Directorate of Distance Education
NALSAR University of Law, Hyderabad
&
Truth Labs, Hyderabad

Reading Material

Advanced Post Graduate Diploma
in
Criminal Law and Forensic Science

1.2.5 Forensic Chemical and General Science

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FOREWORD

Phenomenal advances in Science and Technology and application of some such knowledge put to use by the criminals for illegal purposes has recently led to proliferation of cyber crimes and technology based crimes, etc. At the same time many conventional crimes are now being committed using new technologies through use of smart phones, computer software and hardware usage based on SMS messages and telephone call data, etc and these evidentiary items are acting as an essential proof for investigating many sensational crimes like rape, murder, theft, assault, burglary, cheating, etc. In the light of all that, extensive use of forensic science to unravel truth became an indispensable tool for criminal investigation and trials.

Against this backdrop, the knowledge of forensic science and its deep understanding and appreciation by all the end users viz. Police, Prosecutors, Advocates as well as the Judiciary, is paramount for ensuring peace and tranquillity in the society.

It is therefore necessary to familiarize the legal fraternity, notably the lawyers and legal officers who are one of the first respondents to be contacted by the victims and perpetrators of crime to be afforded an opportunity to get acquainted with the sociological, criminological and psychological factors that affect a normal person to commit a crime, the laws that are enacted for tackling the crime followed by investigation and Prosecution of crime as well as punishment and the roles and responsibility of the agencies that are assigned the tasks.

Similarly, it is also necessary for them to understand the technological nuances and delicate scientific intricacies involved in handling various types of evidence analyzed in different branches of forensic science by the experts of a modern forensic laboratory.

The advanced PG diploma course in Criminal Law and Forensic Science now offered from NALSAR is primarily aimed at fulfilling the above objectives and accordingly the reading materials prepared for the purpose will serve as a basic guide for understanding the fundamental concepts, processes and procedures for all those involved in handling the issues.

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UNIT I

LEARNING OBJECTIVES:

In this unit you will introduced to:

1. Alcohol and its various laboratory tests.
2. Adulteration of Petroleum products.
3. The conditions necessary to initiate and sustain combustion.
4. The telltale signs of an accelerant-initiated fire.
5. The laboratory procedures used to detect and identify hydrocarbon residues.
6. Different types of Oils and how to distinguish them.
7. Examination of chemicals used in trap cases.
8. How explosives are classified.
9. Some common commercial, homemade, and military explosives.
10. How to collect physical evidence at the scene of an explosion.
11. The laboratory procedures used to detect and identify explosive residues.
12. The different instruments used for identification and detection of explosive residues.

UNIT I-A-Forensic Chemistry

1.0 INTRODUCTION

Physical evidence of the following categories is examined to identify the chemical constituents of the substances so as to know their nature, source and the chemical effects likely to be produced when they interact with nature.

1) Alcohol and other related substance such as spurious liquors, adulterated toddy, molasses etc.
2) Adulteration of petroleum substances
3) Cement, Mortar and Concrete
4) Fire Investigation
5) Oils and Fats
6) Acids and Alkalis - Remnants of acid burn cases
7) Examination of Chemicals used in Trap Cases

1.1 ANALYSIS OF ALCOHOL IN LIQUORS/DRINKS

1.1.1 INTRODUCTION

Liquor is normally known as a mixture of water and alcohol. The term alcohol is often used for ethyl alcohol. The liquor is manufactured by the fermentation process in which carbohydrates are fermented in presence of enzymes as per their specifications given in Bureau of Indian Standards (BIS). Country made liquor is alcoholic product usually prepared from fermentation of carbohydrates present in cereals, jaggery, fruits, mahua, palm, molasses etc. The liquors are sold in the market in various brands and covered under Excise Act. The possession, sale, transportation of liquor is allowed only as per the Rules and Regulations of Excise and Prohibition. Many times these liquors are being smuggled from one State to another State, illegal possession, transported without proper valid documents. These samples are seized by the Police and submitted to the Forensic Laboratory for their examination. The liquor is examined in the laboratory for two purposes; firstly, for Excise purpose where, mainly the presence of alcohol plays an important role and accordingly the examination of liquor samples for the qualitative and quantitative analysis is the main purpose of the investigation. Secondly, the liquor is examined for quality control/duplicate samples, which are being sold in the market in which the examination is carried out for other parameters also apart from alcohol contents. The alcohol contents are also reported in percentage of proof spirit, percentage of alcohol (weight by volume) and percentage of alcohol (volume by volume).

Purpose: Qualitative and quantitative estimation of ethyl alcohol in various alcoholic preparations.

Scope: Analysis of various types of alcoholic drinks/liquor in crime exhibits.

1.1.2 METHODS

A) Qualitative Analysis of Liquor

I Test for Ethyl Alcohol

The following tests are to be carried out for the detection of ethyl alcohol in the exhibits.

(a) ***Iodoform Test:*** Take about 1 ml or appropriate of sample (distilled or as such depending upon the nature of sample and concentration of ethanol) and add about 1 ml of 5% sodium hydroxide solution and then add iodine solution (20 gm Potassium iodide + 10 gm Iodine in 100 ml water) drop-wise with shaking until the liquid becomes persistent dark brown in colour. Keep it for 2-3 minutes. If the iodine colour disappears add more drops of iodine solution until persistent brown colour of iodine. Add few drops of dilute sodium hydroxide solution to remove extra iodine. Add equal volume of water, keep it for ten minutes. Yellow crystalline precipitate indicates the positive test for the presence of ethanol.

(b) ***Dichromate Test:*** To about 1 ml or appropriate amount of sample (distilled or as

such depending upon the nature of samples and concentration of ethanol) is added about

0.2 ml of 2% potassium dichromate solution followed by about 1 ml of concentration sulphuric acid. The yellow colour of the dichromate changes to green or blue indicates the presence of ethanol.

II Test for Methanol

a) *Chromotropic Acid Test :* Take about 1 ml or appropriate amount of sample (distilled or as such depending upon the nature of sample and concentration of methanol) in a test tube add about 2 ml of potassium permanganate solution (3 gm potassium permanganate and 15 ml of phosphoric/ortho phosphoric acid in 100 ml distilled water) and shake well. Now add few crystals of sodium bisulphate with shaking till disappearance of colour (potassium permanganate colour) of the solution. Add about 1 ml of chromotropic acid (5% of aqueous solution of sodium salt of chromotropic acid) and add concentrate sulphuric acid slowly with inner sidewall of the test tube to the extent of 15 ml. Appearance of violet colour indicates the presence of methanol.

b) *Schiff's Reagent Test*: Take about 4.5 ml of sample (distilled or as such depending upon the nature of sample) in a test tube and add 0.5 ml of ethanol (if the concentration of ethanol is high in the sample, the sample is fortified accordingly so that 5 ml volume should contain only 0.5 ml ethanol. Add 2 ml of 3% Potassium Permanganate solution and .2ml of phosphoric acid. Keep it for 10 minutes. Add 1 ml of 10% oxalic acid followed by 1ml of concentrated sulphuric acid. The contents are cold at room temperature. Now add 5 ml of schiffÊs reagent, keep it for half an hour and observe the colour. Appearance of purple colour indicates positive test for the presence of methanol. The parallel experiments may also been carried out with control sample containing 0.5 ml solution (0.5% methanol in rectified spirit/ethanol) mixed with 4.5 ml of water and a blank sample having 5 ml water. The colour appeared in the test sample may be matched with the colour of the control/standard sample of methanol which is equivalent to 2 mg of methanol. Thus the semi-quantitative examination of methanol may be carried out.

III Test for Copper & Iron

Take about 5 ml or appropriate amount of sample add 1 drop of Nitric acid and 1 ml of 0.025 M potassium Ferrocyanide solution. Prussian blue colour indicates presence of iron and chocolate colour indicates the presence of copper.

IV Test for Furfural

Take about 5 ml or appropriate amount of sample (distilled or as such depending upon the nature of sample and concentration of furfural) in a test tube, add about 1 ml aniline and about 0.5 ml hydrochloric acid and keep it for 15 minutes. Appearance of red colour indicates the presence of furfural.

Alternative method for testing furfural:

a) Take about 2 ml or appropriate amount of the sample distilled or as such depending upon the nature of sample in a test tube, add about 0.2 ml of aniline and about 0.4 ml of glacial acetic acid. If the furfural is present in the sample, red colour develops in a few seconds & reaches its maximum intensity in 5-10 minutes.

Take about 2 ml or appropriate amount of the sample distilled or as such depending upon the nature of sample in a test tube, add about 1 ml of aniline acetate solution (10% V/V solution of aniline in glacial acetic acid). Appearance of red colour indicates the presence of furfural. The colour develops at room temperature of 25-30^0C and reaches its maximum intensity in 1-5 minutes.

Quantitative Analysis of Liquor

I Determination of Ethanol

Depending upon the nature of sample and examination required and resources available any one of the following methods can be used for the quantitative analysis of ethyl alcohol.

Determine the specific gravity of the distilled sample by specific gravity bottle and apply the bottle correction and temperature correction for 60^0F as per the table showing weight in grains of the spirit of temperatures 61^0 to 100^0 given under the instructions for ascertaining the real alcoholic strength of drugs chemicals, medicines dietetics and toilet preparations entered for test prepared by R.L. Jenks, F.I.C., Examiner for Customs and Excise, Calcutta (Central Board of Revenue) 1914-1928 Revised-1936 and find out the quantity of alcohol (% of proof spirit and % of alcohol V/V) from the table showing the relation between the specific gravity of spirits at $60^0/60^0$ F and the percentage of ethyl alcohol by weight and by volume with the corresponding percentage of proof spirit issued under the authority of the Commissioner of Her MajestyÊs Customs and Excise, London, Her Majesty‘s stationery office 1955, Reprinted 1971.

Example of Calculation: At temperature of 76^0F (24.5^{o}C) F=CX1.8+32=76.1^{o}F

1. Weight of 50 ml specific gravity bottle : 26.6870 gm
2. Weight of bottle plus distilled water : 76.6720 gm 3. Weight of water : 76.6720-26.6870 = 49.9850 gm
4. Weight of 1000 ml water : 49.9850 x 20 = 999.7 gm (-)
5. Temperature correction : 1.64 (to be added) at 76^{o}F 6. Weight of 1 liter water : 999.7 + 1.64 = 1001.34
7. Bottle correction : 1001.34 – 1000 = 1.34+
8. Weight of exhibit and bottle : 73.8250 gm
9. Weight of the exhibit : 73.8250 – 26.6870 = 47.138 gm
10. Weight of the 1000 ml exhibit : 47.138 x 20 = 942.76 gm
11. Weight of exhibits with bottle correction : 942.76 – 1.34 = 941.42 gm
12. Temperature correction : 6.00 (at 76^0F)
13. Corrected weight of the exhibit : 940.46 + 6.00= 946.46 gm
14. Specific gravity of the exhibit : 946.46/1000 = 0.94646

15. Percentage of proof spirit : 75.69
16. Percentage of alcohol V/V : 43.25

II Other Determinations

The following determinations (some or all depending upon the nature of examination and infrastructure available), if required, may be carried out as per IS:3752:1988.

i) Determination of ash
ii) Determination of total acidity
iii) Determination of volatile acidity
iv) Determination of fixed acidity
v) Determination of residues on evaporation
vi) Determination of esters
vii) Determination of higher alcohols
viii) Determination of aldehydes
ix) Determination of copper
x) Determination of furfural

1.1.3 ILLICIT LIQUOR

1.1.3.1 DEFINITION

A mixture of alcohol and water is normally known as liquor. The term alcohol is often used for ethyl alcohol. Alcohol is produced by the fermentation of sugar or starch containing plant material. Country liquor is a distilled alcoholic beverage made from locally available cheap raw material such as sugarcane, rice, palm, coconut etc. The alcoholic content is between 25% and 45%. Common varieties of country liquor are *arrack* (from paddy or wheat), *desi sharab* and *tari*. Illicit liquor is mostly produced clandestinely in small production units. With no legal quality checks on them, alcohol concentration of illicit liquor varies up to 56%. Adulteration is common with methylated spirit being a common adulterant, which sometimes causes incidence like mass poisoning with consumers losing their lives or suffering irreversible damage to their eyes. Since it is cheap illicit liquor is common among the economically lower class of the society. In many parts of India, illicit production of liquor and its marketing is a cottage industry with each village having one or two units operating illegally. The possession, sale, transportation of liquor is allowed only as per the Rules and Regulations of Excise and Prohibition. Many times these liquors are being smuggled from one State to another State, illegal possession, transported without proper valid documents. These samples are seized by the Police and submitted to the Forensic Laboratory for their examination.

1.1.3.2 TODDY

General background and description

The method of tapping of toddy differs from place to place. Usually taperÊs use plant extracts for seasoning the inflorescence before tapping. The purpose of using these various plant extracts is the arresting of the maturation of the inflorescence and the increasing of the sap flow.

Definition: Toddy is obtained as juice/sap of palmyra and other palm tress.

Available forms: Available in liquid forms.

Source and form of crime/questioned sampled: The State Excise and Prohibition department forwards the samples referred from detail outlets managed by dealers engaged in the business of sale of toddy/alcohol.

Control sample: Specific standard samples approved by state Excise duty rules, which permit the withdrawal of duty free samples for testing.

1.1.3.3 LIQUORS (IDL/IMFL)

General background and description:

The term alcohol in popular use refers to ethyl alcohol (ethanol). Pure ethyl alcohol is a transparent colourless volatile liquid having an aromatic odour and burning taste. It is obtained by the enzymatic fermentation of carbohydrates like sugars, starches etc. The final fermented mass contains about 10 % alcohol, which is purified and concentrated by distillation.

Definition: Alcohol is the active ingredient of many social beverages such as wines, beers, whiskies and brandies. IDL is the distillate obtained from fermented mash of cereals, potato, fruits, molasses, jaggery or any other source of fermentable carbohydrates.

Available forms: Available in liquid forms.

Source and form of crime/questioned sample: The State Excise and Prohibition department forwards the samples referred from detail outlets managed by dealers engaged in the business of sale of alcohol/illicitly distilled liquors.
Control sample: Specific standard samples approved by state Excise duty rules which permit the withdrawal of duty free samples for testing.

1.1.3.4 LABORATORY ANALYSIS OF LIQUOR

At the forensic lab, the examination of liquor is conducted for two main purposes. Firstly, for Excise purpose where, mainly the presence of alcohol plays an important role therefore a qualitative and quantitative analysis is carried out. Secondly, the liquor is examined for quality control or duplicate samples, which are being sold in the market wherein the examination is carried out for alcohol contents which is reported in percentage of proof spirit, percentage of alcohol (weight by volume) and percentage of alcohol (volume by volume).

Methods and procedures

Method-I: Physical examination Method-II: Chemical examination Method-III: Instrumental Methods

1.2 ADULTERATION OF PETROLEUM PRODUCTS

1.2.1 INTRODUCTION

A petroleum product is obtained by the fractional distillation of crude oil and is a complex mixture of hydrocarbons. Petrol and diesel are the main fuels or sources of energy used in vehicles in India. Adulteration of these fuels at the point of sale and during transportation is on the rise. The adulteration of these fuels leads to degradation of engine performance and fugitive emissions. These fuels are adulterated with cheaper products or by-product or waste hydrocarbon stream for monetary gains. Petroleum products are sent to forensic labs to test the purity, detection of adulterants etc.

1.2.2 DEFINITIONS

According to „The Motor Spirit and High Speed Diesel (Prevention of Malpractices in Supply and Distribution) Order, 1993 by Section 3 of Essential Commodities Act (E.C. Act) (Central Act 10 of 1955)

Adulteration: Is the introduction of a foreign substance into motor spirit / high speed diesel, illegally or unauthorized with the result that the product does not conform to the requirements and specifications of the product. The foreign substances are called adulterants which when introduced alter and degrade the quality of the base transport fuels.

Malpractices: Includes the following acts of omission, commission with respect to motor spirit and high speed diesel:

- Adulteration
- Pilferage
- Stock variation
- Unauthorised purchase
- Unauthorised sale

Spirit: Is a hydrocarbon oil (excluding crude mineral oil) which has a minimum RON88, which either by itself or in admixture with any other substance, is suitable for use as fuel in spark ignition engines.

High Speed Diesel: Is a hydrocarbon (excluding mineral colza oil and turpentine substitute), which has its flash point at or above 35^0C and Cetane 48 minimum and is suitable for use as a fuel in compression ignition engines.

Kerosene: Is a middle distillate mixture of hydrocarbons meeting Bureau of Indian Standards Specification (IS 1459/1974) with important characteristics of flash point at a minimum of 35^0C and a smoke point at a minimum of 18mm.

Petroleum Products include:

- LPG and CNG etc.
- Motor spirit all grades and naphtha
- Aviation spirit
- Solvents of all types
- Aviation turbine fuel
- Kerosene
- Light Diesel oil
- High Speed Diesel Oil
- Fuel oil of all grades
- Lubricating oils and greases including base oil
- Wax of all grades
- Bitumen

1.2.3 ORIGIN

19^{th} century belonged to the automotive industry, where petrol and diesel were used as the main fuels although now a days many alternate fuels like CNG, LPG,

alcohol, dimethylether, biodiesel, methanol, etc. are emerging in the market. Adulteration of petrol and diesel is indulged primarily due to the significant price difference between these products and the adulterants. In India, petrol is taxed more than diesel which is taxed more than kerosene. Industrial solvents and recycled lubricants are other materials with little or no tax. There are standards or specifications which are laid down by enforcing agencies in most countries with regard to the quality of the fuels that need to be supplied to the consumers. In India, the Bureau of Indian Standards (BIS) notifies specifications for petrol and diesel.

1.2.4 TYPES OF ADULTERANTS

Blending or mixing of the adulterants into the base fuel varies depending on the type and quantity of the adulterant. This variation is due to the availability, profitability and blendability of the adulterants.

Examples of adulteration include:

- Blending small amounts of distillate fuels like diesel or kerosene into petrol.
- Blending variable amounts of industrial solvents composed of hydrocarbons whose boiling range is the same as petrol.
- Blending small amounts of spent waste industrial solvents, which would be costly to dispose off in an environmentally approved manner-into petrol or diesel.
- Blending kerosene or heavier fuel oils into diesel.
- Commonly used adulterants in petrol base fuel are: kerosene, diesel, naphtha, industrial solvents, pentane, hexane, benzene, toluene etc.

Commonly used adulterants in diesel base fuel are: kerosene, aromex, iomex.

1.2.5 REPERCUSSIONS OF FUEL ADULTERATION

- Fuel adulteration is the deterioration in engine performance.
- Increased tailpipe emissions of hydrocarbons, carbon monoxide, oxides of nitrogen and sometimes carcinogenic pollutants.
- Economic losses – considerable loss of the tax revenue. The country is losing more than Rs10,000 crores annually as a result of fuel adulteration.

1.2.6 TESTING FOR ADULTERANTS IN A FORENSIC LAB

If adulteration is suspected three samples of 1 litre each is taken. One is given to the forensic lab for testing, the second is kept with the concerned department and third is given to the dealer, transporter or concerned person. The samples are taken in glass or aluminium containers. Wherever applicable control samples are also taken which contain solvents, SBP etc.

The main purpose of examination of the suspected liquid is to determine the following:

a) Whether the given sample is a petroleum compound, if yes is it a motor spirit or high speed diesel.
b) To ascertain if the fuel sample is adulterated and determine the type of adulterant.

A) Test to detect the presence of petroleum compounds

1ml of the sample is taken on a spot tile and 1:9 ratio of formaldehyde and conc. sulphuric acid is added. Appearance of violet-brown colour indicates presence of hydrocarbons which is positive for a petroleum compound.

Certain properties of the fuel change when blended with an adulterant. In a forensic lab these properties are tested to detect adulteration.

B) Tests to detect adulteration in petrol

- Density
- Distillation
- Colour Test
- Filter paper test
- Analytical methods involving TLC/HPLC/GC

1) Density – Density is a measure of mass per unit volume. It is measured by using a hydrometer or by the Automatic Density Meter Method.

In the hydrometer method the sample is taken in a measuring cylinder. The bulb of the hydrometer is dipped in the sample; on stabilization the density is read at room temperature. Using conversion table, the density at 15^0C is calculated.

In an Automatic Density Meter Method the temperature is set to 15^0C and the sample is injected. The instrument gives three measurements, density, specific gravity and API gravity (American Petroleum Institute).

The density of petrol at 15^0C is 710-770kg/m^3. Increase in density above 770kg/m^3 indicates the presence of possible adulterants like kerosene, diesel, naphtha, benzene, toluene etc. Density below 710kg/m^3 indicates the presence of possible adulterant solvents mainly aliphatics.

2) Distillation – In this process the sample of motor spirit or high speed diesel is subjected to distillation and percentage volume recoveries at different temperatures are noted. 100ml of the sample is distilled. The temperature at which the water drop distils is noted as Initial Boiling Point (IBP) and the temperature is noted after every 10% volume distils over. The highest temperature reached during distillation is also noted which is the Final Boiling Point (FBP). Depending on the nature of adulterant the IBP and FBP varies. Depending on the volatility of the sample the volume of the residue varies. High boiling compounds usually leave more residue than low boiling compounds.

3) Filter Paper Test – Petrol is a highly volatile liquid, whereas kerosene and diesel are less volatile. Hence a drop of petrol on a filter paper will completely vaporize without leaving any traces but petrol adulterated with kerosene or diesel leaves an oily patch with a characteristic smell of kerosene or diesel. However, if the petrol is adulterated with volatile hydrocarbon solvents it would be difficult to determine it using the Filter Paper Test.

4) Thin Layer Chromatography – The TLC plate is spotted with the petrol standard, reference dyes oil orange and oil red and the suspected sample. The solvents used are hexane, toluene and acetic acid. On running the TLC the orange dye from the petrol standard separates out and is visible as two spots, one pink and another orange. If any other dye is used there will be a change in these spot colours after spraying dilute sulphuric acid.

If the petrol is adulterated with kerosene or diesel the TLC plate is spotted with standard petrol, kerosene and diesel along with the suspected sample. The TLC is run using the same solvent system mentioned above. After running the TLC for visualization Rhodamine solution and bromide are used. Standard petrol shows

pinkish orange fluorescence, kerosene shows bluish violet and diesel violet fluorescence under UV light.

5) High Performance Liquid Chromatography (HPLC) and Gas Chromatography (GC) – Standard petrol, kerosene and admixtures of petrol and kerosene of varying concentrations are injected into the HPLC or GC along with the suspected sample. The retention times and peak areas of the suspected sample is compared with the known admixtures thereby conducting a quantitative estimation.

This technique is very good for detecting and quantifying kerosene in petrol and other medium boiling hydrocarbon solvents like mineral turpentine oil, ATF etc.

However, if the petrol is adulterated with solvents having a similar boiling point as petrol it would be difficult to identify the adulterant.

6) Gas Chromatograph coupled with Detailed Hydrocarbon Analyser (GC-DHA) - In cases where the petrol is adulterated with solvents having a similar boiling point as petrol making its detection difficult with the conventional GC; a GC-DHA is used in such cases where the identification of adulterants like naphtha, special boiling point solvents etc. The confirmatory test for adulteration of petrol is the Research Octane Number (RON) value determination, which according to BIS is supposed to have a minimum value of 88. GC-DHA is a quick and reliable method for determining the RON. Adulterants like special boiling point solvents, alpihatics etc lower the RON whereas adulterants like C9 aromatics, narrow cut aromatics increase the RON to above 88.

C) Tests to detect adulteration in Kerosene

- Density
- Distillation
- Viscosity

1) Density – It is conducted in a similar manner as mentioned for petrol. The density of standard kerosene at 15^0C is 0.78 to 0.82 gm/cm^3.

2) Distillation – As given above. The Final Boiling temperature is below 300^0C.

3) Viscosity – Viscosity is a physical property of a liquid and is the property of it resistance to flow. Using a viscometer the viscosity of the sample is measured. The most common and accepted method is the Kinematic Viscosity. It is a product of time in seconds and calibration constant of the viscometer and expressed in units of centistroke (CST).

D) Tests to detect adulteration in Diesel

- Density
- Distillation
- Viscosity
- GC

1) Density – The method is as given in petrol. A standard high speed diesel has a density of 820 – 870 kg/m^3 at 15^0C. Increase in the density above 870 kg/m^3 indicates the presence of adulterants like heavy aromatic naphtha, light viscous oil etc.

Decrease in the density below 810 kg/m^3 indicates the presence of possible adulterants like kerosene and middle distillates.

2) Distillation – As given above in tests for adulteration in petrol. The entire sample should distil below 400^0C. The distillation range for standard diesel is 150^0C to 380^0C.

3) Viscosity – As given above in kerosene. Prescribed range of kinematic viscosity for high speed diesel is 1.8 to 5 CST as per Bureau of Indian Standards specifications. Decrease in viscosity indicates the presence of adulterants like kerosene etc. and Increase in viscosity indicates the presence of low viscosity grade oil etc.

4) Gas Chromatography – The test is conducted similarly as mentioned in the tests for adulterants in petrol. Pure Diesel, Kerosene and various admixtures are prepared in ether and injected into the GC. Quantitative determination of the adulterant kerosene in diesel is possible by comparing the chromatographs of the standards with the suspectedsample.

1.2.7 ADVANCES IN TESTING FUEL ADULTERATION

With the advent of technology several new instruments are available which estimate important parameters in petrol and diesel.

(a) The ‗Fox FTIR' fuel analyzer is claimed to be ideal for the analysis of commercial fuels especially since it is portable.

(b) ZeltexZX101CC Portable Octane analyzer gives results in less than 20 seconds and can 10 separate calibrations for unleaded petrol, leaded petrol, kerosene, diesel etc. and requires less than 250ml of the sample.

1.3 CEMENT, MORTAR AND CONCRETE

1.2.8 INTRODUCTION

Forensic Science Laboratories receive cement cases under different crime heads like Essential Commodities Act., Indian Penal Code (IPC) and occasionally under Cement Orders Act. Cement is one of the most important materials in building construction. In chemical examination, testing of cement is done to check its purity and characterization. Hence only a few parameters like soluble calcium oxide, silica etc. are determined as per Indian Standards specifications. Concrete and Mortar are referred to Forensic Science Laboratories in cases of building collapse.

Purpose: To know the precise chemical composition of cement, mortar and concrete and to assist investigating agencies and law enforcement bodies.

Scope: Detection and estimation of the constituents of cement, mortar and concrete in crime cases.

1.2.9 CEMENT

Portland cement may be defined as a product obtained by intimately mixing together calcareous and argillaceous, or other silica, alumina, and iron oxide-bearing materials, burning them at a clinkering temperature and grinding the resulting clinker. In 1824 Joseph Aspdin gave the name portland cement because this product

resembled the colour of the stones from Portland, England. Cements are mainly mono silicates of calcium, soluble in dilute acids and alkali.

I) COMPOSITION OF PORTLAND CEMENT

Lime CaO	60-67%	
Silica SiO_2	17-25%	
Alumina	Al_2O_3	03-08%
Iron Oxide	Fe_2O_3	0.5-06%
Magnesia	MgO	0.1-04%

SODA & POTASH	NA_2O & K_2O	0.2-01%
Sulfur Trioxide	SO_3	01-2.75%
Free Lime	CaO	00-01%

The Main Constituents of Cement are:

Tetracalcium Alumino Ferrite 4 CaO, Al_2O_3, Fe_2O_3

Dicalcium	Silicate	2 $CaOSiO_2$	30%
Tricalcium	Silicate	3 $CaOSiO_2$	40%
Tricalcium	Aluminate	3 $CaOAl_2O_3$	11%

11%

II) TYPES OF CEMENTS

There are many types of cements available, but few of them are discussed here.

Rapid Hardening Portland Cement- is similar to that of ordinary Portland cement, but is grounded finer and slightly altered in composition. Its setting time is similar, but it develops its strength more rapidly.

Quick setting Portland Cement - it differs from normal Portland cement in its setting time, which is less, compared to portland cement. Its rate of hardening may be similar to that of ordinary or rapid hardening Portland Cement.

White Portland Cement - is an ordinary Portland cement containing a low proportion of iron oxide, so that its colour is white instead of grey.

Water proof Portland Cement- is ordinary Portland Cement in which at grinding stage small proportion of calcium stearate or non-saponifiable oil is added.

Hydrophobic Cement - is a material obtained by grinding Portland Cement clinker with a water repellent film forming substance such as fatty acid in order to reduce the rate of deterioration under favorable storage or transport conditions.

Low-heat Portland Cement - is a material in which chemical composition has been so adjusted as to reduce the heat of hydration.

Portland Pozzolona Cement – in ordinary Portland cement, a pozzolonic material like brick powder, flyash etc. are added in the range of 20-40%. This cement is called Portland Pozzolona Cement and is generally used in the preparation of plaster materials.

1.2.10 OTHER BUILDING MATERIALS

Stone powder - is poly silicates of calcium, magnesium and iron etc. and is practically insoluble in dilute acids.

Concrete - is the hard mass obtained by solidification of the inert material like sand, coarse stone, water and cement.

Mortar - is the mixture of sand and cement for plastering the brickwork.
Sand - is mostly silica in defined form and insoluble in dilute mineral acids, should be clean, strong, durable uncoated well-graded particles. The particles should be free from alkali, organic matter, loam or other deterious substances. The diameter of the sand particles should not be above 6 mm.
Aggregate - The aggregate should consist of crushed rock, gravel or other inert material. The particles should be clean, though, hard and durable. It should not contain soft, flat and elongated material. The maximum length of aggregate should not be more than 112 mm.
Brick - is an important building material. Varieties of bricks are available in the market. Their qualities are determined on the basis of physical parameters. There is no much chemical examination involved in deciding their fitness etc.

1.2.1 SAMPLING

Cement - When the sample is drawn from a cement bag, the details printed on the bag and another marking thereon should be carefully noted and incorporated in the forwarding letter. 1 kg sample of cement should be sent in an airtight plastic jar if available or it should be securely packed in polythene bag and then in brown paper to avoid exposure to moisture. Sampling is done as per the procedure as laid down in the Indian Standard Procedures of random sampling.
Mortar - 1-2 Kg of mortar sample accompanied by 1 kg each of cement and / or lime and sand if available from the field shall be sent for analysis. Every article should be independently packed.
Concrete - Concrete lumps, about 3-5kg accompanied by 1 kg each of cement, sand and aggregate if available from the field shall be sent for analysis. Every article should be independently packed.

1.2.2 METHODS OF ANALYSIS

I CEMENT

1) Thymolphthalein Test - (Thymolphthalein Indicator 0.1% in ethyl alcohol) - Take 100- 150 mg of cement sample in a test tube, add 1-2 ml water and 2 drops of indicator, development of blue colour indicates the presence of cement, No colour indicates that the sample is stone powder.
2) Heating test - Take 0.5 gm of sample, heat it for about 20 min. on a steel plate.
a) Change in colour adulterated cement.
b) No change in colour unadulterated cement.
3) Performance Test - Make thick slurry of cement with about 1 part of cement with one part of water and put in an empty matchbox. The cement gets hardened. The performance is tested after 24 hrs. just by removing matchbox and checking approx. strength of the cement by fingers, if the block breaks easily, the setting property is said to be poor. If the block does not break by fingers. The performance is said to be good.
4) Determination of „Calcium" by EDTA Titration - (By Patton Reeder`s indicator) - Take filtrate from ferric oxide and alumina determination in 250 ml Vol. flask adjust Vol. to 250 ml. Take out 25ml soln. in titration flask add 50 ml water, 5ml (1:1) glycerol with constant stirring then add 5ml diethylamine, further add 5-6 pellets of NaOH (pH should be more than 12) shake well, further add 50mg of Patton Reeder`s indicator, shake well and titrate against 0.01M EDTA soln. colour change violet to blue.
1ml 0.01 M EDTA = 0.5608 mg of CaO.

(60 % CaO = 100% Cement) and CaO% = 3 Silica %

II MORTAR

Mortar is the blend of cement and sand in various proportions used for various purposes. The mortar used for brickwork in house walls is generally 1:4 in proportions. For testing of mortar and brick good piece of mortar adhering to brick from debris should be collected.

1) **Testing of Mortar** - Heat good piece of mortar approx. 200 gms is heated in oven at 110□C for 15 min. cool and then weigh. Separate the cement portion from sand by slowly grinding the lump in iron mortar. (to separate sand from cement lumps.) Sieve the material and make three fractions. Powder, fine sand and coarse sand. Weigh individually and record. Take about 5-10 gm of each fraction in beaker, add 5-10 ml 3.3 N HCl till all the material is wet with HCl, if required, add further 5-10 ml HCl, to dissolve the material. The cement portion gets dissolved and sand portion gets separated from cement, digest on water bath for 10 minutes & filter the liquid through filter paper, wash with water till chloride free. The filtrate is evaporated and silica determined as in earlier part, from silica cement portion in each fraction is determined, from total weight, weight of sand obtained by subtracting wt. Of cement and hence the ratio of cement to sand is calculated. Also % of cement in the sample is calculated.

2) **EDTA Titrations** - For filtrate same as cement normally the ratio of cement: sand used in plastering work is 1:4 (The ratio used for compound walls and such other work is 1:6 to 1:8).

IIICONCRETE

Concrete is a blend of cement, sand and aggregate in different proportions used for different purposes. Normally samples from debris selected are pieces of beams and slabs taken for analysis. About 1/2kg sample is required for analysis dry the piece from slab/beam in oven at 110□C for 15 minutes, cool, and weigh. Then grind the sample so that cement particle gets separated from sand and aggregate. Sieve the bulk with different mesh size sieves, to separate powder, fine sand, coarse sand and aggregate. Weigh the fractions so separated individually. Take about 5-6gm from powder fraction and fine sand fraction, about 50-60 gm from coarse sand and about 100-150 gms of aggregate fraction for actual silica and calcium oxide determination. Take all the four fractions as above in 250 ml beakers, add sufficient quantity of 3.3 N HCl to dissolve the adhering cement particles. Then digest on water bath for 10-15 minutes and filter. The filtrate so obtained is used for silica determination.

IVSILICA

Filtrate evaporate the filtrate to dryness on hot plate, dry silica remains in the beaker along with calcium and aluminium salts. Then add 3.3 N HCl and digest on water bath for 5 mins. Filter the silica through ashless filter paper, wash with water until chloride free. Dry the silica in oven and further in furnace at 800□C-1000□C for 2 hrs, Wash the silica so obtained. From silica calculate the weight of cement obtained in different fractions (20% silica = 100% cement). Each fraction contains some cement portion and rest being fine sand, sand and aggregate respectively. Take sand and fine sand fractions together. Thus calculate the total cement, total sand and total aggregates present in the sample, and hence calculate the ratio of cement: sand: aggregate also calculate the cement percentage. From filtrate of silica, calculate CaO % as detailed in cement, from CaO% also calculate the % cement in each fraction, and

hence get the ratio of cement: sand: aggregate, and also % of cement in the sample. Compare the results obtained by silica and CaO.

1.2.3 CONCLUSION

Cement is complex mixture and testing of cement is a difficult task. In Forensic Context one has to certify whether the sample is cement or not, and if so, the percentage of cement in the sample. The initial tests like Thymolphthalein test, Heat test, Performance test along with percentage of acid insoluble, calcium oxide and silica data can allow one to frame a report regarding the cement percentage with acid insoluble and cement with non cementitious material. If stone powder is used for adulteration the acid insoluble amount for adulteration percentage but if lime or other material is used for adulteration then acid insoluble will be less and calcium oxide will be more, the correct cement percentage can be assayed from silica content. The relative standard deviations of 0.44 % and recovery of 99 % was obtained for EDTA titration. The relative standard deviations of 0.88 and recovery of 94 % was obtained for silica determination. Hence the results of the analysis of cement by the above methods are quite accurate and reproducible. In case of Mortar and Concrete the ratio of Cement: Sand and Cement: Sand: Aggregate is very important, hence selection of the sample plays an important role, finally the cement content determined by above method assures accuracy and reproducibility.

Other instrumental techniques for the cement analysis

1. ICP
2. XRD

These techniques can be used for the analysis of contents/elements of the cement, as per the literature available in the laboratory.

1.4 FIRE INVESTIGATION

1.2.4 INTRODUCTION

Fire Investigation deals with the examination of a fire scene to determine the origin and cause of fire. A fire investigator essentially determines the nature of fire, its progress from the area of origin and the cause of ignition. A fire scene is extremely difficult to process since there is large-scale destruction of materials as a result of the fire as well as due to the fire suppression activities and also every fire scene is investigated as a potential case of arson until proven otherwise.

Arson maybe defined as willful and malicious burning of another‘s property or the burning of one‘s own property. Arson might be committed to defraud an insurance company or concealment of other crimes such as murder or burglary. In most non-fire crime scenes the first thing that is done after the discovery of the crime is securing the crime scene; however in a fire scene before the arson investigator arrives numerous individuals including fire fighters and police officers would have visited the crime scene. Preservation of the fire scene is the last thing fire fighters consider when trying to put off the fire. In spite of the many difficulties in fire investigation, a careful and thorough search of the scene studying the burn patterns as well as the laboratory results from the analysis of fire debris provides useful information in the investigation.

An important factor in fire investigation is not the findings of items but the relevance of the findings; interpretation of evidence is crucial. For example the presence of ignitable liquids at a scene does not prove positive for arson, as there

might be a justifiable reason for it being there, e.g. kerosene being used as a fuel in lamps.

Fires can be broadly classified as either accidental or deliberate.

Accidental Fires: Many of the accidental fires may have a certain degree of contributory negligence attached to them (which is of interest to the insurance companies as it may result in the reduction in insurance settlement; however it is up to the court to decide the level of negligence based on the forensic expert's report). Accidental Fires can be classified into three categories:

1) Human error – such as incorrectly extinguishing smoking materials, improper use of electrical appliances.

2) Electrical fires – maybe caused as a result of faulty or old electrical wiring, faulty and dangerous appliances or inappropriate use of fuses in electrical appliances.

3) Natural causes – such as lightening strikes, lava from a volcano have all been known to cause damage and loss due to fire.

4) Deliberate Fires- These types of fires are altogether different in terms of their causes and the motivation behind them. In general such incidents have been started by some form of flammable material used to accelerate the fire. This is usually but not always a flammable liquid. Motivations are often varied and complex and include:

- An attempt to cover up other crimes such as theft, fraud or murder
- As part of a serious of crimes of a known arsonist
- A grudge against a particular race, religion
- Bankruptcy or financial difficulties in order to claim insurance.

1.2.5 WHAT IS FIRE?

Fire can be used for constructive purposes or can be misused by man. When used for a salubrious purpose for example to cook food or for warmth, it is a boon to mankind. But man has misused the power of fire giving rise to hostile fire, which injures or kills people and destroys property.

The three main requirements for a fire to occur are heat, oxygen and fuel. In most cases there is also a requirement for an initial ignition source to provide energy to overcome any energy barriers and ignite the fuel present. The fuel, oxygen, heat and appropriate ignition source comprise the fire diamond or quadrangle (Fig 1.1). Once the fuel has been ignited the fire is self sustaining unless the fuel, oxygen or heat are removed resulting in the suppression of the fire. After the fire has been established the fuel, oxygen and heat alone comprise the fire triangle.

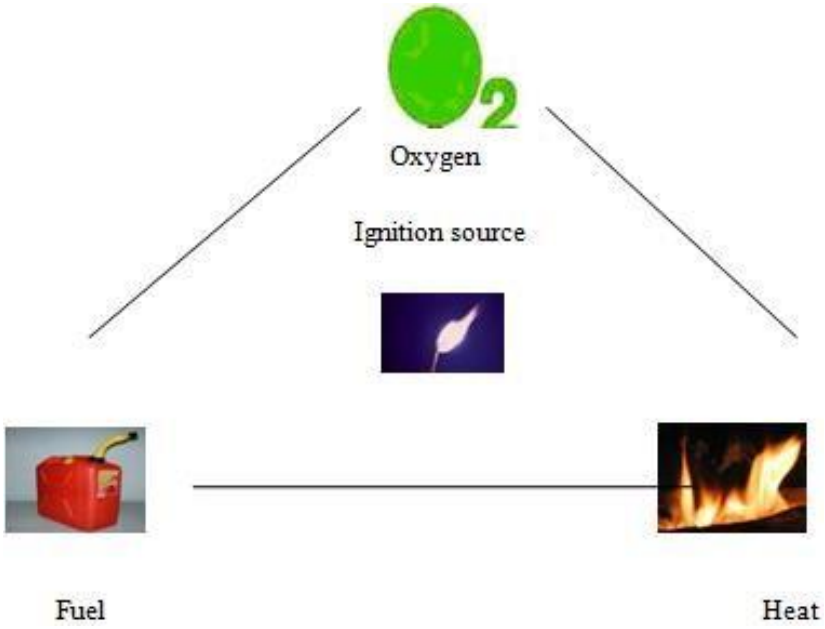


Fig. 1.1 The fire quadrangle

Fire is overall a series of oxidative reactions where the fuels present are being oxidized in exothermic reactions i.e. a chemical reaction that releases energy in the form of heat.

For example, the combustion of propane can be represented as follows:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Propane, which is a hydrocarbon, is the fuel that burns with oxygen, releasing carbon dioxide and water as combustion products. Combustion is a rapid exothermic reaction between oxygen and a fuel usually a hydrocarbon resulting in the production of large amounts of heat and light. All reactions require energy input to start them, to break the molecular bonds and re-arrange the molecules to form new products. Consider this requirement for energy input as an energy barrier between the reactants and products of a reaction. The higher the energy barrier, the more amount of energy is required to initiate the reaction. The energy barrier in the conversion of iron to rust is relatively small, and can be surmounted with the help of heat energy present in the surrounding environment. But this is not so in the case of propane or petrol or diesel. These energy barriers are quiet high and therefore enough heat energy should be supplied to exceed the energy barrier to start the oxidation of these fuels. This is provided by the ignition source which could be a lighted match or electrical discharges, sparks or chemicals. Once the combustion starts, enough heat is liberated to maintain a self-sustaining fire until either the oxygen or fuel is exhausted.

Water and carbon dioxide are the major products of combustion with other products including carbon monoxide (the asphyxiating effect of smoke) and oxides of sulphur, nitrogen and other compounds which maybe present and which contribute to smoke.

Types of Fuels - Fuels range from simple hydrocarbon gases to chemically complex solids, which could be natural, synthetic or semi-synthetic. Examples of fuel include hydrogen, methane, propane, petrol, diesel, kerosene, paint thinner, wood, paper, polystyrene, PVC, polyurethane etc. Under appropriate conditions these fuel burn releasing heat and combustion products.

Oxidizing agents - Other oxidizing agents that help in the combustion of hydrocarbons include sodium nitrate, potassium chlorate, though oxygen is the most common oxidizing agent. For example, explosives are substances that undergo a rapid exothermic oxidation reaction, producing large quantities of gases. This sudden build up of gas pressure results in an explosion. Detonation occurs so rapidly that oxygen in the air cannot participate in the reaction, thus many explosives have their own source of oxygen. Chemicals that supply oxygen are called oxidizing agents.

Ignition sources – Ignition sources maybe of chemical, mechanical or electrical origin. Some common sources of ignition are lighters, matches, candles etc. a match is perhaps the most common igniting device. Another effective source of ignition can be a candle on a pile of paper. The ignition device could also be a complex electrical timing device.

Either commercial timers or modified clocks can be used to time when a circuit closes and switches on an initiator.

An interesting phenomenon often invoked by arson suspects as being the cause of fire is spontaneous combustion. A fire caused by a natural heat-producing process in the presence of sufficient air and fuel. This is however a rare phenomenon since the conditions under which spontaneous combustion can develop are rather limited. For example, hay stored in barns provides a good growing media for bacteria whose activities generate heat. If the hay is not properly ventilated, the heat builds to a level that supports other types of heat-producing chemical reactions in the hay.

1.4.3 INVESTIGATION OF A FIRE

Scene Investigation Laboratory Analysis

Fires are investigated in order to detect deliberate ignition, to identify dangerous appliances or materials. The fire investigation should begin examining the fire scene for signs of arson as soon as the fire has been extinguished. Time is the enemy for an arson investigator as volatile substances that cause or accelerate a fire rapidly dissipate. A fire scene is a dangerous place and one should approach with caution. Collapsing floors, falling beams, broken glass, smouldering materials, noxious gases aren‘t uncommon.

In the context of a suspected deliberate fire an accelerant is a substance almost always a liquid that has been placed at the scene to facilitate the spread of fire. Accelerants are often ignitable liquids that are easily available. The most commonly used accelerants are petroleum-based products like petrol, diesel, kerosene, turpentine, and lighter fluid. These are chemically complex liquids made up of hundreds of compounds. These compounds differ in their boiling point ranges. Solid accelerants, which are rarely used, include paper, black powder and magnesium flares. Typical gaseous accelerants include natural gas and propane.

Fire investigation consists of two phases, the first involves examination of the fire scene and the second the laboratory analysis of samples recovered from a fire scene normally when arson is suspected.

1.4.3.1 Scene Investigation

A search of the fire scene must focus on finding the fireÊs origin. Evaluating materials found where the fire started helps investigators determine whether it was accidental or a case of arson. Firstly a preliminary investigation is undertaken from outside without disturbance of the scene itself. This should include a systematic photographic record, sketches, and reference plan of the site to ascertain exactly the damage, information regarding the normal day to day activities, what was stored

where, who was the last person known on the premises, what did they do etc.. Any available witnesses should be interviewed and background information gathered such as where smoke was seen first, colour of the smoke, colour of flames, timing and so on. Many accelerants and combustible materials produce characteristics flame and smoke colours. For example, petrol produces a yellow flame and white smoke. The evidence provided by witnesses is often important to any investigation as it details possible origins and fire progressions. In all cases attempts should be made to corroborate witness statements either by other witnesses or through recovery of physical evidence.

Locating the point of origin

Locating a fire‘s point of origin requires an understanding of how fire moves through a structure. Fires typically spread sideways and up from the point of origin, but the pattern can be influenced by structural and decorative elements of the building and other factors Prevailing drafts and winds, secondary fires due to collapsing floors and roofs, stairways and elevator shafts, holes in the walls, floors or roofs; and the effects of the fire fighter in suppressing the fire are all factors which should be considered before determining conclusive findings. Usually, the largest amount of damage occurs near the point of origin but this is this is not always the case. Low level burning (charring/burning of floor or skirting for example) can be an indicator of point of origin. The presence of ÂVÊ shaped patterns can sometimes point to a seat of fire. Fire tends to rise and spreadso that it burns a wall or other vertical surface in a V-shape, with the foot of the ÂVÊ pointing to the origin of fire.

Fig. 1.2 Fire scene showing a ¸V‘ shape pattern indicating the point of origin towards the foot of the ¸V‘

Once the seat of fire has been located a scenario of fire spread may be formulated based upon the physical evidence present. Such a scenario should include answers to the questions, where did the fire start?, what materials were present?, what ignition source was present?, could these ignition sources ignited the materials?, how did the fire spread?. Investigators can estimate the intensity of the fire by assessing the fire‘s effect on structural materials. Steel beams buckle whenever the fire is extremely intense, crack and flaking (spalling) on walls and floors indicate areas of high heat. Similarly wooden beams, floors, and walls may char, leaving a pattern that looks like alligator skin. When this happens, smaller scales tend to be near the hottest point of

the fire. Glass can also be revealing when examined at a fire scene. One can determine whether the glass was broken by thermal or mechanical stress and also whether the glass was broken prior to or after the fire. For instance glass with small amount of soot deposits found under other debris is a strong indicator that the window was broken prior or early in the fire. Once the most likely point of origin is located it is common for the area to be excavated. This involves removing all the debris in a careful controlled manner recording positions of all removed items by drawing or photography or both. If samples are taken their location is noted. Comparative samples should also be taken as far as is practical from areas other than the area of interest as being representative of the material under fire conditions. While it is important to locate the origin of fire it is also important to find answers to questions such as which was the first fuel ignited? What was the likely ignition source? What was the time factor involved from ignition to growth and how did the fire spread form item to item?

