**.

Ink developed by heat mostly gave Brown colour over the text or secret message; vinegar also reveals its hidden message in brown colour **(Chen et al., 2019)**. While inks visualized under UV light gave Blue fluorescence; including dilute Laundry Detergent, Vegetable juices, Fruit juices, Biological fluids and other Chemical fluids etc.

Table No. 1: Results and Observations seen in Organic and Biological fluids by using Physical Development Methods

FLUIDS	SAMPLES	HEAT	UV LIGHT
ORGANIC FLUIDS	Lemon juice	Yes	Yes
	Orange juice	Yes	Yes
	Apple juice	Yes	Yes
	Onion juice	Yes	Yes
	Garlic juice	Yes	Yes
	Ginger juice	Yes	Yes
	Grape juice	Yes	Yes
BIOLOGICAL FLUIDS	Milk	Yes	Yes
	Saliva	Yes	Yes
	Urine	Yes	Yes
	Sweat	Yes	Yes
	Blood	Yes	Yes
CHEMICAL FLUIDS	Vinegar	Yes	Yes
	Baking soda	Yes	Yes
	Detergent	Yes	Yes
	Saline solution	Yes	Yes
	Sugar solution	Yes	No

For Chemical Development Methods, Silver Nitrate and Iodine Fuming give the best results as compared to other chemical developing methods including the pH developing method. Other than that, there are a few chemicals that can be used for some specific chemicals to get results.

The Iodine solution on reacting with organic fluids gave Purple colour. While reacting with Biological and Chemical fluids it gives Brown colour, whereas Saline is an exception as it gives Black colour on reacting with Iodine solution. While Phenolphthalein gives Pink colour when treated with Baking soda. The Silver Nitrate mostly gives Brown colour when treated with different kinds of invisible inks.

Table No. 2: Results and observations seen in Organic fluids by using Chemical Development Methods

FLUIDS	SAMPLES	IODINE FUMING	SILVER NITRATE	PHENOLPHTHALEIN
ORGANIC FLUIDS	Lemon juice	Yes	Yes	Yes
	Orange juice	Yes	No	No
	Apple juice	Yes	Yes	No
	Onion juice	Yes	No	No
	Grape juice	Yes	No	No
BIOLOGICAL FLUIDS	Milk	Yes	Yes	Yes
	Saliva	Yes	Yes	No
	Urine	Yes	No	No
	Sweat	Yes	Yes	Yes
CHEMICAL FLUIDS	Vinegar	Yes	No	No
	Baking soda	Yes	No	Yes
	Detergent	Yes	Yes	Yes
	Saline solution	Yes	No	No
	Sugar solution	No	No	No

Table No. 3: Development of Invisible Inks by other Chemicals

S. No.	INKS	DEVELOPED BY CHEMICALS
1.	Phenolphthalein	Ammonia Fumes Sodium Carbonates
2.	Thymolphalien	Sodium Carbonate
3.	Vinegar	Red Cabbage Water
4.	Dil. Acetic Acid	Red Cabbage Water
5.	Ammonia	Red Cabbage Water
6.	Sodium Chloride	Silver Nitrate
7.	Copper Sulphate	Sodium Iodide Sodium Carbonate Potassium Ferrocyanide
8.	Cerium Oxalate	Manganese Sulphate Hydroxy Peroxide
9.	Starch	Iodine solution
10.	Lead (Ii) Nitrate	Sodium Iodide
11.	Cobalt Chloride	Potassium Ferricyanide
12.	Iron Sulphate	Sodium Carbonate Sodium Sulphate Potassium Ferricyanide
13.	Cobalt Nitrate	Oxalic acid
14.	Mercuric Nitrate	Hydrogen Sulphide
15.	Silver Nitrate	Expose to Sunlight

To find out the sensitivity of developing methods over a period of time, these samples were examined and analysed at regular intervals of five days for one month. One which few more details were observed; which are as follows:

- The visibility of organic fluids which were deciphered by physical method decreased with time except for the Grape juice which was constant under UV light.
- The visibility of organic fluid which was revealed by chemical methods remained constant.
- The visibility of biological fluids also varied for both methods i.e. Development by Physical and Chemical Methods.
- The visibility of chemical fluids was constant for both developing methods; physical and chemical methods except Detergent which showed irregularity **(Sahu and Hussain, 2017).**

Conclusion

Secret writing samples can be deciphered by both, Physical and Chemical methods. All the methods give different results with different chemicals. Among all the Physical methods mentioned; development by Heat is the best method. Though; being destructive in nature it gives results universally with every kind of invisible ink used. But the exposure of heat on the surface of paper should be limited so as not to damage the paper or sample. Even this developing method does not take much time and the visibility is good as well. The observation under UV light is also a good technique as it is a non-destructive method and gives results most of the time. While among Chemical methods, Iodine fuming is known to be the best method as it is also a non-destructive technique; thus,

it does not damage the paper. This is because the fumes of Iodine evaporate after a few minutes of development and leave the treated paper as such, that is why it is a need to be photographed the revealed message instantly after development. Whereas Silver Nitrate and Phenolphthalein give good results for up to a month but both of these techniques are destructive; thus, less preferred **(Sahu and Hussain, 2017)**.

Hence, the Heating method and Iodine fuming method are the best visualisation and deciphering methods for secret inks.

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