Looking for signs of Arson

The most common forms of arson make use of flammable liquids as accelerant materials. Flammable liquids are used as accelerants because they are cheap and readily available. Fortunately, only under the most ideal conditions will combustible liquids be entirely consumed during a fire. When liquid is poured over large area, it is highly likely that a portion of it will seep into a porous surface such as cracks in the floor, upholstery, rags, plaster, soil, carpets, where enough of it remains unchanged that can be detected in the forensic lab. Anytime localized burning is indicated the areas should be checked for odours of flammable liquids. Often burnt trailers will be seen on the floor area indicating the pour pattern of the liquid. Another sign of arson is the presence of irregularly shaped pattern on the floor or on the ground resulting from pouring an accelerant onto the surface.

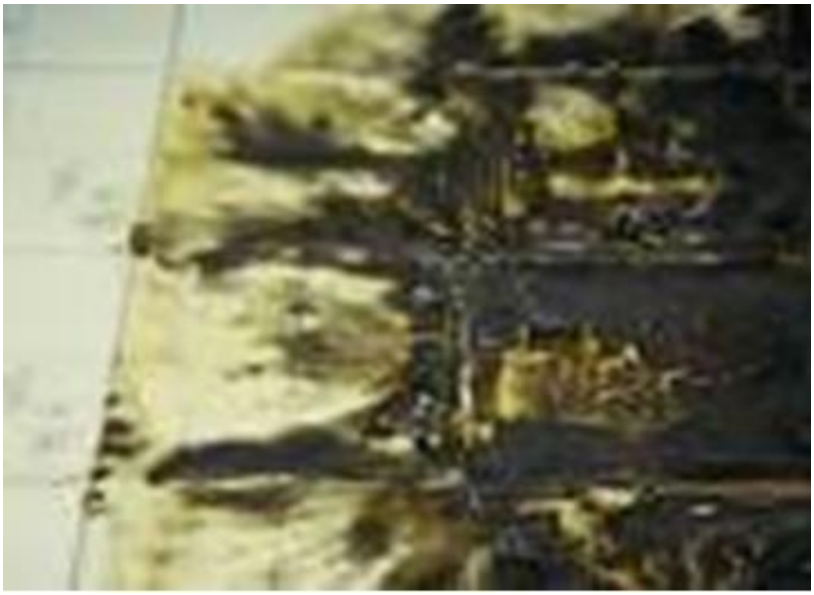


Fig 1.3 Petrol spill burn pattern

1.4.3.2 Laboratory Analysis

Evidence collection and packaging

Crucial to any investigation is the recognition, recovery and preservation of evidence.

The correct collection of fire debris from the fire scene especially for the detection of ignitable liquids is of great importance. Since each scene is different it is not possible to have a set protocol for collection of evidence. In general when collecting debris samples from fire scenes those items are selected which have a high probability of yielding considerable levels of ignitable liquid residue. Electronic sniffers (portable vapour detector) or canine detection teams can be used to help identify areas where there is a probability of finding ignitable liquids. As a matter of routine, two or three quarts of ash and soot debris must be collected at the point of origin of fire when arson is suspected. Ideally, the sample should be porous with an absorbent surface to retain the accelerant residues.

Some sample matrices may produce interfering compounds either through pyrolysis or degradation, which can lead to difficulties in the interpretation of the laboratory data. This is particularly a problem with synthetic polymeric materials such as polyurethane foam.

It is important to ensure that any evidence, which is to be submitted to the laboratory for analysis, has been packaged correctly. The packaging material should preserve the volatile residues of accelerants used in arson and prevent contamination. In general fire debris must be packaged in sealable, airtight containers. The table below lists the advantages and disadvantages of some commonly used containers used to package fire debris.

Container	*Advantages*	*Disadvantages*
Nylon bags	• Flexible • Can hold large samples • Convenient to carry • Can be sealed easily by making a swan neck knot.	• Can be easily punctured. • Loss of volatiles of the sample by diffusion through the bag.
Glass jars	• Cannot be punctured • Lasts long	• Can break easily • Not suitable for heating during sample preparation • Screw tops not particularly airtight
Unlined metal cans	• No organic matter that can cause interference during analyses • Very tough • Good sealing capabilities	• Tendency to rust at a rate depending on the type of sample and the storage conditions.

Lined metal cans	• Not susceptible to rusting • Good sealing capabilities	• Some linings can cause interference during analyses

The other types of packaging materials that maybe used include Kapok bags (polyethylene/polyolefin composite material), laminated bags (polyethylene-aluminium/polyamide) and Duo bags (polypropylene/polyethylene)

It is extremely important to ensure the integrity of the container. The container should be clean and should not be a source of contamination. Therefore a container control sample should also be submitted to the laboratory along with the fire debris sample to ensure the integrity of the container, since any volatiles if present can be analyzed and the results from the fire debris can be interpreted accordingly. This also serves as an air check of the area of the fire scene where the fire debris was packaged. At least three samples should be sent to the lab for analysis:

1) A container control sample
2) A comparative sample or control sample – this is the same material as that of the sample but taken at a site removed from the sampling site. Such samples indicate any volatile material that may be present in the material to begin with. (for example, the sample suspected of holding an accelerant residue happens to be a section of charred carpet, investigators take a piece of the same carpet from an unburned area, whenever possible, for comparison purposes. Many carpets, linoleum flooring already contain volatile hydrocarbons that may show up when lab analysts test for accelerant residues. An unburned section of carpet usually provides an uncontaminated sample against which to compare the suspect sample.)
3) The fire debris sample

Analysis of Ignitable Liquids

Identifying ignitable liquids in fire debris is a significant challenge for fire debris analysts. It involves the extraction of volatile ignitable liquid from the fire debris followed by its chemical analysis. The success of forensic scientists is attributed to the significant advances in analytical chemistry technology. With the development of the Gas Chromatograph forty years ago, forensic scientists made it the chief instrument for fire debris analysis. Twenty years later with the advent of the Gas Chromatograph – Mass Spectrometer it was possible to identify ignitable liquids with greater confidence.

Laboratory Analysis

It is essential that correct record keeping is carried out to ensure that the continuity of evidence is complete. The following are the general steps in analysis:

- Physical examination of the item is carried out, especially looking for any puncture sites.
- Extraction and concentration of volatile components which may be present. There are a number of methods which can be used to trap and concentrate any volatile components present. Some of the methods are listed below:

i) Direct headspace analysis
ii) Passive/dynamic headspace analysis
a) passive headspace analysis

b) dynamic headspace analysis
c) solid phase micro extraction (SPME)

iii)Bracket distillation

- Analysis of negative control, comparative samples and positive control samples
- Interpretation of results

a) Extraction and sampling techniques – headspacesampling

As ignitable liquids contain volatile compounds when the sample is heated the volatile compounds vaporise. Since the volatile compounds present in the sample are represented in the headspace after heating, analysing the headspace can help identify the type of ignitable liquid present. The headspace may not only contain volatile compounds of the ignitable liquid, but also possibly pyrolysis products of the sample matrix. Low temperatures do not favour volatilisation. An optimum temperature should be chosen to achieve best representation of the volatile compounds in the headspace. The temperature is dependent on the type of packaging also for example; nylon bags should not be heated above 120^{o}-130^{o}C. The vapour or headspace is removed with a syringe. When the vapour is injected into the gas chromatograph, it is separated into its components.

b) Analytical Instrument – GCMS (Gas chromatography mass spectrometry)

Gas chromatography rapidly separates mixtures of compounds into individual components by identifying how far each part of it moves through an inert gas. Since each type of molecule has a different rate of movement, the various components of the complex mixture are separated.

A Gas chromatograph consists of the following parts:

- A carrier gas
- An injection port from where the sample is added.
- Column and associated column oven. The column is heated to move the molecules through the column.
- The detector system- In a GC-MS the Mass Spectrometer acts as the detector

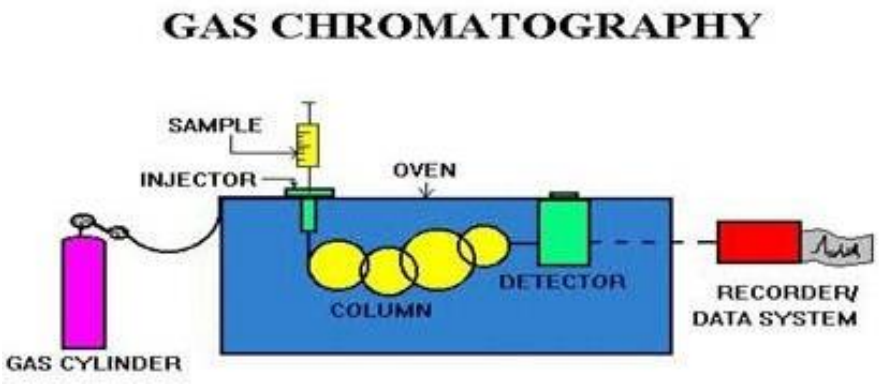


Fig 1.4: Schematic representation of a Gas Chromatograph

No two substances have the same chemical fingerprint, and each compound‘s fingerprint can be determined with mass spectrometry.

A typical MS consists of three parts:

- An ion source
- A mass analyzer
- A detector system

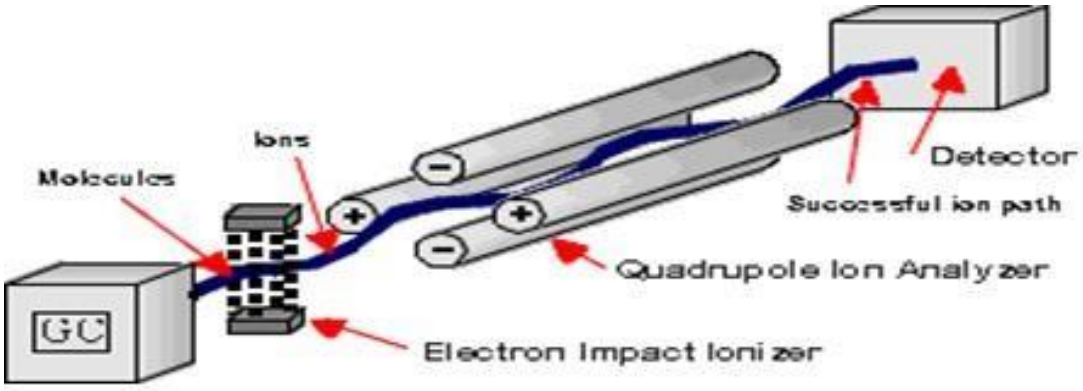


Fig 1.5: Schematic representation of a Mass Spectrometer

The mass spectroscope bombards a compound with a beam of high-energy electrons that break-up or fragment the compound and form positively charged particles called ions. The ions are then transported by magnetic or electrical fields to the mass analyser. The mass analyser separates the ions according to their mass-to-charge ratio. The charge (z) of ions is one. Therefore an ion‘s path will depend on its mass. The analyser focuses each of the ions through a slit and into the detector. A detector counts the number of signals with a specific mass. The detector sends information to a computer that records all of the data produced. The fragmentation pattern of the unknown compound is then compared by computer to known fragmentation patterns. A technician injects a liquid or vapour sample into the injection port at one end of the column, where it is heated or vaporised. The vapour enters the column and flows with the moving carrier gas and reaches the detector. Various compounds move at different speeds and reach the detector and different times and thus separate from one another. The detector signals a recorder that prints a graph that represents each of the compounds detected. This graph is called a chromatogram.

When the vapour in the headspace is injected into a gas chromatograph, it is separated into its components, and each peak is recorded on the chromatogram. The identity of the volatile residue is determined when the pattern of the resultant chromatogram is compared to patterns produced by known petroleum products. Identifying an accelerant such as petrol, by gas chromatography is an exercise of pattern recognition. Typically a forensic analyst compares the pattern generated by the sample to chromatograms from accelerant standards obtained under the same conditions. There may be a mixture of accelerants or the accelerant residue may be mixed with heat-generated breakdown products of materials burning at the fire scene making a gas chromatographic pattern difficult if not impossible to interpret. In these cases GCMS have proven to valuable technique for solving difficult problems in the detection of accelerant residues.

When using analytical instruments like the GCMS it is essential to ensure that the instrument is clean and that the peaks observed are due to the sample being analysed, not carried over from previous injections and this is done through running of blank samples between every sample, with the negative control being injected first. Basically the gas chromatograph separates the hydrocarbon components and produces a chromatographic pattern characteristic of a particular petroleum product.

c) Interpretation of results in the analysis of ignitable liquids

Ignitable liquids, which can be used as an accelerant, can be classified into two main groups: petroleum and non-petroleum.

Non-petroleum based ignitable liquids: Non-petroleum ignitable liquids comprise only a small fraction of ignitable liquids. This group comprises of oxygenated solvents and natural products extraced from plants. The characteristic feature of oxygenated solvents is the presence of significant amounts of oxygenated compound. These are generally very volatile.

Turpentine and citrus oil extracts are the common naturally derived ignitable liquids. Turpentine is composed of compounds called terpenes. Turpentine is extracted from coniferous woods. Citrus oil is extracted from citrus fruit peals and the major component of citrus oil extracts is *d*- limonene. *d*- limonene is found in cleaning solutions like screen wash.

Petroleum-based ignitable liquids: Petroleum based ignitable liquids are refined from crude oil. Petroleum is one of the most consumed substance in the modern world. It not only provides raw material for the ubiquitous plastic but also serves as a fuel for transportation and industry. The word petroleum is derived from the Latin word petra and oleum which literally means rock oil and refers to the hydrocarbons that widely occur in the sedimentary rocks.

Petroleum distillates is a term commonly used to refer to aliphatic hydrocarbons. Aliphatic hydrocarbons can be divided into two groups: petroleum distillates and synthetic paraffinic hydrocarbons. Petroleum distillates include white spirit, kerosene and mineral spirit. The paraffinic hydrocarbons in comparison to petroleum distillates have lower flammability, lower aromatic content and narrower boiling range.

Petroleum products in the boiling range of *n*-pentane (C_5) to eicosane (C_{20}) with boiling points between 36^{o}- 205^{o}C are of particular interest to a fire debris analyst.

Petroleum distillates can be classified as light, medium and heavy petroleum distillates based on the boiling point range and chemical composition of the flammable liquid as shown below.

Class	Hydrocarbon range	Examples	Distillation range
Light petroleum distillates	C4-C11	Petroleum ether, some cigarette lighter fluids	40o- 60o C
Petrol	C4 – C12	All brands grades of petrol	40o- 190o C
Medium petroleum distillates	C5 –C12	Charcoal starters, some paint thinners, dry cleaning solvents	175o- 260o C

Heavy petroleum distillates	C10 - C25	Diesel fuel, lamp oil	190o- 340o C
Miscellaneous	Variable	Alcohols, ketones, fuel additives,	Variable

LIGHT PETROLEUM DISTILLATES

The light petroleum distillate primarily contains alkanes and some cycloalkanes. The alkanes produce a characteristic chromatogram. The aromatics, if present are found in the range of benzene to C_9 aromatics.

MEDIUM PETROLEUM DISTILLATES

The medium petroleum distillate primarily contains alkanes and some cycloalkanes. The aromatics if present are at a lower concentration than the aliphatic compounds. A medium petroleum distillate is characterized by a „bell-shaped‰ chromatogram with prominent *n*- alkanes: nonane, decane, undecane and sometimes dodecane.

HEAVY PETROLEUM DISTILLATES

Similar to the medium petroleum distillates, the heavy petroleum distillates are characterised by their *n*-alkane pattern. The aromatics are present but are less abundant than the alkanes. Heavy petroleum distillates contain a much broader boiling point range of compounds. The major *n*-alkanes are between C_{12} and C_{17} although other *n*-alkanes
like *n*-nonane, *n*-decane and *n*-undecane may be present, the *n*-alkanes can extend up to
C_{23}. The heavy petroleum distillate is characterised by the presence of pristane and phytane that co-elute with C_{17} and C_{18} respectively. Aromatics may still be present but in this class the methylnaphthalenes and dimethylnaphthalenes become prominent.

PETROL

Petrol is the most abundant refinery product of petroleum. Since petrol is a common compound it is the most frequently encountered accelerant. Petrol is not a true petroleum distillate but a blended product that covers the boiling point range from 40^0 to 190^0 C. Petrol is characterised by the presence of large amounts of aromatics and is not characterised by the *n*-alkane series. Large amounts of aromatics are added to petrol to increase engine performance and fuel efficiency.

Since petrol is a complex mixture of hydrocarbons, not all their components evaporate or burn at the same rate, the most volatile evaporate first and as the temperature increases the heavier compounds evaporate. During combustion this evaporation happens at a much faster rate. Hence the results of partially burnt petroleum products found in fire debris have different chemical and physical properties than the original fuel. Since petrol is highly volatile this evaporation happens when petrol is exposed to air and therefore samples from fire scenes should be collected as soon as possible. This evaporation of petrol is generally referred to as *weathering.*

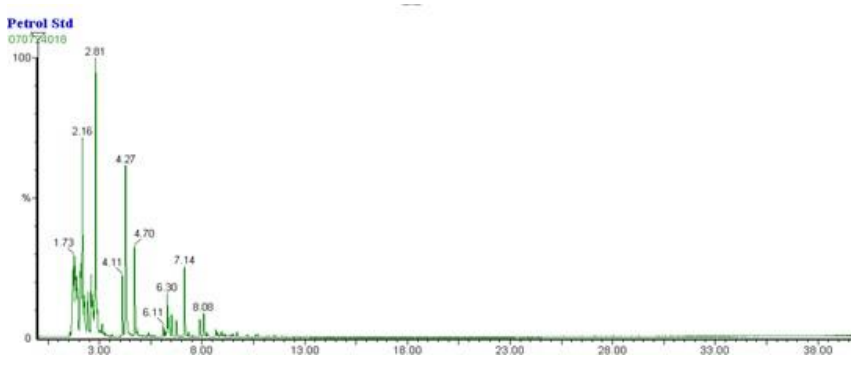


Fig. 1.6 (a) Light petroleum distillate

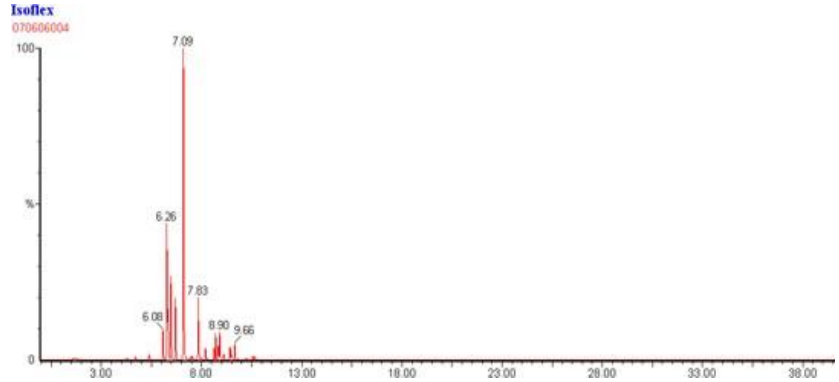


Fig. 1.6 (b) Medium petroleum distillate

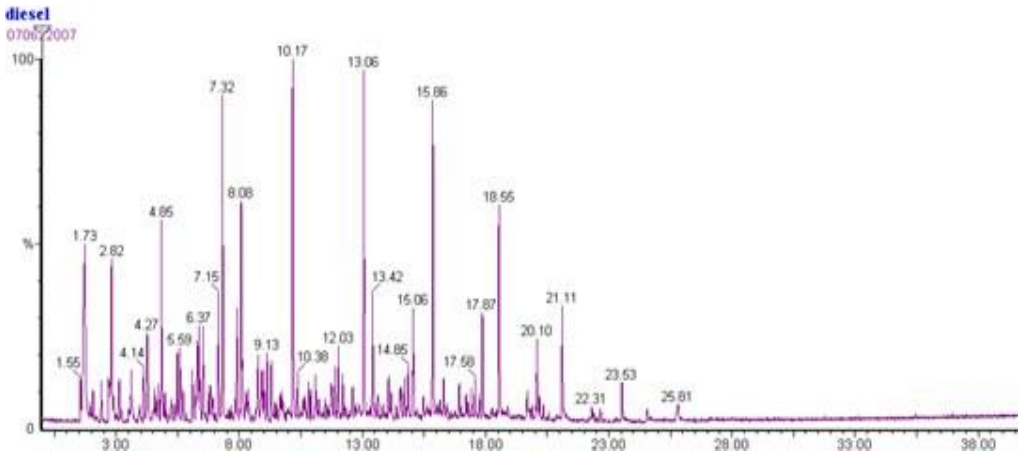


Fig. 1.6 (c) Heavy petroleum distillate

For example, in the two chromatograms shown below in Fig 1.8 a gas chromatographic analysis of debris recovered from a fire site shows a chromatogram similar to a known diesel standard, thus proving the presence of diesel.

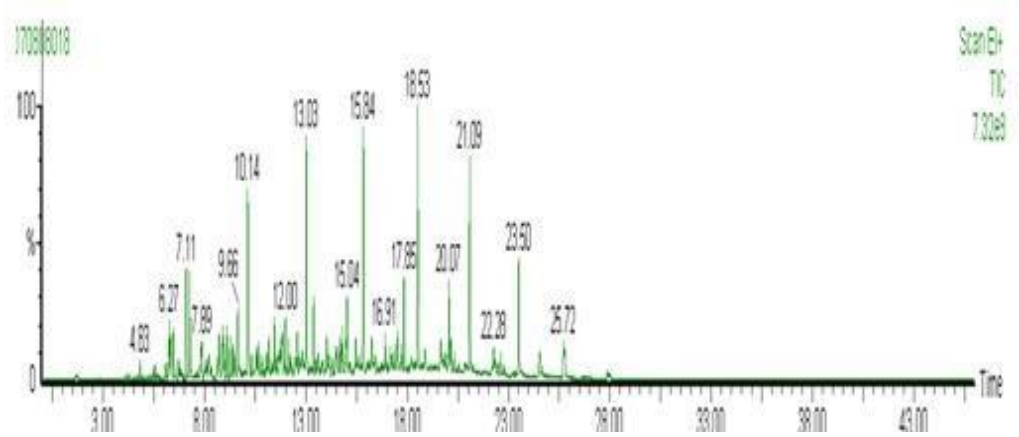


Fig. 1.7 (a) Chromatogram of fire debris sample

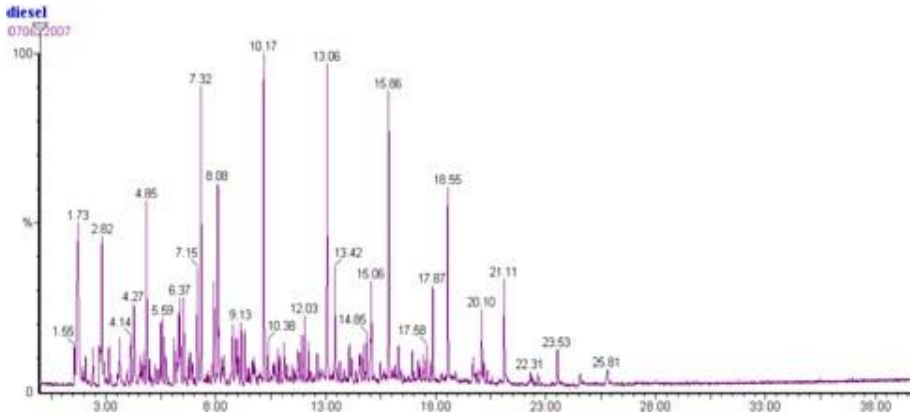


Fig. 1.7 (b) Chromatogram of diesel standard

Fig. 1.7: Chromatograms of (a) fire debris sample recovered at the fire scene and (b) diesel standard.

1.5 OILS & FATS

1.5.1 INTRODUCTION

Oils and fats analysis covers a major area in forensic chemistry as these are often adulterated in various ways viz adulteration of lower grade, different origin (vegetable oil by animal fat or vice-versa) or misbranding or contrabanding of products etc. the cases as above may occur frequently as oils and fats are extremely used as cooking media and also in industries like paints, varnishes, pharmaceutical industries. There may be theft cases or illegal possession related to oils and fats. In the above case the samples are frequently sent for their examinations for different purposes under Essential Commodities Act (E.C Act).

Oils and fats may be divided into two classes based on their origin, vegetable oil and animal fat. The words oil and fat are synonymous. They differ in their physical state i.e oil is liquid and fat is solid. The vegetable oils include groundnut, sunflower, linseed, coconut, mustard, palm, sesame, cottonseed, rapeseed, soyabean, castor, pea-nut, rice bran oils etc. there may be hardened fat from vegetable oil by the hydrogenation of oils (product-Vanaspati). The animal fat is available in the form of butter, ghee, tallow and lard. Some times tallow or lard is added to vegetable/*desi*-ghee or vanaspati.

In case of analysis of samples forwarded to forensic laboratories under E.C.Act, the samples are very often required to be examined for various parameters based on physical and chemical properties of individual oil and fat to ascertain the nature, quality, adulteration etc. Sometimes chemical tests are performed to identify a specific oil, adulteration, or rancidity (fouling of oils).

The examination of oils and fats is based on their composition. Oils and fats are tri-glycerides of fatty acids of saturated and unsaturated acids (oleic, linoleic, linolenic) in varying proportions. These may contain fatty acids of definite carbon number in higher proportion in some oils viz arachidic acid in arachis oil, groundnut, nut and peanut oil, crucic acid (in mustard, rapeseed and rape oil), normal and iso propionic and butyric acid in butter and ghee (both animal fat) or vary in the percentage of free acids (due to hydrolytic splitting of glycerides of enzymes) or vary in the nature and percentage of sterols in the unsaponifiable matter in animal fats and vegetable oils (cholesterol in animal fat and phytosterols in vegetable oils) or vary in drying properties (the tendency to form solid film due to unsaturation.) or vary in their tendency to undergo addition with iodine or iodine monochloride (due to variation in unsaturation present). The above variation in fatty acid profile and other not fatty acid or non glyceride constituent (unsaponifiable matter i.e. sterols: higher alcohols) are responsible to impart effect on their physical and their chemical properties viz. colour, refractive index, melting point, saponification point, alkaline hydrolysis behaviour, additive reactions etc. the differences in physical behaviour and parameters based on chemical characteristics (saponification value, acid value, acetyl value, Reichert-Meissel value, polenske value etc.) provide analytical guideline or clues to the classification or characterization of different oils and fats. Chemical tests are often performed to detect adulteration or rancidity. However, quality assurance or adulteration checking become very often difficult when values on some parameters overlap. Then the help of other physical characteristics or special parameter viz. Reichert-Meissel value, polensky value in case of adulteration of ghee or vanaspati by hard and tallow or by instrumental technique specially GC for fatty acid profiling. Various options are to be applied profitably to get the analysis done in a short time. The interpretation of the values on parameters requires special knowledge and expertise.

Purpose: To determine the quality and adulteration of oils and fats.

Scope: Analysis and characterization of various oils and fats.

1.5.2 METHODS

A) CHEMICAL TESTS

I Ground Nut Oil

Take one ml of the sample of oil in a conical flask, add 5 ml of 1.5 N alcoholic potash and saponify completely on a boiling water bath using an air condenser to avoid loss of alcohol. It takes about 10 minute. During the saponification swirl the flask many times, cool, add 0.1 ml of phenolphthalein indicator. Neutralize the solution exactly by adding dil. Acetic acid (One volume of glacial acetic acid + two volumes of distilled water) followed by an extra amount of 0.4 ml of acetic acid. Mix 50 ml of 70% alcohol fit a thermometer into the flask with the help of a cork in such a way that the bulb of thermometer is dipped in the liquid but does not touch the bottom of the flask. Heat the flask on a water bath until the temperature reaches 50^0C to become solution clear. Keep the flask for cooling in air with frequent shaking until the temperature of the solution comes to 40^0C. Appearance of turbidity in between 39 to

40^0C indicates the presence pure groundnut oil. Cool the flask with constant shaking in a cooling bath at $15^0 \pm 1^0$ C in such a way that the temperature falls roughly at the rate of 2^0C per minute. Note the turbidity temperature, which is the temperature at which the first distinct turbidity appears. This turbidity temperature is once again confirmed by a little further cooling which results in the deposition of precipitate. Dissolve the precipitate by heating the contents at 50^0C on a water bath. Again cool as above and make an experiment for duplicate determination of turbidity temperature. Duplicate shall agree with in $\pm 0.5^0$C.

II Sesame Oil

Take 5 ml of the oil sample or melted fat in a cylinder or test tube with a glass stopper add 5 ml of hydrochloric acid and 0.5ml of furfural solution (2% freshly distilled furfural in ethanol). Fit the glass stopper and shake vigorously for two minutes. Keep the mixture separate. The appearance of pink or red colour in the lower acid layer indicates the positive tests for the presence of sesame oil. Confirm it by adding 5 ml of water and shake again. If the colour remains the sesame oil is present if colour disappears the sesame oil is absent.

IIICotton Seed Oil

Take about 5ml of the oil sample or melted fat in a test tube and add equal volume of sulphur solution (1% w/v solution of sulphur in carbon disulphide and add an equal volume of amyl alcohol). Shake thoroughly and heat it on a water bath (70^0 to 80^0C) for few minutes with occasional shaking. To boiled off carbon disulphide and stop foaming. Keep the test tube in an oil bath at 110-115^0C for about two and a half hours. Appearance of red colour at the end of the period indicates the positive test for the presence of cottonseed oil.

IVPalmolein in Ground Nut Oil

Take 60-75 gms of samples and heat it to 130^0C before its testing. Add ca 45ml of the heated fat into an oil sample bottle. Keep the bottle in water bath. Cool the bottle in water bath with stirring using the thermometer to keep the temperature uniform. When the sample reaches a temperature ca 10^0C above the cloud point, being stirring steadily and rapidly in a circular motion so as to prevent super-cooling and solidification of fat crystals on the sides or bottom of the bottle. Do not remove the thermometer from the sample at this stage. The test bottle is maintained in such a position that the upper levels of the sample in the bottle and the water in the bath are about the same. Remove the bottle from the bath and read the temperature. The cloud point is that temperature at which that portion of the thermometer immersed in the oil is no longer visible when viewed horizontally through the bottle.

This test is useful for the detection of palmolein in groundnut oil. Presence of palmolein over 10% in groundnut oil readily gives cloud at a higher temperature than that of groundnut oil due to the presence of palmitic gly-cerides in higher amounts in palmolein/palm oil.

V Linseed Oil

Take one ml of the oil sample in a boiling tube of about 100 ml capacity. Add 5ml chloroform and about one ml of bromine drop-wise till the mixture becomes deep red. Cool the test-tube in an ice water-bath. Add to it 1.5ml of rectified spirit drop wise

with shaking the mixture until the precipitate which is first formed just dissolves and then add 10ml of diethyl ether. Mix the contents and keep the tube in the ice water-bath for half an hour. Appearance of precipitate indicates the positive test for the presence of linseed oil.
This test is not applicable for the detection of linseed oil in presence of mohua oil.

VICastor oil and its differentiation from Rancid Oils
Take about 5ml of suspected rancid oil sample in a round bottom flask add to it about 2 gms activated charcoal. Mix the content thoroughly and heat it on a boiling water bath for about half an hour with constant shaking. The bleached oil is filtered on a filter paper. The filtered oil may now be passed through a mini column made up of neutral alumina –10 gms using 50ml hexane as eluent. This bleached and neutralized oil is used for TLC as given in the detection of castor oil besides as reference standard.

VII Argemone Oil in Edible Oils
Ferric chloride test - Take about 5ml of filtered oil and dissolve in 5ml of toluene in a stoppered glass test tube. Add to it 5 ml of concentrated hydrochloric acid. Shake vigorously and allow the acid layer to separate. Separate the acid layer with the help of separating funnel to a test tube. Add 1 ml of Ferric chloride solution(10 gm Ferric chloride in 10ml concentrated hydrochloric acid and add 90ml of water. If required filter it) through the side wall of the test tube. Mix the reagent and acid layer well. This can be achieved by gently rotating the test tube between the palms of the hand. Heat the test tube boiling water bath for about 10 minutes. Formation of needle shaped (straight/curved) reddish brown crystals in clusters on cooling indicates the positive test for the presence of Argemone oil. The method is not sensitive enough to detect argemone oil in less than 0.1% level.

VIII Mineral Oils in Edible Oils
Take 22 ml of the 0.5 N alcoholic KOH solution in a conical flask, add 1ml of the suspected oil sample. Boil it on a water bath using an air or water cooled condenser till the mixture becomes clear and free from any oil drops on the side wall of the flask also.
Take out the flask, transfer the contents to a wide mouthed warm test tube, add 25 ml of boiling water along the side of the wall with care. Shake the tube lightly from side to side while adding water. The appearance of turbidity indicates the positive test for the presence of mineral oil.

B) DETECTION OF RANCIDITY IN EDIBLE OILS
Method 1- Kries Test - Take about 5ml of suspected oil sample and shake vigorously with 5ml of 0.1% Phlorogucinol solution in diethyl ether and 5 ml of conc. HCl for 20 seconds. Appearance of pink color indicates the presence of incipient rancidity.
Method 2 – UV Spectrophotometric method - Take an accurately weighed amount of oil sample in a 25 ml volumetric flask so that the absorbance of its solution in iso-octane lies between 0.2 to 0.8 using a 1 cm quartz cell. Scan the sample by UV Spectrophotometer using iso-octane as blank/reference between 220 to 320 nm.
Sample gives three wavelength □ max. at 230,268, and 278 nm. For quantification select the wavelength □ max. of maximum absorption near or/ at 230,268, and 278 nm, and the absorbance (A) at these points.

Specific Absorbance $E_{1\ cm}^{1\%}$ (λ max.) = Absorbance (A)/c X d Where c = concentration of the sample solution in gm/100ml
d = length of the cell in cm

C) DETERMINATION OF PHYSICAL PROPERTIES OF OILS

I Determination of moisture and volatile substances

Weigh 5-10 gms of suspected sample of oil or fat in a tared metal dish of about 7cm dia and 3-4 cm deep with lid. Mixed the sample thoroughly bi stirring. Loose the lid and heat in an oven at 103± 2oC for 3 hours. Take out the dish from the oven and close its lid. Cool it in desiccator having phosphorous pentoxide and weigh. Heat once again for 1 hour and weigh. Repeat the process to get concurrent readings with a difference of 2 mg

%age of moisture = Weight Loss/Weight of oil taken X 100

II Determination of Specific Gravity

Determine the specific gravity of the oil by specific gravity / density bottle or a pyknometer method at ambient temperature by noting down the weight of specific gravity bottle with oil, with water and the empty bottle.

$$\text{Specific Gravity} = \frac{\text{Weight of bottle with oil - Weight empty bottle}}{\text{Weight bottle with water – Wt of empty bottle}}$$

D) CHEMICAL CHARACTERISTICS

Acid Value: It is the number of milligrams of potassium hydroxide required to neutralise the free fatty acid present in one gm of the oil or fat. The acid value is determined by directly titrating the material in an alcoholic medium with aqueous sodium or potassium hydroxide solution.

Saponification value: - It is the number of milligrams of potassium hydroxide required to saponify completely one gram of oil or fat. The material is saponified by refluxing with a known excess of alcoholic potassium hydroxide solution. The alkali solution consumed for saponification is determined by iterating excess alkali with standard hydrochloric acid.

Iodine value: - Iodine value is the number of gram of iodine absorbed by 100 gm of oil or fat. Many methods for its determination are in use. Out of these Wijs is widely accepted and recommended method by the BIS. It gives the information about the amount of unsaturation or number of double bonds in a fat sample.

1.6 ACIDS & ALKALIS

1.6.1 INTRODUCTION

An acid is a substance which when dissolved in water releases hydrogen ions. Acid is a chemical which has a pH less than 7. pH is a measure of acidity or basicity of a solution. It is measured on a scale of 0 to 14 with 7 being neutral. Solutions with a pH less than 7 are said to be acidic in nature whereas those greater than 7 are said to be basic in nature. Alkali is a carbonate or hydroxide of an alkali metal. Alkalis are bases which dissolve in water and bases are compounds which have a pH greater than 7. Acids which have a pH of less than 2 and alkalis which have a pH greater than 11.5 are capable of causing chemical burns.

Alkalis are commonly found in drain cleaners, fertilizers, industrial cleaners etc. Acids are commonly found in car batteries, bathroom cleaners, rust removers, in

industrial areas like the dyeing or tanning industries etc. More than 65,000 new chemicals are available in the market and an estimated 60,000 new chemicals are produced every year. However the harmful effects of these chemicals on the human body are largely unknown.

Scope: Crime exhibits containing corrosive chemicals.

Purpose: To detect the presence of hydrochloric acid, sulphuric acid, nitric acid and alkalies in crime exhibits.

1.6.2 METHODS

The following methods are to be used for the detection of the constituents of the hydrochloric acid, sulphuric acid and nitric acid in the crime exhibits.

I Test for Hydrochloric Acid

A) Test for Acidic Nature:

1. ***pH Paper Test :*** Moist the pH paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the pH. pH less than 7 indicates the presence of acid and more than 7 indicates the presence of alkali.

2. ***Litmus Paper Test :*** Moist the blue litmus paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the colour change of the paper. Colour changing from blue to red indicates the presence of acid. If red litmus paper changes to blue, than it is indicates the presence of alkali.

B) Test for Chloride: Take the appropriate portion of the exhibit in a beaker add distilled water, shake well and filter it. Take few ml. of the filtrate in a test tube and add 1 drop of nitric acid followed by few drops of 0.2 M silver nitrate solution. A white curdy precipitate is obtained which is soluble in excess of ammonium hydroxide solution.

C) Physical Examination:

2) Hydrochloric acid is also known as Muriatic Acid and Spirit of Salt. The commercially available acid is yellow colour, fuming when highly concentrated and giving dense white fumes in the presence of ammonia vapour. It is distinguished from sulphuric acid by its colour and from nitric acid by the absence of orange fumes when poured on metals.

3) HCl produces a green stain on a black cloth but does not corrode it. The stain is first red and then turns green.

II Test for Sulphuric Acid

A) Test for Acidic Nature:

1. *pH Paper Test* : Moist the pH paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the pH. PH less than 7 indicates the presence of acid.

2. ***Litmus Paper Test*:** Moist the blue litmus paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the colour change of the paper. Colour changing from blue to red indicates the presence of acid.

B) Test for Sulphate: Take the appropriate portion of the exhibit in a beaker add distilled water, shake well and filter it. Take few ml. of the filtrate in a test tube and add few drops of concentrated hydrochloric acid followed by0.25 M barium chloride solution. White precipitate indicates the presence of sulphate.

C) Physical Examination:

1) Sulphuric acid is also called „Oil of Vitriol‰. The strong acid is an oily liquid, colourless when pure, the commercial ones have a slight brownish colour. It is heavier than water and when mixed with water releases heat. It corrodes animal matter and chars vegetable matter.

2) The dark brown stain on the skin is characteristic of sulphuric acid.

IIITest for Nitric Acid

A) Test for Acidic Nature:

1. ***pH Paper Test :*** Moist the pH paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the pH. PH less than 7 indicates the presence of acid.

2. ***Litmus Paper Test*****:** Moist the blue litmus paper with distilled water and impregnate it with exhibit as such or its distilled water extract and observe the colour change of the paper. Colour changing from blue to red indicates the presence of acid.

B) Test for Nitrate: Depending upon the nature of exhibits and availability of resources, any one of the following methods can be used for the detection of nitrate. Take the appropriate portion of the exhibit in a beaker, add distilled water, shake well and filter it. The filtrate may be used for performing the tests.

i) Ring Test: Add about 3 ml of a freshly prepared saturated solution of ferrous sulphate to about 2 ml of the nitrate solution (filtrate of the exhibit) in a test tube and pour 3-5 ml conc. sulphuric acid slowly down the side of the test tube so that acid forms a layer beneath the mixture. A brown ring will form where the liquids meet which indicates the positive test for the presence of nitrate.

C) Physical Examination:

1) Commercial Nitric acid varies in colour from a deep orange to a light yellow. It release orange coloured acid fumes.

2) Nitric acid produces yellow stains on the skin and other tissues of the body. These stains become brighter when touched with an alkali.

1.6.3 ACID ATTACK

1.6.3.1 INTRODUCTION

1.6.3.2 What is an acid attack?

Acid throwing also known as vitriolage is a form of violent assault. Vitriolage is the act of throwing acid on someone with a malicious intent. Acid throwing is one of the most horrific crimes mainly targeted at women which results in disfigurement, blindness, scarring of the face and body. The commonly used acids for acid attacks are sulphuric acid, nitric acid, hydrofluoric acid and hydrochloric acid.

Acid attacks on women have been recorded in a large number of countries like China, Nigeria, Afghanistan but the highest number of cases occurs in South East Asia. In Bangladesh alone there were 400 cases of acid attacks reported in the year 2003. The occurrence of acid attacks are on the rise due to the easy and inexpensive availability of acids.

Reasons for acid attack – Socio-economic factors

The main reasons for these attacks are refusals of relationship or marriage proposal, spurned sexual advances, inadequate dowries, failing to bear a son, family disputes, land disputes, political rivalries etc. Acid throwing is also used to enforce caste system.

Acid Burn Injuries

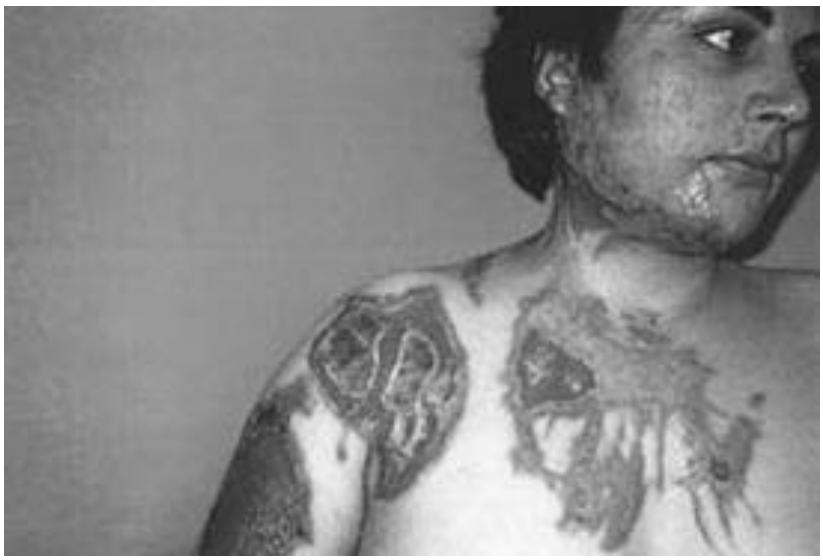
Acid burn injury is a type of chemical burn injury. Chemical burn injury is a burn injury caused by chemical agents such as alkalis, acids or organic compounds. Chemical burn injuries are not as common as thermal and electrical burn injuries.

The injuries caused due to acid throwing are severe burns, blistering, acid burns to the eyes, respiratory tract and lungs. In some cases the skin melts exposing the bones and even dissolving the bones. The effects include permanent disfigurement, scars on the face and body, narrowing of the victim‘s nostrils, eyes, ears etc. The victim is traumatized physically, psychologically and socially.

Acid burns result in coagulation necrosis (i.e. death of a group of cells) due to precipitation of the protein and is characterized by clearly demarcated dry and hard eschar (scab or a hard crust). Whereas in the case of alkali burns the burn is characterized by soft, oedematous, translucent swollen eschar due to absorption of altered blood pigments.

Acid burns usually cause second degree burns wherein blistering of the skin is visible. Second degree burns not only involves the superficial dermis layer of the skin but also the underlying layers. Prolonged contact with strong mineral acids like sulphuric acid or nitric acid may cause third degree burns. Third degree burns cause extreme damage to the dermis, it involves all the layers of the skin. Charring of the skin is seen along with eschars. The colour of the scab indicates what type of acid was used.

The extent of damage on the human body depends on the strength of the acid, quantity of the acid, the duration of contact with the skin and penetration power of the acids concerned. If the acids are absorbed through the skin, they may cause systemic effects such as metabolic acidosis or renal failure.



1.6.3.2 FORENSIC APPLICATION IN ACID BURN CASES

In Forensic Science, most examination of burns is required when there is suspicion that the burn was non-accidental or when the victim has died; but it is not so in the case of acid burns where the perpetrator throws acid on the victim with a malicious intention and hence a thorough forensic examination is required to determine the nature of the acid used.

The evidence which is sent to the forensic lab for analysis is usually in the form of affected clothing, body tissues like skin, containers containing corrosive chemicals. Wherever possible unaffected clothing material or skin sample should be taken as control samples. Acid attacks usually result in charring and blackening of the skin, cloth or any organic matter.

The methods involved in the forensic examination include:

b) Physical examination

c) Chemical examination

a) Physical Examination involves the visual examination of the skin wherein the colour of the skin and charring indicates acid attack. The colour of the stains on cloth and on the skin indicates the type of acid.

b) Chemical Examination involves test for pH, chemical tests which indicate the presence of chlorides, sulphates, nitrates etc. (for sample preparation for chemical examination the affected clothing material, body tissue or skin is distilled. Different amounts of the distillate are subjected to chemical examination.)

1.6.3.3 CASE STUDIES

Acid attacks against women are on the rise. Almost 75% of the acid attacks are on women. The figures reported are only tip of the iceberg since many of them go unreported especially in the rural areas. Acid throwing has a devastating effect on the victims. The victims not only need physical treatment for the acid burns but also psychological treatment to cope with the reactions expressed by the people who look at them. The survivors need sophisticated medical treatment which include skin grafts, plastic surgeries etc. which is very expensive and since most the victims belong to poor families they are unable to bear the expenses leaving the victim with permanent scars. Acid attacks have deplorable effect on the victims psychologically, socially and financially.

Case study 1: A 16 year old girl from an underprivileged family was attacked by a young man because she refused to marry him. Her father had to spend all of his life savings for her treatment, but she lost one eye and had permanent scars. After the attacks she started to isolate herself from social life and stopped going to school. Fortunately, she received assistance from UNICEF and Acid Survivors Foundation (ASF). She now works as a tailor with the ASF. Many NGOs like ASF are now helping the victims by providing medical care for example volunteer plastic surgeons, counselors, nurses etc.

Case study 2: A 40 year old women received nitric acid burns from her husband whom she wanted to divorce since he was having an extra martial affair. When she filed a complaint against him she was brutally killed. The lives of the victims and their families is at risk if they try to bring the perpetrator to justice, especially if the perpetrators belong to an influential family. The offenders often threaten the victim and their families to withdraw their cases.

Case study 3: A 19 year old girl was attacked by her employer, she was blinded and disfigured as a result of the acid attack. She filed a case against her employer who was given a light sentence by the lower court. However with the help of the press the case was moved to the High Court of Karnataka when the offender was sentenced to life imprisonment. It was the first time that a life imprisonment was awarded for an acid attack offender. She was also given a compensation of Rs 500,000 the highest ever payout given to a survivor.

1.7 EXAMINATION OF CHEMICALS USED IN TRAP CASES

1.7.1 INTRODUCTION

Law Enforcement Agencies arrange a trap for illegal transaction (bribe) with the help of the complainant where in the accused is given currency notes on which chemical like phenolphthalein or anthracene powder has been applied. Now a days phenolphthalein is being used in most of the trap cases. If the accused touches the notes then the part of the chemical, which may be in traces, is transferred on his hands or fingers. If he keeps these currency notes in his pocket, bag, briefcase or file etc, this chemical is also transferred to these objects (LocardÊs Principle of exchange). In case of phenolphthalein the object (hand, bag, pocket etc) are washed with a colorless solution of sodium carbonate (or sometimes with lime water), which becomes immediately pink confirming the touching of currency notes/ transferred of phenolphthalein to the object. These washings are being collected and sent to the forensic laboratories along with other relevant articles to establish the presence of phenolphthalein which can be considered as vital evidence in the court. The pink color of this solution persists for some days or months depending on the quantity of the phenolphthalein and strength of the alkali solution. It gradually fades and sometimes becomes colorless at the time of trial in the court. This creates unnecessary doubt and investigating officer is put in an awkward position. However this phenomenon can be explained by the scientist on scientific basis that the color of the phenolphthalein fades due to its breaking down into 2(4 –hydroxy benzoyl) benzoic acid and phenol in alkali medium.

As mentioned earlier, anthracene powder is also rarely used for this purpose in trap cases as it does not pose such problem of color fading and has an advantage because

of its fluorescence property. The hands, clothes etc of the suspect can be immediately examined under u. v. light, violet/blue fluorescence[1&2] can be clearly seen. This proves direct contact of the suspect with currency notes. Pure anthracene exhibits blue fluorescence but impure anthracene due to presence of tetracene, naphthacene etc exhibits yellow with green fluorescence.

Purpose: Detection and identification of phenolphthalein, sodium ions, carbonate ions, calcium ions, anthracene etc.

Scope: Phenolphthalein, anthracene, sodium carbonate and calcium hydroxide in crime exhibits.

1.7.2 METHODS

A) Phenolphthalein

The hand washings, bag washings, cloth washings etc of the suspect collected in dilute sodium carbonate-water solution or lime water along with other relevant articles from the scene of crime such as currency notes, clothes, bags etc shall be sent to the laboratory for the chemical examination.

In case of untreated objects, ethyl alcoholic wash/ extract of the appropriate portion of the exhibits can be taken for the examination for the detection of the phenolphthalein. Alternatively, dilute solution of alkali (sodium carbonate) in water can also be used for washing/extracting the exhibits. These washing shall be used only for the detection of the phenolphthalein and not for the detection of the sodium and carbonate ions.

In case of alkali treated objects, wash the appropriate portion of the exhibits with water and used for the detection of the phenolphthalein, sodium and carbonate ions etc.

Test for Phenolphthalein

1) **pH Test** - Observe the pH of the solution exhibit with the pH paper. More than pH 9 (pH range 8.3-10) with pink /red color indicates the positive test for the presence of phenolphthalein.

2) **Acid –Alkali Test** - Take an appropriate portion of the exhibit solution. Add few drops dilute hydrochloric acid. The pink color of the exhibit disappears. Now add few drops of dilute solution of sodium hydroxide in water, the pink color reappears. If required, this test can also be performed on residue obtained after evaporation of ethanol extract of the exhibit, but in this case first add alkali solution and then acid. Appearing and disappearing of pink color indicates the positive test for the presence of phenolphthalein.

3) **Instrumental techniques - Spectrophotometric examination:** Take a portion of the exhibit solution, filtered and scan to note its λ_{max} absorbance value by spectrophotometer in appropriate dilution using a standard solution of phenolphthalein in aqueous alkali (sodium carbonate) for comparison. The pink color of phenolphthalein in aq. Sodium carbonate solution gives the lambda max in between around 550-555 nm. Aqueous solution of sodium carbonate is used as blank solution for the experiment.

Other instrumental techniques like HPLC, FTIR, GC-MS are also being used for the detection of Phenolphthalein.

B) Anthracene

Articles from the scene of crime such as currency notes, clothes, bags etc along with traces of powder collected by carefully brushing the suspected area of contact of accused shall be sent to the laboratory for the examination.

In case of the object of anthracene, the appropriate portion of the object/ exhibit (after examination under u.v. light) can be wash with ethyl alcohol for the examination.

Test for Anthracene

1) Color Test - Observation under U.V. light – Violet/blue/green fluorescence.

Separation and purification of Anthracene from seized material

Currency notes, shirts, pant, handkerchiefs, diaries, books etc in anti-corruption cases/bribe trap cases collected over a year were examined a long with commercial anthracene by TLC technique using Chloroform developing solvent. The suspected portion after locating under UV lamp of every exhibit was initially extracted in ethanol/ether, then subjected to TLC/GLC examination.

C) Test for Carbonate ions

1) Test with acid: To a potion of the exhibit solution add few drops of dilute hydrochloric acid, effervescence are observed. If needed, the resulting gas can be passed through baryata water/ lime water. Turbidity/ curdy white precipitate appears. If the gas is passed for long time, the precipitate or turbidity slowly disappears. The exhibit may be gently heated with dilute hydrochloric acid to produce sufficient effervescence/ gas.

2) ***Barium Chloride Test*****:** To a portion of the exhibit solution add few drops of barium chloride solution (about 5-6 % barium chloride in water. Formation of white precipitate, which is soluble in mineral acids, indicates the positive test for the presence of carbonate ions. Bicarbonate ions do not form white precipitate, as they do not react with barium chloride solution.

3) ***Silver Nitrate Test*****:** To a portion of the exhibit solution add few drops of silver nitrate solution (about 2 % in water). Formation of white precipitate, which is soluble in ammonia solution, indicates the positive test for the presence of carbonate ions.

D) Test for Sodium

1) Color Test - Uranyl Zinc Acetate Test - Take a portion of exhibit solution and make it neutralized with acetic acid. Add few drops of uranyl zinc acetate reagent, shake/ stir with glass rod. Formation of yellow precipitate or cloudiness indicates positive test for the presence of sodium.

E) Test for Calcium

1) Test with Sodium Rhodizonate - Take one drop of neutral or weakly acid test solution add a drop of freshly prepared 0.2% a sodium rhodizonate solution add one drop of 0.5 N sodium hydroxide solution, a violet colour indicates the presence of calcium.

2) Flame test - Take appropriate portion of the exhibit as such or its water (distilled) extract evaporate to dryness, moisten with a few drops of conc. Hydrochloric acid to make past. Take a small portion of paste with the platinum wire and introduce into the non-luminous flame of a semi-micro burner. A persistence golden yellow flame indicates the presence of sodium and a brick red (yellowish red) flame indicates the presence of calcium.

UNIT I-B-Forensic Explosives

1.8 ORIGIN

Explosions are violent, sudden, noisy and startling. Black powder has been known for centuries and used in small quantities for mining after about A.D. 1650 and it took several centuries before black powder became a standard military tool after 1800. Black powder is extremely dangerous to use because it is easily ignited by any spark. Its essential ingredients (potassium nitrate, charcoal and sulphur) have been available since ancient times, and chance or deliberate ignition of a mixture of these ingredients may not have been so rare.

1.9 DEVELOPMENT

Particularly influential for the development of explosives was the work of Sobero who first made nitroglycerin (NG), in 1846 by reacting strong nitric acid with glycerol, a by- product of soap manufacture, resulted in an oily product called glyceryl trinitrate. Nitrocellulose (NC) was also discovered in the same year. Practical use of NG was pioneered by the Nobel family in the years following 1859. Alfred Nobel invented the blasting cap in 1863, which revolutionized the mining industry. The cap was similar to caps filled with potassium chlorate made by Forsyth in 1805, and with mercury fulminate by Ballot and Egg in 1815. He also discovered that Kieselguhr, a diatomaceous earth, absorbed up to three times its own weight of NG to form a relatively dry, leak resistant paste, which came to be known as ÂdynamiteÊ. The word was derived from ÂdynamosÊ, the Greek word for ÂpowerÊ. Further an even more powerful explosive called gelignite, which was a jelly like mixture of nitroglycerine and nitrocellulose was created. Other explosives have been made, such as chlorate and perchlorates, sprengel explosives, liquid oxygen explosives (LOX), nitrostarch, nitamon and nitramex explosives.
Other momentous advances in the explosives technology include:

1) The development of safety fuse (essentially black powder core inside a tough yarn) by William Bickford in 1831,

2) Picric acid, which was used as a shell in Europe during the 1880's and carried through WW1 on a large scale. However, the discovery of TNT phased out the use of piric acid and the army and navy began to use this new and better explosive.

3) Trinitrotoluene or TNT, an excellent military explosive though not used until 1904.

4) Invention of detonating cord (a sensitive high explosive core inside a thin plastic tube or textile yarn) in 1908 in France.

5) The chance discovery of ammonium nitrate as being a very powerful explosive in 1947, when the ship Grand Camp carrying fertilizer grade ammonium nitrate (AN) blew up at its dock in Texas city following a fire.

6) Introduction of the slurry explosives in the late 1950Ês.
7) The shock tube based detonators (‚Nonel‘: a plastic tube with a wall coating of HMX and aluminum) in the early 1970Ês.

8) Water-in-oil emulsion explosives in the late 1970‘s.

It is now thought that there are about 20,000 known molecules that are explosives, and perhaps 600 of those have been studied enough that they could be used or have been used. The forensic analysis of explosives has two interests. On intact material, it is to determine if the material is an explosive. On explosive residues, it is to determine the nature of the explosive and to profile its origin. Identifying the nature of the explosive involved may lead to the author of the crime. Explosives are usually regulated and controlled by the government. Thus, they are not easily obtained by regular citizens. Explosives are often stolen or smuggled from one country to another. Once the nature of the explosives used is identified, it is possible to relate it to recorded thefts or smuggled activities. Some terrorist groups have been known to use one particular explosive consistently, thus allowing the investigation to head one direction or another. Also, when several explosions occur over a certain time span, it is possible to establish links between them if the same explosives have beenused.

1.10 COMPOSITION OF EXPLOSIVES

Explosives are defined as materials which can undergo rapid decomposition when initiated, resulting in the formation of more stable material and liberating heat during the process. All explosive compounds can be considered to be composed of two essential components- a fuel and an oxidiser. These react together very rapidly liberating large amounts of energy. Majority of the explosives generally contain C, H, O and N. Carbon and hydrogen provide the fuel for the oxygen in the oxidiser. Explosives also contain molecular groups which have explosive properties. Examples of these molecular groups are:

1. Nitro compounds
2. Nitric esters
3. Nitramines
4. Derivatives of chloric and perchloric acids
5. Azides
6. Various compounds capable of producing an explosion, for example, fulminates, acetylides, nitrogen rich compounds such as tetrazene, peroxides and ozonides, etc.

The oxygen is generally attached to nitrogen, as in groups NO, NO_2 and NO_3. The exception to this rule are azides, such as lead azide (PbN_6), and nitrogen compounds such as nitrogen triiodide (NI_3) and azomide (NH_3NI_3), which contain no oxygen.

In an event of a chemical reaction, the nitrogen and oxygen molecules separate and then unite with the fuel components. During the reaction large quantities of energy are liberated, generally accompanied by the evolution of hot gases. The heat given out during the reaction (heat of reaction) is the difference between the heat required to break up the explosive molecule into its elements and the heat released on recombination of these elements to form CO_2, H_2O, N_2 etc.

Energetic materials are made in two ways. The first is by physically mixing solid oxidizers and fuels which results in a composite energetic material such as black powder (mixture of charcoal, sulfur and potassium nitrate). The second process involves creating a monomolecular energetic material, such as trinitrotoluene (TNT) and nitroglycerin (NG), in which each molecule contains an oxidizing component and a fuel component. Such compounds are called molecular explosives.

1.11 CLASSIFICATION OF EXPLOSIVES

A chemical explosive is a compound or a mixture of compounds which, when subjected to heat, impact, friction, or shock, undergoes very rapid, self-propagating, heat- producing decomposition. This decomposition produces gases that exert tremendous pressures as they expand at the high temperature of the reaction. The term detonation indicates that the reaction is moving through the explosive faster than the speed of sound in the un-reacted explosive; whereas, deflagration indicates a slower reaction (rapid burning). Chemical explosives are classified into high explosives and low explosives, based on their speed of decomposition.

1.11.1 LOW EXPLOSIVES

Low explosives (LE) undergo deflagration by creating a subsonic explosion [less than 2000m/s] and lack high explosiveÊs over-pressurization wave. It is a surface phenomenon. In such cases, the maximum damage sustained is close to the point of ignition. Low explosives such as black and smokeless powders decompose relatively slowly because of which they produce a propelling or throwing action that makes them suitable as propellants for ammunition or skyrockets. Under confinement the burning rate increases dramatically leading to an explosion.

Propellants are combustible materials containing within themselves all the oxygen needed for their combustion. Black powder is a relatively stable mixture of potassium nitrate or sodium nitrate, charcoal and sulfur. Propellants can be initiated by a flame or spark. Propellants include both rocket and gun propellants. One group of gun propellants is smokeless powder which consists of nitrated cotton or nitrocellulose (single base powder), nitroglycerin mixed with nitrocellulose (double base powder), nitrocellulose and nitroglycerine mixed with nitroguanidine (triple base powder). Most rocket propellants are composites based on a rubber binder, ammonium perchlorate oxidizer, and a powdered aluminum fuel; or composites based on a nitrate esters, usually nitroglycerine or nitrocellulose and nitramines.

1.11.2 HIGH EXPLOSIVES

A High Explosive (HE) is a compound or mixture which, when initiated, is capable of sustaining a high speed detonation shockwave to produce a powerful blast effect. During the process of detonation, the high explosive is largely decomposed into hot, rapidly expanding gas. The energy release is due to break down at molecular level.

Ingredients of high explosives are classified as Explosive Bases, Combustibles, Oxygen carriers, Antacids, and Absorbents. Some ingredients perform more than one function. An explosive base is a solid or liquid which, upon the application of sufficient heat or shock, decomposes to gases with an accompanying release of considerable heat. A combustible combines with excess oxygen to prevent the formation of nitrogen oxides. An oxygen carrier assures complete oxidation of the carbon to prevent the formation of carbon monoxide. The formation of nitrogen oxides or carbon monoxide, in addition to being undesirable from the standpoint of fumes, results in lower heat of explosion and efficiency than when carbon dioxide and nitrogen are formed. Antacids increase stability in storage, and absorbents absorb liquid explosive bases.

A systematic approach to the relationship between the explosive properties of a molecule and its structure was proposed by VanÊt Hoff in 1980 and Plets in 1953. According to Plets, the explosive properties of any substance depend upon the

presence of definite structural groupings. However a better way of classification is by its performance and uses. High Explosives can be divided into two classes based on their susceptibility to initiation:

1) Primary explosives
2) Secondary explosives

Primary explosives differ considerably in their sensitivity to heat and in the amount of heat they produce on detonation. Their detonation velocities are in the range of 3500-5500m/s. They have a high degree of sensitivity to initiation through shock, friction, electric spark or high temperatures and explode whether they are confined or unconfined. They undergo a very rapid transition from burning to detonation. On detonation the molecules in the explosive dissociate and produce a tremendous amount of heat and/or shock. This will in turn initiate a second, more stable explosive and hence are often referred to as initiating explosives. Typical primary explosives include lead azide, lead styphnate, lead mononitroresorcinate (LMNR) etc. Mercury azide and mercury fulminate are also primary explosives not frequently used today.

Secondary explosives differ from primary explosives in that they cannot be detonated readily by heat or shock and are generally more powerful and can only be initiated to detonation by the shock produced by the explosion of a primary explosive. On initiation, the secondary explosive compositions dissociate almost instantaneously into other more stable components. The detonation is so fast that a shockwave is generated that acts on its surroundings with great brisance (or shattering effect) before the pressure of the exerted gas can take effect. Because they are formulated to detonate only under specific circumstances, secondary explosives often are used as main charge or bolstering explosives. Values of their detonation velocities are in the range of 5500-9000m/s.

Secondary explosives comprise of a majority of high explosives used for military and commercial blasting. Examples of military explosives are dynamite, TNT (trinitrotoluene), PETN (pentaerythritol tetranitrate) RDX (cyclotrimethylene trinitramine) and tetryl (2, 4, 6-trinitrophenyl methyl nitramine). RDX is the most popular and powerful military explosive. TNT has wide applications in shells, bombs, grenades, demolition explosives and propellant compositions. PETN is used by the military in TNT mixtures for small-caliber projectiles and grenades. Ammonium nitrate soaked in fuel oil is an explosive known as ANFO, such commercial explosives are inexpensive and safe to handle and have found wide applications in blasting operations in the mining industry. They do not contain nitroglycerine or other aromatic nitro compounds.

Secondary explosives are further divided into two sub classifications: Main charge and Booster explosives. The main charge explosives are divided into two additional categories: Detonator sensitive and Non-detonator sensitive. Detonator sensitive explosives are reliably initiated with a detonator. E.g.: Dynamite. Non-detonator explosives or blasting agents are those that cannot be initiated with a detonator and therefore require a booster to function.

In most cases, detonators are blasting caps composed of copper or aluminum cases filled with lead azide as an initiating charge and PETN and RDX as a detonating charge.

ANFO is the most common type of blasting agent. A booster is an explosive charge containing a high-brisance explosive utilized to initiate a main charge explosive that is incapable of being initiated with only a detonator. Within the firing train or initiation sequence, the booster is initiated with a detonator which in turn initiates the larger quantity of explosive, the main charge.

Pyrotechnics include illuminating flares, signaling flares, colored and white smoke generators, tracers, incendiary delays, fuses, and photo-flash compounds. Pyrotechnics usually are composed of an inorganic oxidizer and metal powder in a binder. Illuminating flares contain sodium nitrate, magnesium, and a binder. Signaling flares contain barium, strontium, or other metal nitrates.

Explosive and incendiary (fire) bombs are further characterized based on their source. "Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. "Improvised" describes weapons produced in small quantities, or use of a device outside its intended purpose, such as converting a commercial aircraft into a guided missile.
Plastic Bonded Explosives commonly referred to as PBX generally consist of a PETN, RDX or HMX base explosive, plasticizers and binders resulting in a less sensitive, water- proof explosive. The binder makes it less sensitive and highly malleable. They have very high performance for brisance and are characterized by high mechanical strength and good stability. Plastic Bonded Explosives are used in various forms such as Sheet, Detonating Cord, Paste, and Pressing Powders. E.g.: Semtex, C4
C4 is a relatively stable, solid explosive with a consistency similar to modeling clay – ideal for molding into any article. When detonating, C-4 decomposes to release nitrogen and carbon oxides gasses which expand at about 8,000 meters per second, applying a huge amount of force to everything in the surrounding area.

1.12 IMPROVISED EXPLOSIVE DEVICE

Improvised Explosive Device (or IED‘s) is a term used to describe a home-made explosive device. IED's may be created using various household chemicals or military components in the right combustible combinations. Various packages can also be used to deliver the bomb like paper bags, steel pipes (pipe bombs), card board boxes and milk crates. Ingredients as simple as cooking oil have also been known to be used in IEDÊs. They can be set off by a timer, a timed fuse or a cell phone.

The definition of IED originated from UK armed forces is:

“An explosive device, constructed using non-commercial methods, usually in a domestic setting; or a device using ammunition that has been modified to allow it to be initiated in a non-standard way and for a purpose not envisaged by the original equipment manufacturer (OEM)”

IEDs differ depending on the role intended to perform. They may be designed to cause widespread loss of life and destruction of infrastructure, or for targeted attacks on personnel and vehicles. The amount of material in an IED, the type of explosive material, the manner in which the device is constructed, and the location or the type of bag in which it is placed all have a bearing on the specific destructive potential for each IED.

IED generally consist of the following components -

- Power sources: The majority of IED contains an electric initiator and hence requires an electric power source. Batteries are a common power source. Mechanical action like a spring under pressure, can store sufficient energy to cause the functioning of a non-electric initiator.

- Initiators: Improvised initiators causing low explosives or highly sensitive high explosives to detonate can easily be made. Examples of improvised initiators include a modified flash bulb, a percussion primer, or even improvised hobby fuses that impart flame much as time fuse, only at an uncontrolled burn rate. An example for high explosive initiator is an improvised blasting cap. Triacetone triperoxide (TATP) is a formulation used in improvised initiators.
- Explosives: When an explosive is incorporated into a device, it is not necessarily in contact with all other IED components. Often, these components will survive in some form after a device detonates.
- Switches: Many IED contain both an arming switch and a fusing switch. The arming switch is a safety for the IED and works by disarming (electrically disengaging) the fusing switch. When the arming switch is armed, the fusing switch becomes functional; however, the circuit is still closed. When the fusing switch is activated, the circuit becomes open and will connect battery power to the initiator (blasting cap). Thus detonation occurs.
- Fragmentation and shrapnel: Materials are added to the device for inflicting maximum casualties. Examples include ball bearings, nails etc
- Wiring: Wiring is required to combine the components of an IED. The quality of the wiring may be inconsistent with the quality of the item.
- Timer/Delay Mechanism: The simplest delay mechanism is the slow-burning fuse. The use of mechanical clocks and wristwatches is also a common and effective method of delayed detonation in terrorist devices. The basic idea of clocks and wristwatches is to use the rotating hands to complete an electrical circuit and detonate the bomb. Digital and electronic timers are also often used.

Table 1: Types of IEDÊs and their initiation systems

Initiation modes	Initiation systems
Timed	Chemical decay
	Clockwork
	Electronic timer
Command – initiated	Suicide (Person-borne IED can also be timed)
	Radio-controlled (RCIED)
	Command wire (CWIED)
	Passive infrared
	Active infrared
	Projectile controlled (PCIED) – uses a rifle bullet to connect a circuit from a distance
Victim-operated (VOIED)	Booby traps
	Pressure pads
	Pull switches

1.13 EXPLOSIONS

Explosions can be divided into three groups based on their source of energy: Physical Explosions such as the over-pressurized steam boiler, Chemical Explosions as in the chemical reactions of explosive compositions and Atomic Explosions; and also based on their locus: Dispersed (detonation of a cloud of flour in air) and Condensed Phase (detonation of a stick of dynamite).

Physical explosions: A physical explosion can arise when a substance whilst being compressed undergoes a rapid physical transformation. At the same time, the potential energy of the substance is rapidly transformed into kinetic energy, and its temperature rises rapidly, resulting in the production of a shockwave in the surrounding medium.

Chemical explosions: A chemical explosion is the result of a chemical reaction or change of state which occurs over an exceedingly short space of time with the generation of a large amount of heat and gas.
During a chemical explosion an extremely rapid exothermic transformation takes place resulting in the formation of very hot gases and vapors. Owing to the extreme rapidity of the reaction (one-hundredth of a second), the gases do not expand instantaneously but remain for a fraction of a second inside the container occupying the volume that was once occupied by the explosive charge. As this space is extremely small and the temperature of explosion is extremely high, the resultant pressure is therefore very high enough to produce a _blast wave‘ which will break the walls of the container and cause damage to the surrounding objects. If the blast wave is strong enough, damage to distant objects can also occur.
Atomic explosions: The energy produced from an atomic or nuclear explosion is a million to billion times greater than the energy produced from a chemical explosion. The shock waves are similar to those produces by a chemical explosion but will last longer and have a higher pressure in the positive pulse and a lower pressure in the negative phase. The heavy flux of neutrons produced from an atomic explosion would be fatal to anybody near the explosion, whereas those who are at some distance from it would be harmed by the gamma radiation. Atomic explosion also emit intense infra-red and ultra- violet radiation.

1.14 EXPLOSIVE TRAIN

An explosive composition is initiated or detonated via an explosive train. The explosive train is an arrangement of explosive components by which the initial force from the primer is transmitted and intensified until it reaches and sets off the main explosive composition.

COMPONENT	ACTION	COMMENTS
Primer	Initiating device	Initiated by percussion, stabbing, electrical current, heat, etc.
Detonating	Detonate base charge	Ignited by primer. Small quantity of primary explosives.

Flash	Ignite base charge	Ignited by primer. Burn explosively but will not detonate.
Delay	Controlled time delay	Pyrotechnic formulation burns without gas.
Relay	Initiate the next component	Its role is similar to the detonating component.
Booster	Initiate main explosive composition	Used to initiate blasting agents or cast TNT.
Base charge	Detonate main composition	Usually a secondary explosive.

Almost all explosive trains contain a primary explosive as the first component. The second component in the train will depend upon the type of initiation process required for the main explosive composition. If this main explosive composition is to be detonated then the second component of the train will burn to detonation so that it imparts a shockwave to the main composition. This type of explosive train is known as a _detonator‘. However, if the explosive train is only required to ignite the main composition, an _igniter‘ is used which will produce a flash instead of a detonation.

1.15 EFFECTS OF EXPLOSION

- Blast pressure – positive and negative
- Thermal
- Fragmentation
- Ancillary

The first effect following the explosion or detonation of an explosive is _positive blast pressure‘. When an explosive charge explodes or there is a failure of a containment vessel following a deflagrating low explosive in a pipe bomb, the expanding product gases push on the surrounding air to produce and force out a shock wave. The larger the explosive charge, the higher the peak shock pressure at any given distance from the charge. Similarly, the further away from the charge, the weaker the shock front. Figure 1 depicts the moment of the explosion when the blast pressure generated from the explosive impacts the surrounding area, creating a crater in the soil; the thermal (heat) effect, positive blast pressure rising from the epicenter, and the fragmentation effect that is actually ahead of the blast pressure are shown.

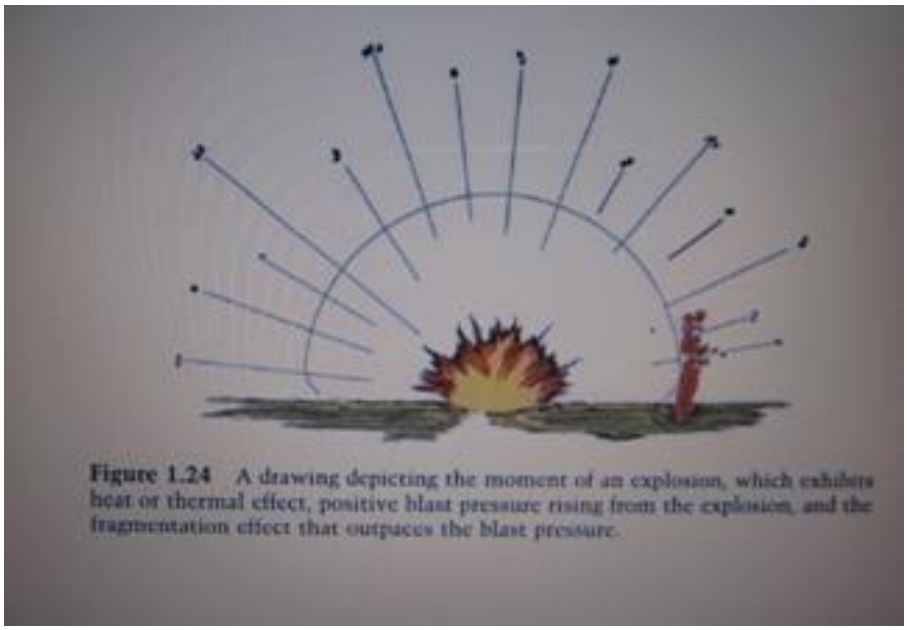


Figure 1: The moment of Explosion

The forces caused by this explosion impact the area not only in the direction depicted in the drawing but also around the epicenter. This outward movement of air from the seat of the explosion is the positive pressure effect. Additionally, this outward moving pressure forms the shock front, which is only a fraction of a centimeter thick and which compresses the surrounding air. A vivid example of this effect can be observed by throwing a pebble in a body of water.

Positive pressure is extremely short in duration, in the range of microseconds or millionths of a second. The positive pressure wave creates high air or wind velocities. However, as these pressures are very short in duration and depend on the quantity of explosives being utilized, the high pressure readings rapidly and significantly dissipate with distance from the seat of the explosion. This rapid drop-off of pressure has been observed in the effects of bombing incidents. After the energy generated in the positive- pressure phase of an explosion is expended, the longer-lasting, lower-velocity _negative blast pressure‘ phase begins. The shock front compresses the air to form a partial vacuum. After that energy is gone, the air, similar to a compressed spring, recoils or reverses its movement and rushes inward to fill the void so as to return the area to a balanced state of ambient pressure. Although the air velocity is considerably less than in the positive-pressure phase, negative pressure can produce damage. This is especially true in instances where the positive-pressure phase has weakened walls, doors, and windows, etc., the negative pressures then complete the damage. As in the positive phase, the larger the explosion, the more readily one will be able to observe the negative- pressure phase, as it is more stable.

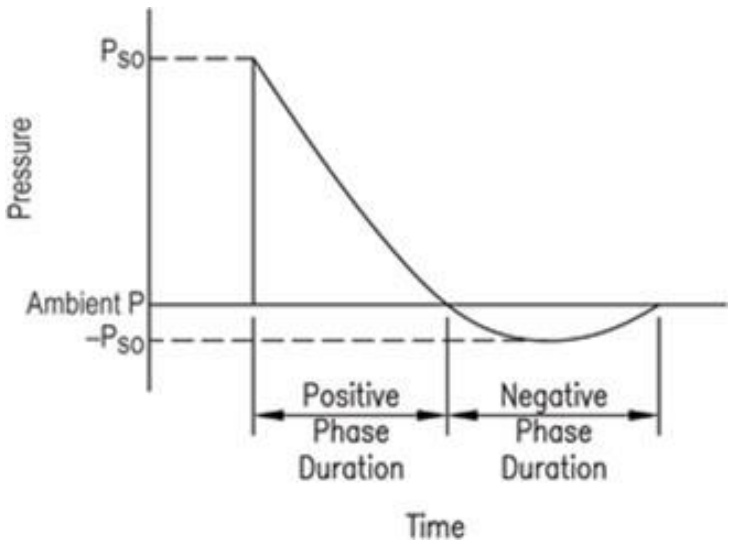


Figure 2: Time after explosion

Fragmentation and shrapnel are missiles that are a result of an explosion and may be a part of the explosive casing, container, and earth building material, target area or other items affected by the explosion. Fragmentation may be complete items, subassemblies or pieces thereof, or pieces of equipment or buildings. Shrapnel on the other hand are added materials (usually metal), which are placed in or around an explosive to intentionally produce additional property damage and injuries. The fragmentation effect of an explosion does not depend on an exploding explosive or bomb but results from accidental explosions of other materials such as gases, dust and mechanical assemblies.

1.16 EXPLOSION SCENE INVESTIGATION

The responsibility of the investigator at the explosion scene is to effectively assess a scene to determine not only if there was an explosion but also whether the explosion was the result of criminal activity or an accident. The investigator should be able to recognize the observable physical differences in the way the scene appears in order to assess which type of fuel, whether explosives, fuel gases or vapors, or dust, was utilized in the explosion.

A seated explosion is one having an identifiable crater or a place where there is an area of greatest damage or an epicenter of an explosion. Normally, a seated explosion is the result of the initiation of an explosive (condensed phase fuel) material at or near the surface. It is noted that the failure of a containing vessel (mechanical explosion involving a rail tank car, e.g., BLEVE) can result in the formation of a seat or crater.

A non seated explosion is associated with a fuel-air or dust explosion. They are explosions in which there is no physical evidence of a single location where the explosion occurred. These explosions are generally the result of the ignition of diffuse fuels such as gases, vapors of pooled liquids, and dusts.

These explosions have the capability of producing various types of results or effects, which have to be observed by the investigator to begin the investigative process. Understanding the effects like blast pressure, fragmentation, incendiary, ancillary will help in determining the type and source of that explosion.

The scientific method for crime scene investigation involves the following steps:

1) Recognize the need – respond to explosion, protect the scene, assess resources.

2) Define the problem – devise a tentative investigative plan.
3) Collect data – describe, observe and document. Photograph, diagram and collect evidence.
4) Analyze the data – test predictions with established knowledge.
5) Develop a tentative working hypothesis – develop a tentative working hypothesis from data analysis.
6) Test the working hypothesis – compare hypothesis to all known facts and test data.
7) Select the final hypothesis – determine the cause of explosion.

1.17 COLLECTION AND TYPES OF PHYSICAL EVIDENCE

The most important aspect of detecting and identifying explosive residue is the collection of samples from the scene after the initial emergency of a bomb or explosive incident. The scene must be systematically searched to recover the remains of the detonating device and explosive.
Generally a crater is formed at the origin of the blast. While the explosive residues will be found on debris near the origin, the detonating devices and the explosive containers will be found from this area in a circular pattern. Because of the transitory nature of some explosive by-products, odor and other observations should be noted immediately upon arrival at the scene and documented if possible. Evidence of bomb debris, bomb devices, explosive debris, explosive devices, electrical devices, timing devices, wiring, connectors and any items that seem strange or foreign to the setting should be collected as evidence. Any undetonated devices should be exploded or rendered safe by the bomb squad before submission to a laboratory for analysis. Items collected should be packaged in jars, cans, or special vapor barrier plastic bags and carefully marked. If the suspected object is like a detonator, fuse, cartridges, rockets etc., they should be separately packed in cotton wool placed in a wooden box and sent through a messenger to a laboratory dealing in explosives or the expert may be called to the site for guidance. If the substance is solid, a small amount may be collected on paper or on tin foil and transported to the laboratory for identification. Similarly, a semisolid substance could also be identified. In case of liquid substances, they could be transported as such for identification of the chemical substances. Flammable items must be packaged in metal paint-type cans with metal covers and well marked.

1.16.1 POST-EXPLOSION RESIDUES

The analysis of post-explosion residues is usually based on finding and identifying residues from the original explosives, rather than products formed during the explosion. These products are usually either gases or inorganic salts. In case of an almost complete explosion, the residual amounts of unexploded residues would be compatible with the available analytical methods. However the residual explosive has to be isolated from large amounts of debris, covering wide areas, including a large number of items some of which cannot be brought to the laboratory. Items are usually collected according to their proximity to the explosion center and preliminary field tests may be used for screening the debris on the explosion site.

1.16.2 SAMPLING TECHNIQUES

It is necessary to recover samples for detection of invisible traces of explosives from a wide variety of types of evidence, and sampling techniques need to be chosen accordingly. The following sampling methods are often used.

1. **Swabbing:** The detection and identification of traces of explosives on items or individuals at the scene of explosion is aimed at establishing whether a contact with explosives occurred. Hand swab extracts are often heavily contaminated and successful clean up procedures are an important prerequisite for the identification of the explosives. The swabs are then subjected to one of the extraction techniques like syringe elution, centrifugal micro filter extraction, one pot extraction and constricted tube extraction.

2. **Solvent washing** for recovery of soluble materials.
3. **Contact heater** for adsorbed and absorbed volatile explosives.
4. **Vacuum sampling** to trap particulates.
5. **Adhesive lifts** for particulates.

1.18 LABORATORY ANALYSIS OF EXPLOSIVES

The analysis of explosives is quite complex and involves detailed examination of the evidence collected.

1.16.3 MICROSCOPIC EXAMINATION

Soil and debris are examined for the presence of unexploded or partially burned explosives and explosive residues. Any parts of timing devices, electrical devices, plastic wires, or other bomb components should be examined microscopically. This examination could locate discrete, unconsumed particles, which could then be analyzed directly without tedious extraction and clean-up procedures. Black powder and smokeless powder are relatively easy to locate in debris because of their characteristic shapes and colors.

1.16.4 EXTRACTION

After microscopic examination, residues of explosives and explosive components are extracted for laboratory analysis. The debris to be analyzed is subjected to two extractions: aqueous and organic. The extract is then filtered and evaporated to recover the explosive residue. The aqueous extract is analyzed for inorganic ions and for some water-soluble organic ingredients. The organic extract, often obtained using acetone, is analyzed for organic explosives and related compounds. Post explosion analysis is usually characterized by small amounts of residues present in a complex, highly contaminated matrix. Organic impurities, which are co-extracted with the explosive residues in the organic extraction, constitute a major problem in the subsequent analysis.

1.16.5 CLEAN-UP PROCEDURES

A suitable clean up procedure is therefore an important and often crucial step in analysis. A clean up procedure could either be general or it could be designed to precede a specific analytical method. After the clean up, the extracts are concentrated and subjected to a variety of analytical methods.

1.16.6 PRESUMPTIVE TESTS

Most explosives undergo chemical reactions with certain reagents to produce a color. Identification of colour reaction is based on the fact that the colour produced is characteristic of a specific compound or group of compounds. The sensitivity of most colour reactions used in explosive analysis is in the range of 10^5-10^7g. Presumptive tests have the advantage of being quick, easy to use and relatively inexpensive. Such tests are used for screening samples. These tests can be carried out on the extract or the cleaned up extract. All analysis should involve a positive and negative control sample. Negative controls are set up to ensure that testing equipment is clean, to show that the reagents when mixed together without the sample do not give a colour change which could be countered as a positive. Positive control are set up to show that the reagents work correctly with known samples, shows the color expected and can be used to test the sensitivity of the method.

A number of simple colour tests to be performed on acetone and water extracts to screen for the presence of organic and inorganic explosives respectively are listed below.

Table 3: Spot tests for various ions

Explosive substance	Colour reaction		
	Griess reagent	Diphenylamine	Alcoholic KOH
Chlorate	No colour	Blue	No colour
Nitrate	Pink to Red	Blue	No colour
Nitrocellulose	Pink	Blue-black	No colour
Nitroglycerin	Pink to Red	Blue	No colour
PETN	Pink to Red	Blue	No colour
RDX	Pink to Red	Blue	No colour
TNT	No colour	No colour	Red
Tetryl	Pink to Red	Blue	Red-violet

1.18.5 SCANNING ELECTRON MICROSCOPE WITH ENERGY DISPERSIVE X-RAY ANALYSING SYSTEM

A scanning electron microscope (SEM) is essentially a high magnification microscope which uses a focussed scanned electron beam to produce images of the sample. The primary electron beam interacts with the sample and generates low energy secondary electrons, which tend to emphasize the topographic nature of the specimen. When the electron beam strikes a target X-rays are generated, which are sorted according to their energy values by the X-ray analyzer. The elementÊs concentration can also be determined by measuring the intensity of the X-ray emission.

SEM-EDX is a non destructive technique that is used to identify a wide range of elements and should be performed before any sample extraction stages. SEM-EDX is not of use for elements which have an atomic number less than that of 10 which

means that organic explosives cannot be analyzed using this method. However it is commonly used for the analysis of inorganic explosives and pyrotechnics.

1.18.6 THIN LAYER CHROMATOGRAPHY (TLC)

TLC is commonly used for detection of explosives, specifically to differentiate between smokeless powders (single and double base). The technique uses a solid stationary phase and a moving liquid phase to separate the constituents of a mixture. The sample is applied onto the plate coated with silica gel or aluminum oxide and then placed upright into a closed chamber containing a suitable solvent. Care is taken to see that the level of the solvent is below the sample spot. As the solvent migrates upwards by capillary action, the components of the sample migrate at different rates, resulting in separation. When the solvent front moves a sufficient distance, the development is complete and the plate is removed from the chamber and dried. The spots or bands on the developed layer are visualized, if required, under UV light or by chemical treatment.

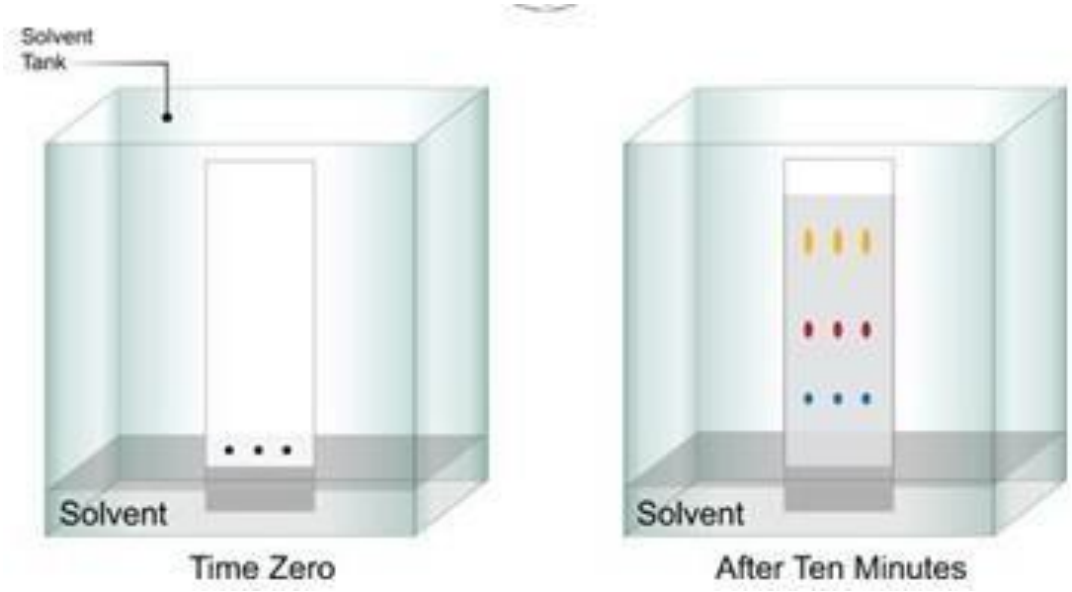


Figure 3: The solution is applied near one end of a plate coated with silica or alumina. The plate is then immersed in a solvent, which rises up the plate by capillary action.
In most situations, visualization is by way of a spray reagent, generally a modified Griess reagent which will identify nitro groups present within the explosive molecule. The technique is still widely used though it has been largely superseded by instrumental techniques.

1.19 INSTRUMENTAL ANALYSIS

1.16.7 LIQUID CHROMATOGRAPHY-MASS SPECTROMETRY (LC-MS)

Liquid Chromatography is a physical separation method in which the components to be separated are selectively distributed between two immiscible phases: a mobile phase is flowing through a stationary phase bed. Liquid chromatography-mass spectrometry (LC- MS, or alternatively HPLC-MS) is an analytical separation and detection technique. Liquid chromatography methods are well suited for the analysis of polar, non- volatile, and heat sensitive compounds. It can resolve low

concentrations of the explosive compounds in the presence of co-contaminants and interferences that defeat analysis by UV detector. It provides chromatographic data (retention times) and mass spectral data to allow confirmation of the identity of analyzed components. LC-MS is a very sensitive technique which makes it ideal for trace analyses.

1.19.2 GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)

Gas chromatography-mass spectrometry (GC/MS) is a method that combines the features of gas chromatography and mass spectrometry to identify different substances within a sample. The GC-MS is composed of two major building blocks: the gas chromatograph and the mass spectrometer.
The gas chromatograph utilizes a capillary column. The difference in the chemical properties of different molecules in a mixture will separate the molecules as the sample travels the length of the column. The molecules take different amounts of time (called the retention time) to come out of (elute from) the gas chromatograph, and this allows the mass spectrometer downstream to capture, ionize, accelerate, deflect and detect the ionized molecules separately. The mass spectrometer does this by breaking each molecule into ionized fragments and detecting these fragments using their mass to charge ratio.

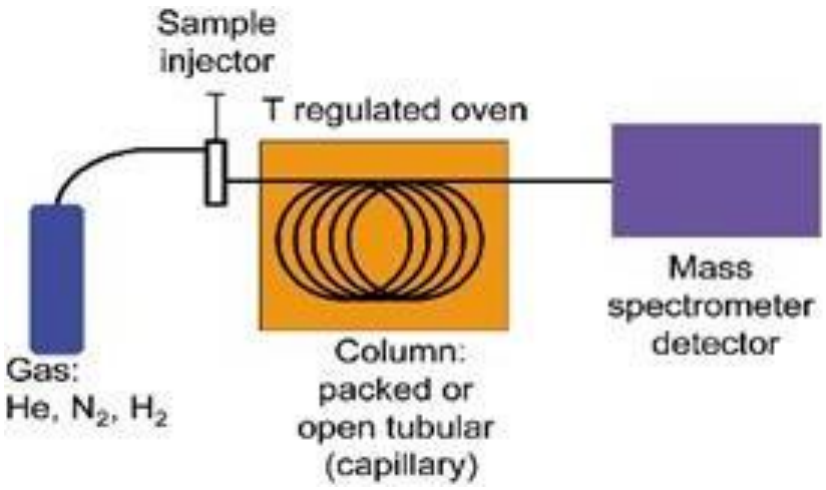


Figure 3: Schematic diagram of GC/MS

The small amount of residue recovered and the interfering compounds present in the post-blast debris complicate the identification of an explosive at the scene. GC can be a valuable tool in the separation of the explosive from the interfering substance. For the analysis of explosives, thermal energy analyzer (TEA) has been found to be superior in sensitivity and selectivity over Flame ionisation detector (FID), electron capture detector (ECD) and thermionic specific detector (TSD). GCMS is a powerful tool for the detectionof low levels of organic explosives in post-explosion debris and for identification of nitro-esters and nitro-aromatics.

1.16.8 ION CHROMATOGRAPHY

Ion chromatography is used specifically for the analysis of inorganic residues. It has the ability to detect volatile ions such as ammonium. The main advantage of the

technique is its sensitivity however does not provide a definitive identification of the explosive material. This is often used in conjunction with IR and SEM.

1.16.9 FOURIER TRANSFORM INFRA RED SPECTROSCOPY (FTIR)

The spectroscopic identification of explosive materials by FTIR has the advantages of being able to give real time identification, non-destructive analysis, and minimal sample preparation. Previous research has shown that explosives (E.g. TNT, RDX and HMX) can be identified from non-energetic materials by their spectral signatures in the mid-IR region. Spectra of unknown samples are best identified by searching a spectrum of interest against spectral libraries and then evaluating the quality of possible matches. When organic molecules are irradiated with light within this region, the radiation is absorbed and converted into molecular vibrations. While it is widely accepted that an IR spectrum is characteristic of the entire molecule, it is also known that certain groups of atoms (i.e., functional groups) give rise to peaks that occur at or near the same frequency regardless of the structure of the rest of the molecule. FTIR is an extremely useful technique for confirming the identity of pure compounds, but has limited value if used for mixtures of compounds. Nitro groups have two main stretching bands which are used to identify the compounds using FTIR.

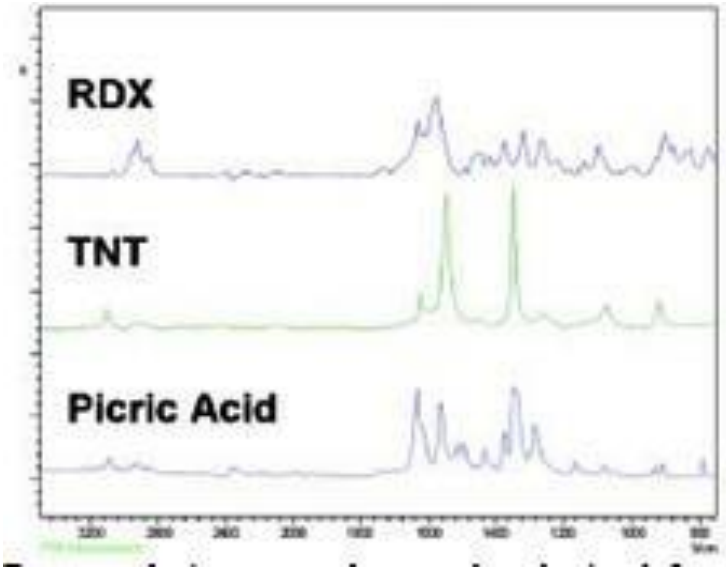


Figure 4: The distinct FTIR spectral signatures that can be obtained for common military-grade explosives at the mg/ml level with an attenuated total reflectance (ATR) accessory. The difference in the three spectra in terms of peak position, width and intensity can be seen.

1.19.5 CAPILLARY ELECTROPHORESIS (CE)

Capillary Explosives has also been applied to the investigation of post blast residues. The technique provides 10 to 20 times greater efficiency than HPLC and involves injecting a small quantity of material onto a thin fused silica column. Separation takes place at high voltage based on mass to charge differences of the ions present. This technique can be used in conjunction with IR and SEM but complex matrices tend to make CE yield results with poor reliability.

1.20 CONTAMINATION CONTROL

None of the most important issues with respect to the analysis of trace explosives is contamination. Stringent controls must be in place to ensure that background contamination is monitored and minimized. The single most important control measure is physical separation of all activities involving explosives in bulk amounts from the trace activities. Bulk explosives severely contaminate any surfaces which they contact.

Control samples are processed along with the trace forensic samples to monitor the levels of contamination. Effective quality control procedures ensure that any traces of explosives found in debris originated from the scene and not from contamination or spurious results.

LEARNING OUTCOME:

After studying this unit you should be able to:

1. Perform the various laboratory tests and make observations.
2. Parts and procedure of various Instruments involved in the detection procedures.

GLOSSARY

1. Alcohol
2. Liquor
3. Adulteration
4. Cement
5. Mortar
6. Accelerant
7. Endothermic reaction
8. Energy
9. Modus Operandi
10. Flash point
11. Pyrolysis

SUGGESTED READINGS:

1. Analytical Methods in Forensic Toxicology - Dr. S. N. Tiwari.
2. Textbook for Forensic Chemistry - U Arvind.
3. Textbook for Forensic Chemistry - S. A. Iqbal.
4. Explosive, Seventh Edition - Rudolf Meyer.
5. Test Methods for Explosives - Muhamed Suceska.
6. The Ultimate Book of Explosives, Bombs and IEDs - Dr. N. C. Asthana.
7. Explosives - Delvin. S.
8. Practical Bomb Scene investigation - Thurman.
9. Fire Debris Analysis - Eric Stauffer.
10. Forensic Investigation of Explosions - Beveridge.

UNIT II

LEARNING OBJECTIVES:

In this unit you will be introduced to:

1. How alcohol is absorbed into the bloodstream, transported throughout the body, and eliminated by oxidation and excretion.
2. The techniques that forensic toxicologists use to isolate and identify drugs and poisons.
3. Classification of Poisons.
4. The psychological and physical dependence of drugs.
5. The laboratory tests normally used to perform a routine drug identification analysis.

UNIT II-A-Toxicology

2.0 INTRODUCTION

Toxicology deals with the science that embodies the knowledge of the sources, characters and properties of poisons, the symptoms they produce, the nature of their fatal effects, the remedial measures that should be taken to combat their actions or effects. The word ‗toxicology' is derived from the Greek word-‗toxicon', which was used as a poisonous substance to arrowheads. The term ‗forensic toxicology' covers any application of the science and study of poisons to the elucidation of questions that occur in judicial proceedings. The forensic toxicologist is expected to detect and identify poisons.

A poison is defined as the substance, which is capable of producing injury or death when absorbed. Appropriate dosages can differentiate poison and also the remedial measures. All chemicals can produce injury or death under certain conditions. Hence, a poison can be defined as a substance that is capable of producing detrimental effects on a living organism. As a result, there may be a change in the structure of the substance or functional processes, which may produce injury or even death. The toxicologist is specially a trained expert to examine the role of such substances and their adverse effects. The variety of potential adverse effects and the diversity of chemicals present in our environment contribute to make toxicology a very broad field of science. Therefore, toxicologists are usually specialized to handle various areas of toxicology. The professional activities of toxicologists fall into four main categories i.e. Forensic, Industrial, Clinical and Environmental Toxicology. Forensic toxicology emerged on the hybrid of analytical Chemistry and toxic principle effects. Forensic toxicologists are also primarily concerned with the medico legal aspects of the harmful effects of chemicals on human and animals. The expertise of forensic toxicologists is primarily utilized in establishing the cause of death and elucidating its circumstances in postmortem investigation. The work of forensic toxicologist is therefore considered as highly complicated as small quantities of poisons and their metabolites are to be isolated, purified and quantified from highly complex matrices. Orfila ‗Father of Toxicology' stressed the necessity of adequate proof of identification, emphasized the importance quality assurance (purity of the standard etc.) and anticipated the need for pharmaceutical, clinical, industrial and environmental *toxicology.*

2.1 CLASSIFICATION OF POISONS

For the purpose of toxicological analysis, poisons are classified on the basis of their chemical properties and method of isolation from tissues and other biological fluids, which are given below:

(I) Noxious Gases:

(1)Carbon Monoxide
(2)Carbon dioxide
(3)Hydrogen sulphide
(4)Pyridoxine
(5)Chlorine
(6)Nitrous oxide
(7)Methane gas
(8)Methyl isocyanides

(9) War gases
(10) Ammonia
(11) Tear gas (chloracetophenon)

(II) Volatile Inorganic:

1) Cyanide
(2)Phosphine
(3)Arsine
(4)Phosgene
(5)Stilbine
(6)Carborylchlor
(7)Fluorocarbon
(8)Iso cyanide. Volatile Organic:
(9)Methanol
(10) Ethanol
(11) Pyridine
(12) Ketones
(13) Formaldehyde
(14) Acetaldehyde
(15) Chloral hydrate
(16) Hydrocarbons
(17) Chloroform

(III) Non-volatile Inorganic:

(A) Anions:

(1)Chloride
(2)Bromide
(3)Iodide
(4)Solenoids
(5)Dichromate
(6)Chlorates
(7)Azides
(8)Nitrite
(9)Sulphides.

(B) Cat ions:

(1)Mercuric
(2)Arsenic
(3)Barium
(4)Thallium
(5)Lead
(6)Antimony
(7)Bismuth
(8)Copper
(9) Level of Aluminum and Zinc.

(IV) Non-volatile Organic Neutral Compound:

1. Insecticides (Organophosphorous, Organochloro, Carbamates and synthetic Pyrethroids)
2. Neutral Drugs.

(V) Non-volatile Organic Acidic Compounds:

Acidic Drugs like Barbiturates, Sulpha drugs.

(VI) Non-volatile Organic Alkaline Compounds:

All basic drugs i.e. Alkaloids etc.

(VII) Miscellaneous Poisons:

(1)Mechanical.
(2)Plant poisons.
(3)Food poisons/Afflotoxins.
(4)Animal and insect poisons.
(5)Water-soluble Drugs.

2.2 SCOPE

Brief Forensic Analysis procedure followed for examination of suspected materials collected by the Medical Officers and Investigating Agencies in the form of human animal organs collected from the cremation or exhumation and tins, cloths etc., collected during investigation, powder substances, pills, tablets, liquids, waste materials etc., collected to know the contaminants or pollutants. Animal organs collected during postmortem of cattle or fish etc., collected after suspected poison.

2.3 CATEGORIES

The samples received for the examination in Toxicology Division can be broadly categorized in to:

- Gaseous and Volatile poisons
- Inorganic poisons (Metallic and Anions)
- Neutral poisons (Organic non Volatile)
- Basic poisons/drugs (Organic non volatile)
- Acidic poisons/drugs (Organic non volatile)
- Miscellaneous poisons

2.4 GASEOUS AND VOLATILE POISONS

2.4.1 GENERAL BACKGROUND

Gaseous poisons exist in an industrial environment, only a few are seen frequently in forensic practice. Carbonmonoxide is available in illuminating gas, automobile exhaust fumes, and fire combustion smoke, furnace gas, heavy auto traffic garages and refineries.

Definition: Volatile poisons and gaseous poisons are those poisons, which have low melting point and boiling point.

Available forms: Available in solid, semi solids, liquids and gaseous forms.

Available forms of cyanide: Cyanide is generally available in the following chemical forms such as Potassium cyanide (KCN), Sodium cyanide (NaCN), Potassium ferrocyanide ($K_4Fe(Cn)_6$), Ammonium thocyanate (NH_4SCN), Silver cyanide

(AgCN), Mercuric cyanide ($Mg(CN)_2$) Hydrocyanic acid (HCN), etc. In the form of certain glycosides, hydrocyanic acid occurs in large number of plants.
Volatile poisons are in various forms as cyanide, alcohols, phosphorus, phenols etc.
Source and form of crime/questioned sample: Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary is in the form of viscera, body fluids, material objects and plant materials.
In survival cases like living persons stomach wash, vomited material and stained cloths etc., blood sample, urine and faeces if available. Suspected material recovered from the possession of the victim or accused and from the scene of crime such as medicines, containers, foods and drinks, residual poisonous materials etc.
Control sample: Pure forms volatile and gaseous poisons standardized for Laboratory purpose procured from recognized Laboratories are used for comparative chemical analysis.
Data base of pure volatile and gaseous poisonous substances available in various instruments is utilized for comparative chemical analysis.

2.4.2 METHODS AND PROCEDURES Method – I: Physical examination **Method – II:** Individual testing methods **Method I:** Physical Examination

I. Noxious Gases:

These include irreparable gases like carbon monoxide, carbon dioxide, hydrogen sulphide, chlorine, nitrous oxide, ammonia, methane, methyl isocyanide, tear gas and war gases. These are demonstrable by analysis of air samples collected at the scene of exposure. Gases may be analysed directly or indirectly from the blood by individual specific tests. However, many toxic gases are not readily detected in the blood samples. The analytical procedures are usually successful for air samples at the scene.

II. Volatile poisons:

These include both organic and inorganic chemical compounds which may be isolated from finely chopped biological materials by simple process of steam distillation from either an acidic or basic medium.
Analytical Procedures: **Physical examination:** Macroscopic characteristics.
The following examination is done by naked eye.

a) Appearance
b) Colour
c) Form – Crystalline or amorphous.

Method II: Individual testing methods

(A) Gaseous poisons

I Carbon monoxide

Carbon monoxide is a colourless and odourless gas and available in illuminating gas, automobile exhaust fumes, fire combustion smoke, furnace gas, heavy auto traffic garages and refineries.
The normal carbon monoxide level in human may vary from 0 to about 5 percent in smokers.
Symptoms: Nausea, vomiting, vertigo, and convulsions, cyanosis, paralysis of respiratory centre. Bright cherry red blood, pink discoloration of skin surface is the main symptoms of carbon monoxide.

Carbon monoxide has an affinity for combining with haemoglobin more than 200 times greater than oxygen. This causes sinister toxicity by preventing normal transportation and supply of oxygen to cells.
Further, a person surviving several hours after an exposure has already eliminated a major percentage of carbon monoxide from his body. If death is occurred after 10 hours, the terminal concentration is almost negligible.

Identification:

(1) Take two small porcelain-evaporating dishes. Place 1 ml of normal blood into one dish. Place 1 ml suspected blood in another dish. Heat both the dish very gently. The normal blood will change to a brown black whereas if carbon monoxide is present it will become brick red. This test is sensitive to 40% carbon monoxide.
(2) Take a drop of blood and dilute with 10-15 ml of water. Compare with blood diluted in the same manner. Blood containing carbon monoxide is pink. This test is sensitive to 50% carbon monoxide.

II Carbon-dioxide
Carbon dioxide is relatively inert and unlike the monoxide has no poisonous or cumulative effects. However, it can still kill from being unable to sustain respiration. Three percent in the atmosphere will cause headache, drowsiness, giddiness and loss of muscle power.
Sources are often industrial, as carbon dioxide is used very widely in the manufacture of many products. The minimum fatal concentration is said to be 25-30%, the high concentration causing sudden death being 60-80%.
An unexplained feature of carbon dioxide is the speed of its toxicity on many occasions. Pure asphyxia should take several minutes, leading to cyanosis and congestion; but dioxide death can be very rapid where high concentration are present, with no Âasphyxial signsÊ. Vagrants Âsleeping roughÊ
Near limekilns have died due to the very heavy gas creeping over then during the night, but modern fatalities are associated with wells, deep shafts and farming exposure. In chalk rock, carbon dioxide can accumulate in deep holes.

IIIAmmonia
Ammonia gas is an uncommon poison outside industry. It was formarly used extensively in refrigeration, but has been largely replaced by more inert fluids. Ammonia is still used criminally for aiding assaults and robberies, by being thrown in the face and this is sometimes also done in attempts to blind or scar. In gaseous form, escapes in factories may cause severs lung symptoms, the maximum permissible concentration being only 100 parts per million. Choking, coughing, pulmonary odema may be followed by bronchopnoumnia.

IVPhosphine
Phosphine is a colourless, flammable, highly toxic gas with an odor of decaving fish. Phosphine is a highly toxic gas. This gas affects the central nervous system and blood. *Toxicity:* A concentration of 2000 p.p.m. Is lethal to man in a few minutes. Concentration of 400-600 ppm. is dangerous to life after exposures for 30-60 minutes.

(B) Volatile poisons

I Cyanide

Cyanide is extremely rapid acting and capable of causing death within minutes. The classical odour of bitter almonds is not detected by everyone and seems to be genitically determined. Hydrocyanic acid and the cyanides are true protoplasmic poisons, since they arrest the activity of all forms of living matter by unhibitting tissue oxidation and suspending vital function. Onset of symptoms of cyanide poisoning depends on the type of exposure. Hydrogen cyanide vapours are the most rapidly acting, with symptoms occuring within seconds and death within minutes. When cyanide salts are ingested, onset of toxicity is delayed somewhat due to slow absorption. The severity of acute poisoning is determined by the dose and exposure time.

Use: Sodium and Potassium cyanides are used industrially in connection with electroplating, coating silver case, hardening of steel and iron, in tanning, in photography and gold recovery. Calcium cyanide is used as a fertilizer. Sodium and Potassium cyanides are also used as fumigating agents for citrus and other fruits in ships, railways and warehouses, etc.

Detection:

1) ***Pursion blue test:*** Take 1 ml of the distillate and make it alkaline with 10% NaOH add 1 ml freshlyprepared 10% Ferrous Sulphate solution. Boil the solution, cool it at room temperature, and make it acidic by dropwise addition of Con.Sulphuric Acid. Appearance of Prussian blue colour indicates the presence of cyanide. Sensitivity-5 g/ml.

2) ***Copper acetate*** *– Benzidine/o-tolidine Test:* Take 1 ml of the distillate and make it just acidic by drop wise addition of Dil. Sulphuric acid solution and to it is added successively 1 ml aquous solution of 0.5% cupric acetate. Add 1 ml of 0.01% o-tolidine in 2% acetic acid solution. Appearance of blue colour indicates the presence of cyanide.

Toxicity: Cyanide is rapidly fatal, producing a histotoxic anoxia by poisoning the oxidative enzymes at cell level. Immediate measures are necessary and treatment must be rapid.

Fatal dose: The smallest quantities that have proved fatal are about 50 mg. of pure hydrocyanic acid. The minimum fatal dose of pure potassium cyanide is about 0.2 to 0.5g. and that of Sodium cyanide is about 0.15 g. Fatal period; Two to ten minutes.

II Acetone

Synonyms**:** Cetone; Dimethyl Katone; 2-Propanone Aclear, colourless, volatile, mobile, Inflammable liquid,

Tolerance: 1000 ppm in air. Sweet smelling liquid. Missible in water, ethanol, chloroform and Ether.

Symptoms: Irritation to mucous membrane, possible kidney and liver demage, headache,

Dizziness, dermatitis, fainting, hypoglycemia, CNS depression, bronchial irritation and pulmonarycongestion, irregular respiration, weakpulse, lower temparature, dyspnea, stupor, death by ketosis (acidosis).
Uses: Paints, Warnish and lequer solvent, to clean and dry parts of precision equipments, delurtrant for cellulose acetate fibres, specification testing of vulcanized rubber product.
Toxicity: Acetone is one of the solvents absued in Âglue-sniffingÊ severe toxic effects have been associated with blood concentration of 200 to 300 mg/ml a blood concentration of 550 mg/ml has been reported in a fatality upto 20 ml has been ingested without ill-effects.

Identification:
Test stomach contents or urine: Take 10 ml of urine plus 3 gm of sodium hydroxide. To this mixture, add 20 drops of 10% alcoholic solution of Salicylaldehyde. Gently warm to 70^{o} C intense purple-red ring at interface.

Chemical test of Acetone:
Iodoform test: To one ml of the distillate in a test tube is added few drops of 10% NaoH followed by dropwise addition of iodine solution till the solution become brown. The contents are then warmed on a low flame. Few drops of Naoh solution are added to change the colour of the solution from brown to yellow. (If after warming, the solution becomes colourless few drops of idine solution are added). The tube is kept over night
and precipitate is observed under microscope. Characteristic hexagonal crystal is of iodoform are seen. Acetaldehyde and amyl alcohol, if present, will also give the test.
Disposition in the body: Absorbed through the lungs and skin. It is execreted in the urine and through the lungs; large amounts are mainly excreted unchanged but small doses may be oxidized to carbon dioxide or utilized in the body as acetone or format. Acetone is the main metabolite of isopropyl alcohol; it occurs naturally in the blood and urine of diabetics. Acetone is one of the solvents used in Âglue sniffingÊ. Serve toxic effects have been associated with blood concentration of 200 to 300 mg/ml; the maximum permissible atmospheric concentration is 1000 ppm.

IIIAcetaldehyde
It can be isolated from tissue and other biological material by acid distillation.
Chemical tests: To 1 ml of the distillate is added 2 ml of ShiffÊs reagent and kept aside for 30 minutes. A purple colour is obtained. Formaldehyde also gives purple colour. To the developed purple colour is then added 0.5 ml of Con. Sulphuric acid. The purple colour disappears, if it is due to acetaldehyde. (In the presence of formaldehyde the purple colour still persists).

IVBenzene (C6H6)
Synonyms: Benzol; coal naphta; benzole; phenyl hydride.
Aromatic odour, which burns with a smoky flame. Practically immicible with water; miscible with dehydrate alcohol, acetone, ether and glacial acetic acid.
***Uses*:** In the manufacture of drugs, chemicals, insecticides, glues, adhesives, varnishes, dyes, paints, explosive, polishes, inks, „dry-cleaning‰ photography and rubber manufacture. Common solvent in clinical and chemical laboratories.
Identification: Benzene is absorbed from the gastrointestinal tract, through the skin, and from the lungs. About 50% of inhealed benzene is retained in the body;

eventually upto 50% of the retained benzene may be eliminated via the lungs. Only very small amounts (approximately 1 %) appearing unchanged in the urine. The remained of the retained benzene is excerted in the urine, mainly as phenol together with small amounts of catechol and cuinol. The urine will also eliminate higher than normal total sulfates and appreciable amounts of phenol as metabolites. (Complete within 24-48 hrs.).
Benzene is rapidly metabolized and is elminated in about 2 days; as unchanged benzene, about 1 percent; glucoronate conjugate, about 10 percent; and etherel sulfate, about 10 percent.

V Carbon Disulphide (CS_2)
Synonyms: Carbon bisulfide, dithio, carbonic anhydride. Colourless or yellow, odorous, flammable liquid. B.P. 46-47^{O}C.
Will dissolve sulfer. Soluble in Ether, CHCl3. CS2 distills very slowly and it is therefore advisable that 250 ml of the distillate should be collected. Second fraction contains most; first distillate gives poor yield.

Chemical tests:
1. Add FelhingÊs solution to 10 ml of urine and boil Grey precipitate.
2. To 10 ml (second distillate), add 5 drops of formaldehyde. 7 drops of 30% KOH, then 3 drops of 10% lead acetate Creamy to black colour or precipitate. Sensitive to 0.1 mg per 10 ml.

VICarbon Tetrachloride (CCL4) Synonyms: Chlorinated hydrocarbon.
Heavy, colourless, nonflammable liquid, sweet
Identification:
Isonitrile test: Place a small amount of suspected liquid in 10 ml of water, or use 10 ml of distillate. Then add 1 ml of purified aniline and 2 ml of 20% sodium hydroxide and gently heat this mixture for several minutes. A positive result produces a foul odour of phenylisonitrile (pink colour). Other chlorinated hydrocarbons, e.g. chloral hydrate and chloroform also give positive test.

VII Chloroform
Synonyms: Chloromiumneesthesium; Chloroformun Pronarcosi; Trichloromethane.
Chloroform is easily separated from organic mixtures by distillation with steam. In fatal cases of chloroform poisoning an examination of blood is very necessary as chloroform passes rapidly into the circulation.

A colourless mobile volatile liquid. B.P. about 61^{O}C; Referactive index 1.44.64. Miscible with dehydrated alcohol and ether.
The vapour of chloroform when passed through a red-hot exit tube is split into chlorine and Hydrochloric acid. Chlorine is known to turn blue when a piece of blotting paper is moistened with starch and iodide of potassium. Hydrochloric acid gives a white ppt. to a solution of silver nitrate.
Identification:
1. Fujiwara's test: To 1 ml of the distillate is added 1 ml of pyridine and 2 ml of 20% Sodium Hydroxide solution in a test tube and heated in a water-bath for 1 minute. A pink to red colour indicates the presence of chloroform.
2. To 1 ml of the distillate is added 1 ml of strongly alkaline solution of 2-naphthol and than heated. A blue colour turning to green and finally brown is observed.

Disposition in the body: Almost completely absorbed after oral administration, rapidly absorbed after inhalation and subject to first-pause metabolism in the liver and lungs. It is rapidly distribute through out the body and is taken up by adopose tissue.

VIII Turpentine

Synonyms: Oils of turpentine; oleoresine from Finus; oil of Pine. This is a colourless oil having a peculiar odour. It is immissible in water but miscible with alcohol, ether and chloroform. Absorbed through skin or by inhalation. Death may occur with a few hours; a pine oil is less volatile and is less toxic.

It is separated from tissue material by steam distillation. The distillate is collected in an ice cold container and is extracted with ether which on evaporation at room temprature leaves oil of turpentine.

Treatment: Dilute with milk, then gastric lavage. Saline cathartics (sodium sulfate, 30g.) do not give fats or oils. Vallium is short acting barbiturates for restlessness or convulsions

Identification:

A drop on a piece of filter paper translucent. Recognized by its characteristic odour. To one drop of the oil is added one drop of con. Sulfuric acid on a spotting tile. A deep reddish-brown colour is produced.

IXEthyl Alcohol

1) Potassium dichromate test: Add 1 to 2 drops of the sample to 1 ml of water followed by 1 ml of a saturated solution of potassium dichromate in 50% V/v sulphuric acid.

Indication: A green colour is given by acetaldehyde, ethanol, isopropylalcohol, methanol and propanol.

2) Iodoform test: A few drops of a strong aqueous solution of iodine in potassium iodide are added to a little of the distillate in a test tube and then sufficient 10% solution of caustic soda is added to change the colour of the solution from brown to yellow. On gently heating on a water bath, a yellow precipitate of iodoform isformed, which is identified by its characteistic smell and by its hexagonal crystals under a microscope.

Besides alcohol, other substances such as aldehyde, acetone, amyl alcohol, lactic acid, etc., give the iodoform reaction.

X Methyl Alcohol

Methyl alcohol is isolated by acid distillation from tissues and stomach wash.

Chemical tests:

1) ***SchiffÊs reagent test:*** To 4.5ml of the distillate is added 0.5ml of ethyl alcohol. To it is added 2ml of 3% KMno4 solution and 0.2ml of phosphoric acid and kept aside for 10 minutes. Then 1ml of 10% Oxalic acid is added followed by 1ml of Con. Sulphuric acid and the contents are cooled to room temperature. Then 5ml of SchiffÊs reagent is added to it and the colour is noticed after 30 minutes. Purple colour is observed. A positive control with 0.5ml of solution (0.5% solution fo methyl alcohol in rectified spirit) mixed with 4.5 ml of distilled water and a blank control with 5ml of distilled water are also performed side by side. The colour developed in the sample is matched with that of the control sample for quantitative estimation.

2) ***Chromotropic acid test*****:** To 0.5ml of the distillate in a test tube is added 0.2ml of 5%

potassium permangante solution. After 5 minutes saturated solution of Sodium bisulphate is added drop by drop until the permanganate colour is discharged. If a

brownish colour still persists, a drop of phosphoric acid is again added to it and then a drop of sodium bisulphate solution. To this colourless solution is then added 5ml of freshly prepared chromotropic acid solution (prepared by dissolving 50 mg. of sodium salt of chromotropic acid into 100ml of con. Sulphuric acid and then heated in a hot water bath at 60 ^{o} C for 30 min., and then cooled) □ A violet colour is obtained.

XI Petroleum Distillates

Incidence of poisoning: Petroleum distillate ingestion involve a relatively small number of poisoning, approximately 7% of the cases and constitute a major cause of hospitalization of victims. Liquid products are more frequently encountered as causes of poisoning and include lubricants, mineral seal oil such as furniture polishes, fuels, cigarette and charcoal lighter fluids. Solvents paint and varnishes, etc. Gasoline sniffing as a means of intentional abuse has been a cause of toxicity.

Petroleum distillates are often stored in unmarked bottles or other common, unlabelled containers in home or workplace. This puts them within easy reach of unsuspecting children who mistake them for something more palatable. One of the major sources of petroleum distillate poisoning in adults is gasoline siphoning, resulting in pulmonary aspiration.

XII Kerosene

Synonyms: Coal oil, Petroleum Bye-product, varsol

Use: Solvent for insecticide, diluent, fuel, cleaning agent.

Properties: Liquid, Characteristic odour, Volatile flammable, oil soluble

Symptoms: Strong odour one breath, gagging and coughing, irritation to eyes and hands, fullness of the head, headache, blurred vision, inabriation.

Test: Place 1 drop on a piece of paper --- transcluent, Burns with a smoky flame. Gasoline or kerosene may show distinct absorbency. Due to the presence of other petroleum distillate. Impurities characteristic to a particular brand product. Scan in the UV range, the NIR, and also Gas Chromatography.

Kerosene, benzene, toluene, or gasoline, plus Margquis reagent □ red.

XIII Nitrobenzene

Oil of Mirbane; Nitrobenzol

Greenish-yellow crystals or yellow, oily liquid. Soluble in alcohol, benzene and ether; slightly soluble in water.

Toxicity: Highly toxic by ingestion, inhalation and skin absorption.

Urine may have characteristic shoe polish odour; will be brown due to p-aminophenol.

Symptoms: Characteristic odour of bitter almonds (shoe polish), headache, dullness, nausea, vomiting, Bslck tounge, diarrhea, weak respiration, Irregular pupils. Toxic symptoms may some times be delayed.

Identification: Seperated by steam distillation. Distillate Max. 270 nm; Min. 228 nm. Steam distil into chloroform; separate the chloroform and then evaporated □ oily

Nitrobenzene (b.p 207 ^{o} C) to 2 ml of Nitrobenzene, add 2 ml of H2So4 and three ml of fuming nitric acid □ dinitrobenzene crystals (MP. 90 ^{o} C). To the dinitrobenze (above) plus several drops of absoluted alcohol (to dissolve), Add 3 drops of sodium hydroxide (40%) And 1 ml of fructose (1%)□ violet colour □ brown.

XIV Acetic Acid

Acetic acid is also known as glacial acetic acid or strong vinegar. It is a colourless liquid having characteristic penetrating odour. It is used in various industries.

Symptoms: Odour of vinegar, burns on skin, mouth, esophagus, severe gastro intestinal corresion, abdominal pain rapid and weak pluse, slow and shallow breathing, convulsion, collapse, shock, death.

Identification in stomach contents:

1) Turns blue litmus pink.
2) Characteristic smell.
3) On addition of neutral ferric chloride (neutralisation is done by ammonium hydroxide) solution red colour is formed.
4) Genlty heat with ethyl alcohol + 1 drop of sulphuric acid = fruity smell of ethyl acetate.
5) A drop of the test solution is mixed on a spot place with a drop of a 5% solution of lanthanum nitrate and a drop of 0.01N iodine solution. A drop of 1N ammonia is added and in a few minutes (in the presence of acetate) a blue or blue brown ring develops around the drop of ammonia.

XV Oxalic acid

Oxalic acid and its sodium or potassium salts are used as bleaching and cleaning agents, ink eradicator, metal polisher and rust remover. It is a colourless, crystalline solid having bitter acidic taste. It is soluble in water, alcohol and sparingly soluble (1gm/100ml) in ether. The acid is also available in some vegetables. It is a powerful reducing and strong corrosive agent.

Symptoms: Burning in mouth, stomach and throat, extreme thirst, welling of tongue, nausea, vomiting diarrhea, cold cyanotic skin, dilate puils, dyspnea, tremors, brown blck appearance of stomach contents, severe damage to kidneys. Anuria, edema, muscular weakness twitching of facila muscles, possible circulatory and respiratory failure, coma, death.

Identification: Acidify gastric contents, vomit or residue with hydrochloric acid. Add large volume of alcohol to dissolve the oxalate and heat gently on steam bath to precipitate extraneous proteins. Keep adding alcohol heating and filtering until no more proteins are precipitated. Finally, heat until all the alcohol is evaporated. Add minimum water, transfer this residue to a separatory funnel and extract with large volume of ether. As oxalates are more soluble in alcohol or water than in ether, several extractions are necessary. Finally, evaporate the ether and to several aqueous portions following tests are done:

1) To 1 ml solution add 1 drop of sulphuric acid and then add dilute (1:200) potassium permanganate solution colour of permanganate goes away due to reduction.
2) Add a few drops of strong solution of ferrous sulphate lemon yellow precipitate.

2.5 INORGANIC POISONS (METALLIC AND ANIONS)

2.5.1 GENERAL BACKGROUND

The poisons in this group have been used frequently, probably because in general they are potent, tastless, readily available, and produce symptoms similar to many common diseases. For example, the substitution of arsenious oxide for the contents of one or

two prescribed capsules can have fatal results with all the appearance of a straightforward drug overdose suicide.

Definition: An inorganic poison may be metal, a metalloid, metal element, a salt, an acid or a base.

Available forms: Available forms may be a liquid or in a solid form. The important metallic poisons in this group are: Arsenic, antimony, mercury, lead, copper, thallium, zinc, manganese, barium and radioactive substances. The salt of the metals are mostly toxic and hence are of great toxicological importance.

Source and form of crime/questioned sample: Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary are in the form of viscera, body fluids, material objects and plant materials. In survival cases like living persons stomach wash, vomited material and stained cloths etc., blood sample, urine and faeces if available. Suspected material recovered from the possession of the victim or accused and from the scene of crime such as medicines, containers, foods and drinks, residual poisonous materials etc.

A number of unrelated poison are in gaseous form. Through there are very many of these in existence especially in the industrial environment, only a few are seen frequently in forensic practice.

Control sample: Pure forms of inorganic poisons standardized for Laboratory purpose procured from recognized Laboratories is used for comparative chemical analysis. Database of pure inorganic poisonous substances available in various instruments is utilized for comparative chemical analysis.

2.5.2 METHODS AND PROCEDURES

Sample Preparation: The metallic substances from tissue may be isolated by two processes viz. 1. Dry ashing process 2. Wet digestion process.

Dry ashing process:

This process involves heating the tissues at 450^{o} C. It is used only when the metallic substance is non-volatile. The process converts the material into ash, which is then tested for different metals.

Wet digestion process:

In the wet digestion process, the organic matter comprising the tissue is destroyed by oxidation, using an excess of oxidizing agent, leaving behind inorganic ions. Nitric acid and sulphuric acid mixture is generally used as oxidizing agent.

Analytical procedures: Individual testing methods.

I Arsenic

Arsenic is a grey substance which is said to be non-poisonous as it is insoluble in water and therefore incapble of absorption from the alimentary canal. However, it is continuously changing into arsenious oxide or white arsenic which is testless and most poisonous. Arsenic causes toxicity by combining with sulphydry enzymes, thus interfering with cell metabolism. Compounds of arsenic are in common use in the arts, industry and agriculture and are consequently prepared in large quantitieas. The element or its derivatives are (1) Arsenious oxide (Ar_2O_3) (2) Sulphides of arsenic (Ar_2S_3) (3)

Copper arsenite and others.

Chemical tests:

Gutzeit test: The solution obtained from the Wet digestion process is tested by this technique. One ml of the solution is taken into a Gulzeit apparatus, 2 pellets of pure Zinc metal are put into it and add 5 ml of dilute sulphuric acid are poured over the contents. The evolved gas is purified by passing over lead acetate paper. (To obsorb sulphide gas) and finally is reacted with mercuric chloride test paper. A yellow stain on the paper indicates the presence of arsenic.

II Barium

In its metallic form, there are no toxic manifestations, but some of the soluble compounds in large doses are poisonous. The principal salts are the chloride, nitrate and the carbonate, the first being the most poisonous. These are constituents of certain rate poisons. The nitrate is also used in green fire and fireworks. Barium sulphate is insoluble and therefore non toxic when used as an opaque medium in roentgenology.

Barium sulphide is used as a depilatory and the chromate is used as a depilatory and the chromate is used in dyes and paints. The barium ion is highly poisonous. It has a local irritant action. In addition it induces a change in permeability of polarization of the cellular membrane which results in stimulation of all muscle cells indiscriminately.

Barium salts thus acts as cardiac poisons the ventricles of the heart after death being found rigidly contracted. They also paralyse the CNS.

The fatal dose of absorbed barium is approximately 1 gram. Death occurs usually from two to twelve hours.

Chemical tests:

Residue obtained by dry digestion is dissolved in 2 ml of conc. Hydrochloric acid, boiled and filtered.

(1) Flame Test: A persistence apple green flame is observed.

(2) A portion of the acidified solution is boiled with few drops of conc. Nitric acid, made alkaline with ammonium chloride and ammonium hydroxide solutions, filtered if necessary and to the clear solution is added excess of ammonium carbonate solution. A white precipitate which dissolve in acetic acid indicates the presence of Barioum.

IIIAntimony

Antimony occurs in the form of an oxide and sulphide, and is present as an impurity in many mineral ores, poisoning by it is rare. The mechanism of poisoning is similar to that of arsenic poisoning by combining with suphydryl enzymes and thus interfering with cell metabolism.

The compounds important from a medicolegal point of view are tartar emetic (antimony- potassium tartrate) and butter of antimony (antimony trichloride). The other antimony preparations include antimony sulphide, antimony hydride (stibine), and organic preparations.

When antimony trichloride (butter of antimony) has been taken, the symptoms produced are more markedly those of a corrosive like hydrochloric acid than of an irritant.

Fatal dose: The toxic dose of tartar emetic is about 0.75 gram in single dose. After ingestion of tartar emetic, death usually occurs within 24 hours.

Chemical test:
Reinsch's Test*:* A bluish black deposit on the copper strip indicates the presence of antimony.
The stained strip after necessary cleaning is heated in the Reinsch tube and viewed under the high power of the microscope. Characteristic needle shaped crystals of Sbo are obtained.

IVCopper (TAMBA)
Copper is not poisonous in the metallic state but some of its salts are poisonous. The two most commonly known salts of copper are the solphate or blue vitrol (Nila tutia), and the subacetate or verdigris (Zangal). Copper sulphate is a crystalline salt with blue colour and a metallic taste. Copper is a powerful inhibitor of enzymes. Copper subacetate is a bluish green salt formed by the action of vegetable acids on copper cooking vessels which are not properly tinned. Two other copper compounds viz, the arsenite and the acetoaressenite have already been considered along with arsenic. The chloride and carbionate are also irritant poisons.

Chemical tests:
1. The analysis of copper is done in the residue obtained after incineration of the organic material in the muffle furnace.
2. In the presence of copper the dry residue generally assumes a greenish blue tinge. The residue is obtained in 5 ml of conc. Hydrochloric acid boiled and filtered. The presence of copper is established by performing the following test in the clear filtrate. 5ml of the acidic solution is diluted with 2ml of water, warmed and then to it is passed hydrogen sulphide gas. A brownish black precipitate is obtained. The precipitate is filtered through Whatman filter paper, washed trice with boiling water and then dissolved in 2ml of nitric acid. The nitric acid is removed by evaporation and the residue is taken in 1.0ml of water. This solution is subjected to the following test.
(1) Two drops of the aqueous solution are taken in a spotted tile and to it is added few drops of ammonium hydroxide. A blue colour is obtained.
(2) The blue coloured solution obtained in test (1) is made acidic by adding few drops of acetic acid and then a few drops of potassium ferrocyanide solution are added to it. A chocolate brown colour is obtained.

V Mercury
Metallic mercury, also known as quicksilver, is a liquid metal having a bright silvery luster. It exists in nature as the metal itself and as the sulphide (cinnabar or ras sindoor). Metallic mercury is not poisonous if taken by mouth because it is not absorbed but causes poisoning if finely divided and inhaled, swallowed or rubbed into the skin. It vaporizes even at room temperature to an extent sufficient to permit the inhalation of toxic amounts. The vapour may be source of danger in industry and even in the research laboratory.
Mercury and its salts are used very extensively in the arts, commerce, denistry and medicine. It is used in the metallic form as inorganic mercurous (monovalent) and mercuric (divalent) salts, and in combination with organic molecules. Mercuric compounds being soluble are intensely poisonous.

Mercuric chloride obtained in the form of white crystalline powder or tablets are use as a germicyde, coloured by cosin, methylene blue or other dye. It has an archid metallic taste, no smell and by far the most common cause of acute poisoning. The other poisonous mercurial salts are mercuric oxide, mercuric ammonium chloride, mercurous chloride or calome, mercuric potassium iodide, mercuric nitrate and mercuric cyanide.
Fatal dose & fatal period: The fatal dose of corrosive sublimate is about 200 to 300mg death may occur within a few hours but is usually delayed for 3 to 5 days.

Chemical tests:
Reinsch Test: A silvery shinning deposity on the copper strip indicates the presence of mercury.
After necessary cleaning the dired shining copper strip pieces are heated slowly in a Reinsch tube and the deposit on the cooler side is viewed under a microscope. Shining round globules of metallic mercury are observed.

VILead
Acute lead poisoning is extremely rare. The only common soluble salt is the acetate, and this is dangerous only in large doses. The fatal dose of absorbed lead has been estimated to be 0.5 gram. Fatal dose of lead acetate is about 20gm. fatal period is uncertain. Death may occur on the second or third day. Acute poisoning is rare, and may be followed by chronic poisoning.

Chemical test:
The analysis of lead is done in the solution obtained by wet digestion process of the organic material. The presence of lead is established by the following tests:
(1) To one ml of the test solution is added one ml of dilute hydrochloric acid. A white precipitate is obtained which dissolve on boiling and reappears on cooling.
(2) To one ml of the aqueous test solution is added one drop of dilute nitric acid and one ml of potassium iodide solution. A bright yellow precipitate is obtained. On boiling the content, the precipitate dissolves out and on cooling golden yellow spangles are obtained.

VII Zinc
The residue contained by dry digestion method is dissolved in 2ml of conc. Hydrochloric acid, boiled and filtered. To 0.5ml of the filtrate is added few drops of nitric acid and
boiled. The solution is made alkaline by adding ammonium chloride and ammonium hydroxide solutions and the filtered. The clear filtrate is tested for the presence of Zinc.
To 1 portion of the ammonical solution is passed hydrogen sulphide gas. A white precipitate indicates the presence of Zinc. The precipitate is filtered, washed thrice with 10ml portions of boiled water and dissolved in 2ml of dilute hydrochloric acid. The solution is again boiled to remove any traces of remaining H2S gas. To it is added saturated caustic soda solution dropwise. A white precipitate is obtained. On adding excess of alkali and boiling the precipitate dissolves. To this clear solution, hydrogen sulphide gas is again passed. A white precipitate confirms the presence of Zinc.
A portion of the ammonical solution is acidified with acetic acid and 0.5ml of potassium ferrocyanide solution is added to it. A white gelatinous precipitate is

obtained. Few drops of bromine water when added to the precipitate producing a yellow colour which on boiling forms a bluish green precipitate.

VII Bromide

To a portion of the extract and equal volume of silvernitrate solution. A yellow ppt. Which is insoluble in 30% v/v solution of nitric acid and slightly soluble in dil. Ammonia solution indicates the presence of bromide.

To a portion of the sample add 5ml of chlorine water and 3ml of chloroform. A yellow colour, which is extracted into the chloroform layer, indicates bromide.

IXChloride

To a portion of the extract add an equal volume of silver nitrate solution. A white curdly precipitate of Afcl insoluble in dil nitric acid but soluble in dil. Ammonia solution and in potassium cyanide and sodium thiosulphate indicates Cl.

Dipheny carbazide reagent (chromyl chloride test). Add a small quantity of solid potassium dichromate to a few drops of test solution. Add 1 drop conc. Sulphuric acid. Gently heat the mixture. The gas evolved turns dipheny carbazide spot on filter paper violet.

X Chlorate

Acidify a portion (2ml) of the sample with dilute sulphuric acid and add 1ml of a 1% solution of indigo carmine. A deep blue colour formation indicates the presence of chlorate.

Place a few drops of the test solution (2ml) in a micro crucible and add 2 drops of magenese sulphate in phosphoric acid reagent. Warm gently a violet colour appears.

XIFluoride

Add 2ml of a 0.25% solution of calcium chloride to 2ml of the extract. A white gelatinous precipitate which in insoluble in 30% v/v solution acetic acid and slightly soluble in dilute hydrochloric acid.

Zirconium-alizarin Reagent: On a spot plate mix 2 drops each of alizarine S (0.1% aqueous solution) and Zirconyl Chloride solution (0.1g. solid in 20ml of conc.

Hydrochloric acid and diluted to 100 kl). Add a few drops of extract. The decolourisation of Zirconium take to a clear yellow solution indicates fluoride.

XII Nitrite

Place a few drops of the test solution in a semi-micro test tube. Add 10 drops of Indole reagent. (0.15% solution of Indole in rectified spirit) and 5 drops of 0.8 M sulphuric acid. A purplish colouration indicates nitrite.

Place a few drops of the neutral or acidic solution of the sample on a spot plate an mix it with a drop of sulphanilic acid reagent followed by a drop of the --- napthal amine reagent. A red colour is formed.

XII Nitrate

Place a few drops of test solution on a spot plate. Add a drop of con. H2So4 and a small crystal of brucine. Stir with a glass rod. A blood – red colour is produced if nitrate is present.

Mix on a spot plate a few drops of the neutral or acetic acid solution of the sample with a drop of sulphanilic acid reagent and a drop of the ----- nepthyamine reagent and

add a few milligrams of pf Zinc dust. A red colouration indicates nitrate. Place a drop of the acid solution of the sample on a quantitative filter paper. Add a drop of ammonium molybdate reagent followed by a drop of 0.05% benzidine acetate. Add the paper over ammonia vapour. A blue stain is formed (in the presence of arsenates 1 drop of tartaric acid-ammonium molybdate reagent is used in place of ammonium molybdate. Warming is necessary before exposure to ammonia vapour).

XIII Sulphite

Warm 2 ml of the test solution in a semi-micro test tube with a bittle dil. Hydrochloric acid in a hot water bath and expose the evolved gas to filter paper containing a stain of Ni(II) hydroxide. The stain aquires a black colour.

XIV Sulphide

Mix on a spot plate a few drops of the alkaline test solution with a drop of 1% solution of sodium nitroprusside. A violet colouration appears.

XV Hydrochloric acid

Hydrochloric acid is a colourless gas having an intensely irritating odour.
It is extremely soluble in water. The commercial grade acid is a gas in water having yellow colour and is used as metal cleaner, flux for soldering in industry and in medicine.
This acid is normally found in stomach at approximately 0.2% to 0.5% w/v concentration.
Symptoms: Salivation, ulceration, neusca vomiting, paralysis of limbs are some of the special symptoms.

Identification: (In stomach contents)

1. Turns blue litmus pink (Red).
2. Keep nearby a glass rod previously dipped in ammonium hydroxide solution --- white fumes of ammonium chloride. To a 2 ml of test solution add 1 ml 10% silver nitrate solution and 1 ml 10% nitric acid white precipitate of silver chloride which can be dissolved in ammonia.
3. Quantitative determination can be done by titration with standard sodium hydroxide solution.

2.6 NEUTRAL POISONS (ORGANIC NON-VOLATILE)

2.6.1 GENERAL BACKGROUND

Organophosphorous Insecticides:

Lange and _kreger‘ in 1932 observed the strong cholonegic effects of vapours of diethylphosphorous fluoridate in human being. However the practical development of these compounds as insecticides is mainly due to the original and extensive work of _Schrader‘ and his co-workers from 1937. The organophosphorus compound has a great variety of pesticidal properties like insecticides, acaricides, nematocides, herbicides, defoliants and fumigants. Most of the compounds of this group are required only in small quantities for the control of pests. Pesticidal activity is also very rapid. Many of the compounds break down to non-toxic compounds very rapidly in vertebrate animals. Also they do not accumulate in the body animal. Though many

of the early compounds of this group had relatively high toxicity to vertebrates, recently a large number of organophosphrous compounds with moderate to low toxicity to mammals have been synthesized and have been put in the market. More than 100,000 different organophosphorus compounds have been synthesized and evaluated as pesticides of these more than 80 are widely used in agriculture.

Definition: These are considered as derivatives of the corresponding acids or hydrogen phosphide (phosphine).

Available forms: Available in solid, semi solid and liquid forms.

Organophosphrous Insecticides, Derivatives Of

1. Phosphoric acid (ddvp-phosphamidon etc.)
2. Thiophosphoric acid (parathion, memeton etc.)
3. Dithiophosphoric acid (malathion etc.)
4. Pyrophosphoric acid (tepp, schraden etc.)
5. Phosphonic acid (epn)

Derivatives of phosphorus acid have the ending _ITE' and those of phosphoric acid the ending _ATE'. For example the diethyl ester of phosphorus acid carries the name diethylphosphite and that of phosphoric acid is called diethyl phosphate.

Derivatives of Phosphoric Acids

The insecticidal and acaricidal properties increase when we go from phosphates to phosphates. The inportant derivatives of phosphoric acid having insecticidal activities listed below.

Sr. No.	NAME OF INSECTICIDE	CHEMICAL NAME
1.	Dichlorvos DDVP, Nuvan	O,O-dimethyl o-2,2-Dichlorovinyl phosphate
2.	Naled	O,O-dimethyl –O-2,2-dichloro – 1,2-dibromoethyl phosphate
3.	Phosphamidon (Dimecron)	O,O-diethyl –O-(2,2-chloro-N, N-diethyl-carbamyl)- Methylvinyl phosphate
4.	Phosphinon (Phosthenon)	O,O-dimethyl-O-(2,2-dichloro-1-chloroethoxy vinyl) phosphate
5.	Phosdrin (Mevinphos)	O,O-dimethyl –O-(1-methyl-2-carbo-methoxy vinyl) – phosphate
6.	Bidrin	(3-dimethoxy phosphinyloxy) – N-N-dimethyl crotonamide, dimethyl phosphate of 3-hydroxy N-N-dimethyl elscrotonamide)

7.	Birlane (Chlorfenviphos)	2-chloro-1-(2,4-dichlorophenyl) vinyl
8.	Gardona	2-chloro-1 (2,4,5-trichlorophenyl) vinyl dimethyl phosphate
9.	Dimefox (pestox, Hnanne)	Bis-dimethyl flurophosphate
10.	Mipa fox (pestox-15, Isopestox)	N,N-disopropyl phosphorodiamide fluoride)
11.	Avenin	O,O-dimethyl –N(isopropoxycarbamoy) phosphate
12	Cyolane (Dithiolane, Iminophosphate)	Diethyl-N-3-dithiolanyl-2-iminophosphate)

Derivatives of Thiophosphoric Acid

Replacement of one of the oxygen atom by sulfer in the derivaties of phosphoric acid generally decreases the toxicity of the compound for mammals without any substantial changes in insecticidal or acaricidal activity. Today more than 30 derivatives can be either a thiolo or thino structure.

Thiolo derivatives are more toxic to mammalÊs then thiono derivatives. When the thiono isomers are heated or acted by the certain reagents, they are converted into thiolo isomer.

Among the large number of compounds used as pesticides, the following are widely used.

Sr. No.	Name Of Insecticide	Chemical Name
1.	Parathion	O,O-dimethyl O-4- nitrophenyl
2.	Methyl Parathion	O,O-dimethyl –O-4- nitrophenyl thiophosphate
3.	Paraoxon	O,O-dimethyl –O-P- nitrophenyl phosphate
4.	Thiophos ME	O,O-dimethyl-O-ethyl – O-4-nitrophenyl thiophosphatee
5.	Fenitrothion (Sumithion)	O,O-dimethyl-O,4-nitro-3-methylphenyl thiophosphate
6.	Chlorothion	O,O-dimethyl-2-chloro-4-nitrophenyl thiophosphatee
7.	Dicapthon	O,O-dimethyl-O-2 – chloro-4-nitrophenyl thiophosphatee
8.	Ronnel	O,O-dimethyl-O-2,4.5-trichlorophenyl thiophosphatee
9.	Bromophos	O,O-dimethyl-O-2-5-dichloro-4-bromophenyl thiophosphatee
10.	Fenthion (lebaycid)	O,O-dimethyl-O-(-4-methyl marcapto-3-methyalphenyl) thiophosphate
11.	Dasanit	O,O-dimethyl –O-p-(methylsulphinyl) phenylphosphate

12	Diazinon	O,O-dimethyl-O(2-esopropyl-4-methylpyrimidyl-6) thiophosphate
13.	Demeton (Systox)	O,O-dimethyl-2-ethylmercaptoethyl thiphosphate
14.	Methyldemeton (Metasystox)	O,O-dimethyl-2-ethylmercapto ethyl thiophosphate
15.	Dursban	O,O-dimethyl-O-3,5,6-trichloro pyridyl thiophosphate
16.	Potasan	O,O-dimethyl-O-(-4-methyl-Coumarinyl 7 thiophosphate.
17.	Endothion	O,O-dimethyl-S-(5-methoxy-pyronyl-2-methyl) thiophosphate
18.	Vamidothion	O,O-dimethyl-S-2-(-1-N-methoxy-pyronyl –2-methyl) thiophosphate
19.	Acetofos	O,O-dimethyl-S-carboethoxy methyl thiophosphate.

Derivatives of Dithiophosphoric Acid

More than 25 different derivatives of dithiophosphoric acid are being used as insecticides in agriculture. In most cases the toxicity of the derivatives of dithiphosphoric acid is less than the corresponding compound of thiophosphoric acid. But the chemical stability of the compounds increased in dithiophosphoric acid derivatives.

Some of the important derivatives of dithiophosphoric acid are given below.

Sr. No.	Name of Insecticide	Chemical Name
1.	Malathion (Carbophos)	O,O-dimethyl-S-1,2-dicarboethoxy ethyl dithiophosphate.
2.	Dimethoate (Rogor)	O,O-dimethyl-S-(N-methyl-carbamoylmethyl) dithiophosphate.
3.	Morphothion (Ekatin-M)	O,O-dimethyl-S-(morpholinocarbamoyl methyl) dithiophosphate.
4.	Formothion (Anthio)	O,O-dimethyl-S-(N-methyl-N-formylcarbamoylmethyl) dithiophosphate.
5.	Thimet (Phorate)	O,O-diethyl-S-(ethylthiomethyl) dithiophosphate.
6.	Ethion.	O,O,O,O-tetraethyl-S,S-methylene bis (dithiophosphate).

7.	Ekatin (Thiometon)	O,O-dimethyl-S-(2-ethylmercaptoethyl) dithiophosphate.
8.	Disyston (Dithiosystox, Disulfotone).	O,O-diethyl,-S-(2-ethylmercaptoethyl) dithiophosphate.
9.	Tetrathion	O-methyl-O-ethyl-S-(2-ethylthiorthyl) dithiophosphate.
10.	Phosalone	O,O-diethyl-S-(6-chlorobenzolinyl-3-thyl) dithiophosphate.
11.	Imidan (phthlophos)	O,O-dimethyl-S-napthylimidomethyl) dithiophosphate.
12.	Guthion (Azino-phosmethyl)	O,O-dimethyl-S-(3,4,-dichloro-4-keto-1,2,3-benzotriazinyl-3-methyl) dithiophosphate.
13.	Menazone (Sayfos).	O,O-dimethyl-S-(4,6-diamino-1,3,5, triazinyl 2-methyl) dithiophosphate.

Miscellaneous Organophosphrous Compounds:

Sr. No.	Name of Insecticide	Chemical Name
1.	Trichlorfon (Diptrex).	O,O-dimethyl-(1-hydroxy-2,2,2-Tri-Chloroethyl) phosphate.
2.	EPN	(O-ethyl-O-(4-nitrophenyl) benzene Thiophosphate)

Source and form of crime/questioned sample: Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary are in the form of viscera, body fluids, material objects and plant materials. In survival cases like living persons stomach wash, vomited material and stained cloths etc., blood sample, urine and faeces if available. Suspected material recovered from the possession of the victim or accused and from the scene of crime such as medicines, containers, foods and drinks, residual poisonous materials etc.

Control sample: Pure forms of neutral poisons standardised for Laboratory purpose procured from recognized Laboratories is used for comparative chemical analysis. Database of pure neutral poisonous substances available in various instruments is utilized for comparative chemical analysis.

Detection and identification of organophosphorus insecticides

The major portion of the analytical methods for detection and determination of residues of organophosphorus insecticides are based on chromatographic techniques mainly G.C. and T.L.C.

2.6.2 FUNGICIDES

To increase the food production, control of plant disease ranks only next to control of insects. Homer, as early as 1000 BC mentioned the use of sulfur as a fungicide.
Schulthess in 1761 suggested for the first time the use of copper sulfate as seed dresser. The discovery of Bordeaux mixture in 1882 has been a big step in control of plant diseases.
In India, control of plant diseases has been practiced from an ancient time. In earlier days, they have been using certain cultural practices and some natural compounds.
_Ozanna' was the first person in India to advocate the use of copper sulphate in 1888 for
control of sorghum smut diseases. In 1904, Lawrence used the Bordeaux mixture for the first time in India. Subsequently, a number of synthetic fungicides were developed and have been widely used in India.

I Organic Sulfur Fungicides

Some of the derivatives of dithiocarbamic acid has insecticidal and fungicidal properties. However, dithiocarbamic acid itself is not known to exist in the free state. When the substituted primary and secondary aliphatic and aromatic amines are treated with carbon disulfide in alcoholic solution, substituted dithiocarbamates are produced.

Isolation of Organic Sulfur Fungicides:

Dithiocarbamates are water-soluble compounds hence their isolation from biological materials is a difficult task. Two methods are suggested for their isolation from biological and non-biological materials.
1. Take 50-100g. of biological materials in a conical flask, add to it 50ml ethyl alcohol or methyl alcohol and heat gently for about 15min. at 60 o C. cool the flask and keep aside for 2h. Filter the material through Whatman No.1 filter paper. Concentrate the filtrate, on hot water, to minimum required amount and use it for further test.
2. Dithiocarbamates are somewhat soluble in ÂButenolÊ hence these compounds are isolated from biological materials by usual extraction procedure with Butenol. Concentrate the extract in vacuum and use for further test.

Test for Dithocarbamates:

1) Test by conversion into cupric salts soluble in organic solvents:
A characteristic feature of water-soluble dithiocarbamates and their N-methyl substituted derivatives is seen, their precipitation as brown cupric salts, which dissolves in water- immiscible organic liquids to produce red-brown solution.

II Copper Fungicides

Bordeaux mixture: A mixture of copper sulfate and lime was initially applied as a paste and this gained wide recognition under the name of „Bovillie Bordelaise‰ (Bordeaux mixture).

Burgundy Mixture: Burgundy mixture or soda mixture is prepared by Masson by allowing on part of copper sulfate pentahydrate to react with one or two parts of crystalline sodium carbonate in solution (Na_2CO_3 $1OH_2O$).

Copper oxychloride ($CuOCl_2$): Copper exychloride is one of the low soluble copper fungicides produced by the action of air on cupric chloride solution or scrap copper. It is marketed in the form of wettable powder containing 50 and 90% copper oxychloride.

Copper oxide (Cu_2O): Red oxide of copper is used as a seed treatment fungicide.

2.6.3 HERBICIDES

Now days, herbicides are widely used in agriculture. This widespread use contributes to their presence in some poisoning cases in forensic toxicology. Residue analysis of theses compounds was initially carried out by colorimetric methods or by thin-layer chromatograph (TLC). At present, gas chromatography (GC) is more commonly used in the residual analysis of these herbicides in different matrices due to the high sensitivity obtained with nitrogen-phosphorus (NPD) and electron – capture (ECD) detectors and to the selectivity and identification of residues achieved by coupling GC with mass spectrometry (MS). An alternative technique with growing use in the determination of pesticides residues, is high performance liquid chromatograph (HPLC).

I Ureas

Substituted ureas are also one of the oldest herbicide groups used in agriculture, phenylureas being one important class of these substituted ureas, and sulphonylureces is another main class.

These compounds are mainly extracted from water and biological materials with (1) dichlormethane or (2) chloroform Another important procedure is solid-phase extraction (SPE), C18 being the phase normally employed.

The sample with low water contents are usually extracted with (1) methanol (2) dichloromethane and (3) acetone with mechanical shaking.

Clean up of extracts is some times carried out by column. Chromatograph on Florisil or Silica gel.

II Dinitroanilines

Dinitroaniline herbicides are usually soil applied in a wide variety of agronomic crops.

These compounds are extracted from water and biological materials with dichloromethane partition. Methanol or ethanol is widely used in the extraction of these compounds are extracted from water and biological materials with dichloromethane partition. Methanol or ethanol is widely used in the extraction of these compounds from the samples with low water contents. Generally, the clean-up of extracts, is accomplished by LLP along with florisil column.

IIIChloroacetamides

These herbicides also termed anilides are used pre-emergence for the control of annual grass and certain broad-leaf weeds.

Extraction of these compounds from water and biological materials has been done by liquid-liquid partition with dichloromethane, along or in mixture with acetone or acetonitrile followed by a Florisil column clean – up or by SPE, usually with C18 cartridges, without further clean-up.

IVThiocarbamates

Thiocarbomates have been used as herbicides in maize and wheat. The extraction of these compounds from water and biological materials has been carried out at different pH with good recoveries using dichloromethane or hexane and a Florisil column clean-up has often been required.

Water miscible solvents, like methanol, acetonitrile, and acetone are generally used for the extraction from the samples of low water contents.

Detection and Determination: Gas Chromatographic Method:

Various groups of the herbicides, i.e. phenoxyacids, benzonitries and substituted ureas cannot be directly analysed by GC and suitable derivatives have to be obtained prior to GC determination.

Determination of benzonitriles at residue level have been commonly accomplished by derivatization with dizomethane or with trimethyl silyl diazomethane followed by GC analysis.

Some phenylureas can be determined directly by GC. However alkylation of phenylureas have been carried out commonly with alkyl iodide.

Direct GC determination of intact suphonylurea herbicides has not been achieved due to their thermal instability. Alkylation of sulphonylureas has been carried out to overcome thermal instability and improve chromatography. Diazomethane has been used in the methylation of these compounds with good results.

2.6.4 PYRETHROID INSECTICIDES

The pyrethroids are now broadly recognised the fourth major class of synthetic organic insecticides. Since the commercial production of the first photostable pyrethroid in 1976, this group of compounds has achieved worldwide use, with widespread agriculture and environmental health applications of the major insecticide classes. The pyrethroids as a group are among the most potent as insecticides but have been considered to exhibit comparatively low toxicity to mammals.

Permethrin, cyfluthrin, cypermethrin, deltamethrin and fenvalerate are broad spectrum synthetic pyrethroid insecticides with greater photostability enhanced insecticidal activityand low mammalian toxicity. Their effectiveness against a wide range of insects at extremely low dosages and limited persistence in the environment stimulates interest for use in agriculture around the world. Owing to their availability, these insecticides are misused in homicidal and suicidal poisoning. Consequently, characterization of these insecticides is necessary in Forensic Toxicology.

Attempts are made to provide the maximum information regarding extraction, purification detection and determination of these pyrethroid insecticides by different methods in different matrices.

Toxicity: Toxicity of some pyrethroid insecticides is given below:

Fenvalerate: Accute oral toxicity in rats – 320-400 mg/kg. Cypermethrin: Accute oral toxicity in rats – 303mg/kg.

Deltamethri: Accute oral toxicity in rats – 128-138mg/kg.

Detection, Identification and Determination:

Almost all the analytical methods for detection of pyrethroid residues are based on chromatographic techniques, mainly GC and some on HPLC and TLC.

Metabolites of pyrethroids are relatively non-toxic or of low toxicity. For this reason, the different methods developed for pyrethroid residues analysis have dealt primarily with the analysis of parent compounds.

TLC Method: For the detectin and determination of residues of pyrethroids in various biological and non-biological matrices, few chromogenic reagents are reported in the literature which are listed below:
Phosphomolybdic acid (20% w/v in ethanol) for detection of permethrin, cypermethrin and deltamethrin.
Palladium chloride (0.5% w/v, in 12 mol/dm^3 HCl) for detection of deltamethrin.
Sodium hydroxide (20% in dist. H_2O) phophomolybdic acid (1% in dist. H_2O) and o-tolidine (0.1% in 10% acetic acid) for the detection of pyrethroid insecticides with a nitrile group (cypermethrin, deltamethrin, fenvalerate, cyfluthrin).
Treatment with Br_2 followed by 0.1% o-tolidine with UV irradition (5 min) or under sunlight for 2 min.
Silver nitrate impregnated alumina G plate and irradiation with UV radiation for the detection of halogenated pyrethoids.

2.7 BASIC DRUGS / POISONS (ORGANIC NON- VOLATILES)

2.8.1 GENERAL BACKGROUND

Basing on their physiological action, basic drugs are broadly classified into the following groups:

1. **Narcotic*:*** These drugs affect brain in over and above therapeutic dose.
e.g.Opium, Morphine, Heroine, Codiene
2. **Deliriant poisons:** They also affect the vital part of Brain ;
e.g. Atropine, Hyoscyamine, Cocaine, Muscurine (Fungi mushrooms)
3. **Spinal affecting drugs:** These effect heart. e.g.Strychnine, Brucine.
4. **Cardiac arrest drugs:** These affect heat. e.g. Quinine, Acotinine, Nicotine.

Drug abuses are common. Drugs are consumed by the victim in more than therapeutic doses and hence they go into the blood and urine. So in any clinical cases, extraction of drugs in urine, blood and stomach contents are essential in order to identify the exact nature of drug consumed by the victim. Extra care should, therefore, be taken to take the sample of blood, urine and stomach contents.

Definition: Drugs, which are alkaline in nature, are called basic drugs. These readily react with acids.

Available forms: Drugs/poisons are available as powders, plant products etc.

Source and form of crime/questioned sample*:* Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary are in the form of viscera, body fluids, material objects and plant materials. In survival cases like living persons stomach wash, vomited material and stained cloths etc., blood sample, urine and faeces if available. Suspected material recovered from the possession of the victim or accused and from the scene of crime such as medicines, containers, foods and drinks, residual poisonous materials etc.
Control sample: Pure forms of basic drugs/poisons standardised for Laboratory purpose procured from recognized Laboratories is used for comparative chemical analysis.
Database of pure basic drugs/poisonous substances available in various instruments is utilized for comparative chemical analysis.

2.7.2 METHODS AND PROCEDURES

Analytical Procedures: Individualtestingmethods.

Identification of basic drugs:

Screening test: - Take the extract portion from urine or blood or stomach contents or viscera. Add chloroform and dissolve the contents of the dish in it. Take a few drops of the said chloroform extract on a spot tile. Add a few drops of Mayer's reagent to it. A white or gelatinous whiter precipitate will show the presence of basic drug in general.

Conduct a similar test with another reagent phosphotungistic acid. A red precipitate indicates the presence of basic drug in general.

Colour tests:

Alkaloid	Reagent	Observation
Morphine	MarquiÊs Con. Hno3 MandelineÊs	Violet colour Bright orange-yellow Dark reddish brown
Heroin	MarquiÊs Con. Hno3 MandelineÊs	Reddish purple Pale yellow Reddish brown
Codeine	MarquiÊs Con. Hno3 MandelineÊs	Dark violet Greenish yellow Olive green
Nicotine	Mercuric chloride+ Picric acid	Rose red colour branding needle crystals
Strychnine	Potassium+Conc. dichromate H2So4	Play of colours Red colour appears. Colour disappears on addition of stannous chloride and reappears on addition of conc. HNO3
Brucine	Con. Hno3	Red colour appears. Colour disappears on addition of stannous chloride and reappears on addition of con. HNO3
Cocaione	Cobalt thicyante MandelineÊs Add pot.alume	Greenish blue dark orange ractangular violet crystals

	and dil. KMNO	
Atropine	Evaporate with HNo3 dissolve in acetone add CH3OH+KOH	Violet colour
Quinine	Acidified with H3So4 added 25ml of bromine Water, shaken well & added 2ml of dil. NH2OH	Bright green colour
Phenothiazine	F.P.N. reagent	A variety of colour ranging from pink red, orange violet to blue.
Caffeine	Con. HCL+KLCLO3 Crystals. Evaporated to dryness. Cool add ammonia	Purple colour

Gas Chromatography:
Gas chromatography will detect a wide range of basic drug samples of concentration in the order of 1 lg/ml. the analysis depends on the fact that one nitrogen atom atleast is present in all basic drugs. This nitrogen atom will produce a single in an alkali flame ionization detector. The method of extraction of drugs and selectivity of detector ensure minimal interference from other compounds which do not contain nitrogen.

I Benzodiazepenes
Benzodiazepines are therapeutically used as tranquilizers, hypnotics, anti-convulsants and centrally acting muscle relaxants range among the most frequently prescribed drugs. Diazepam and Nitrazepam are commonly available and are widely associated in crimes.
There are approximately 33 Benzodiazepines containing diverse chemical functionality available. However number of Benzodiazepine drugs for frequent use in the Indian market is limited. Forms of drugs are normally capsules, tablets, injections etc.

Identification:
As this is a large group of drugs containing diverse chemical functionality no one color test is specific for this class of drug. A combination of TLC with selected reagent spray as well as UV will lead to particular banzodiazepine identification.

A) Chlordiazepoxide
Colour tests: Marquis Test – Yellow.
Toxicity: Toxic reaction may be produced by plasma concentrations greater than 3 ug/ml; plasma concerntrations in the region of 20 ug/ml may produce coma or death, but fatalities caused by chlordiazepoxide alone are rare.

B) Diazepam Tranquilliser
***Colour test*:** Formaldehyde-sulphuric acid-orange
Specific Tests:

Dragendorff spray	-	Positive
FPN reagent	-	Yellow Acidified Iodoplatinate soln -
Positive Marquis reagent	-	Yellow

Toxicity: Toxic effect may be produced by blood concentrations greater than 1.5 ug/ml; fatalities caused by diazepam alone are rare, but may occure at blood concentrations greater than 5 ug/ml.

C) Oxazepam Tranquiliser
Colour Test: Formaldehyde-sulphuric acid-Orange.

***Solubility*:** Souluble in Ethanol, Chloroform, Ether, Dioxan; Insoluble: Water

Toxicity: Blood concentration greater than 2 ug/ml may produce toxic effects.

D) Methaqualone
Methaqualone is a hypnotic drug which is now omitted from nay pharmacopieas. However due to its addiction effect it is produced by clandestine laboratories. India is considered as the main source of methaqualone for African countries. In combination with diphenhydramine it is known as mandrax. It is a white crystalline powder having. It is soluble in ethanol, ether and chloroform.
Identification:
1. Methaqualone has characteristic UV wavelength maxima in ethanol 225, 263, 304 & 316 nm and in 0.5 N Sulphuric Acid 234 & 269 nm.
2. Crystal test:

a. Potassium permanganate solution
---□ serrated plates (sensitivity 1 in 200)
b. Sodium carbonate solution
---□ bunches of prisoms (sensitivity 1 in 200)

II Narcotic Drugs
Narcotic drugs produce Narcosis like sleep. In Greek „Narco‰ means to „deadlen‰ of „be numb‰ Due to this property some of these drugs are used as pain killer and hence some of the drugs are known as Narcotic Analgestics. Apart from this action the euphoric effect produced by these drugs lead to abuse.
The term „Narcotic‰ medically refers to opium and opium derivatives or synthetic substitutes that produce opium like effects.
Drugs belonging to this category can be listed in the following categories.
1. Narcotics of natural origin e.g. opium, Coca leaves.
2. Semi synthetic Narcotic e.g. Heroin, Morphine, codine.
3. Synthetic Narcotic e.g. Pethidine, Methadone.

Narcotics of natural origin:
The poppy plant and Coca plant are the source of naturally occurring narcotic drugs.

A) Opium
Opium is the latex obtained by incision from the unripe Ped of the poppy plant. Opium is a dark brown coloured semi solid mass. It contains more than 45 alkaloids, the main alkaloids are morphine, codein, thebain, papavarin & Narcotin. Generally the alkaloids present in the opium, do not exist as free bases, but in combination with acids, the main are being meconic acid, lactic acid and Sulphuric acid. So it is very important to test for meconic acid along with other alkaloids.
To test the alkaloids of opium, the biological material should be extracted in alkaline medium or chloroform
Colour Test: Half of the extracted material is dried in a porcelain basin, the residue is taken in 1 ml of 0.5% acetic acid and tested as below:-
Marquis test:- One drop of the solution is taken into a porcelain basin and dried. To it is added one drop of Marquis reagent (one drop of formalin in one ml of concentrated sulphuric acid) – A purple-red colour is produced, which gradually changes to violet and finally to blue.

Frohde's Test: One drop of the solution is taken into a porcelain dish and dried. To it is added one drop of Frohde's reagent. (1 % Ammonium molybdate solution in concentrate sulphuric acid). – A violet colour changing to green and finally pink is noticed.

Test for Meconic Acid:
This test is performed in the direct acidic aqueous solution or in the aqueous layer left after extraction of the organic poisons.
To one ml of the neutral solution is added few drops of neutral ferric chloride solution, when a blood red colour is formed, which persist even on boiling and by adding dilute hydrochloric acidas well as mercuric chloride solution. The colour is, however, discharged by the addition of stannous chloride solution.

Estimation of opium by instrumental methods;
1. GLC; after purification, the residue is taken in0.5 ml of alcohol or other appropriate solvent and 5 micro litre of it is injected in the GLC column.
2.

B) Morphine and Codeine
Morphine is the principal alkaloid extracted from opium. About 10 to 15 % of the opium exudates contins morphine. Morphine is one of the most effective drugs for relief of pain. Codeine is the another alkaloid found in opium in a smaller percentage (one or two) than morphine. Codeine is used in cough suppressant drugs and anti-diarrhoeal preparations.
One portion of the (biological tissues) extracted material is dried in a porcelain dish, the residue is taken in 1 ml of 0.5 % acetic acid and tested for morphine and codeine.
Marquis Test:- One drop of the solution is taken into a porcelain dish and dried. To this add one drop of marquis reagent (one drop of formalin in one ml of concentrated sulphuric acid)
Purple violet colour indicated the presence of morphine and codeine. (or) all opium alkaloids.

Meck's Test: One drop of the solution is taken into a porcelain dish and dried. To this add a drop of MerkÊs reagent (0.1 gm of selenious acid dissolved in 1 ml of concentrated sulphuric acid)
Morphine : Deep green colour. Codeine : Green/blue colour.
Frohde's Test: One drop of the solution is taken into a porcelain dish and dried To this added a drop of FrohdeÊs reagent. (1 % Ammonium molybdate solution in concentrated sulphuric acid)
Morphine : Purple becoming grey/purplecolour. Codeine : Blue/green colour.

C) Synthetic Narcotics
Synthetic narcotics are produced only in the laboratory by using chemicals. These drugs imitate the effect of the opiates but are not prepared from opium. Methadone and Pethidine are the most widely available synthetic narcotic drugs.
Methadone:
Colour Tests:
Libermann's Tests: One drop of the extract is taken in a porcelain dish and dried. To that add a drop of libermannÊs reagent. (10 g of potassium nitrate is dissolved in 20 ml. Of concentrated sulphuric acid and the contents are diluted to 100 ml bythe same acid.) – BROWN – ORANGE indicates the presence of Methadone.
MandelinÊs Test:: A drop of alkaline extract is taken in a porcelain dish and dried. To this add a drop of MandelinÊs reagent (1% solution of ammonium vanadate in concentrated sulphuric acid) – Green blue colour indicates the presence of methadone.

IIIAnti Histamines
Histamine is a naturally occurring chemical substance in body tissues, which in small doses, has deep and diverse (many) actions on muscles, blood capillaries and gastric secretion. To combat this action anti-histemines are used.
Anti histamines which reduces the action produced by histemine.
e.g :- Pheniramine, Promethazine.

A) Pheniramine
As such it is a slightly yellow oily liquid. Practically insoluble in water; soluble in ethanol, chloroform and ether.
The salts of pheneramine (Phenairamine maleate) soluble in water, ethanol and very slightly soluble in ether.
Colour Tests:
One drop of the extract (Alkaline Biological tissue – shaken with Chloroform) is taken in a white dish, dried and add a drop of cyanogens bromide reagent (cyanogens bromide reagent- 1. Decolorise the bromine solution by addition of potassium cyanide salt and then add more bromine solution, until the solution is pale yellow. 2. Prepare a saturated solution of aniline water. These solutions are stable for one weak. Mix equal volume of the two solutions immediately prior to the test) – Orange colour indicates the presence of Pheneramine.
Libermann's Test:- Red – organge colour indicates the presence of Pheneramine.

B) Promethazine
The salt of promethazine (promathazine hydrochloride) is a white or faintly yellow crystalline powder, which is slowly oxidized on prolonged exposure to air, becoming blue in colour melting point about 222o with decomposition.
Colour Tests:

Formaldehyde – sulphuric acid – blue violet. MandolinÊs Test - Green – violet

IVSupha Drugs

Sulpha Drugs „Wonder Drugs‰ are used against a broad range of bacterial in fections. Sulphanilamide was one of the first sulfa drugs and these days it has been replaced by more effective derivatives.

The use of sulphonamide for a prolonged period or its use is large does produce toxic effects and may cause death. Due to idiosynorasyproduce toxicity.

Colour Tests:

1. To a drop of the solution taken on a spotting tile added pdimethyl amino benzaldehyde solution. Yellow to orange colour is obtained. (The reagent is prepared by dissolving 0.1 gm of pdimethyl amino benzaldehyde in 10ml of water containing few drops of conc. HCL)
2. 0.5 ml of the acetone extract is taken in a test tube. To this added 0.5 ml of dil. HCL (3N). The test tube is placed in water bath to remove acetone.
3. The test tube is cooled in an ice bath and to it is added 1 ml of 1% NaNo 2 solution and cooled in ice bath. To this 1 ml of Bnapthol solution in 5 N Naoh is added. An orange red colour ppt is obtained.

2.8 ACIDIC DRUGS/POISONS (ORGANIC NON VOLATILE)

2.8.1 GENERAL BACKGROUND

Poisons have been classified differently by different persons engaged in the detection of poisoning cases. Some of the important organic poisons are barbiturates, salicylates etc.

Barbiturates are drugs most frequently involved in adult poisoning. The synonyms of barbiturates are: -

Sleeping pills, guufballs, yellow jackets (Nembutal), red devils (seconel) blue deave (Amytal). These are mostly used as Anticonvulsant, Subhypnotic, sedative, dyprotic, Annaestic, antidote for convulsants (Strachhnine). The MLD value is 1 to 3 gms for 70 Kg. Man depending upon derivative potency, short acting members (rapid onset) are more potent, longacting members are less potent. The symptoms of drug poisoning may be Lethargy, ataxia, sleep to deep coma, lower body temperature, marked fall in blood pressure, respiratory depression, anaxia, cynosis, flaccid limbs, retention of urine is common, usually contriction of pupil but dialation in pupil later mayoccur, deep coma, death due to respiratory arrest, frequently associated with marked cardiovascular collapse or prenumonia.

Definition: Drugs which are acidic in nature are called acidic drugs. They readily reacts with base. The main acidic drugs are Barbiturates and Salycillates.

Available forms: Drugs/poisons are available as powders, plant products etc.

Source and form of crime/questioned sample: Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary are in the form of viscera, body fluids, material objects and plant materials. In survival cases like living persons stomach wash, vomited material and stained cloths etc., blood sample, urine and faeces if available. Suspected material recovered from the possession of the victim or accused and from the scene of crime such as medicines, containers, foods and drinks, residual poisonous materials etc.

Control sample: Pure forms of acidic drugs/poisons standardised for Laboratory purpose procured from recognized Laboratories is used for comparative chemical analysis.
Database of pure acidic drugs/poisonous substances available in various instruments is utilized for comparative chemical analysis.

2.8.2 METHODS AND PROCEDURES

Identification of Individual acidic drugs:

I Barbiturates

Color tests: It must be stressed that result from a color test is only a presumptive indication of the possible presence of barbiturate derivative. Further no information as to which particular barbiturate is present can be made with this test.

a) Dille – Koppayani Test:

Solution 1 : Dissolve 0.1 gm cobalt acetate tetrahydrate in 100 ml absolute methanol then add0.2 ml glacial acetic acid.
Solution 2 : Mix 5 ml Isoprophylamine with95 ml absolute methanol. Method:
Place a small amount of the extracted material on a spot tile adde 3-4 drops of solution 2 A purple color or blue – violet color indicates the presence of barbiturate.

b) Zwikker's Test:

To the extracted material (in chloroform) add 2-3 drops of 0.5% ml of 5% pyridine in chloroform and shake --- The color of chloroform layer becomes purple then add1 drop of glacial acetic acid, if the color of the chloroform layer changes form purple to weak blue, the presence of non thio barbiturate is indicated.
If chloroform layer becomes green, when pyridine in chloroform added, it indicates probable presence of thio barbiturates. This green color changes to light green when acetic acid is added.
Confirmation and identification of the barbiturate is established by thin layer chromatography or by Gass Chromatography or by HPLC, UV and FTIR.

II Salicylates

Salicylic acid derivaties are used as an analgesic, antiphretic and antirheumatic agent. They are rapidly absorbed and can be detected in the urine within 30 minutes. It has long half-time (24 hours) and allergy of these drugs is not common.
Symptoms:- Nausea, vomiting and serious metabolic acidosis, pamino phenol in urine (brown-black urine), irritability, cynosis, initial excitement and convulsions are followed by stupor and depression, renal and brain damage, respiratory failure, collapse, coma and death.
Aspirin, Salycylic Acid and Salicylamide
Screening colour test can be done directly in urine and plasma. The estimation of plasma levels of salicylate should be done whenever positive urine tests are obtained because the ingestion of one or two aspirin tables within preceding24 hours may give positive urine test.
(1) 1 ml urine + 3 drops of ferric chloride solution – A violet colour indicates the presence of salicylate.
(2) 0.5 ml urine or plasma is added to 4.5 ml of 0.55% ferric nitrate in 0.04 N nitric acid – A purple colour proportional to concentration of salicylate is obtained (quantitative test). Note :- Aspirin or Salycylate must be hydrolysed to salicylic acid

by boiling with few drops of 1 N hydrochloric acid, cooling and neutralizing before applicable to the above test.

(3) McNally"s test:- About 1 mg or substance (extracted material) is dissolved in a few drops of acetone and 1 to 2 ml of water is added. 1-2 drops of 0.5% copper sulphate solution in 10% acetic acid is added followed by a pinch of solid sodium nitrite. The mixture is shaken, heated gradually to boiling and maintained it boiling for a few minutes

– Red colour formation takes place if aspirn and salicylic acid is present.

–

IIIPhenols

Phenols (carbolic acid, cresols, andresorcinols) are used as disinfectant antiseptic, preservative, antipyretic and in industry for dyes and intermediates. They are corrosive to skin and having characteristics odour. They produce cardiovascular disturbance. Phenols may be produced by body decomposition of tissue proteins. Some phenol derivative (p-aminophenol) may be normal metabolic of other drug.

Symptoms :- Nausea, vomiting, white burns on mouth, lips and mucosal membranes, local anaesthetic action, severe gastrointestinal irritation and abdominal pain, brown purple urine, albumin urea, hematurai, fleeting excitement followed by coma, death due to cardiovascular collapse and respiratory failure.

Colour Test:

1) Ferric chloride test – Add ferric chloride solution to ethanolic solution of sample.

Blue colour - Phenol, parachloro – phenol

Blue violet colour - Sallol, salicylic acid sallicylamide.

2) Liberman"s test –

Reagent: Dissolve 1 gm of potassium nitrate in sufficient sulphuric acid to produce 10 ml.

Method: Place 1-3 mg substance is spot tile and add2-3 drops of the reagent.

Blue red colour - Phenol Violet colour - Resorcinol

Green colour - Alpha,napthol, beta napthol Brown to black - Cresols, p-amino phenol

2.8MISCELLANEOUS POISONS

2.9.1 GENERAL BACKGROUND

Mechanical Poisons:

Mechanical poisonous substances are included in section 328 IPC within the meaning of poison, and include powdered glass, pins, needles; inhalation of glass fibers, chopped animal hairs etc. out of these, and powdered glass has some medico-legal importance. Rarely, needles or pins are swallowed for suicidal purposes. Glass powder is some times used for homicidal purposes and destroying cattle but rarely selected for suicidal purposes. Glass does not produce the desired effect, if it gets entangled in the mucous or food in the stomach. Similarly, it will not have any bad effects, if it is well powdered.

Plant Poisons:

There are some poisonous plants, which are often used by the criminals as a weapon in different types of crimes. These can be used in homicidal / suicidal acts, abortificients, travelers cheating, as cattle poisons and fish toxicants.

Definition: Mechanical poisons are actually not poisons because they are not absorbed but produce symptoms of irritant poisoning solely in consequence of their mechanical action to their sharp angular edges and points, and cause irritation of stomach and bowels. Glass is a non-crystalline substance. Chemically ordinary glass is mostly sodium- calcium-silicate. Heat resistant glass (e.g. borosil) contains about eighty percent silica and some boron oxide. Optical glass contains comparatively larger amount of lead, barium and zinc oxide. Coloured glass contains oxides of various metals known to give coloured compounds. Sunglass contains rare earths as additional elements.

A poisonous plant is one which, as a whole or a part thereof, under all or certain conditions, and in a manner and in amount likely to be taken or brought into contact with an organism, will exert harmful effects or cause death either immediately or by reason of cumulative action of the toxic property, due to the presence of known or unknown chemical substances in it, and not by mechanical action.

Available forms: Among mechanical poisons glass pieces, powdered glass, pins, needles etc., are of medico-legal importance. Among plant poisons opium, Dhatura, Calotropis etc., are important.

Source and form of crime/questioned sample: Samples collected during postmortem examination and at scene of crime are received from Investigating Officers and Judiciary are in the form of viscera, body fluids, material objects etc.

Control samples: Pure forms of miscellaneous poisons standardised for Laboratory purpose procured from recognized Laboratories is used for comparative chemical analysis. Database of pure miscellaneous poisonous substances available in various instruments is utilized for comparative chemical analysis.

2.9.2 METHODS AND PROCEDURES

I - Detection of Mechanical Poisons:

Glass fragments picked up form stomach contents or found adherent to the tenacious mucus secretion or fecal matter are washed with water and then with ether. Alternately, the contents of the bowel or the dejecta can be destroyed by hydrochloric acid and potassium chlorate. The organic matter passes into solution and the glass is left. In suspected cases of homicidal poisoning by glass, the organs removed should not be taken in glass containers. The particles are then viewed by naked eye, magnifying lens and then under microscope. They are seen as transparent and amorphous particles.

The picked up particles are melted in a spatula on flame. When the particles are in molten state, the material is touched with a thick platinum wire and on pulling up the wire, a glass thread is formed.

Refractive index:- Refractive index is a very useful property in the identification of glass which can be determined by immersion method. In this method, glass fragment is placed in a mixture of two miscible liquids(One with higher and the other with lower refractive index) is used, one of them being added gradually till the glass in the liquid mixture becomes invisible. The refractive index of that mixture of liquid may be determined by abbe‘s refractometer, which will be the refractive index of the glass.

Spectrographic Analysis**:** Glass can be identified by emission spectrographic analysis by identifying its elemental composition.

II - Analysis of Plant Poisons:

A large number of plants are known for their poisonous effects but commonly used poisonous plants have been only selected and their method of characterization has been reviewed. Some of these plants are:

1) Neurotic Plant Poisons: Eg. Papaver somniferum. (Opium)
2) Spinal Plant Poisons: Eg. Strychnos nux vomica (Kuchila)
3) Cerebral Plant Poisons:

Eg (i) Cannabis sativa (Indian Hemp)
(ii) Erythroxylum coca (Coca Plant)
(iii) Atropa belladonna (DeadlyNight-shade)
(iv) Dhatura fastuosa (Dhatura)

4) Cardiac Plant Poisons:

Eg. (i) Nicotiana tabacum
(ii) Aconitum napellus
(iii) Digitalis Purpura

5) Irritant Plant Poisons:

Eg. (i) Abrus Precatorius
(ii) Calotropis gigantean
(iii) Cystisus laburnum
(iv)Texus Baccata
(v) Croton Tiglium
(vi) Argemone Mexicana
(vii) Gloriosa Superba
(viii) Plumbago rosea & Plumbago zeylanica

6) Miscellaneous

(i) Cyanogenic glycosides
(ii) Ergot

Isolation - The detection of vegetable poisons depends on the isolation of their alkalodis and glucosides from the stomach contents or organs of the body and the suspected articles of food, or remainings of the vegetable materials and their identification by the application of chemical and instrumental analysis. Hence, selection of isolation/extraction method is very much important because plant peisons vary in their active principles, they may be insolumble in water but soluble in ether while with acids they form salts which dissolve in water but not in either. This fact of solubility is made useof in separating them from organic mixture for which selection of extraction procedure is essential. Therefore, four main factors must be considered before the selection of extraction procedure.

1. Analytical aim.
2. Types of materials.
3. Sources available and
4. Nature of poison.

Isolation /extraction method is mentioned individually for each plant. Conventional methods of extraction e.g. Modified Stassotto method and Ammonium sulphate methods have already been described earlier.

1) Neurotic Plant Poisons

Papaver somniferum:

Common Names: Opium poppy, poppy, white poppy, and carnation poppy.

Opium is the air-dried, milky exude obtained by incising the unripe capsules of Papaver sominiferum (N.O. Papaveraceae). Poppy capsules (Post Ka Doda) when they are ripe and dry contain a traces of opium andare used for their sedative and narcotic action. Poppy seeds (Khas-Khas) are innocuous and are used as food. They are sprinkled over some Indian sweets. They yield a bland oil known as poopy seed oil (Khas Khas Kha Twenty-five alkaloids have been proven to exist in various varieties of opium and several more have been announced, but their existence has not been confirmed. Three acids are found combined with the alkaloids in opium viz. meconic, lactic and sulphuric acids. At present there are three neutral principles – meconin, meconoisin and opinion as

Well as pectin, glucose, mucilage, caoutchoue, waxand odorous fatty and colouring matters. The pharamaceutically important opium alkaloids are commonly subdivided into two chemical groups:

i. Isoquinoline derivatives as papaverin and narcotine.
ii. The phenanthrene derivaties such as morphine and codeine.

Opium ranges in consistency from more or less plastic when fresh to becoming hard or tough on ageing. It has a very characteristics odour and a very bitter taste.

The following is a list of the major alkaloids found in opium.

Morphine	-	10-20%
Narcotine	-	0.75-10%
Papaverine	_	0.5 –1.0%
Thebaine	-	0.2 – 1.0%
Codeine	-	0.2-0.8%
Narceine	-	0.1-0.5%

Chemical Analysis of Opium: To ascertain the presence of opium in the suspected material. It is necessary to detect the presence of morphine and other main alkaloids and also the presence of porphyroxine and meconic acid.

Isolation: Opium alkaloids may be extracted from biological material by obtaining basic chloroform extract. Extracted materials are dried and the residue is used for the different tests.

Tests for Morphine:

A portion of extracted material is dried and the residue is dissolved in of 0.5% acetic acid filtered and tested.

1. Frohde‘s Test: One drop of the solution is taken in a porcelain basin and dried. To it is added one dropof Frohde‘s reagent (1% ammonium molybdate solution in Conc. H2SOR). A violet colour changing to the green and finally pink is noticed.
2. Marquis Test: One drop of the solution is taken in to a porcelain basin and dried. To it is added on drop of marquis reagent (one drop of formalin in one ml of conc. Sulphuric acid). A purple red colour is produced which gradually changes to violet and finally to blue.

Test for Porphyroxine:

Two drops of the acetic acid solution of the extracted residue is taken into a porcelain basin, mixed with few drops of dilute hydrochloric acid and warmed over a low flame. A pink or rose red colour is obtained.

Test for Meconic Acid:
A neutral solution of ferric chloride added to an aqueous extract gives a blood red colour which is not destroyed by boiling or by adding hydrochloric acids ormercuric chloric solution.

Crystal Tests: A portion of residue is purified by thin layer chromatographic technique. The area of the unsprayed developed plate corresponding to the Rf value of alkaloids (e.g. morphine) is scrapped off, eluted with2 ml of chloroform and then dried. The residue is taken in few drops of dil. HCl. One drop of this solution is transferred to a cover slip by means of a glass rod and one drop of the reagent is added to it and mixed. The crystal formation is made by hanging drop technique and examined under microscope after gaps of few hours.

With 5% mercuric chloride solution morphine gives Tufts

With potassium cadmium iodide reagent (1g. cadmium iodide and 2 g KI) morphine gives needles.

With KI 5% solution – orangeplates.

Spinal Plant Poisons
Strychnos nux vomica:
Common name :- (Kuchila, Kuchla)
This tree belongs to N.O. Loganiacease. Its ripe fruit contain nuxvomica seeds, which are poisonous. Seed contain two main alkaloids strychnine and brucine united with strychnic igasuric or caffeotannic acid. Besides, the seeds contain to a small extent a glucoside named logamin. The break, wood, seeds and leaves contain brucine, but no Strychnine.

ChemicalAnalysisofStrychnine:
The alkaloids are extracted from the tissues and other biological materials by organic solvents from alkaline aqueous solution. The extracted organic layer is evaporated to dryness. The residue is taken in 2 ml of 0.5% acetic acid and in this acetic acid solution the following tests are performed.
1. Mandelin‘s test: One drop of the acetic acid solution of extracted residue is taken into a porcelain basin and evaporated to dryness. To it is added one drop of Mandelins reagent (1% solution of ammonium vanadate in conc. sulphuric acid). A deep violet blue or deep purple colour is obtained.
2. Play of Colour Test:- Into a white porcelain basin two drops of the acetic acid solution are taken and dried. To the dried residue is addeda pinch of manganese dioxide followed by a drop of conc. Sulphuric acid. Lines are drawn by means of a glass rod through the MnO2 and sulphuric acid. A play of colours is observed. First a momentary blue colour is observed which changes to violet colour which gradually changes to reddish purple, red then orange and finally to yellow. In the presence of very small quantity of strychnine, the change of colours is rapid but with large amount, the violet colour persists for some time. Nitrate ions interfer with this test.

2) Cerebal Plant Poisons
A) Cannabis Sativa L:
Common names: Indian hemp, Marihuana

This plant belongs to N.O. urticaceae. Which grows in all parts of the world is an annual plant and attains a height of 3 to16 feet. The wild growing plant on the contrary has numerous branches. There are considerable differences in gross appearance due to origin of seed, condition of soil, elimate and proximity of other plants during growth. The resin occurs mainly in the in florescence (flowering area), The levels & Stems particularly at the top of the plant. The only parts of the plant which appear to be always free from resin are the roots and other lower parts of the stalks. The highest amount of resin is found in the flowering top up to the time of flowering the male and female plant produce resin nearly equally. But after shedding their pollen, the male plants soon die. The leaves of the cannabis are compound and consist of 5 to 11 separate leaflets. Each leaflet is characteristically hair covered, veined and has scrrated edges. These hair are very important item for botanical identification of this plant and make a microscopic investigation inevitable.

There are two types of hairs.
a) Cystolith hairs
b) Glandular hairs
The cystolith hair contains a deposit of calcium carbonate at their base.
Active Principle – The active principle (ie resin) of this plant contain cannabinol, cannabidiol, cannabidiodic acid and Tetrahydro cannabinol as main constituentsÊ tetra hydrocannabinol (THC) is mainly responsible for the physiological properties of the plant. Tetrahydrocannabinol is anoily liquid from which two main isomers may be crystallized. In India this herb is used in the following three forms. (i) Ganja (ii) Bhang and (iii) Charas.

1) Ganja – This consists of the dried levels and fruiting tops of the cultivated female cannabis.
2) Bhang – This consists of the dried levels and fruiting shoots twigs of both male and female plants.
3) Charas – Charas is the crude resinous matter collected from the levels and flowering tops of the plant. As sold in India Charas is a greenish mass with a peculiar characteristics odour like that of marigold flowers. When kept for some time it turns to a brownish gray colour becomes hard and friable.

Microscopic Test:- A. Place a small portion of the dry material on a microscopic slide. Add one to two drops of water and flatten the preparation by slightly rubbing it with a cover glass. Inspection should be made at low and medium magnification (30X to 100X). The cystolith hairs contain a deposit of calcium carbonate at their base. Add a few drops of 20 percent hydrochloric acid to the preparation under the cover glass. Watch carefully for effervescence under the microscope.

Chemical Tests:
Fast Blue B Salt test:- Solid reagent – Fast Blue B salt
This solid reagent is made by diluting Fast blue B salt with anhydrous sodium sulphate (2:5:100) Solution I - Chloroform. Solution II – 0.1 N aqueous sodium hydroxide solution. Place a small amount of extracted residue in a test tube and add a very small amount of solid reagent and 1 ml of chloroform (Sol-I) Shake and add 1 ml of solution II, shake and allow the test tube to stand for two minutes. Purple red colour in the chloroform layer is noticed.

B) Atropa Belladonna

Common names – Deadly night shade

This plant belongs to N.O. solanaceae and grows in the Himalayan range at high altitudes nearly all the parts of the plant viz the leaves berries and roots are poisonous. They contain atropine, hyoscyamine and scopolamine (hyoscine) as main constituents.

Chemical tests:

(i) Vitalis Test:- The extracted residue is treated with a few drops of fuming nitric acid, heated to boiling and evaporated to dryness on a water bath. After cooling the residue is moistened with a few drops of fresh prepared alcoholic KOH sol., when a violet colour is produced this soon changes to red and finally disappears. The colour may be made to reappear by adding more alcoholic sol. of KOH.

(ii) GerrardÊs Test: If one or two cubic centimeters of 2% sol of mercuric chloride in 50% alcohol are addedto a portion of the residue, a red colour develops immediately Hyoscyamine produces a yellow colour which becomes red on warming while scopolamine (Hyocine) does not produce any change in colour.

C) **Dhatura fastuosa** Common names – Dhatura

This plant belong to N.O. Solanaceae and exits in two different varieties viz. Datura alba- A white flowered plant (Safed Dhatura) and Datura niger, a blackor rather deep purple followed plant (Kala Dhatura). Both these varieties grow commonly on waste places all over India. All parts of these plants are poisonous but the seeds and fruits are considered to be the most noxious. The main alkaloids are atropine, hyoscine and hyoscyamine. The seeds are generally used by road poisoners to stupefy travelers to facilitate robbery and theft and rarely to destroy life.

Analysis of Dhatura:

Physical appearance: Seeds of Dhatura are hard, flattened, kidney shaped very much resembling to those of capsicum seeds but have a double ridged convex order.

Microscopic test: The fragments of the seeds of dhatura picked up from the vomit or stomach contents when seen under a microscope dipped in a drop of glycerine characteristic features having structure like those of eye lids is seen Comparison can be done with control dhatura seeds fragments.

Chemical test:

Vitalis test :- in a porcelain basin small amount of extracted residue is taken and two or three drops of acetic acid solution are taken in to it and evaporated. To the dry residue is added one drop of fuming nitric acid and again evaporated to dryness on a hot water bath. After cooling, a drop of alcoholic caustic potash solution is added to it. Violet colour is produced which immediately changes to red and then disappears. On adding few more drops of alcoholic KOH the colour reappears.

CARDIAC PLANT POISONS

Nicotiana tabacum

Common names – Tobacco, Tambaku.

This plant belongs to N.O. Solanaceae, and is originally a native plant of America, but is now cultivated largely all over India. The dried leaves of tobacco are used in India as articles of luxury by almost all classes of people, who use them either in the form of smoke or snuff, or chew them with lime along or with lime and pan. The leaves yield two active principles, nicotine and nicotianine. Nicotine is the active principle of this plant. Nicotine poisoning may be caused by absorption either through intact or broken skin, by inhalation or ingestion. Nicotine first stimulates,

then depresses and paralyses the cells of the peripheral autonomic ganglia, brain (especially midbrain), and spinal cord. Skeletal muscle, including the diaphragm is paralysed.

Analysis:

Colour Tests: Nicotine is isolated by distillation from alkaline solution but, the extract gives all the tests given by other alkaloids with general alkaloidal reagent such as;

a) MayerÊs reagent – A yellowish white ppt.
b) Phosphomolybdic acid reagent - yellowish white ppt.
c) Silico tungstic acid reagent – A white ppt.
d) Dragendorffs reagent – An orange coloured solution or ppt. *SchindelmisserÊs Test*:- To a portion of the extracted residue is added on drop of fomalin followed by a dropof conc.sulphuric acid. Rose-red colour is obtained. (In excess of formalin a green colour instead of rose-red is obtained).

4) Irritant Plant Poisons

A) Abrus Precatorius

Common names- Jequirity, Indian Liquoric, Gunchi or Rati. This is a beautiful climbing plant belonging to N.O. Leguminosae and found all over India. Though all parts of plant are poisonous the seeds are commonly used as poison. They are egg shaped have a beautiful red colour with a black spot on one pole. They are of the size of a small pea, about 0.85 cm. long and 0.65 cm broad and have anaverage weight of 120 mg. They are used by the gold smiths in India for weighing silver and gold. The active principle is abrin (-methyl-amino-(-e-indolypropionic acid) ; a toxalbumen and its action resemble those of vipering snake bite with intense local symptoms and haemorrhages following by general symptoms of drowsiness. The root and stems also contain an active principal glycyrrgizin. Abrin loses its activity when boiled and therefore, the seeds when cooked may be used without any harmful effective.

Screening Tests:-

Fast Blue B-Potassium hydroxide test: In a small portion of extracted residue ethanolic solution of Fast blue B salt and 1% aqueous sol of KOH is added. Red to orange colour is observed.

Marquis reagent Test:- In the alcoholic solution of extracted residue, when 1% Farmalin in H2SO4 is added Pink colour is observed.

B) Calotropis gigantean or procera Common names – Madar, Akdo,

Calotropis gigantean has purple flowers and grows hide in wastelands throughout India white calotropis procera has white flowers and grows generally in desert. Both these plants belong to the N.O. Asclepiada ceae and closely resemble each other in chemical and physiological actions. These plants yield three active principles uscharin calatoxin andcalctin madar juice is often used for procuring criminal abortion. It is either administered by the mouth or introduced in to the uterus on a abortion stick. It is sometimes used as cattle poison.

Colour Tests:

a) A portion of the extracted residue is alcohol is taken in a porcelain basin and alcohol is evaporated. The basin is then cooled and then a drop of concentrated H2SO4 is added to it. A Pink to purple colour is noticed after few minutes.

b) Frohde‘s Test – In the alcoholic extract frohde‘s reagent is added (1gm ammonium molybdate dissolved in 100 ml. of con. H2SOR) Deep green colour changing to blue and finally to Green colour is noticed.

C) Cystisus laburnum Common name – Laburnum:

This belongs to N.O. Leguminosae. The wood bark, pods and seeds produce toxic effects when taken internally. The active principle is an alkaloid cytosine. It is also known as sophorine or Baptitoxine. It is soluble 1 in 1:3 of water 1 in 3.5 of ethanol and 1 in 2 of chloroform.

Chemical Tests

a) Action of concentrated sulphuric acid without effecting any change of colour but on heating the solution acquires a yellow colour.

b) When mixture of H_2SO_4 and HNO_3 is added yellow colour is noticed.

6) Miscellaneous Cyanogenic glycosiders

Release of HCN is relative to the presence in intact plants of substances called cyanogenic glycosiders, which give HCN on either enzymic or non-enzymic hydrolysis. Biosynthetically cyanogenic glycosides are formed from the structurally related amino acids bia aldoximes and nitriles by a five step pathway. Certain plants vegetables and fruits such as bitter almond, linseed plant and flower, small jowar plant or millet, crtain oil seeds and beans the ordinary bamboo shoot, the skin of cassava etc. are highly poisonous due to the natural development of certain toxic glycosides i.e. cyanogenic glycosides in them. These cyanogenic glycosides are rapidly hydrolysed in the stomach and free hydrocyanic acid is liberated which may cause fatal poisoning to men as well as animals. Cases of cattle poisoning often occur by eating young jowar plant or linseed plants by the animals. The followers of linseed plants having immature seeds were found to contain cyanogenic glycoside producing as much as 0.6% of free hydrocyanic acid.

Chemical Tests:-

Picrate papers are prepared by dipping rectangular pieces of filter paper in saturated (0.05m) agueous picric acid previously neutralized with $NaHCo_3$ and filtered. A portion of material to be tested is placed in a test tube and few drops of water and toluene are added and the material is handled with glass rod. The tube is then firmly corked with a moistered picrate paper suspended inside from the cork and left to incubate at 40^{o} C for 2 hours. A colour changes form yellow to reddish brown indicaling the enzymic release of HCN.

UNIT II-B-Narcotics

2.10 INTRODUCTION TO NARCOTICS

The term Narcotics refers to analgesic accompanied by sleep or stupor. The substance that produce narcosis are known as Narcotics. The term ―Narcotic‖ is derived from the Greek word ‗Narkotikos', which implies a state of lethargy or sluggishness.

A drug can be defined as a natural or synthetic substance that is used to produce physiological effects in humans or other higher order animals.

Drugs of abuse affect the brain structures that regulate feelings of reward, personal empowerment and pleasure, which constitute an important component of their addictive properties, along with developed tolerance.

Scope

Narcotics section deals with examination of suspected narcotic and psychotropic substances received as case property from the investigating agencies and law enforcement agencies in the form of solids, liquids, pastes and plant materials or plant products.

Classification

Narcotic Drugs:

Narcotic drug means Coca leaf, Cannabis (hemp), Opium, Poppy straw and include all manufactured goods.

Controlled under UN 1961 convention.

Psychotropic substances:

Psychotropic substances means any substance natural or synthetic or any natural material or salt or preparation of such substance or material included in the list of psychotropic substances specified in the schedule.

* Controlled under UN 1971 convention
* Drugs added to the lists after 1971 are called New psychotropic substances which include designer drugs.

Based on their action on central nervous system NDPS drugs are classified into three types.

1. Depressants or Downers:- They decrease the activity of CNS (central nervous system) resulting in relaxation.

Ex: Opium, Morphine, Benzodiazepine group of drugs Barbiturates etc.

2. Stimulants or Uppers:- They increase the activity of CNS (central nervous system)

Ex: Cocaine, Khat, Amphetamines etc.

3. Hallucinogens or All Arounders: They create illusions delusions or hallucinations.

Ex: Cannabis, LSD, PCP, Psicilocin mushrooms etc.

New psychotropic substances are both natural and synthetic which are added to the list of Narcotic Drugs or Psychotropic Substances after UN 1971 Convention.

Designer drugs are synthetic substances which resemble a controlled drug both in chemical structure and with similar effect on CNS (central nervous system).

I) Depressants (Narcotic)

1. Opium: It is the coagulated juice of Opium poppy and any mixture with or without any neutral material of the coagulated juice of the Opium poppy, but does not include any preparation containing not more than 0.2 percent of morphine.

∗ Opium poppy means: The plant of the species Papaver sominiferum L. and the plant of any other species of Papaver from which Opium or any phenanthrene alkaloid can be extracted and which the Central Government may by notification in the official Gazette declare to be Opium Poppy for the purpose of NDPS act.

∗ Opium is the milky latex fluid contained in the un ripened seed pod of the Poppy plant. It contains the phenanthrene alkaloids Morphine, Codeine and Thebaine and other substances.

Poppy straw: All parts (except the seeds) of Opium poppy after harvesting whether in original form or cut, crushed or powdered and whether or not juice has been extracted there from.

Morphine: It is the chief alkaloid of Opium both in amount and medical importance.

In Medicine Morphine is used to alleviate severe pain before or after surgery.

Opioids act by attaching to specific proteins called Opioid receptors. Which are found in the brain, spinal cords and gastro intestinal track. When these drugs attach to certain Opioid receptors, they can block transmission of pain messages to the brain.

Codeine: It is less efficacious than Morphine and is used for milder pain.

Thebaine: It has stimulatory rather than depressant effects. It is converted into many other drugs which include hydrocodone, hydro morphine, Oxycodone, Oxymorphine, buprenorphine, etorphine etc.

Heroin: It is an illegal highly addictive drug. It is processed from Morphine. Pure Heroin is a white powder with bitter taste. Because of impurities left from the manufacturing process or the presence of addictives such as sugar, starch, powdered milk, Heroin may vary in colour from white to dark brown. Pure Heroin is rarely sold on street. The drug is injected, sniffed/snorted or smoked. Injection is the predominant method of administering the drug by abusers.

Black tar Heroin: It results from crude processing methods used to illicitly manufacture the substance. It may be sticky like roofing tar or hard like coal and its colour may vary from dark brown to black.

Oxycodone: It is a semi synthetic Opioid structurally resembling codeine and approximately equivalent to morphine in producing the effects.

They are available as tablet, capsule and liquid forms.

Dextropropoxyphene: It is an analgesic in Opioid category.

Pentazoine: Sold under the brand name Fortwin in injection form is an opioid used to treat moderate to severe pain.

Laboratory Examination:

Standard Reference Material:

For the purpose of analysis standard reference material can be obtained from chief controller of factories, Govt. Opium alkaloid works and Indian Pharma Copoeia Commission. Drug data base available in various instruments and online data bases like NIST, PUBCHEM, Drug Bank can be used for comparative purposes.

Test methods

I. Physical Examination
II. Chemical Examination
III. Instrumental Methods

I. Physical Examination:

Physical appearance and any odour noticed during analysis are noted.

For plant material Macroscopic and Microscopic characters are noted.

II. Chemical Examination:

Colour tests:

Meconic Acid: A small portion (approximately 1 mg) of the suspected material is placed on a spot plate. Two drops of water is added and stirred with a glass rod until the water becomes brown. One drop is transferred to a spot plate well containing one or two drops of 10% Ferric chloride solution. A dirty blood red colour indicated the presence of Meconic acid in suspected Opium sample.

Porphyroxine: A small quantity of Opium is placed on a spot plate, two drops of water is added and stirred with a glass rod until the water turns brown. One drop is transferred to a spot plate well containing one drop of 2N HCl. Upon gentle heating a red colour develops if Porphyroxine is present.

Tests for other opiates:			
Alkaloid	Marquis	Mecke	Froehde
Heroin	Purple violet	Dark green	Purple becoming
green/ purple			
Morphine	Purple violet	Dark green	Purple becoming
Green/Purple			
Codeine	Purple violet	Green/Blue	Blue/Green
6-acetyl morphine	Purple violet	Dark green	Yellow/Green
Acetyl codeine	Purple violet	Dark green	Purple becoming
paler			
Papaverine	No colour	Dark blue	Light green
Noscapine	Bright yellow	Green/Blue	Cherry red

Reagent Preparation:

Marquis: Reagent 1: Carefully Mix 100ml. Of Concentrated Sulphuric Acid with 1 ml of 40% (v/v) formaldehyde solution .

Mecke Reagent: Dissolve 1g. of selenious acid in 100ml. Of Concentrated Sulphuric Acid.

FroehdeTest: Dissolve 1g. of molybdic acid or sodium molybdate in 100ml. Of hor sulphuric acid.

B) Thin Layer Chromatography

III. Instrumental Methods:

GC, HPLC, FTIR GC-MS, HPTLC and Raman Spectrometry can be used.

Quantitative analysis of Morphine is preferably done on HPLC.

Quantitative analysis can also be carried on GC.

II. Stimulants (Narcotic)

a. Cocaine & Coca Leaf:

One of the oldest known drugs, Cocaine is the methyl ester of Benzoyl ecgonine and its salts.

It is extracted from leaf of erythroxylon Coca L. bush. The green to yellow-greenish elliptical leaves of different erythroxylon species vary in size and appearance. Characteristic are the two lines parallel to the midrib on the underside of the leaf.

There are basically two chemical forms of Cocaine. Cocaine Hydrochloride salt and Cocaine base. Cocaine Hydrochloride salt or the powdered form of Cocaine dissolves in water and is taken intravenously or intra nasally when abused. The free base form is smokable.

Crack Cocaine: it is derived from powdered Cocaine Hydrochloride salt.

Source and form of crime/questioned sample:
From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:
a. Standard reference material can be imported through Chief controller of factories following NDPS rule 67 (B).
b. Database of pure Cocaine is available in various instruments Libraries and can be utilised for comparison purpose.
c. Online Database like NIST, PUB CHEM, Drug Bank etc, can be used for comparing the results.
d. Authentic information available in reference books like Pharmacopoeia can be used for comparing the results.

Methods and procedures:

I. Physical Examination

Physical appearance is noted.
Coca leaf is examined by Macroscopy and Microscopy.

II. Chemical analysis:

Coca leaf is immersed in boiling ethanol to extract the alkaloids.
The alcoholic extract is subjected to TLC and GC-MS for qualititative analysis.

Cocaine:-
Scott"s test:
Reagent
1. Dissolve 1g of cobalt thiocyanate in 50ml of 10% (v/v) acetic acid then add 50ml of glycerine.
2. Conc. HCl
3. Chloroform

Method:
Step 1: Place a small amount (approximately 1mg) of the suspected material in a test tube add 5 drops of reagent 1 and shake the test tube for 10 seconds. Cocaine and related substances produce a blue precipitate and a blue solution.
Step 2: Add a drop of reagent 2 and shake the mixture for a few seconds the blue solution should turn pink. If the blue colour still does not change add one further drop. If still no change, repeat the test with a smaller portion of suspected material.
Step 3: Add 5 drops of reagent 3 and shake. If Cocaine is present the lower chloroform layer will produce intense blue colour while the upper layer will be pink. A positive result at each stage is required in order to be considered as a positive test for Cocaine.

Thin layer chromatography:

Method III:

Instrumental methods:- GC, GC-MS, HPLC, HPTLC, FT-IR, Raman Spectroscopy.

III. Hallucinogen (Narcotic)

a) Cannabis: Cannabis is an annual dioecious herb.

Cannabis means

a. Charas that is the separated resin, in whatever forms whether crude or purified, obtained from the cannabis plant and also includes concentrated preparation and resin known as Hashish oil or liquid Hashish.

b. Ganja that is the flowering or fruiting tops of the cannabis plant (excluding the seeds and leaves when not accompanied by the tops)

c. Any mixture with or without any neutral material or any of the above forms of cannabis or any drink prepared there from.

Source and form of crime/questioned sample:

From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers

Methods:

I Physical Examination

a) Macroscopic Examination

b) Microscopic Examination

Cannabis is the most frequently used recreational drug only behind alcohol, caffeine and tobacco.

It is usually smoked sometimes eaten.

The most common species of cannabis is cannabis sativa.

Average plant grows from 5-12 feet tall. Some species may grow up to 20 feet.

The hallucinogenic property of _Ganja' is due to tetrahydrocannabinol (THC).

THC content varies in different parts of the plant, generally decreasing in the following sequence; resin, flowers and leaves. Little THC is found in stems, roots and seeds.

Cannabis resin: The resin is separated and made into slabs.

Liquid Cannabis: It is the concentrated extract of either herbal Cannabis material or of cannabis resin. It is either dark brown or dark green in colour and has the consistency of thick oil or paste.

Microscopic characterestics:-

Cannabis sativa can be identified by microscopic structures on the surface of the plant namely trichome i.e., hair like projections from a plant epidermal cell.

Two types of trichomes occur and can be observed with a binocular microscope with a magnification factor of 40.

a. **Non glandular trichomes:-** They are numerous unicellular rigid and curved hairs with a slender pointed apex.

Crystolythic trichomes: Found on the upper surface of the cannabis leaves have a characteristic bear claw shape and many have calcium carbonate crystals (cystolyths) visible at the base.

Non cystolythic trichomes occur mainly on the lower side of the leaves, bracts and bracteoles and lack the enlarged base.

The simultaneous presence of these bear claw shaped trichomes on the upper surface and the fine slender non-cystolythic trichomes on the lower surface of the leaves is a unique characteristic of cannabis.

b. **Glandular trichomes:** They occur as sessile glands, i.e., trichomes without stalk which are generally found on the lower epidermis.
Small bulbous glandular trichomes with one celled stalks.
Long multi cellular stalks on the bracteoles surrounding the female flowers.

Chemical Examination:
Colour test:-
1. Fast blue-B salt test:
2. Carefully mix 2.5g of fast blue B salt with 100g of anhydrous sodium sulphate.
3. Chloroform
4. Dissolve 0.4g of NaOH in 100ml of water.
5. Place a small amount of the suspected material in a test tube add small amount of reagent 1. Add 25 drops of reagent 2 and shake the test tube for a minute. Add 25 drops of reagent 3 and shake for 2 minutes.
Purple-red colour of the lower (Chloroform) layer indicates the possible presence of Cannabis.

2. **Duqueneris-Levine test:**
1. Dissolve 2g of vanillin in 100ml of 95% EtOH then add 2.5ml of acetaldehyde.
2. Conc. HCl.
3. $CHCl_3$**.**
Place a small amount of the suspected material in a test tube. Add 2ml of reagent 1 and shake the test tube for one minute. Add 2ml of reagent 2 and shake again for a few seconds and allow the mixture to stand for a few minutes. If a colour develops within 2-3 minutes add 2ml of reagent 3 and shake the mixture gently.
Result: Violet colour of the lower (Chloroform) layer indicates the possible presence of Cannabis.

Thin layer chromatography:
Instrumental methods:
GC, GC-MS & HPLC are suitable techniques.
Depressants (Psychotropic substances)
1) Benzodiazapines.
Common Benzodiazepines:
Diazepam(Valium)
Chlorodiazepoxide(Librium)
Nitrazepam
Medazepam
Flunitrazepam(Rohypnol)
Oxazepam
Alprazolam
Lorazepam

2) Source and form of crime/questioned sample:
From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:
1. Standard reference material may be obtained from Indian Pharmacopeia Commission.

2. Library database available in the instruments can be utilized for comparison.
3. Authentic books like pharmacopeia may be referred.

Methods and Procedures:

Physical Examination:
Physical appearance: solid, injection tablet etc... may be noted.

Chemical Examination:
Colour tests
No single colour test is suitable for all the Benzodiazepines.
Zimmermann Test:
Reagent:1. Dissolve 1g. of 1,3-dinitrobenzene in 100ml. Of methanol.
Reagent 2: dissolve 15g. of Potassium Hydroxide in 100ml. Of water.
Method: Place a small amount of the suspected material on a spot plate.

Result: Reddish-Purple or pink colour indicates the possible presence of diazepam or some related benzodiazepine derivatives.
Thin Layer Chromatography:

Instrumental Method:
GC, HPLC, GC-MS, FT-IR, HPTLC, Raman spectroscopy, UV spectroscopy

2.11 BARBITURATES:

They are used as sedatives, hypnotics, anaesthetics and anti convulsants. They are a class of drugs derived from barbituric acid.
They are usually classified according to the duration of their clinical effects into long intermediate, short and ultrashort acting compounds.
Long acting;
3 to 60 minutes. Length of action is up to 8 hours.
E.g.: Barbital & Phenobarbital
Intermediate acting;
On set in 15 to 30 minutes. Length of action up to six hours.
E.g.: Amobarbital, butabarbital.
Short acting;
Onset in 10 to 20 minutes. Remain effective for six hours.
E.g.; Pentobarbital, Secobarbital.
Ultra short acting
on set 0 to 45 seconds. Length of action up to 30 minutes.
E.g.; Thiopental sodium.

Source and form of crime/questioned sample:
From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:
Standard reference material may be obtained from Indian Pharmacopeia Commission.
Library database available in the instruments can be utilized for comparison.

Authentic books like pharmacopeia may be referred.

Methods and Procedures:

Physical Examination:

Physical appearance: solid, injection tablet etc... may be noted.

Chemical Examination:

Colour tests

Dille-Koppanyi test:

Solution1: Dissolve 0.1g. of Cobaltous acetate tetrahydrate in 100ml. Absolute methanol, then add 0.2ml. glacial acetic acid.

Solution2: Mix 5ml isopropylamine with 95ml absolute methanol.

Method: place a small amount of the suspected material in a depression of a spot plate. Add three drops of solution1. And three drops of solution2. A purple colour indicates the possible presence of barbiturates.

3. Thin Layer Chromatography

4. Instrumental Method:

GC, HPLC, GC-MS, FT-IR,HPTLC, Ramanspectroscopy,

UV spectroscopy

Methaqualone / Mecloqualone

Clandestinely prepared Methaqualone appears as brown grey or black tacky powder. The colour depends on the ampunt of impurities present. It is also available as tablets and capsules.

Source and form of crime/questioned sample:

From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:

Standard reference material may be imported through CCF GOAW following NDPS Rule 67(B)

Library database available in the instruments can be utilized for comparison.

Authentic books like pharmacopeia may be referred.

Methods and Procedures:

Physical Examination:

Physical appearance: solid, injection tablet etc... may be noted.

Chemical Examination:

Colour tests:

Cobalt thiocyanate test:

Reagent1: 16% HCl. Solution

Reagent2: 2.5g. cobalt thiocyanate in 100ml. Water.

Method: Place a small amount of the suspected material into a test tube. Add one drop of reagent1. And one drop of reagent 2. A blue colour indicates the possible presence of Methaqualone or Mecloqualone.

Fischer Morris Test:

Reagent1: Concentrated formic acid

Reagent2: 5% aqueous sodium nitrite solution.

Method:

Place a small amount of suspected material into a test tube. Add seven drops of reagent 1 and 5 drops of reagent 2. Let stand for 1-2 minutes then add 15-20 drops of chloroform. Shake let it stand and aobserve the colour in both the layers.

Name of the drug	Cobalt thicyanate test	Fischer-Morris test	
Methaqualone	blue	No colour	yellow
Mecloqualone	blue	No colour	yellow
Cocaine	blue	Faint green	Faint green
phencyclidine	blue	tinged	tinged
Caffeine	pink	No colour	No colour
Heroin	blue	Faint yellow	yellow
Diazepam	Blue green	Faint yellow	Faint yelow

1. Thin Layer Chromatography

2. Instrumental Method:

GC, HPLC, GC-MS, FT-IR, Ramanspectroscopy,
UV spectroscopy

Stimulants (Psychotropic substances)

Amphetamines:

Amphetamine
Methamphetamine
MDMA

Amphetamines are synthetic stimulants with effect similar to Cocaine but longer lasting and cheaper. Abused by students truckers on long haul, workers labouring long hours, soldiers pilots trying to stay awake for 48 hours straight.

ATS may produce one or more dose-related symptoms, including increased alertness and euphoria, increased heart rate, blood pressure, respiration and body temperature. Agitation, tremors, hypertension, memory loss, hallucinations, psychotic episodes, paranoid delusions, and violent behaviour can result from chronic abuse. Withdrawal from high doses of ATS could result in severe depression. ATS are illegally produced in a variety of preparations (powder, tablets, or capsules), and they may be injected, ingested orally, snorted, or smoked.

Mehtamphetamine: Potent Central Nervous System Stimulant.

Frequent method of abuse is injection.

Source and form of crime/questioned sample:

From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:

Standard reference material may be imported through CCF GOAW following NDPS Rule 67(B)

Library database available in the instruments can be utilized for comparison.

Authentic books like pharmacopeia may be referred.

Methods and Procedures:

Physical Examination:

Physical appearance: solid, injection tablet etc... may be noted.

Chemical Examination:

Colour tests:

Marquis Test:
: Carefully Mix 100ml. Of Concentrated Sulphuric Acid with 1 ml of 40% (v/v) formaldehyde solution .
Amphetamines give orange colour which slowly turns brown.
Simons Reagent 1: Dissolve 1g. of Sodium Nitroprusside in 100ml.of 5%(v/v)aqueous acetone.
Simons Reagent 2: Dissolve 2g. of Sodium Carbonate in 100ml. Of water.
Method:
Place a small amount (1-2 mg of powder, or 1-2 drops of a liquid) of the suspected material in a depression on a spot plate. Qualitative and quantitative analysis of ATS 19 Add one drop of Simon Reagent 1 and stir. Add one drop of Simon Reagent 2, and then one drop of Reagent 3. Observe the colour of the mixture.
MDMA and Methamphetamine give blue green colour.

Thin Layer Chromatofraphy

Instrumental Method:
GC, HPLC, GC-MS, FT-IR, HPTLC, Raman spectroscopy, UV spectroscopy
Bath salts: Is the informal street name for a family of designer drugs often containing substituted cathinones which have effects similar to amphetamines and Cocaine.The drug is swallowed injected snorted or used rectally.
Mephedrone
Methylone
MDPV
Source and form of crime/questioned sample:
From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.
Standard reference material:
Standard reference material may be imported through CCF GOAW following NDPS Rule 67(B)
Library database available in the instruments can be utilized for comparison.
Authentic books like pharmacopeia may be referred.

Methods and Procedures:
Physical Examination:
Physical appearance: solid, etc... may be noted.

Chemical Examination:
Colour Tests:
Zimmermann test: Reagent:1. Dissolve 1g. of 1,3-dinitrobenzene in 100ml. Of methanol.
Reagent 2: dissolve 15g. of Potassium Hydroxide in 100ml. Of water.
Method: Place a small amount of the suspected material on a spot plate.
Mephedrone turns purple Methylone purple and MDPV yellow.
Thin Layer Chromatography

Instrumental Method:
GC, HPLC, GC-MS, FT-IR, HPTLC, Raman spectroscopy, UV spectroscopy
KHAT
General background

KHAT pronounced as cot is Catha edulis L.

It grows 10 to 20 feet tall flowering ever green shrub native of East Africa and Southern Arabia.

It is a psychotropic substance. The psychoactive substances are cathine and cathinone.

The fresh young leaves of Catha edulis L have been consumed by chewing. Compulsive use results in manic behaviour in a paranoid type of illness, sometimes accompanied by hallucinations.

Laboratory Examination

I. Physical Examination

(a) Physical appearance: Plant material, leaves etc.

II. Extraction:

Solvent extraction

The plant material i.e., the leaves are cut into small pieces and subjected to solvent extraction. The extracted drug is subjected to chemical analysis.

Colour test:

The extracted drug is dissolved in Methylene chloride and subjected to colour test, TLC and instrumental analysis.

Chen"s test:

Reagent 1: 1%(v/v) aqueous acetic acid

Reagent2: Dissolve 1g. of coper(II) sulphate in 100ml. Of water.

Reagent3: Dissolve 8g. of sodium hydroxide in 100ml. Of water.(2N)

Method: Place two drops of the extract in one well of the spot plate and add the reagents one after the other.

Results:

Slow forming yellow orange colour.

II Thin Layer chromatography

III Instrumental Analysis:

GC-MS. LC-MS. HPLC, HPTLC

Hallucinogens (Psychotropic substances)

1. LSD
2. Psilocybin mushrooms
3. Ketamine

LSD

It is a semi synthetic form of an ergot fungus toxin that infects rye and other cereal grasses.

It was associated with the hippy movement.

Sample:- Generally it is encountered in paper dosage form where crystalline LSD is dissolved in alcohol and drops of the solution are put on blotter paper or the paper is dipped in solution. Micro tablets, gel and suger cubes are other forms.

The drug is chewed, swallowed or placed on tongue through which it gets adsorbed into the body.

Laboratory Examination:

I. Physical appearance: paper blot/ sugar cube/ gelatine squares/ micro tablets (micro dot)

The presence of LSD may be signalled early by placing the suspect paper under long wavelength ultraviolet (UV) light. The presence of LSD is indicated by a blue fluorescence.

Colour test:

Ehrlich test:

Reagent:- Dissolve 1g. of 4-dimethylamine benzaldehyde in 10ml of methanolthen carefully add 10ml of Conc. Orthophosphoric acid

Method: The reagent is added to sample methanol extract in a depression in spot plate warned if necessary.

Result:- Violet colour is produced if LSD is present.

Few other ergot alkaloids also give the test positive.

TLC:

Instrumental Technique:

The presence of the drug is confirmed by Instrumental method of analysis. GC, GC-MS, HPLC are preferred methods.

Psilocybe Mushrooms

The main alkaloid present in these species are the phosphorylated indole amines. Psilocybin, baeocystin and Psilocin.

When eaten these sacred or magic mushrooms affect mood and perception similar to mescaline and LSD.

Source and form of crime/questioned sample:

From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:

Standard reference material may be obtained through CCF GOAW following NDPS Rule 67(B)

Library database available in the instruments can be utilized for comparison.

Authentic books like pharmacopeia may be referred.

Methods and Procedures:

Physical Examination:

Macroscopic Examination

Microscopic Examination

Chemical Examination: Psilocybin is extracted from dried and pulverized mushrooms using methanol by shaking or sonicating.

Colour Tests:

Ehrlich Test: Dissolve 1g. of 4-dimethylamine benzaldehyde in 10ml of methanolthen carefully add 10ml of Conc. Orthophosphoric acid

Method:

Place a small amount of suspected material on a spot plate. Add two drops of Ehrlich reagent. After a few minutes a violet to grey violet colour indicates the possible presence of psilocybin or psilocin.

Thin layer Chromatography

1. Instrumental Method:
GC, HPLC, GC-MS, FT-IR,
UV spectroscopy

Ketamine:

Primarily used as a veterinary anesthetic. IIndividuals feel detached from their pain and environment. In addition has both analgesic and amnestic property. It is abused by criminals in Drug Facilitated Sexual Assault cases.

Source and form of crime/questioned sample:
From Forwarding Authorities who include police officers of the rank DSP and above and Judicial officers.

Standard reference material:
Standard reference material may be obtained from Indian Pharmacopoeia Commisssion.
Library database available in the instruments can be utilized for comparison.
Authentic books like pharmacopeia may be referred.

Methods and Procedures:
Physical Examination:
Physical appearance: solid, etc... may be noted.

Chemical Examination:
Instrumental Methods:
GC, HPLC, GC-MS, FT-IR, Raman spectroscopy, UV spectroscopy
The following analytical protocol should be followed by forensic science laboratories while reporting an NDPS drug.
GroupA: FTIR, Mass spectrometry, Nuclear Magnetic Resonance spectroscopy(NMR), Raman Spectroscopy.
GroupB: Thin layer chromatography (TLC), Gas Chromatography (GC), High performance Liquid Chromatography (HPLC), Capillary Electrophoresis, Ion mobility Spectrometry(IMS), Microcrystal tests, Macroscopy and microscopy in case of Cannabis.
GroupC: Colour tests, Melting point, UV-VIS Spectroscopy, Fluorescence Spectroscopy.
One of the following combinations should be adapted in the laboratory.
1. One technique/method from group A and at least one method/trechnique form either group A,B or C.
2. When a group A technique method is not used, then atleast three techniques/methods/parameters should be used. Two of the three methods must be based on uncorrelated techniquesfrom group B eg: two un correlated TLC systems would be counted as two parameters, which means either the mobile phase or the stationery phase (plate coating) are completely different.
3. When a hyphenated technique is used (eg: GC-MS, LC-MS/MS, GC-FTIR, HPLC-PDA, HPTLC etc.) with standard reference/Control sample, then it would be

considered that sample has been analyzed by two techniques/parameters for its identification.
If a hyphenated technique is used as the sole means of identification of narcotic drugs when standaard reference material is available, it should be applied to two sets seperate samples drawn from the same exhibit.
The choice of the test methods / techniques to be adapted for the examination exhibit lies with the discretion of examining officer as he is the best judge for the right approach to the case problem.

Drug Precursors
1.Acetic Anhydride
2. Acetone
3.N-acetylanthranilic acid.
4.Ephedrine
5.Pseudoephedrine
6.Ergometrine
7.Ergotamine
8.1-phenyl-2propanone(P-2-P)
9.Isosafrole
10.Lysergic acid
11.Piperidine
12.Piperanol
13.Phenylacetic acid.
14.Safrole
15.MethylEthylKetone
16.3 ,4-Methylenedioxyphenyl-2-propanone
17.Toluene

LEARNING OUTCOME

After studying this unit you should be able to:
1. Perform the chemical tests for various poisons.
2. Understand the classification of Poisons.
3. Understand the proper collection and preservation of drug evidence.
4. Understand the concept of various instruments used for the detection and identification of drugs.

GLOSSARY

1. Poisons
2. Gas chromatography
3. Depressants
4. Insecticides
5. Volatile poisons
6. Non- volatile poisons
7. Metallic poisons
8. Screening tests
9. Barbiturates
10. Stimulant
11. Narcotic

SUGGESTED READINGS

1. Analytical Methods in Forensic Toxicology – Dr. S. N. Tiwari.
2. Forensic Toxicology – Nicholas. T. Lappas.
3. Forensic Medicine & Toxicology - Dr. S. N. Tiwari.
4. Drug Abuse & Drug Prevention – Kohli.
5. Analysis of Plant Poisons- Dr. M. P. Gautam.
6. Encyclopedia of Narcotic Drugs & Psychotropic substances, Vol 1 to 3 – Giriraj Shah.
7. Criminal Poisoning – John Harris Trestrail.
8. Concepts in Toxicology- John. H. Duffus.
9. Handbook of Mass Spectra of Drugs – Sunshine.

UNIT III

LEARNING OBJECTIVES:

In this unit you will be introduced to:

1. Types of Failures and their mechanisms.
2. Cause for Failure.
3. Investigation of the scene and sample collection.
4. Various Laboratory tests.
5. Forensic Speaker Identification.

UNIT III – FORENSIC ENGINEERING & FAILURE ANALYSIS

3.0 INTRODUCTION

Forensic Engineering Section deals with a variety of cases which apply engineering principles and methodology.
The following types of cases are generally examined in forensic engineering section:

i) Reconstruction of events involving automobile accidents, rail accidents, air- craft accidents, industrial accidents etc
ii) Failure Analysis Involving Metallurgical Components & Other Products / Machinery
iii) Examination of material recovered in structural failures such as collapse of bridges, buildings, dams etc
iv) Video Authentication

v) Forensic Speaker Identification.

A part or assembly is considered to have failed under one of the three conditions:

a) When it becomes completely inoperable.

b) When it is still operable, but is no longer able to perform the intended function, or

c) When serious deterioration has made the part unreliable or unsafe.

The principle sources of failure include several aspects of design, material selection, material defects, fabrication of processing, reworking, assembly, inspection, testing, quality control, storage and shipment, service conditions maintenance, un anticipated exposure to conditions.
One of the above or several sources may contribute the occurrence of failure. The following are factors that lead to failure:

3.0.1 DEFICIENCIES IN DESIGN

Fatigue Fracture: When components are subjected to alternating stresses, the part may fail due to fatigue which can not be eliminated based on service conditions.
Material and Fabrication: When a proper material is not specified based on the load, environmental condition, the component may result in failure. During fabrication, some defects may present in the part which is not considered during assembly, eventually may lead to failure. Defects in castings, forgings, weldings, etc.,
Conformance to Specifications: The component some time may not conform to specifications as per designer.
Ex: Instead of hardened and tempering, the part might not subjected to specified heat treatment.
Some typical deficiencies that can result in failure are mainly: Selection of Material:
Material selection needing proper strength levels such as:

- Inadequacy of mechanical properties of the part.
- Selection of material.

- Improper operating conditions.
- Imperfections in materials/parts.

1) Casting
2) Forging
3) Extrusions

- Deficiencies in processing

1) Cold formed parts
2) Machining & grinding
3) Improper heat treatment
4) Pickling and electroplates
5) Welding
6) Reworking

- Errors in Assembly

Improper Service Conditions:

In several cases of failures, it may be attributed to improper service conditions such as:

- Abnormally severe conditions of speed, loading, temperature, and chemical environment and irregular maintenance, inspection and monitoring.

3.1 FAILURE MECHANISMS (TYPES OF FAILURES)

Analysis of a failure of a metal structure or part usually requires identification of the type of failures. Failures can be broadly classified in to the following:

1. Ductile and Brittle fractures
2. Fatigue Failures
3. Distortion Failures
4. Wear Failures
5. Fretting Failures
6. Liquid Erosion Failures
7. Stress Corrosion Failures
8. Liquid Metal Embrittlements
9. Hydrogen Damage Failures
10. Elevated Temperature Failures
11. Corrosion Fatigue Failures

Failure can occur by one or more of several mechanisms, including surface damage such as corrosion or wear, elastic or plastics.

Classification of Fractures:

The operating conditions in service should consider such as loading conditions, rate of crack growth, and macroscopic and microscopic appearance of fracture surfaces.

Loading conditions:

A fracture that can result from loading being at low or moderate or extremely fast and overload fracture.
The loading conditions usually described are tension, compression, cyclic, bending, torsion, direct shear and fatigue.

Crack-Growth Rate:

Cracks that lead to fracture can be described as ductile fracture grow usually at a low rate generally less than 20 ft per second. In addition factors such as temperature, crack- growth rate are affected by chemical composition, crystal structure, microstructure and grain size.

Macroscopic Examination:

The macroscopic appearance of a fracture surface is described by term such as bright or gray, smooth or rough, crystalline or sulking, granular or fibrous, flat – face and shear- face.

Microscopic Examination:

The microscopic appearance of a fracture surface is described in terms of the microscopic features that are present.
For example, a dimple rupture exhibits mainly dimples and a cleavage fracture exhibits mainly cleavage facets.

3.1.1 DUCTILE & BRITTLE FRACTURE Ductile Fracture

Ductile fractures are characterized by tearing or slippage / sliding accompanied by considerable deformation and energy absorption. The ductile fracture in mast materials have a gray, fibrous appearance.

Brittle Fracture

Brittle fractures are characterized by rapid crack propagation with less expenditure of energy without appreciable grass plastic deformation.
Brittle tensile fractures have a bright, granular appearance, flat face type, and are produced under plastic strain conditions with title or no necking.
Microscopic examination of brittle fractures will reveal inter granular or trans granular facets.
Intergranular facets are grain surfaces that have been exposed by crack propagation along grain boundaries. The transgradular facets observed on brittle fractures are produced by cleavage along numerous parallel crystallographic planes, thus creating a terraced fracture surface.

3.1.2 FATIGUE FRACTURE

Fatigue fractures result from cyclic loading, and appear brittle on a macroscopic scale. They are characterized by incremental propagation of crack until the crass section has been reduced to where it can no longer support the applied load, and fast fracture

occurs. The surface is characterized by beach marks, Progressing from the origin of crack.

Fatigue Failures: Fatigue is the progressive localized permanent structural damage that occurs in a material subjected to repeated or fluctuating strains at stresses having a maximum value less than the tensile strength of the material.

Fatigue fractures are caused by the simultaneous action of cyclic stress tensile stresses and plastic strain.

The process of fatigue may be considered as consisting of three stages:

1. Initiation of damage leading to a crack initiation.
2. Crack propagation until the remaining uncracked cross-section at a part becomes too weak by carry the loads imposed.
3. Final, sudden fracture of the remaining cross section.

Factors Influencing Fatigue: In general, fatigue life can be expected to depend on the following:

1. Type of loading (unianial, bending, torsional)
2. Shape of the loading curve
3. Frequency of loading cycle
4. Loading pattern
5. Magnitude of stresses
6. Part size
7. Fabrication method and surface roughness
8. Operating temperature
9. Operating atmosphere
10. Stress-ratio

Fatigue Limit: The horizontal portion of S-N curve representing the maximum stress that the metal can withstand for an infinite number of cycles is called fatigue limit or endurance limit.

Fatigue Strength: The maximum stress that can endure to specified number of cycles. Usually, the number of cycle (106 cycle) that is considered.

Stages of Fracture in Fatigue: The fractured surface that result from fatigue failure has a characteristic appearance that can be divided into three zones or stages of fracture.

Stage-I: is the initiation of cracks and their propagation by slip-plane fracture extending inward from surface at approximately 45^{o} to the stress axis.

Stage-II: The transition from stage I to stage-II fatigue fracture is the change of orientation of the main fracture plane in each grain from one or two shear planes to many parallel plateaus separated by longitudinal ridges.

Stage-III: This stage occurs during the last stress cycle when the cross section is unable to sustain the applied load.

3.1.3 DISTORTION FAILURES

Distortion Failure occurs when a structure or component is deformed so that it

a) No longer can support the load it was intended to carry.

b) Is incapable of performing its intended function, or

c) Interferes with the operation of another component

Distortion failures can be either plastic or elastic, and may or may not be accompanied by fracture. There are two types of distortions, size distortion, which refers to a change in volume, and shape distortion (bending or warping).
Distortion failures are considered to be self evident – for example – damage of a car body in collision.
The valve may have stuck open because of faulty lubrication; the valve spring may have broken because of corrosion had weakened it. Some common causes of distortion failures are:

Overloading: Applied load that exceed the designed load may result in distortion or fracture.
Usually, the fallowing may be considered for investigations:

Safety Factors: In design, some factor of safety is usually taken into consideration. By calculating the fracture with that of factor of safety may enable the cause for failure.
Amount of Distortion: In designing structures using limit analysis, designers do not always consider the amount of distortion that will be encountered.

Effect of Temperature: Distortion failures caused by overload can occur at any temperature at which flow strength of the material is less than the fracture strength.

Usually, at temperatures higher than abut Tm/2, phenomena such as creep may cause distortion failure. Creep is a relatively long-term phenomena and can be distinguished from overload distortion.

Faulty Heat Treatment: Mistakes made in heat treating are among the most common causes of premature failure.

Faulty Hardening: Carburizing which increases the surface hardness and provides resistance to wear and indentation, can, if improperly controlled, may become cause for failure.

Faulty Repairs: Products often are repaired to correct deficiencies that are found in the parts during inspection. Repair welding and brazing are generally potential sources of unwanted changes of the properties.

3.1.4 WEAR FAILURES

Wear is a surface phenomenon that occurs by displacement and detachment of material. Wear usually results in progressive loss of weight and alteration in dimensions over a period of time.

All mechanical components that undergo sliding or rolling contact are subject to some degree of wear. Typically, components such as bearings, gears, seals, guides, piston rings, splines, brakes and clutches.

Lubrication implies the intentional use of substance that reduce friction between contacting surfaces. Lubrication is a mitigating factor in wear, and thus lubricated and non-lubricated wear.

Types of wear:

Wear is a distortion due to use, Gradual deterioration often is implied and the effects are mostly surface phenomenon. Wear failures may be gradual, rapid or occasionally, catastrophic. In general, wear may be defined as damage to a solid surface caused by the removal or displacement of material by mechanical action of contacting surfaces. There are several types of wear based on the method of wear.

Adhesive Wear: Known as scoring, galling, seizing and scuffing, occurs when two metallic surfaces slide against each other under load.
Microscopic projections or asperities bond at the sliding interface under very high local pressure, subsequently, the sliding forces fracture the bonds, tearing metal from one surface and transferring it to the other. This results in the formation minute cavities on one surface and minute projections on he other which in turn, can lead to further damage.

Abrasive Wear: Is displacement of material from a surface by contact with hard projections on mating surface, or with hard particles, that are moving relative the wearing surface. Hard particles may be trapped between two sliding surfaces and abrade one or both of them, or they may be embedded in either of the surfaces and abrade the opposing surface. It may occur in dry state or in the presence of a liquid / lubricant.

Erosive Wear: Is abrasive wear involving loss of surface material by contact with a fluid that contains particles. Relative motion between the surface and the fluid is essential to this process. The particles that in flies the damage is applied kinetically. Most often it involves solid particles but may be caused by liquid-impingement. Called liquid impingement erosion.

Corrosive Wear: Is another type of abrasive wear in which chemical or electrochemical reaction with the environment significantly contribute to the wear.

Erosion – Corrosion: Is a type of wear in which there is relative movement between a surface and a corrosive fluid special form of erosion-corrosion called cavitation erosion. It can occur on a surface in contact with a moving liquid that does not contain

particulate matter. In cavitation erosion, the repeated formation and collapse of vapor bubbles at the surface impose large repetitive contact stresses that con cause pitting of spalling.
Surface Fatigue: Is a special type of surface damage whereby particles of metal are detached from the surface under high cyclic contact stresses, causing pitting or spalling.

3.1.5 FRETTING FAILURES

Fretting Failures:

Fretting is a wear phenomenon that occurs between two mating surfaces, it is adhesive in nature, and vibration is its essential causative factor.
Fretting Characteristics:

Fretting occurs at contacting surfaces that are intended to be fixed in relation to each other, but that actually undergo minute motion, called „Slip‰, that is essentially produced by vibration.
Common sites for fretting are in joints that are bolted, keyed, pinned, press fitted, and riveted, in osculating bearings, splines, couplings, clutches, spindles, and seals, in press fits on shafts and in universal joints, base plates, shackles and prosthetic devices.

Recognition of Fretting:

Fretting of ferrous metals in air produces a characteristic reddish-brown debris of ferric oxide which, when mixed with oil or grease, produces a debris that is often called
_Blood‘, _Cocoa‘ or _Redmud‘ debris. Presence of the reddish brown debris is indicative of fretting. Analysis of ferric oxide (– Fe_2O_3, hematite) or hydrated ferric oxide (– Fe_2O_3, tho goethite). These two compounds can be distinguished by X-ray diffraction, because their patterns are different, or by chemical analysis. When the fretted surface after cleaning examined, will reveal very reflective area, as well as depressions and pits containing black patches of Fe_3O_4, which is produced when the oxygen supply is limited.
Prevention of Fretting:

Fretting can be minimized or prevented by:

a) Elimination or reduction of vibration,

b) Elimination of slip,

c) Lubrication,

d) Surface separation, and

e) Induction of residual stresses

Fretting Situations:
The fretting can occur in many situations such as:

a) Sliding shafts

b) In wire ropes

c) In fuel elements because of contact with jagged metal.

3.1.6 LIQUID EROSION FAILURES

Erosion of a solid surface in a liquid medium without the presence of solid, and abrasive particles one of the mechanism of liquid erosion involves the formation and subsequent collapse of bubbles with in the liquid, which is called as ,,Cavitation‰.
When the liquid droplets collide with a solid surface at high speed, a form of liquid erosion called liquid impingement erosion occurs.
Cavitation damage has been observed on ship propellers and hydrofoils, on dams, spillways, gates, tunnels and other hydraulic structures, and in hydraulic pumps and turbines.

Liquid-impingement erosion has been observed on many components exposed to high velocity steam containing moisture droplets of large steam turbines.
A form of liquid-impingement erosion, rain-evasion, frequently damages aerodynamic surfaces of air-craft and missiles when they fly through rainstorms at high subsonic or supersonic speeds.
Liquid impingement and cavitation erosion are of concern in nuclear-power systems, which operate at lower steam quality than conventional steam systems.

Liquid erosion is associated with the progressive removal of material from a surface by repeated impulse loading at microscopic levels.
Characteristics of Erosion Damage:

Materials may be damaged by deformation occurs by the formation of microscopically small craters under the impingement of cavitation shack waves, droplet impingements, or micro jet impingements.
Brittle materials are eroded of microscopic particles from the surface.

The damage may be influenced by several factors such as:

- Flow velocity
- Size of bubbles formed
- Hardness of the materials
- Microstructure
- Corrosive fluid

Analysis of Liquid Erosion:

The analysis involves the observation of several factors:

- Preliminary examination
- Operating conditions
- Spectrographic analysis
- Metallographic analysis
- Hardness measurement
- Conclusions

3.1.7 STRESS CORROSION CRACKING

Stress corrosion cracking is a mechanical environmental failure process in which sustained tensile stress and chemical attack combine to initiate and propagate fracture in a metal part

Failure by stress-corrosion cracking occurs by simultaneous action of chemical environment and tensile stress of the metal part.
Some times the presence of hydrogen in a metal, may result in cracking. Sources of stresses in Manufacture:
The principal sources of local/locked up stress in manufacture include:

a) Thermal processing

b) Stress raises

c) Surface finishing treatment, and

d) Fabrication

Thermal Processing:

Most common source of thermal processing heat treatment such as quenching, welding, cold working drawing etc.,
Stress rises:

Common stress raisers are

a) Geometrical stress raisers – such as notches,

b) Notches due to damage

c) Cracks produced in quenching

d) Inclusions and hydrogen blisters

e) Interfaces in layer type bond material

f) Cold rolling, brazing and soldering

g) Grinding and fabrication works

Crack Initiation and Propagation:

The site of initiation of stress-corrosion crack may be submicroscopic. The tip of an advancing crack has small radius and the stress concentration is great. Under corrosive environment, propagation occurs and may result in failure.

General Features of Stress – Corrosion Cracking:

Stress corrosion cracks undergo extensive branching and proceed in perpendicular to the stress contributing to their initiation.
Effect of Environment:

Stress corrosion cracking often depends on environment composition, and the alloy composition and metallurgical structure.
The table (1) represents the susceptibility of materials and environment.

Substances Damaging	Alloy	Special aspects
Oxygen (O_2)	Cu-alloys	Depends on O_2 concentration
Hydrogen Sulphide (H_2S)	Many commercial alloys	Anaerobic bacteria breakdown of organic products
Oxides of nitrogen	C – steels	The oxides produce nitric acid and nitrates
CO or CO_2 + Moisture	C – steels	-
Ammonia	Cu – Alloys	-
Arsenic and sb compounds	Many commercial alloys	Contained in insecticides and sprays
SO_2	Copper alloys	The oxidesprodace H_2SO_3, H_2SO_4
Chloride + Moisture	„	Marine exposure

3.1.8 LIQUID METAL EMBRITTLEMENT

Liquid Metal Embrittlement (LME) is the decrease in strength or ductility of a solid metal that is caused by contact with a liquid metal.

Liquid metal embrittlement results in either:

a) A decrease in tensile elongation prior to failure, or

b) Fracture without plastic deformation at stress level below normal yield stress.

Normally, a ductile metal subjected to tensile stresses while in contact with a liquid metal may fracture at an abnormally low stress with little or no ductility.
Examination LME fractured surfaces shows complete coverage by the liquid metal. Liquid metal is in contact with the solid and is difficult to remove.

One of the prerequisities is that the solid has little or no solubility in the liquid and forms no inter-metallic compound to constitute an embrittlement couple.
Severe embrittlement occurs near the freezing temperature of the liquid.

Iron lead, Iron – indium, and many other metallic couples, embrittlement occurs below the melting temperature of the liquid. This new phenomenon is called solid metal induced embrittlement (SME) of metals.
Some of the following have been observed.

- Small amountsof elements such as Ph-Te, added to steel to i
- Cd-plated titamium and steels are embrittled during high-temperature service by motter cadmium.
- Indium, used as a high vacuum seal in steel chambers, has caused cracking during bake-out operation.
- Zircaloytubes used in nuclear reactors have been cracked by both solid and liquid cadmium.
- Embrittlement of steel occurs by electroplated or dipped cadmium, Zn or Sn-all which provide corrosion resistance.
- In liquid metal cooled reactors, liquid lithium can cause both corrosion & LME in metals and alloys.

Embrittlement of Ferrous Metals and Alloys:

- Embrittlement by al.

Tensile and stress-rapture tests have been revealed at that molten aluminium at 690^{O}C for short time reduced breaking stress and reduction in Area.

- Embrittlement by Antimony

AISI 4340 steel tested for fatigue in liquid ph-35 ÊSb at 540^{O}C and in Sb at 675^{O}C was very severe by embrittled.

The embrittle in Ph-Sb occurred at 165 to 220^{O}C could lead to embrittlement.

- Embrittlement by Bismuth.

Testing in liquid bismuth at 300^{O}C, no embrittlement occurred in bend test on quenchied-and-tempered steel.

- Some other experiments have proved that embrittlement can occur by cu, Ga, In, Ph, Li, Hg, Se, Ag, Na, and solders depending on temp and type of stress.

3.1.9 HYDROGEN EMBRITTLEMENT

Depending on the type of hydrogen/metal interaction, hydrogen damage of metal manifests itself in one of several ways.
Types of Hydrogen Damage:

The embrittlement occurs only in specific alloys under specific conditions are:

- Hydrogen embrittlement
- Hydrogen-induced blistering
- Cracking from precipitation of internal hydrogen
- Hydrogen attack
- Cracking from hydride formation

Hydrogen Embrittlement:

High strength steels containing hydrogen and tension fails prematurely in a brittle manner.
Steel can be embrittled by a very small amount of hydrogen, often a few PPm may result in embrittlement.
Reduced surface energy theory states that the absorption of hydrogen decreases the surface free energy of the metal and enhances the propagation of crack.
There are several methods through which metals exhibit embrittlement:

- Cracking from hydrogen charging in an Aqueous Environment
- Atmospheric and Aqueous corrosion
- Environments containing Hydrogen Sulphide
- Prickling and Electroplating
- Cathodic Protection
- Cracking from Gaseous Hydrogen
- Cracking from Precipitation of Interval Hyderogen.

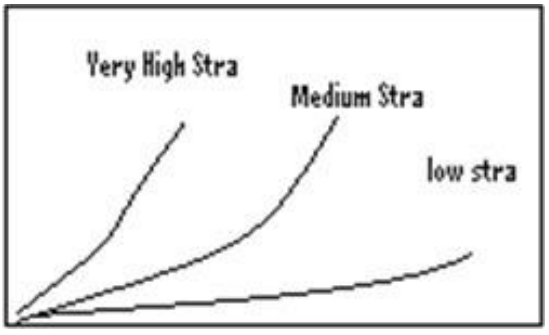
3.1.10 ELEVATED TEMPERATURE FAILURES

At elevated temperatures metals undergo dimensional changes with time are called creep.

The conditions of temperature, stress, and time under which creep and stress-rupture failures occur depending on the metal or alloy, its micro structure, and the on the service environment.

The principal type of elevated temperature mechanical failure are creep and stress-rupture, low cycle or high cycle fatigue, thermal fatigue, tension overload, and combinations of these.

Creep: Most creep curves consists of three distinct stages (Fig) classified into primary creepy secondary creep, and Tertiary creep.
Creep Strains



Primary Creep:

Some times known as transient creep, represents a stage of adjustment within the metal during which rapid thermally activated plastic strain, decreases in rate.

Secondary Creep:

In this stage there exists a balance between work hardening and recovery.It is also known as steady state creep.
It constant creep rate that is the lowest for the metal under given service conditions of stress, temperature and environment. This is known as minimum creep rate.

Tertiary Creep:

Tertiary creep refers to the region of increasing rate of extension that is followed by fracture principally, it may result from metallurgical changes, such as crystallization under load, promote rapid.

3.1.11 FAILURES RELATED TO CORROSION

CORROSION, which is the unintended destructive chemical or electrochemical reaction of a material with its environment, frequently leads to service failures of metal parts or reders them susceptible to failure by some other mechanisms.

All corrosion reactions are electro chemical in nature and depend on the operation of electrochemical cells at the metal surface. The rate, extent and type of corrosion that can be tolerated on the specific application, whether the observed corrosion behavior was normal for the metal used in a given service conditions helps determine what corrective action, if any, should be taken.
The analysis of corrosion failures and the development of suitable corrective measures required the application of the principles of chemistry, electrochemistry, and metallurgy.
Factors that Influence Corrosion Failures:

Several factors, and the possibility of interactions among them, must be considered by the failure analyst.
a) In determining whether corrosion was the cause of, or contributed in some way to, a failure, and
b) In devising effective and practical corrective measures.

The type of corrosion, its rate and the extent to which it progresses are influenced by the nature, composition and uniformity of the environment and metal surface that is in contact with that environment.

Other factors that have major effects on the corrosion process include temperature and temperature gradients at the metal environment interface, the presence of crevices in the metal part or assembly, relative motion between the environment and the metal part, and the presence of dissimilar metals in an electrically conductive environment.

Analysis of Corrosion Failures:

The following factors are need to be considered.

1 <u>History of Failed Part:</u>

Before carrying out tarts that might destroy evidence relating to the failure, it is essential collect and evaluate available information. Information abut the type of

environment. The corrosion behavior of the part is affected by both local and chemical composition in the system.
It available, engineering drawings, and material and manufacturing specification of the parts.

2 On-Site Examination:

On-site examination is in general the same for corrosion failure as for other types of failures. The region of failure itself should be examined and documented making use magnifying aids.
The areas immediately adjacent to and near the failure, as well as related components of the system, should be examined.

3 Photography:

The failed component and related failures of the system should be photographed closely before samples are removed. Colour photographs are particularly useful when colored corrosion products are present; accurate colour rendition is enhanced by use of a gray background.

4 On-Site Sampling:

For on-site sampling the investigator be guided by the information already obtained about the history of the failure.
The bulk environment to which the failed part was exposed should be sampled, and suitable technique should be used to obtain samples and make observations such as composition, moisture, etc.
In addition to taking samples from the failed area, samples from adjacent areas should be obtained for comparison purposes.

5 Precautions:

Removal of specimens, and samples of corrosion product, from the failed part requires careful consideration in the selection of locations and method of removal. The following precautions must be taken:

a) To avoid the destruction of evidence that could be of value in investigating the failure.

b) To avoid further damage to the part or to other related components and structures.

Cuts or separation should be made without affecting the part specially the microstructure which is likely to be affected with heat while cutting.

6 Protection of Samples:

Small parts, and samples collected from large parts, can be protected during transportation to the laboratory by individual packing. Glass vials and PE films and bags are useful. One method of retaining deposited material in sites is to tape a covering of inert plastic over the area.

7 Preliminary Laboratory Examination:

The procedures followed in the preliminary laboratory examination will vary, depending on whether an on-site examination has already been done by the failure investigator.

8 Preservation of Evidence:

The course of investigation should be based on handling of all samples in such a way that maximum information should be gained before any sample is damaged, destroyed or contaminated.
A complete written and photographic record should be kept through all stages of the investigation.

9 Visual Examination and Cleaning:

Samples are first examined visually and with the aid of hand hold magnifying or suitable viewing aids.
At this stage, features such as the extent of damage, general appearance, the color, texture and quantity of the residues are of primary important.

Washing with water or solvent, with the and of us bath, is useful to remove soft adherent residues that obscure the view.
Usually, it is advisable to save the cleaning solution for later analysis.

10 Nondestructive Examination:

For parts in which the damage may have resulted from corrosion or the combined effects of corrosion, stress and imperfections, U.S. examination may enable to get some details.

11 Microscopic Examination:

Examination by both light microscopy and SEM can be used to observe minute features on corroded surfaces, to evaluable microstructure of the metallic parts. Polarized light examination is also necessary some times.

12 Corroded Surfaces:

Viewing the cleaned surface with stereo-microscope clearly shows gross topography of the surface features such as pitting, cracking, surface patterns that can provide information about failure mechanism.

13 Microstructure:

The type of mechanism such as grain boundary attack, inter granular or trans granular type failure can be identified through microstructure examination.

14 Identification and Analysis

To what extent the corrosion has played in the failure, the following must be identified and analyzed:

a) The metal or metals of which the failed part is made

b) The environment to which the failed part was exposed

c) In homogeneities in the metal surface, and

d) The foreign matter and metal surface layers.

Both conventional techniques such as chemical analysis, emission spectorgraphy X-ray diffraction, gas chromatography, X-ray fluorescence special techniques such EPM, Moss spectrometry, electron diffraction may be needed to completely define the composition and structure.

15 Metal of the Failed Part:

Identification of the metal part can be performed through standard procedures by instrumental analysis such as ICP-OES/ or MS. The purpose is to look for the deviations from the specifications.
Specially, some parts in creep and stainless steels the corrosion resistance and other properties of welded joints require close control over the composition.
16 Failure Environment:

The surrounding environment around the failed part is very important. How corrosion contributed to the failure. Both the temperature, composition and temperature of the environment around the part is very important.
17 Inhomogeneities in the Metal Surface:

Severe damage can occur from the presence of inhomageneities in the surface of the metal parts. The corrosion occurs due to embedded particles, such as „tramp‰ iron in the surface and residual stresses.
Corrosion Testing:

Various methods of testing techniques are used in investigating corrosion failures in evaluating the resistance to corrosion. These include accelerated tests, simulated tests and electro-chemical tests.

Corrosion Rates and Corrosion Types:

To determine whether corrosion failure was caused by the use of unsuitable material, it is necessary to known whether the rate and type of corrosion were normal for the given metal-environment combination. There are several standard methods such as ASTM STP and NACF method.
Common Corrosion:

There are several mechanisms of corrosion that have been experienced in practice. The different corrosions that can be classified as:

- Corrosion – Cell – Concentration
- Crevice corrosion
- Liquid Corrosion
- Atmospheric corrosion
- Galvanic corrosion
- Microbial corrosion
- Stress – corrosion

Some Typical Examples of Corrosion Failures

1. Galvanic Corrosion Failure of Malleable Iron Latch in a valve for an automatic sprinkler system.
The valve consisted of a cast copper alloy clapper plate that was held closed by a pivoted malleable iron latch.
Failure: Failure of the latch was caused by extensive loss of metal by galvanic corrosion.

Galvanic Series in Seawater:

Least noble / Adanodie:

Mg & Mg alloy

Zn, Galvanized steel Al – Al – alloys
Cd

Low c – steel Ni – Call In Type 410 SS
50:50 Ph-Sn sold

304 SS

Ph & Sn

Cu & cts alloy Ni-R-alloy Silw
Ti

Cathode, Mast noble Grapulu

Pt

2. Metal Embedded in Concrete
3. Bacterial and Bio-Fouling Corrosion
4. Corrosion of Burned Metal
5. Atmospheric Corrosion

Corrosion in Specific Industries:

- Marine Corrosion
- Nuclear Power Industry
- Fossil Fuel Power Plants
- Automotive Industry
- Air Craft Industry
- Aerospace Industry
- Electronic Industry
- Telephone Cable Plants
- Chemical Processing Industry
- Pulp and Paper Industry
- Brewery Industry
- Pharmaceutical Industry
- Petroleum Industry
- Pipelines
- Mineral Industry
- Structures

- Metal Process
- Batteries
- Dental Alloys
- Emission Control Equipment

Corrosion in the Automotive Industry

Corrosion in recent years become a major concern of automakers around the world. The use of decking chemicals has increased ten fold in N.A since mid 1950 and is the major cause of corrosion of automobiles body panels in the „Seat-belt‰.
Other environmental factors, including air pollution in industrial areas, exposure to marine atmospheres, in coastal areas, acid precipitation and dust control procedures on rural areas, also contribute to the increases corrosion of automobiles.

Auto Industries responded to the corrosion problem in a number of ways, including the use of more corrosion resistant materials, improved paint systems, and better design practice.
Forms of Corrosion

The automotive environment can result in several forms of corrosion. Chief among these are uniform or general corrosion, crevice corrosion, galvanic corrosion, poultice corrosion, and pitting corrosion. Other forms include inside-out corrosion out side – in corrosion, scab corrosion, cathodes defamation, and filiform corrosion.
Uniform Corrosion - Occurs over the entire exposed surface of a component in the form of a general thinning of the metal.

Crevice Corrosion - Is a severe form of localized attack that in normally associated with small packets of stagnant electrolyte that can form at holes or joints or under fasteners.

Galvanic Corrosion - Results from the contact of two dissimilar metals in the presence of an electrolyte. The more active metal or alloy becomes the anode of the couple and may be subjected to rapid attack.

Poultice Corrosion - Is a form of crevice corrosion that occurs under deposits of road debris, such as mud that may be deposited on the underside of fenders and at other locations. The deposits hold corrosive substances such as road salt in contact with the body material and retard or prevent run off. Electrolyte composition gradients are thought to be the most common cause of this form of corrosion.

Pitting Corrosion - Is similar to crevice corrosion in that it is localized attack. It occurs most often in areas of low pH that are depleted in oxygen but have a relatively high concentration of chloride.
Corrosion reducing Methods

In order improve the corrosion resistance of the parts in Automobile, there are several means through which improved the corrosion resistance such as:

Zinc Coated Steel:

Zinc coated (galvanized) steels are the most common coated steels used as body panels.

Aluminium Coated Steel:

Aluminized steels containing 8 to 12% Si in coating are used by automakers for application involving high temperature corrosion resistance, such as exhaust systems, heat shields, and underhood components (Al-4JZn) is a common coating.

Long term coated:

Lead-tin alloy containing 3 to 8% Sn steel offer corrosion protection in gas tanks, fuel lines, and broke lines. Term is cathodic steel substrate and therefore does not offer the sacrificial corrosion protection of galvanized steels.

Organic Composite Coated:

Steel have been developed mainly by Japanese steel makers in cooperation with automakers.

These are coal coated products generally employ an electroplated zinc alloy, chemical conversion coating, and powder coating.

Paint Systems:

The primary function of automotive paint system is to provide a protective barrier against corrosive substance in the outside environment.

This is accomplished through the use of a paint system comprising a conversion coating, one or more coals of primer, and a colored top coat. A typical system might use conversion coating, electro deposited primer 30 øm, a base color coat 15 øm thick and clear top coat 40 øm thick.

Corrosion in other Automotive System:

Some of the other parts of automotive systems such as fuel system, cooling systems electrical systems, exhaust system may undergo corrosion.

3.2 FAILURES IN ELECTRICAL FIELDS

The use of Electrical Power is associated with application of certain voltage and passage of current. The current can be of D.C and A.C. The applied voltage and current drawn vary depending upon the application. The type of failures vary depending upon the end- application and the level of current used. The problems of failures due electrical application is varied. Some of the application and investigations carried out have been presented below.

Electrical Pitting

Electrical pitting is produced by passage of current between two surfaces. In such applications as electric motors, equipment and railway cars and locomotives, there is a possibility of electric current passing through the moving part/parts and bearings. When the current is disrupted at the contact surfaces between them such as railways and rolling elements, arcing or sparking occurs, producing high temperatures and localized damage. The amount of damage shall be proportional to the number and size of localized points.

The characteristic features of such a phenomenon is related to the passage of electric current for prolonged time is the fluting that some time occurs. Fluting is potting in which cavities occur in a regular pattern, forming grooves (flutes). Flutes, when develop considerable depth, produce noise, vibration, and fatigue from local overstressing.
Fluting is found in bearings in rotating electrical machinery, it is reasonable to suspect due to the passage of current associated with defective insulation or inductioneffects.

3.2.1 FAILURE OF ELECTRICAL SWITCHGEAR

Background Information: During routine testing for quality control, electrical switchgear exhibited high contact resistance and resulted in rejection.
Describe the mechanism of failure and discuss the possible mechanism.
Environmental conditions: The switchgears are installed for controlling the power to the equipment. They are usually installed in open atmosphere which is likely to be exposed to

- Varying temperature condition.
- Varying atmospheric condition
- Varying humidity
- Varying load condition
- Varied times

Discussion: The atmospheric exposure leads to the formation of films. Depending upon the constituents such as dust, ammonia, chlorine, SO_2, and nitrous oxides, may develop film of oxide or their compounds. Usually, there films are non-conductive and offer high resistance to the passage of current.

The arcing and sparking results in heating which accelerates the formation of film with time, Film thickness may vary and current passing through the film it difficult as it may act as insulator.

3.3 FAILURES OF METALLIC ORTHOPAEDIC IMPLANTS

Orthopedic Implants are unique in that they are exposed to biochemical and dynamic environment of the body and their design is dictated by anatomy and restricted by physiological conditions. Orthopedic implants are artificial devices that are mounted to the skeletal system of the human body or an animal for various purposes such as supporting bone, replacing bone or joints and reattaching tendons or ligaments.
Prosthetic Devices:

Artificial joints are mainly use to replace painful joints that are degenerate and inflicted with diseases.
In Tumor Resections:

Sometimes large defects are created by extensive bone and joint removals, which are often bridged with custom-made prostheses, modified standard joint prostheses, or fracture-treatment implants Bone Cement and/or other.
Implants for Internal Fixation:

Implants for internal fixation are characterized by their versatility.

- Used to maintain shape of the reconstructed bone in fracture treatment.

- To correct orthopedic surgery
- To stabilize osteotomies
- To perform orthrodeses (stiffening of joints)

Various sizes and types include bone plates, bone-screws, intramedullary rods (nails), pins, orthopedic wire.

The stabilizing difficulties can be listed in ascending order, as follows:
- Joint replacements (endoprostheses)
- Corrective orthopedic surgery
- Fracture treatment
- Tumor resection (most difficult)

Complications Related to Implants:

Internal fixation or joint replacement can fail for several reasons as:

- Failure of the bone to heal
- Bone absorption
- Breakage of the bone
- Loosening of implants
- Bending of implants
- Breakage or
- Disintegration of implants

Implant can undergo surface attack by fretting, fretting corrosion, or wear or corrosion. Metallic Implant Materials:
A number of metals and alloys have proven to be satisfactory as implant materials. ASTM and ISO standardized and listed below:
- Stainless steel: ASTM F55-82

ASTM F 50-82

ASTM F 138-82

ASTM F 139-82 ISO/DIS 5882/1 (Fi 86)
- Un alloyed Titanium: ASTM F 67-83

ISO 5832/II (1984)

- Titamium alloy: Ti-6 Al-4V ASTM F 136-79

ISO: 5832/III (1978)

- Cost Co-Cr-Mo alloy: ASTM F 75-82

ISO 5832/IV (1978)

3.3.1 THE BODY ENVIRONMENT & ITS INTERACTIONS WITH IMPLANTS

The Biochemical Environment. Implants are exposed to the biomechanical and biochemical forces of the body, and certain interactions take place between the implants and the biological environments such as:

- Blood Plasma
- Interstitial Fluid
- Cell Fluid

Chlorine ions are the most critical for metal implants. The normal ptt of the body liquid is about neutral in the range of 7.2 to 7.4ptt. At injured sites, the ptt shifts to acidic value about 5.2; in hematoma, it can drop to 4.0. In cases of infection, the pH shifts to alkaline value.

The Dynamic Environment:

Various types of forces action the implants and the bone. In the intact musculoskeletal systems, the acting forces are balanced.

When loaded physiologically under weight bearing, the bone undergoes small elastic deformations, which act as a fine stimulus that keeps the bone in a healthy condition. The development of fatigue damage depends on the number of load cycles and the intensity of loading.

Table (1) Estimation of load cycles for one leg during walking:

Motion per day, h	Cycles per day	Cycle per year
1	1800	657,000
3	5400	1,971,000
6	10,800	3,942,000

The force (2600 N) was determined on the femoral head in the loading phase during a test of 60kg patient.

Bone Healing:

Normal bone regeneration occurs continuously at a relatively slow rate. About 3% of the Haverzian Systems of the bone structure are usually in stage of remodeling. Depending on the local conditions, different bone repair mechanisms can occur.

Bone Resorption Through Motion:

Clinical and experimental observations indicated that persistent motion beyond certain degree causes bone resorption when mechanical instability present.

Thus, fracture gaps can widen and implants, can become loose. The widening of fracture gaps means increased cyclic loading of the implant unless weight bearing is reduced. Implant loosening can cause either local concentration with increased risk of fatigue.

Local bone resorption followed by mechanical degradation of bone cement and partial loosening of prosthesis stems in a typical sequence of events that is responsible for fatigue failure.

Combined Dynamic and Biochemical Attack:

Dynamic loading in the presence of body fluids can cause wear and fretting corrosion at implant joints, such as screw heads and plate holes, or at artificial articulation surfaces. It is generally agreed stress-corrosion cracking not a concern in high quality implant materials.

Analysis of Failed Devices:

Most of the failed implants have exhibited the various phenomenon that lead to failure.

1) Severe General Corrosion in Chromium Steel Lane Plate

2) Bone screw made from Co-Cr-Mo Alloy casting failed due inherent casting defects.

3) Inter crystalline corrosion on cerclage wire failed due to sensitized 304 type stainless steel.

4) Implanted screw failed due to mechanically forced shearing fracture.

5) Type 316 LRSS screw failed due to fatigue.

3.4 ELECTRONIC COMPONENT FAILURES

Electronic Failure Analysis is required to identify failure modes and establish failure mechanism. A thorough and understanding of electric device fabrication, working principles along with failures permits improvements. Electronic failure analysis is essential to the development of highly reliable electronics.

Electronic packaging required a detailed understanding of the interaction of electrical and mechanical technologies in order to develop robust and reliable electronic systems.

Failure investigations revealed malfunctions related to materials behavior and manufacturing processes. With the miniaturization packaging has become extremely sophisticated. Metal conducting device with width of 10nm ($100^{O}A$) have been reported, and operating frequencies of 10 GHZ are possible with Galium arsenide integrated circuits.

Below given are the possible electronic packaging failure mechanisms with emphasis on small geometrics, high frequencies, and large number of input/output leads (340). Some investigations on electronic devices, revealed the several possible factors that lead to failures are detailed in table below.

Table (1): Failure Mechanisms in Silicon Semiconductor Devices:

Sl. No.	*Device association*	*Process*	*Relevant factors*	*Accelerate factor*
1	SiO_2 and Si-SiO_2 interface	Surface charge accumulation	Mobile ions, V,T, Qm	T, E
		Dielectric Breakdown	E,T	E(T)
		Charge	E,T,Q_f	E,T

		Hot carrier trapping	E, T, Q_m	E, T
2	Metallization	Migration of Al	T, J. A Gradient of T and J grain size	T, J
		Electromigration of Si in At	T, J, A	T. J
		Corrosion	Contamination H, V.T	HVT
		Contact degradation	T, metal, impurities	H.V.T Varies
3	Bonds and other mechanical interfaces	Inter metallic growth	T, impurities, bond strength	T
		Fatigue	Temperature cycling, bond strength	T extremes
4	Hermeticity	Seal leaks	Pressure differential temp cycling	Pressure T

Note: T = Temperature, E= Electric field, V = Voltage, Q = Oxide charge, J = Current density, A = Area, H = Humidity

Failure Mechanisms:

Conventional electron tube of old version were replaced with germanium alloy transistor. The major factor that led to failure temperature. Second factor is the diffusion of silicon.

Oxide Contamination Effect:

The electron devices are produced with deposition of layers of different materials. Oxide as barrier over silicon should be extremely pure and clean. Contamination of oxide layer is one of the contributor to failure.

The common culprit in this oxide is Na^+ which is present in almost any manufacturing environment, generally from salt. Ion contamination is one of main culprit for the reasons of failure.

Purple Plague:

Is a second factor in silicon transistor that resulted in failures. Purple plague arose from bonding a gold wire to an aluminium contact surface, which was commonly used, contact on Silicon. The contact between gold and aluminium leads to the formation five inter metallic compounds. Though good conductor, because of

brittleness and easily broken. They contribute to the growth of voids in gold surface due to diffusion. One of these compounds appear purple under microscope, hence the name purple plague.
Temperature Sensitive Mechanisms:

In semiconductors, there are several joints and metallization for interconnections.
For example Pt-Si contact for a schottky diode most be protected from interaction with At metallization.
Temperature cycling sensitive situation is that of the collector contact for a transistor. There are differences between temperature cycling and power cycling. The heat source and heat flow are different in those situations.

Sometimes epoxies as contact material for connecting collector area to heat dissipating sink may create a problem of vapor generation, degrading device performance.
Another problem with contacts, with resultant hot spot, localized degradation, thermal runaway. These create temperature differences.
Package Differences:

Ceramic packages – are comprised of LSI and VLSI circuit chips have good reliability because of the „Hermetic‰ seal. However, seal is subject to gross-leak and fine-leak.
Another potential problem is the amount of moisture sealed into the enclosure during sealing process.

When devitrifying glass frit was employed to make the seal between the two ceramic halves of the all-ceramic package, large amount of moisture (5000 ppm) could remain in the enclosure. This may result in the mobilizing of ions on the chip surface, which can cause surface inversions and parasitic metal-oxide semi conductor transistors.
The corrosion factor is always present when high humidity is available to the insulator surface between two biased metal lines.

Plastic Packages:

The use of epoxy with low transition temperature (T8), found to have large coefficient of expansion. This has resulted stresses in the temperature cycling. The mismatch of the epoxy with the device was considered responsible for failure.

3.5 FAILURE ANALYSIS OF INTEGRATED CIRCUITS

In recent years electron components are made of innumerable number of parts and integrated in several circuits making use minute parts, and soldered joints. These are basically silicon integrated circuits consisting of semiconductors, capacitors, registers, etc., in to a useable product. Considering the semiconductor devices, usually do not exhibit wear-out within their useful life time.
There regions of interest for the failure mechanisms classified into infant morality, constant failure rate life, and wear-out.
Technique of Failure Analysis:

Here, there are many different failure mechanisms and because of new ones technologies, there is no prescribed methodology for failure analysis. The complexity of integration wakes the process of investigation very complicated and high difficult task. The principal barrier to identifying a device failure mechanism correctly is its complexity.

Modern LSI integrated circuits ca contain over one million transistors and can perform a staggering variety of electrical functions.
The first is testing - the device must be tested completely before the package is opened to identify the portion of the circuit that is failing and to identify and sort out failure mechanism.

1. The Chief tools of testing are computer-driven test sets that can be programmes to check every electrical parameter of the circuit and to record the specific device disperse in comparison with the normal range of each parameter.
2. To pursue the failure mechanism further, the next step is to expose the chip in the package without damaging it or its electrical connections to the outside pins. The process is termed de capping.
3. After decapping, a vital inspection is in order to make use of magnifications 800 x 1100x to observe under bright field and dark field capabilities polarized light in also useful. Defects that are obvious at this point are usually photographed, then using SEM observe more keenly.
4. At this point, it is helpful if the initial testing has indicated that the device conducts current in excess of the specified normal current.

Such excess current can indicate electrical shorts due metallization corrosion, oxide breakdown due to defect, or electrostatic discharge which led to Metallization Failures, or Silicon Oxide Failures and Electrostatic / Electrical Overstress Failures.
P-n-Junction Failure:

The integrity of p-n-junction through laser beam to scan or area of biased semiconductor circuit.
The helium-neon laser beam through microscope, penetration into surface of Silicon integrated circuit may provide additional information.
Metallization Failures:

Corrosion is a common problem because the accelerating factors of electric field, ionic contamination, and moisture are often present.
There are two types of corrosion cells of interest are electrolytic and galvanic.
In galvanic, the electrodes are two dissimilar metals connected in an electrolyte, and the driving force is the difference in electrochemical potentials.
In electrolytic corrosion, the electrodes are similar, and the driving force is the applied potential between them.
Electro migration:

Is the transport of metal ions through conductor resulting from the passage of direct current. It is caused by a modification of the normally random diffusion process to a directional one by the charge carrier electron wind.

Poly silicon – Silicide (Polycide) Structures:

In integrated circuits polycrystalline silicon is used as an FET gate material as well as an inter connecting metallization. The electro-migration i.e. mass transport of one into another.

Stress Cracking and Voiding:

As a result of reduction in size, a reduction in narrow metallization and stress as well as voiding found to result in failure because SC.

Fatigue Failure:

The packaged integrated circuits undergo temperature changes due to climatic changes, equipment start up, and load variations. Because IC package is composed of several components with different thermal expansion coefficients, the temperature changes will induce mechanical stresses. Under certain conditions, these stresses lead to beam wire failures due to fatigue.
Metallic Interface Failures:

Metal – Metal Inter diffusion one failure mechanism due to inter diffusion is the resulting from the improper formation of inter-metallic phases in commonly used Au-Al wire bond system.
Five phases can possibly form from this inter diffusion; Au Al_2, Au Al, Au_2Al, Au_5 Al_2, and Au_4 Al. A temp of 250^oC for a long enough time, all five phases will form. Generally, most common phase formation will be Au_5 Al_2, regardless of time or temperature.

Defect – Related Dielectric Breakdown:

Electric field depends on dielectric breakdown, both defect related and intrinsic breakdown, has been responsible failures.

3.6 SOME TYPICAL FAILURE INVESTIGATIONS

3.6.1 GASEOUS CORROSION OF A HEAT RESISTANT ALLOY

A 150mm diam, 1.6mm thick alloy liner from an internal bypass line in hydrogen reformer was removed from a waste heat bowler because severe metal loss. On the inner surface, along with a sooty residue. Pattern similar to those associated with erosion damage were observed Micro structural examination revealed a bulk matrix composed of massive carbides, indicating the gross carburization, and metal dusting had occurred. X- ray diffraction analysis showed that the carbides were primarily chromium based. The sooty substance was identified as graph.
What was the cause/causes and what remedial steps you just? Steps Involved

1. Background
2. Application
3. Circumstances leading to failure
4. Specimen selection
5. Testing procedure
6. Surface examination
7. Metallographs
8. Chemical Analysis
9. Discussion
10. Conclusions
11. Recommendation Cause for Failure:

Metal during heating in carbonaceous atmosphere at temperature above 425^oC, with very activity in the range 790 to 845^{o}Cand above 925^oC, carbon adsorption and

diffusion into metal matrix induce the formation of chromium carbides, first intergranular and then with in the grains.
Excessive formation and coarsenious of carbides lead to matrix consumption.

3.6.2 AIRCRAFT LANDING GEAR FRACTURE

The right landing gear on a twin turboprop transport collapsed during landing. Preliminary examination indicated that failure occurred at a steel to aluminium (7014) pinned drag strut connection due to fracture of the lower set of drag strut attachment lugs at the lower end of the oleo cylinder housing. Two lug fractures that were determined to be the primary fractures were determined to be the primary fractures were analysed. Examination indicated that stress-corrosion cracking associated with the origins of the principal fractures in the connection was the cause of failure.

The recommendation was to modified design to avoid dissimilar metal combinations of high corrosion potential.

1) Background
2) Circumstances Leading to Failure
3) Pertinent Specifications
4) Specimen Selection
5) Visual Examination
6) Testing Procedure

I. Visual
II. Macrofractograph
III. SEM fractography

7) Metallography

I. Micro-structural Analysis
II. Chemical Analysis
III. Mechanical Properties

8) Discussion
9) Conclusion

I. Most Portable Cause

10) Remedial Action.

3.6.3 FAILURE OF A HELICOPTER MAIN ROTOR BLADE

A Marine Corps helicopter crash was investigated. The failure of one of the main rotor blades that had separated in the air. The rotor blade comprised a long, hollow 6061-T 651 aluminium alloy extrusion and 26 fiberglass „Pockets‰ that provided the trialing – edge air-foul shape visual examination of the fracture surface of the aluminium extrusion indicated fatigue crack growth followed by ductile overload separation. Examination of the fatigue fracture region revealed several pits that appeared to have acted as fracture origin sites. Time to failure was determined using fracture mechanics. It was concluded that failure was caused by fatigue crack that grew to critical length without detection. The crack originated at pits that resulted from the use of an improperly designed heating element used to rare fiberglass repairs.

3.6.4 HYDROGEN – ASSISTED FRACTURE OF A 17-4 PH AIRPLANE WING COMPONENT Cracks were discovered in the cast 17-4 pH SS out board leading edge flap support of an air craft wing during overhaul inspection. Failure analysis focused on an apparently intergranular area of fracture surface. It was determined that the original mode of crack growth was cleavage, probably caused by cost-in hydrogen. The intergranular appearance resulted from heat treatment of the already cracked part, which caused the formation of grain-boundary „Growth figures‰ on the exposed crack surface. It was recommended that the castings be more closely inspected for defects before further processing and that foundry practices be reviewed to correct deficiencies leading to excessive hydrogen absorption during melting and casting.

Electrical Related Failure:

Several wires in aluminium conductor cable fractured within 5 to 8 years of service in Alaskan tundra. The cables were comprised of 19 wire strands. The wires were aluminium alloy 6201-T81. Visual and metallurgical examinations of the cold upset pressure weld joints in the wires established that the fractures were caused by fatigue at the joints. The grain flow at the joints was transverse to the wire axis, rendering the notches of the joints sensitive to fatigue loading. An additional contributory factor was intergranular corrosion, which assisted fatigue crack initiation/propagation.

The failure was attributed to the departure of conductor quality from the requirements of ASTM B 398 and B 399, which specify that „No joints shall be made during final drawing or in the finished wire‰ and that the joints should not be closer than 15m. The failed cable did not meet either criterion.

Background Information:

Several wires in aluminium conductor cables fractured within 5 to 8 years of service in Alaskan Tundra. The cables were comprised of 19 wires strands; the wires were at alloy 6201 – T81.

The Al – electrical conductors were from 65 – 80 km long, high voltage transmission lines installed from 1982 to 1988 to service oil fields in Alaska. The transmission towers were 20m, high with a span length of 80m. The terrain was flat, with east west winds up to 160 km/hr. The temperature range was – 50 to $20^{O}C$.

3.6.5 AIR CRAFT ACCIDENT CAUSED BY EXPLOSIVE SABOTAGE

Damage to a passenger aircraft that resulted from a midair explosion and subsequent emergency landing has occurred.

Circumstances leading tofailure:

The flight of passenger aircraft has occurred 20 min before scheduled landing at which time an explosion occurred, causing injuries to the crew and damage to the front toilet area and to instruments in the cockpit. However the main structure was undamaged. Despite these multiple emergencies, the pilot continued to fly the air croft and attempted an emergency landing.

Although an in-flight explosion was known to have occurred, it was necessary to provide material evidence to a court of Inquiry to establish the location and type of explosion.

Damage:

1. Engines and under carriage were severed.
2. The front toilet and cockpit areas had suffered extensive damage.
3. The paint on the external skin above the front toilet had peeled off.
4. A hole was found on the skin of the toilet roof, with metal lip curling outward.
5. The panels of the toilet had given way.
6. Sharp projectiles had penetrated the panels. Fragments were lodged in the toilet panels.
7. Inside the toilet, the SS washbasin and its fittings were severely damaged.
8. The tissue paper receptacle, made of Al alloy sheet and kept under the washbasin, had disintegrated into a number of pieces.
9. The toilet bowl was caved.
10. Instruments in the cockpit were damaged.

3.6.6 FAILURE OF STEEL COMPRESSION SPRING

Two samples of helical compression springs were returned to the manufacturer after failing in service well short of the component design life. Spring design specifications required conformance to SAE J W 7, Oil Tempered Chromium Silicon Alloy Steel Wire and Spring.

Each spring was installed in a separate heavy truck engine in an application in which spring failure can cause total engine destruction spring failure can cause total engine destruction. The springs were composed of Cr-Si-Steel, with a hardness ranging from 50 to 54 HRC.

Examination of the fracture surface using SEM showed the evidence of fatigue. Final fracture occurred in torsion. X-ray diffraction analysis revealed high inner diameter residual stresses, indicating inadequate stress relief from spring windings.

Circumstances Leading to Failure:

After approximately 80,000 km of service, broken springs were found in two engines. The trucks were used on public high ways and were exposed to a variety of terrains and operating conditions.

Remedial Action:

9. Stress relieving.
10. Effective shot preening.

3.6.7 FAILURE OF REAR AXLE

Following an accident in which a light pickup truck left the road and overturned, one of the rear axles, made of approximately 0.30% C-steel was found to be fractured adjacent to the bearing lock nut. A key was present in the failed area, as were threads for the lock nut. Fractured surface of the failed axle and exemplar fracture obtained from simulation tests were studied using SEM. The examination showed that the outer perimeter fracture in the axle was very flat and composed of cleavage and that the interior portion was composed of both cleavage and dimple.

The examination confirmed that the failure was a one-time impact overload fracture and not the result of any prior crack in the material, indicating that the axle failure did not initiate the accident.

3.6.8 FAILURE OF LOCOMOTIVE AXLES

Background Information:

Axles run in bearings. Usually, they are lubricated. The bearing is essentially a bronze cylinder liner with babbit metal. Typically, the bronze alloy composition is close to Cu- 16 pb-65n-3.5 Zn while the babbit composition is usually Pb-3.5 Sn Sn-11.5 Sb. Friction hearing failure due to overheating. Some of the investigations carried in 1947 and 1954 revealed copper penetration axle failure and the use of nondestructive testing to detect surface cracks. In some cases failure has been attributed to intergranular embrittlement of the steel by molten brass or copper.

There are mainly copper and lend constituents of the bronze friction bearings.

The copper – penetration failure occurred in the following sequence:

- The bearing surface is heated by friction because of loss of lubrication.
- The babbit metal lining melts between about 240 and 315^{o}C and wets the surface, but penetration does not occur.
- The babbit metal is displaced, possibly mechanical action or volatilization.
- Bronze backing is heated to its Mpt (901 to 925^{o}C) and penetrates the axle, causing failure.

In 1959 New York Central Rail Road Company studied copper penetration in over heated Journals – Two types of failures were observed.

1) The first type, referred to as a „Burn-off‰ is indicative of a simple continuous heating to failure due to penetration of bearing metal into journals at elevated temperatures.
2) The second type, referred to as „a cold break‰ also results from overheating, but is a two stage failure process.

The AAR proceedings of 1956, the Baltimore & Olio Railroad stated that at least three factors must exist to cause copper penetration fractures.

- A bearing that contains a metal or metals that will diffuse into the axle material in the grain boundaries.
- Heating to the copper melting range.
- Stress.

Wetting of the axle surface was also considered be a possible fourth prerequisite.
In most of the axle fractures, necking diameter, evidence of twisting, and the presence of cavernous cracks and fissures due to high temperature fatigue in an oxidizing atmosphere.
Another research resulted in axle failure attributed to the following

- Presence of applied tensile stress
- Wetting of the steel surface by molten copper.

- Heating of the steel substrate to temperature high enough to austenitize the steel.

Ultimately it is due to LME.
Liquid-metal Embrittlement:

LME is a phenomenon in which the ductility or fracture stress of a solid metal is reduced by exposure to the surface to a liquid metal.

3.6.9 FAILURE OF SHAFTS

A SHAFT is a metal box – usually cylindrical in shape and solid, but some times hollow

– that is used to support rotating components or to transmit power or motion by rotary or axial movement.
Similar to motion transmission, connecting roads, which translate rotary motion to linear motion and vice versa.
These parts operate under a broad range of service conditions, including dust laden, corrosive environments varying temperatures from extreme low (artistic) to extremely high (turbine).

Shafts and connecting roads may be subjected to a variety of loads – in general tension, compression bending, torsion, or combinations of these. In addition, these parts are sometime subjected to vibratory stresses.
When connected to bearing – wear may be the reason as contributor, most common cause of shaft failure is metal fatigue. The most vulnerable point in dynamically stressed part- typical, a stress raiser.

The stress rouser can arise due to mechanical or metallurgical in nature some times a combination of the both i.e. mechanical and metallurgical.
Mechanical stress raisers such as small fillets sharp corners, grooves, splines, keyways, nicks, and press or shrink fits.
Metallurgical stresses raisers may be quench cracks, corrosion pits, non-metallic inclusions brittle second-phase particles, weld defects or are pits, etc.
Some times, brittle fractures may be encountered particularly in extreme low temperature environments, or as a result of abuse like impact or rapidly applied over-load.

Surface treatments can cause hydrogen to be get diffused in high strength steels and may cause shaft to become embrittled even at room temperature.
Electroplated metals, high strength galvanized bolts, have resulted in failures.

Ductile fracture some times may lead to failures because of accidental overload creep is a form distortion that occurs at elevated temperatures due to stress rupture.
Fractures Origins:

Most common observation of fractures in shaft originate at points of stress-concentration either inherent in design or induced during fabrication or service.
Typical examples such as keyways, edges of press-fitted members, fullest at shoulders, out holes. Some typical stress concentrators produced during fabrication include grinding cracks, machining or nicks, and quenched cracks.
Stress concentrator in forgings may occur due discontinuities, such as lape, seams, pits and cold shuts and subsurface defects such as bursts.
In castings, defects such as internal discontinuities, shrinkage cavities, pipe, segregation, porosity, non-metallic inclusions.

To a lesser extents, shafts can fracture from wrong selection of material. The failure can occur.

a. High ductile-to-brittle transition temperature.
b. Low-resistance to hydrogen embrittlement.
c. Poor chemical or poor mechanical properties.

Examination of Failed Shafts:

The examination of some failed shaft have been attributed to following:

Design Parameters:

During design, the loads, stresses that are likely and factor of safety are necessary for proper design and selection of material and processing. The potential stress raisers or points of stress concentration should be considered and their effect on stress-concentration as well as load estimation should be taken into design.

Processing or finishing treatments such as shot-peening, fillet-rolling, burnishing, plating, coating, etc., can influence on the performance and the analysis should be aware of such parameters.

Stress Systems Acting on Shafts:

The stress system acting on a shaft must be understood before the cause of fracture in the shaft.

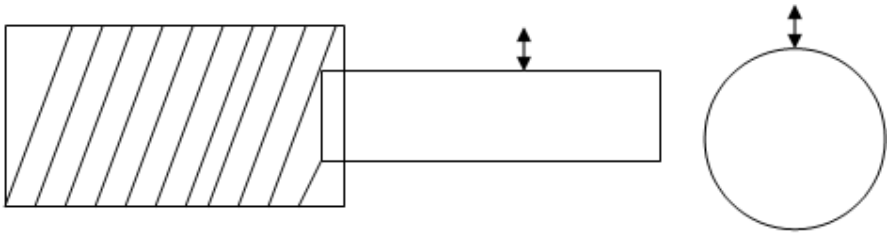
The stress that are to be considered are: a) Tension, b) Torsion, c) Compression and bending, etc.

Fatigue Failure:

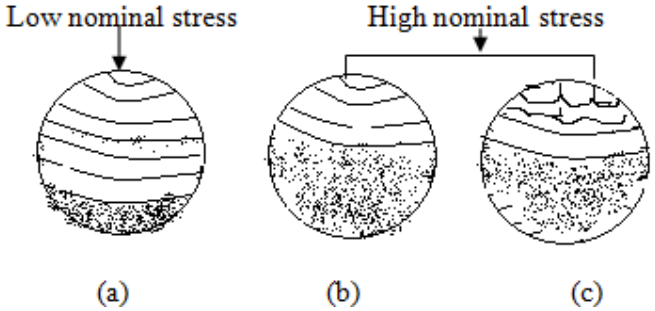
Fatigue in shafts can be categorized in to a) bending fatigue, b) torsional fatigue and c) axial fatigue.

Unidirectional - Bending Fatigue:

A fatigue crack in a stationary cylindrical shaft subjected to a fluctuating unidirectional bending may develop fracture as illustrated below.



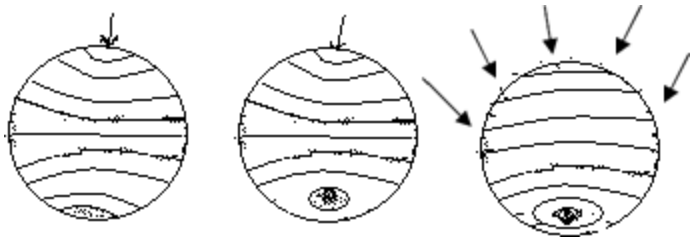
Stationary shop subjected to unidirectional fluctuating bending.



No stress – concentration

Fig (1)Fatigue fracture of typical failed shafts in service due to varied service conditions.

Fig (1a) – Suggests the stress is low.
Fig (1b) – Suggests a higher nominal stress.
Fig (1c) –Typical fatigue crack originating at several individual cracks that ventually merged to form a single crack front.
Such multiple origins indicative of high nominal stress.
A change in section in a uniformly loaded shaft that produces a severe stress concentration will lead to a pattern of beach marks such as shown in Fig (2)



Pattern of beach marks under severe stress concentrates

Fig (2) Fatigue fracture showing typical fractured surface under severe stress concentration.

Reverse Bending Fatigue:

When a shaft is subjected to reverse bending moment, all the points in the shaft are subjected to alternately to tension and compression stresses.
The bending moment is of the same magnitude in either direction. Two cracks of approximately equal length develop from origins diametrically opposite each other and often in the transverse plane.

If bending moment is greater in one direction than the other, the two propagating cracks will differ in length.

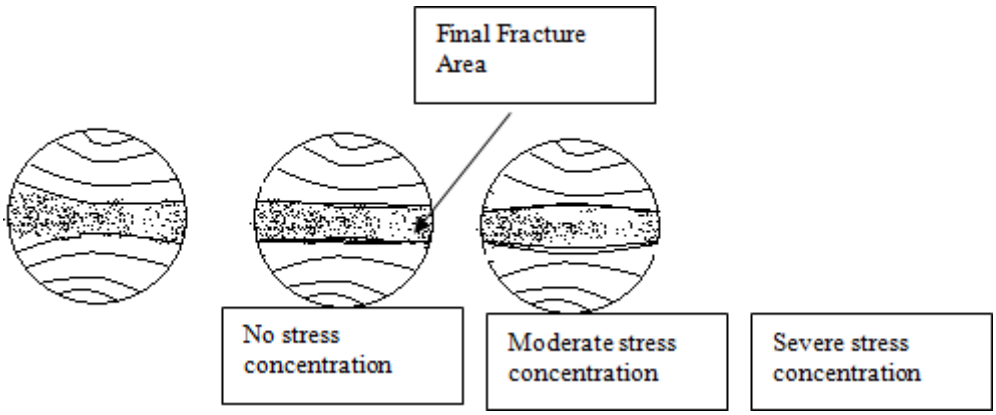


Fig (3): Uniformly loaded non-rotating shaft subjected to reversed bending stresses.

Rotary Bending Fatigue:

The main difference between stationary shaft and rotating shaft subjected to the same bending moment is that in a stationary shaft the tensile stress is confined to a upper portion of the shaft. In rotary shaft, every point on the periphery sustains a tensile stress, then a compressive stress, once every revolution.
The second difference in a rotary bending shaft asymmetrical development of crack front from a single origin. There is a marked tendency of the crack front to extend preferentially in a direction opposite to that of rotation. The crack front swings around about 15^{O} or more as depicted in Fig (4)

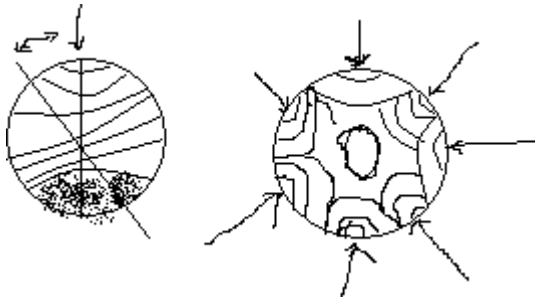


Fig (4) Typical fatigue marks on the fractured surface of a uniformly loaded rotating shaft having subjected to moderate stress.
The crack surfaces are pressed during compression and mutual rubbing occurs. The slight movement of one side of the crack relative to the other frequently causes severe damage to the fractural surfaces and tends to obliterate many marks.

Torsional Fatigue:

Fatigue cracks arising from torsional stresses show the same type of beach marks and ridges as those produced by bending stresses.
Contact Fatigue:

Contact fatigue occurs when components roll or roll and slides against each other under high contact pressure and cyclic loading.
Spalling occurs after many repetitions of loading and is the result of metal fatigue from the imposed cyclic contact stresses, which are all a maximum value beneath the contact surface. Factors that govern contact fatigue are contact stress, material properties and metallurgical, physical and chemical characteristics of contacting surfaces, including lubricant film.

Brittle Fracture of Shaft:

Brittle fractures are associated with the inability of the materials to deform plastically in the presence of stress at the root of a sharp notch, particularly at low temperatures. Brittle fractures are characterized by sudden fracturing at extremely high rates of crack propagation probably at a rate 6000 ft per second or more, with little evidence of distortion in the region of fracture initiation.
Ductile Fracture of Shafts:

Ductile fracture exhibit evidence of distortion at the fracture surface similar to that observed in ordinary tensile test or torsion test specimens.

When a shaft is fractured by a simple application of a load greater than the strength. The appearance of the fracture surface of a shaft that failed in a ductile manner also is a function of shaft shape, the type of stress acting, rate of loading and temperature.
In general, ductility is decreased by

a) Increasing the strength of the metal by cold working or heat – treatment.

b) The presence of notches, fillets, holes scratches, inclusions, and porosity.

c) Increasing the rate of loading, and

d) By decreasing the temperature.

Corrosion of Shaft:

Most shafts are not subjected to severe reduction in life from general corrosion or chemical attack. Corrosion may result in pitting, uniform removal of metal surface with scale or corrosion product.
Corrosion pits have a relatively minor effect on load carrying capacity of a shaft, but they do act as stress concentrators at which fatigue crack can originate. Most large shafts and piston rods are not subjected to corrosion attacks. However, because ship-propeller shafts are exposed to salt-water, they are roll burnished which produce residual surface compressive stress and inhibits fatigue cracks from originating at corrosion pits. Parts such as centrifugal compressor impellers, gas turbine disks and blades after undergo corrosion.

Stress – Corrosion Cracking (SCC):

Stress corrosion cracking occurs as a result of corrosion and stress at the tip of growing crack. Stress corrosion cracking often is accompanied or proceeded by surface pitting.
Usually, the stress level necessary for SCC is below the stress laid required for fracture without corrosion. This critical stress may be well below the yield strength of the material, depending on the material and the corrosion required.

Corrosion Fatigue:

Corrosion fatigue results when corrosion and alternating stress – when severe, corrosion fatigue can occur.

Creep and Stress Rupture of Shafts:

Creep is time-dependent strain occurring under stress imposed at elevated temperatures provided that operational load does not exceed the yield strength of the part.

Some high temperature applications such as gas turbines and jet aircraft engines may required materials to operate under extreme conditions of temperature and stress with only limited amount of deformation by creep.

Common Stress Raisers in Shafts:

Most service failure in shafts are attributed largely to some conditions that cause an intensification of stress. In local places, stress value is raised above the value at which the material is capable of withstanding the number of loading cycles that corresponds to a satisfactory service life. The most vulnerable zone in tortional and bending fatigue is the shaft surface. In most of the shafts, oil holes, keyways, or changes in shaft diameter where stress concentration is likely to occur.

3.7 INVESTIGATION INTO ACCIDENT

Meaning of Accident

An accident means any occurrence in a place whereby -

a) There is loss of life of major injury to any person or any person is lost or falls from vehicle, the ship, boat, cart and auto vehicle etc.

b) There is damage or destruction

c) Is abandoned

d) Is materially damaged by fire, explosion. Weather or other cause.

e) Is in collision

f) Is disabled, or

g) Causes significant harm

h) A collapse or bursting of any pressure vessel, pipeline or valve.

i) A collapse or failure of any lifting equipment, access equipment, hatch-cover, or any item associated with load-bearing parts.

Objective of Investigation:

The prime objective of the investigation of an accident shall be the route cause of the failure and prevention of future accidents through ascertainment of it causes and circumstances.

Reporting Person/Investigating Person:

A person investigating into accident shall, in so far as is practicable, include the following information.

a) Persons involved in accident

b) Name and addresses of the persons

c) Details of vehicle

d) Date and time of the accident

e) Geographical position in which the accident occurred

f) Vehicle, persons affected

g) Environmental conditions

h) Name and date

i) Number of peopleinvolved/killed/effected

j) Brief details of accident, including where known, the sequence of events leading to the accident, extent of damage and whether the accident caused pollution a hazard to the environment/surrounding

k) Photographing the accident

l) Kid-marks, broken parts, damage to the vehicle/property.

m) Preliminary examination

n) Major injury resulted from accident.

Preservation of Evidence:

Following an accident, documentation as proof evidence is very important specially for legal cases. Ensure maximum information and documentation such as

- Photographing/Video taping
- Electronic and magnetic recording
- All documentation considered for evidence pertinent to the accident are kept and that no alteration is made to any recordings or entries in them.

Conducting of Investigation:

The investigator can take the help of his assistants specially qualified or experienced. The investigator may extend to cover all events and circumstances preceding the accident together with subsequent events and circumstances which in the opinion of an inspector may have been relevant to its cause or outcome. The following details shall help the Investigator.

Fire and Explosion

- Business set up to Burn
- Heating forms
- Hot work Accidents
- Chimes Altars
- Textile Fires
- GC Analysis
- On-board Marine Investigation
- Pre-Fire Photographs
- Furniture Fires
- Medium Density Fiberboard Factory Fires

Non-Fire

- Machinery Breakdown
  - Process
    - Direct Control System & Failure Analysis
    - Instrumentation & Control
  - Furnaces, Heaters & Boilers
    - Thermal Oil Heater Failures
    - Furnace Failures
    - Brick Kiln Collapses
    - Furnace Breakouts
    - Electric Arc Steelmaking Furnace Accidents
  - Structures, Pipes & Vessels

- Silos & Chimney Collapses
- Tanks Collapses
- Plastic Pipe Ruptures
- Fiberglass Failures
  - Mechanical & Material
- How Things Fail
- Metallurgical Failure
- Wire Rope Failures
- Elevator Rope
- Casting Failures
- Plastic Pipe Failures
- Corrosion
  - Electrical & Electronic
- Electrical Consulting
- Energy Calculations
- Lightning Claims
- Transformer Failures
- Turbine Consultant
  - Rack Collapses
  - High-Tech Equipment Consultation
- Medical Equipment
- Laboratory Equipment
- Telecommunication Equipment
- Wafer-Fabrication Equipment
- Computers
- Commercial & Consumer
- Military & Government
- Power Plants
  - Miscellaneous
- Break-ins and Burglaries
- Architectural Glass Claims
- Root Cause Analysis
- Marine Cargo Claims
  - Container Fires

- Marine Cargo
  - Forensic Assistance for Marine Claims
- Corrosion of Steel in Transit
- Vehicles, Cranes
- Myths of Crane Repairs
- Vehicle Accident Investigation
- Container Forklifts
- Vehicle Fire Training
- Liability
- Product Liability
- Public Liability
- Equipment Restoration
- QA and OC Services
- Third-Part Inspection/Surveillance
- Expediting
- NDT Services
  - Ultrasonic Testing
  - Long Range Ultrasonic Testing
  - Eddy Current Testing
  - Magnetic Flux Leakage
  - Thermal Infrared
  - Ship Hull Thickness Gauging
  - Thermography
- Erosion/Corrosion Monitoring
- Reporting
- Oil & Gas Services
  - Magnetic Flux Leakage
  - Thermography
- Computer Forensics
- Legal
- Litigation, Arbitration & Subrogation
- Protecting Partnerships
- Computer Crime
- Personal Injury

- Subrogation
- Sitemap
- Third-Part Inspection/Surveillance
- Expediting
- NDT Services
  - Ultrasonic Testing
  - Long Range Ultrasonic Testing
  - Eddy Current Testing
  - Magnetic Flux Leakage
  - Thermal Infrared
  - Ship hull Thickness Gauging
  - Thermography
- Erosion/Corrosion Monitoring
- Reporting
- Oil & Gas Services
  - Magnetic Flux Leakage
  - Thermography

3.7.1 AUTOMOBILE ACCIDENTS

Automobile accidents happen frequently and the mechanics of an accident include the speeds of the involved vehicles, the direction of their travel, the sequence of events of the accident, forces upon the drivers etc. The physical evidence which is to be examined in accident cases are the tyre and skid marks, the location and depth of impact on the vehicles, the condition of the vehicles, the type and location of impact debris, paint, glass pieces, other vehicle-to-vehicle impact marks, road conditions, weather conditions, mental condition of the drivers and accident area.

When a vehicle is moving, it possesses kinetic energy in proportion to the magnitude of its speed and mass. Skidding is a common way of dissipation of a vehicleÊs kinetic energy.

A simple skid is one where the vehicle starts from some initial speed and comes to a full stop by skidding without significant impact.

Analysis

The first step in an analysis is by sketching. The objective of the analysis is to provide insight into the relationship of distance, speed and time to the outcome of the incident. In a system of two colliding vehicles, where there are no forces external to the two vehicles, the linear momentum of the system does not change. To determine the speeds after impact, work-energy concepts are utilized.

The distance traveled after impact, the mass of each vehicle are known, the speed of the vehicle at the beginning of the skid can be determined. Aspects of vehicle center of mass & coefficients of friction are to be determined to study the vehicleÊs behavior in an accident.

3.7.2 GUIDELINES FOR ACCIDENT SCENE EXAMINATION

1. *Hit & Run Accidents:-* The victim, victim's vehicle, the scene of accident have to be thoroughly examined keeping in view Locard's principle of exchange to find and recover the foreign paint transferred to the victim's vehicle, the broken glass pieces, tyre marks, skid marks, spilled contents etc., of the crime vehicle. Tyre marks present at the accident site have to be recorded for subsequent comparison with the tyres of crime vehicle. The length of the skid marks have to be measured and extensive photographs are to be taken.

Subsequently after the seizure of the crime vehicle, the transferred paint, control paint, blood stains, cloth fibres, glass pieces etc., belonging to the victim and his vehicle have to be recovered and sent to the laboratory for linking them to the crime vehicle. Uncontaminated control sample must always be collected from near the surface of the vehicle as was suspected of being in contact with the victimÊs vehicle with the help of a clean scalpel or a knife/blade. Control sample should also include all the paint layers down to the base metal.

2. *Examination of vehicle contents:-* Drivers who consume liquor often hide their bottles under seats, mats, in car pockets or other places where they cannot be easily seen. Investigating Officers should check the vehicles for such things after an accident. In cases where prescription medicines are found in the vehicle, they may indicate that the driver was under medication at the time of the accident. The presence of spilled food items in the vehicle, especially around the driverÊs area, might indicate that at the time of the accident the driver was distracted by eating or drinking.

3. *Identification of Vehicle:-* If the registration numbers of the vehicle are not visible / present, by means of their engine number & chasis number the vehicle can be identified.

4. *Metal Fracture:-* Often, the cause of a crash or accident is blamed on the failure of an important metal part. It may be claimed that the part failed first, which then precipitated the accident. In such cases, it is important to examine the fracture and determine its metallurgical characteristics. A hardness test will determine its approximate strength and provide information as to whether or not it has been heat treated. The type of fracture is also important. A fatigue fracture indicates that the part has been partially cracked for some time prior to the accident. Thus, it can be concluded that the part was weak at the time of the accident and susceptible to failure. A shear fracture, tensile fracture or bending fracture with no indication of fatigue usually indicates that the part failed at the time of the accident, perhaps being damaged as part of the accident process.

Sometimes when a vehicle front end or whatever is reassembled after major repair work, the mechanic may have lost an original nut or washer. If the nut is simply replaced with one that fits instead of the factory specified replacement, it is possible that the replacement nut will not perform properly. When a mechanical failure has occurred, it is best to check that the nut or bolt is meeting the factory specifications.

5. *Improper Welding Repairs:-* Many vehicles and trailers have frames & structural elements made of high strength alloy steel. Such steels are often heat treated to obtain the high strengths required. If these are welded these high-strength alloy parts with common welding rod or wire rather than replace them, the weld metal will not have the same qualities & strength as the original base metal. The material in the heat affected zone (HAZ) is weaker & more susceptible to fatigue failure than before.

6. *Brake Fluid Compatibility:-* Using the wrong kind of brake fluid could precipitate an accident. If a person made a mistake and did not put in the appropriately compatible brake fluid, a brake failure could occur and possibly precipitate an accident.
7. *Tyres:-* Tyres often are blamed for accidents. The most common types of tyre failure occur when a tyre is run under inflated. When this happens, the bending stresses in the tyre wall are greatly increased, and the tyre will heat up. Since the strength of the rubber and carcass of a tyre is sensitive to temperature, the tyre wall will have less mechanical strength at the elevated temperature. The combination of high stresses and heat build up causes the materials in the tyre to fatigue. Eventually the tyre will blow out.

8. *Point of Impact:-* Examination of the scene for tell-tale tyre marks should be done. A skid, rim or other tyre marks that suddenly deviate off in a new direction indicate the point of impact.
9. *Weigh Bridge / Station:-* When analyzing accidents involving trucks, weigh bridge / station can sometimes provide very useful data. When a commercial truck is checked at a weigh bridge / Station not only is its weight checked, but the time it was checked is often stamped on the weigh ticket. This places the truck at a known location at a known time. This is useful if the truck is then involved in an accident after leaving the weigh bride / station and if it is suspected the truck driver was speeding.
10. The site of incident has to be examined thoroughly for physical evidence, which gives lot of useful information regarding the failure. The working mechanism of the system / machine has to be thoroughly understood by collecting all information regarding how, why and when the incident happened. Preliminary Examination of the fail parts has to be done with naked eye and changes in colour & texture from location to location, presence of dents, corrosion spots, visible cracks, etc., to be carefully observed. Photographs of fail parts in as many angles as possible showing clearly the evidence of corrosion or abnormality on the surface has to be taken.

In the laboratory the failed components are subjected to Ultrasonic Testing, X-ray Radiography, Hardness Test, Tensile Strength, etc., are conducted besides microscopic examination.
Control samples have to be collected from the site or from the manufactures / suppliers, etc.

3.8 STRUCTURAL FAILURE INVOLVING CIVIL CONSTRUCTION MATERIAL

Structural failures like collapsing of buildings even during construction, bridges, overhead tanks, etc., result in huge loss of life and property. Conditions of roads get deteriorated within months or few years of construction. Natural calamities like earth quakes resulting in collapse of newly constructed buildings point to suspicion of substandard construction. In such situations the Police is called upon to investigate into the cause of the structural failures. The failures could be several shortcomings such as improper structural design, use of inferior material, improper design mix, improper curing and setting, etc.

The debris of collapse such as cement concretes, bricks, mortar, sand, etc., may have to be collected to ascertain the quality of material used for construction or whether the construction material used was in accordance with the standards.

Failure result from a variety of causes involving both technical / physical problems and human error / procedural factors. In the case of building or civil structures, the effects of natural hazards such as fire, flood, extreme winds, or seismic events, may exceed accepted standards of practice. In these cases, carelessness in site selection, would lead to unnecessary or reckless exposure to natural causes. There is always a technical / physical explanation for a failure, but the reasons for failure occurs are often procedural. The work of the forensic engineer is to investigate those projects that do not provide the expected quality of performance for the expected period of time.

3.8.1 CAUSES OF STRUCTURAL FAILURES

1. Site Selection and Site Development Errors:- Land use planning errors, insufficient or non existent geotechnical studies, unnecessary exposure to natural causes.
2. Programming Deficiencies:- Unclear or conflicting client expectations, lack of clear definition of scope or intent of the project.
3. Design Errors:- Errors in concept, lack of redundancy, failure to consider a load or combination of loads, selection of incompatible materials or assemblies which are not constructible etc.
4. Construction Errors:- Excavation and equipment accidents, improper sequencing, inadequate temporary support, excessive construction loads , non conformance to design intent.
5. Material Deficiencies:- Material inconsistencies, premature deterioration, manufacturing or fabrication defects.
6. Operational Errors:- Alterations to structure, change in use, inadequate maintenance.

3.8.2 INVESTIGATION OF THE SCENE AND SAMPLE COLLECTION

- The investigator should obtain and review construction drawings and other pertinent documents.
- Drawings are valuable in guiding documentation of the as built condition of the structure at the site.
- Sketches of the failed configuration of construction are to be drawn.
- Behavior of adjacent construction during and subsequent to the failure is observed.
- Observations of Inventory of construction materials to establish dead loads should be made.
- Description of fracture surfaces should be made.
- Samples removed from the site are recorded and are labeled and their position is documented with notes and photographs.
- A note of the indications of environmental conditions acting on the facility at the time of failure should be made.
- The materials to be recovered from the site for examination are concrete materials, metal materials, masonry materials, wood materials, soil and rock, sand etc.

3.8.3 FIELD TESTS

1. Borings and Penetration Tests:- They are used to sample soil and rock, evaluate strata locations and estimate in-place strength or density.

2. Test Pits:- These are used to identify subsurface profile, obtain undisturbed samples and conduct in-place strength tests.
3. In – Place Strength Tests:- Used to estimate shear strength of in sites.

4. Load Tests:- Foundation and earth-retaining structures are often load tested in place.

5. Dimensional Measurements:- Conventional and newly developed surveying te
6. Seismic Tests:- They are used for rapid and broad determination of soil and rock strata.

3.8.4 LABORATORY TESTS

4. Load Tests:- Many types of loading are applied, including hydraulic jacks, mechanical jacks, air pressure, imposition of water or other heavy materials, reciprocating machinery or impulse loading. Wall, floor and roof panels, wood trusses, shear resistance of framed walls, window / wall assemblies, beam flexural strength are load tested.
5. Testing of Concrete Materials:- Concrete is made up of cement, sand, coarse aggregate, fine aggregate and water. Any variations in their ratios would lessen the strength of concrete. The water to cement ratio of High strength concrete should be 0.35. Any variation in this would weaken the structure. Testing of concrete includes the Mechanical properties of compression strength, modules of elasticity, thermal expansion, abrasion resistance, bond, creep and shrinkage characteristics, tensile strength, flexural strength, shear strength, fatigue strength, fracture properties, chemical analysis, spectrographic analysis and air content analysis are also performed.
6. Testing of Metal Materials:- Tests of mechanical properties include yield strength, tensile strength, shear strength, creep modules of elasticity, ductility, elongation, fatigue properties, fracture toughness and hardness.
7. Masonry and Wood Material Examination:- Wood is an orthotropic material and its mechanical properties are sensitive to duration of load. Mechanical properties of both the materials are to be tested. Microscopic and chemical analysis are performed for structure, composition and resistance to decay of wood.
5. Weld Testing:- Common nondestructive testing methods for welds of metal fabrications, include radiographic, ultrasonic, visual, dye penetrant, magnetic particle and eddy current methods.
6. Sub – Surface Investigation:- Conditions below the surface of a material such as flaws or embedment are tested using, magnetic „R-meters‰, X – ray and pulse – echo methods. Radiographic, ultrasonic and eddy current methods are used to detect subsurface flaws in metals.
7. Scanning Electron Microscope Examination:- SEM analysis are commonly employed for material composition studies.
8. Test Soil, Sand:- Determination of specific gravity, grain size etc.

By performing the above tests the causes of failure can be determined.

Nature of physical evidence received by the section, nature of examinations conducted and type of analytical information laboratory can provide is given below:

Sl. No	Nature of Physical Evidence	Nature of Examination conducted	Type of Analytical information laboratory can provide.
1.	Cement Mortar pieces from the debris of collapsed building, dam, bridge etc.	a) Chemical tests b) Mechanical tests c) Physical tests d) Instrumental Analysis e) Design/structure evaluation	Whether the collapsed building/wall/bridge/dam/ structure is on account of substandard materials or improper design or human failure or due to aging.
2.	Components recovered and seized in the road/rail/air accidents including evidence of drag marks, skid marks etc. on the ground	a) Chemical tests b) Mechanical tests c) Physical tests d) Instrumental Analysis e) Design/structure evaluation	Whether the accident is caused on account of component failure or human failure or design failure or other reasons.
3.	Manufactured goods used in automobiles, industries and other sensitive installations	a) Chemical tests b) Mechanical tests c) Physical tests d) Instrumental Analysis e) Design/structure evaluation	Whether the goods are meeting the specifications claimed by the manufacturer.

Precautions and guidelines for the collection of physical evidence

In all the above type of cases the Investigating Officer should requisition the services of the Scientists of APFSL for on-site inspection, search for evidence, collection of appropriate evidence etc. In case it is not feasible, the Investigating Officers should collect incriminating materials and documents considering the nature of accident/damage etc. However the site/scene of devastation should be protected from human and environmental factors so as to obtain the true picture of what had happened when the scientists come for inspection.

3.9 VIDEO AUTHENTIFICATION

Video Cassettes, Video CDÊs are being increasingly used in recent times to record certain events secretly in cases such as receiving bribes by using miniature Cameras, Digital Cameras etc., by the victim / investigative journalists. With the advent of cheap and readily available capture media, the number of digital multimedia files has

increased manifold. Editing and manipulating these files can be done easily and seamlessly. In majority of the cases there will not be any other evidence except the Video Cassette/VCD. When these are submitted to the investigating agency the Investigating Officer has to first satisfy himself that the video Cassette/VCD is authenticated and actually depicts a true event / incident.

- *Video Authentication* is the process of verifying whether the digital video in use is genuine (not been tampered with in anyway). This technology assumes immense importance, as without it video can never be admissible proof in the court of law. Video Authentication confirms the integrity of the video.

3.9.1 NATURE OF PROBLEMS

Whether the video cassette/CD

a) Is edited or not?

b) Is tampered or not?

c) Depicts a single uninterrupted incident or not?

d) The pictures therein have been manipulated or not?

e) Various incidents have been joined to form a single recoding or not?

f) Whether the person / persons in the questioned and in the standard is / are one and the same or not?

In other words, digital video authentication proves that any or all of the following facts are true:

(i) No frame in the video stream has been modified,

(ii) No new frame was inserted in the video stream,

(iii) No frame was removed from the video stream.

Recognition Problems:

In addition to the problem of authentication there also arises the problem of recognition of various people in the video. In order to deal with such problems, techniques of advanced recognition methods need to be used, some of these are eigenface, Fisherface and neural-network for facial recognition.

3.9.2 TYPES OF EDITING

1. Real time editing

2. Post production editing

b) Assemble editing – laying one scene after another. Both audio & Video editing is done.

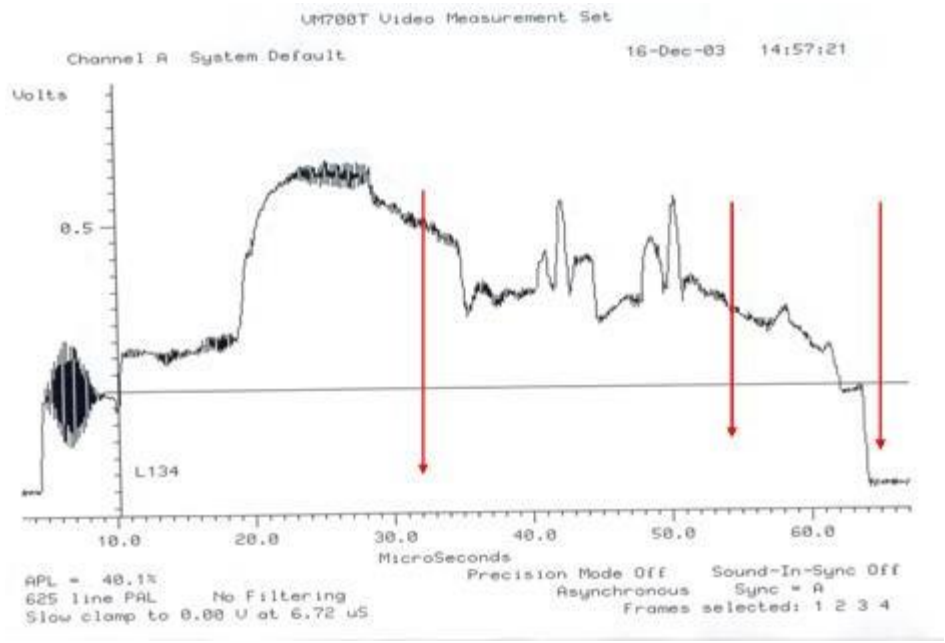
c) Insert editing – replacing original video with new video leaving the audio portion intact.

3.9.3 VIDEO AUTHENTICATION TECHNIQUES

1. Visual Observation: The Video Cassette/CD has to be viewed carefully observing the scenes, background, smears, vertical jumping, horizontal wavering, colour & hue saturation, any discontinuities, jumps, breaks, abrupt increase / decrease in audio

background sounds, sudden strange sounds, variation in level of illumination etc.,

2. Examination under Waveform Monitor: The signal from Video Cassette/CD is fed to Waveform Monitor, which provides voltage verses time display of the video signal there by evaluating the luminance portion of the signal. If there is any signal aberration, which could be due to editing, the Waveform Monitor displays this signal on the screen. Thus the luminance values of the active video signal are carefully studied for any abrupt changes to identify edit points.



A typical output of waveform monitor – peaks showing brightness, minima showing darkness.

The Luminance values of the active video signal are carefully studied for any abrupt changes for identification of edit points.

3. Examination under Vector Scope: The signal output from the disputed Video Cassette/CD is fed to the Vector Scope, which demodulates and displays the (R-Y) colour difference component on the vertical axis and (B-Y) colour difference component on the horizontal axis. By measuring chrominance information and matching burst of multiple signals, Vector Scope facilities detection of edit points.

4. Frame-by-Frame Study: The Video recording is converted into digital video format as to the hard disc of a computer. Frame-by-Frame study of the digital video format can then be studied by using appropriate software such as Dazzle, Virtual Dub etc., to observe any edit points.

5. Observation of Lip Sync: The audio & video is carefully listened & watched from the beginning to the end. The lip movement of the persons in the video with respect to the audio is carefully observed to ascertain whether they are perfectly matching or not. The time delay of audio to video if any can also be measured to establish editing.

6. Study of time Code: Study of time code (an electric signal which tracks individual frames for the purpose of editing) for its continuity frame by frame will also yield edit points.

7. Simulated Studies: Extensive simulated video recording, editing has to be carried out if the original recording devices such as video camera or camcorder are recovered for the study of any colour aberrations (or) any other peculiar characteristics.

3.10 FORENSIC SPEAKER IDENTIFICATION

3.10.1 INTRODUCTION

Voice is frequently encountered as evidence in cases of kidnapping for ransom, threatening calls, anonymous calls, hoax calls, obscene calls, terrorist threats, trap investigation and so on. The scientific investigation of the recorded voice collaborates evidence in respect of speaker identification.

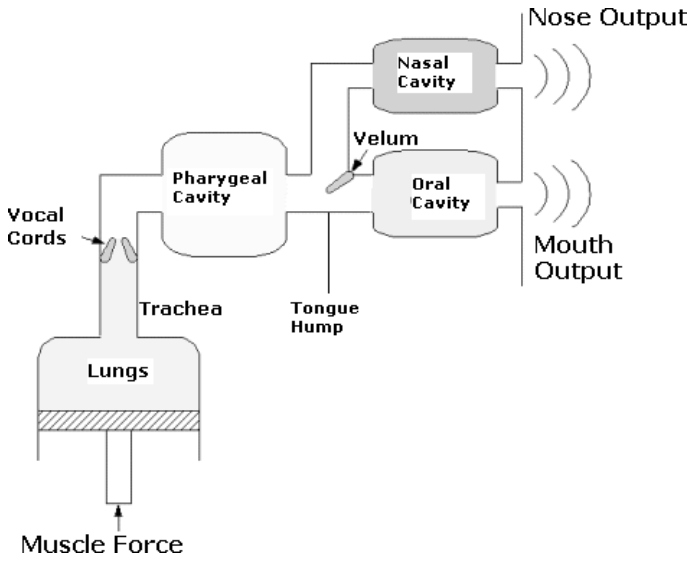
3.10.2 HISTORY

- The history of speech sound analysis goes back a little more than one hundred years to Alexander Bell who developed a visual representation of the spoken word.
- It was in the early 1940Ês that a new method of speech sound analysis was developed. This machine named sound spectrograph was automatic sound wave analyzer, produced a visual record of speech portraying three parameters viz., frequency, intensity and time.
- Today *voice identification & analysis* has matured into a sophisticated identification technique, using the latest technology science has to offer. The research, which is still continuing today, demonstrates the validity and reliability of the process when performed by a trained examiner using established, standardized procedures.

3.10.3 BASIC ELEMENTS OF SPEECH PRODUCTION

Human organs that combine to produce intelligible speech are:

- The lungs & windpipe
- The larynx
- Upper throat
- The mouth
- The nasal cavities



SCHEMATIC DIAGRAM SHOWING THE VARIOUS ORGANS RESPONSIBLE FOR INTELLIGIBLE SPEECH

3.10.4 METHOD OF VOICE IDENTIFICATION

Voice identification is a two step process.

I. Auditory (listening) examination.

II. Spectrographic (visual) examination.

I AUDITORY EXAMINATION

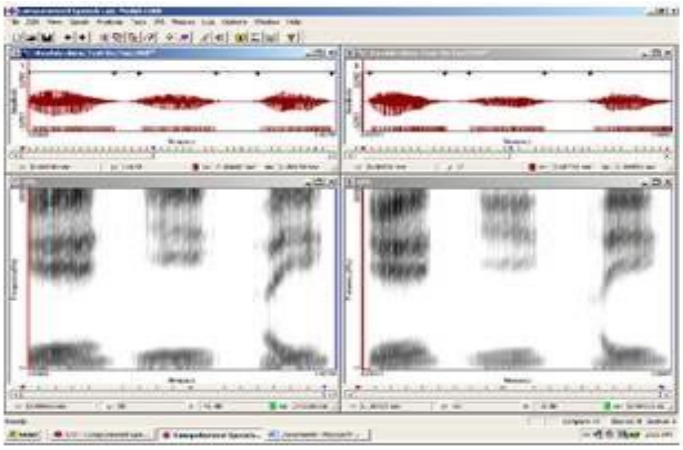
- The inter speakers are differentiated by the attributes of voice production machine, language of speech and manner of speaking. The auditory analysis reveals dynamics of speech such as dialect, pitch, articulation, general voice quality, intonation, stress/emphasis disguise, speech defects etc.
- In some situations, the speaker makes an attempt to disguise the normal voice during recording of the specimen voice sample. The presence of emotional and psychological tensions at the time of recording, some of the spectrographic features are likely to change/shift from the normal.
- The use of good quality listening instrument helps the examiner to assess the apparent age of speaker, dynamics of loudness, degree of nasality and pathology of voice (whispery, creaky, breath of hoarse).
- The level of stylistic modes in speech, viz. Formal, normal, informal, casual, vulgar utterances etc., can lead to access overall personality impression of speaker, typical to the emotion, expressive, pathetic, intellectual, polite, sarcastic, cynic, logical illogical or chaotic behavioral features.
- After listening to the questioned and standard, the auditory features i.e. linguistic and phonetic features (dialect, accent articulation, vocal quality, stress etc.,) are compared. Peculiar speech habits are also scrutinized.

II VOICE SPECTROGRAPHIC ANALYSIS

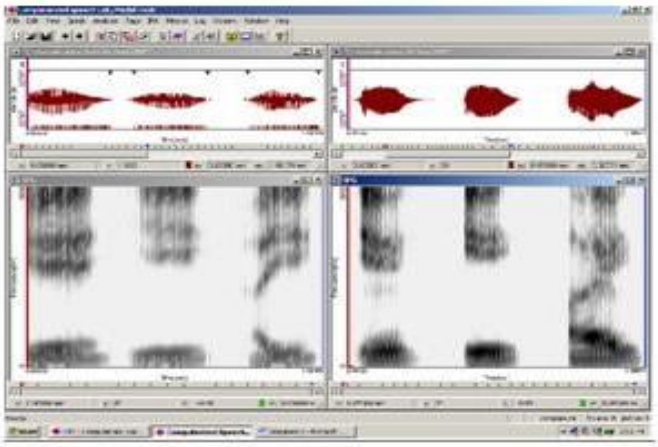
The latest technology introduced in the spectrographic instrumentation facilitates the comparison of two voices, one suspected and the other known or standard by means of a combination of words and sentences selected from speeches to arrive at a conclusion whether the suspect is responsible for a particular voice / speech or not.
Spectrogram is a three dimensional representation of sound.

- Horizontal axis represents *time*.
- Vertical axis represents *frequency*.
- Darkness represents *intensity*.

These three dimensions give information on how the frequency and intensity change with time



Similarity of the above two spectrograms indicates that the samples were spoken by the same individual



Theabove Spectrogramsoftwodifferentspeechsamplesaredissimilarindicatingthe two samples were spoken by two different individuals

3.10.5 REPORTING PROCEDURE

When the analysis is complete the examiner integrates his findings from both the auditory and spectrographic analysis into one of the following five conclusions:

- A positive identification
- Probable identification
- Positive elimination
- Probable elimination
- No decision

3.10.6 ROLE OF I.O

- The technique of speaker identification requires two types of samples namely questioned sample (crime sample) and specimen samples (control samples of suspect). The following are the guidelines for obtaining specimen voice samples for the purpose of speaker identification.
- An accurate transcript of the text of the recorded criminal call / conversation

should first be made.

- Investigating Officer should become familiar with the transcript (the rate of speaking and oral characteristics of the criminal‘s voice) prior to obtaining samples of the known persons.
- Recording system should be set up with a telephone line if the recording of the criminal is to be obtained through the telephone (Direct recording is also acceptable).
- The recording of the specimen sample should be performed in presence of two independent witnesses. The witnesses should speak about their particulars like name, fatherÊs name, residential locality, occupation etc., and he also should speak that „I Mr. Y son of Mr. A residence of B locality, in my presence the speech sample of Mr. X is being recorded.
- In case suspect is not educated and he cannot read the prepared text or transcript, the sample can be recorded by making the conversation with the suspect. The conversation should be prolonged in such a manner that the relevant words are repeated a number of times. The similar text in the same language should be prepared for recording the specimen samples.
- The recording should be repeated as many times as felt necessary.
- A reasonably quiet environment should be maintained.
- Make the suspect conversant with the specimen speech before the recording starts.
- The speaker should be at a distance of about one foot from the microphone and should speak with normal speed and loudness. It is an essential requirement to stabilize the speech of the speaker for which he may be asked to speak continuously for two minutes before he reads the prepared text. The speaker should be directed not to speak too fast or too slow but he should read/speak normally.
- The investigator should make all efforts to eliminate as much background noise as possible by not playing radio, TV and Air conditioners, fans or overlapping conversation.
- In the event of a suspect disguising his voice, the I.O. should ask for the repetition of disguised words, until he feels satisfied.
- Recording should be played back before the suspect leaves; so that any deficiency of the sample can be corrected.

3.10.7 PRECAUTIONS

- The recording system should be tested prior to the actual recording of the samples.
- Original recordings should be properly labeled.
- Recorded cassettes should be properly labeled.
- Questioned and specimen samples should be on separate cassette with proper marking and packing.
- Recorded cassettes should be kept away from „Magnet‰.
- Irrelevant portion of the recording should not be deleted by the Investigating Officer rather than it should be pointed out.

LEARNING OUTCOME

After studying this unit you should be able to:

1. Mention the various types of Failures and their mechanisms.
2. Cause for Failure.
3. Methods for Investigation of the scene and sample collection.
4. Various Laboratory tests.
5. Forensic Speaker Identification.

GLOSSARY

1. Failure
2. Ductile
3. Brittle
4. Fatigue
5. Erosion
6. Creep
7. Corrosion
8. Subrogation
9. Luminance

SUGGESTED READINGS

1. Forensic Structural Engineering Handbook- Mr. Robert. T. Ratay.
2. Forensic Engineering Fundamentals- Mr. Darren Franck and Mr. Harold Franck.
3. Forensic Engineering Investigation- Mr. Randall Noon

UNIT IV

LEARNING OBJECTIVES:

In this unit you will be introduced to:
1. Various Cyber Crimes.
2. Digital Evidence.
3. Memory Forensics.
4. Types of Hard disks.
5. Different types of Data.

UNIT IV-A-CYBER SPACE AND CYBER CRIMES

4.0 INTRODUCTION

In less than a decade, computers and information technology have invaded all realms of our lives. This advent has facilitated in several manner from faster and easier communication channels to wearable gadgets which monitor our health and even ensure safety and security of our homes and loved ones. However; like any other technology of the past, this technology also brings with it a new set of threats and perils. The threats range from unauthorized intrusion to disruption of services and the impact of these threats could be devastating not only at individual level but even to the security of the country. Attacks against critical infrastructure of the country, which are controlled by automated SCADA system, face the threat of disruption.

This imminent danger has made it pertinent to gain knowledge about this emerging technology, the associated threats, unlawful activities, governance, forensics & incident response. This knowledge is increasingly becoming a necessity for the law enforcement agencies, security & intelligence agencies, who are primarily mandated with the task of ensuring the safety and security of the _citizens of this new space‘ or commonly referred to as _Netizens‘. The increase in the number of cyber-crimes has also made it necessary that the legal fraternity and judiciary should also gain knowledge and insight about this emerging technology in order to adjudicate these crimes in an effective manner. In addition to these communities, a general knowledge and awareness by the _netizens‘ themselves would enable them to guard against the potential threats lurking in this new space.

4.1 CYBERSPACE

Cyberspace refers to the virtual and dynamic computer world, and more specifically, is an electronic medium used to form a global computer network to facilitate online communication. In other words, cyberspace is the web of consumer electronics, computers, and communications network which interconnect the world.

History of cyberspace

The origin of cyberspace can be traced back to 1984, when William Gibson published his science fiction book – Necromancer, in which he described an online world of computers and elements of the society who use these computers. The word **cyberspace** first appeared in this book. The author portrayed cyberspace as a three-dimensional virtual landscape. Also, a network of computers creates this space.
According to him, cyberspace looked like a physical space but was actually a computer-generated construction. Also, it represented abstract data.

The book caught the imagination of many writers and in 1986; major English language dictionaries introduced the word _cyberspace‘. According to the New Oxford Dictionary of English, _Cyber Space‘ is the notional environment in which people communicate over computer networks.
Since cyberspace is a virtual space, it has no boundaries, mass, or gravity. It simply represents the interconnected space between computers, systems, and other networks. It exists in the form of bits and bytes – zeroes and ones (0‘s and 1‘s). In fact, the entire cyberspace is a dynamic environment of 0‘s and 1‘s which changes every second.

These are simply electronic impulses. Also, it is an imaginary location where the words of two parties meet in conversation.

Cyberspace vs. Physical World

The key differences between cyberspace and physical world are given in the table below:

Physical Space	Cyberspace
Static, well-defined, and incremental	Dynamic, undefined, and exponential
Has fixed contours and boundaries	Is as vast as the human imagination and has no fixed shape

The seamless connectivity of the cyberspace is a boon for communication and information exchange; however, it has its own set of challenges. Like any other technology that has evolved in history, this too has its share of shortcomings and challenges and one such challenge is curbing unlawful and criminal activities. The next section, elaborates the concepts and details of cyber-crimes.

4.2 CYBER CRIMES

Any new technology or invention is both a boon and bane to the society and digital or computer or cyber technology is no exception to this rule. There is always a group of users who want to use and explore the new technology for the welfare of the society at large while there is a group of miscreants who abuse the technology for personal gains or sadistic pleasures. History is full of incidents which illustrate the difference between the above-mentioned two groups of users. These differences, obviously, create a necessity for governance and policing.

Cyber-Crimes, in simplest terms, could be defined as criminal or unlawful activities in which the computer is either a victim, or an attacker or medium for carrying out an attack, or both a victim and an attacker or repository of an evidence or data. Computer Crimes or Cyber-Crimes or Digital Crimes can be broadly classified in the following manner:

i. Cyber Crimes Against Person(s):

In these forms of cyber-crimes, an individual or a specific group of persons are targeted. Some of the common cyber-crimes of this genre are as follows:

a) ***Cyber Bullying***: Cyber bullying or cyber harassment is a form of annoying or teasing or harassing through electronic means such as emails, mobile phones or social media.

b) ***Cyber Pornography:*** Cyber pornography is the act of using cyberspace to create, display, distribute, import, or publish pornography or obscene materials. Often such explicit content may involve images of the victim. A variant of this crime involves exploitation of children and such attackers are termed as ‒online pedophiles/ predators‖, lure children and teenagers into engaging in sexual acts.

c) ***Email Spoofing:*** Spoofing is the act of disguising a communication from an unknown source as being from a known/genuine/trusted source. Email spoofing refers to the act of sending fake emails, appearing to be originating from known/genuine sources or senders. These emails may be defamatory, derogatory or even threatening. Email spoofing is often done along with another form of cyber-crime known as ‒phishing‖ in which the sender may send URL links containing malware which can steal data or sensitive information from the victim‘s computer.

d) ***Cyber Defamation:*** It is the act of publishing of defamatory material against another person with the help of computers or internet.

e) ***Hacking:*** Hacking generally refers to unauthorized intrusion into a computer or a network. The computer systems/mobiles/emails/social media profiles of the victim may be hacked in order to steal data or even harass the victim.

f) ***Online cheating:*** In the name of lotteries, jobs, free goods, charity, cheap offers, matrimonial profiles, inheritance of property, skilled workers, OTP frauds, ATM frauds, skimming, simming and vishing criminals are cheating person(s) online to the tune of multi crores.

ii. Cyber Crimes Against Property

These forms of cyber-crimes involve vandalizing computer networks or resources, physically damaging computers, hard disks or similar electronic devices. Cyber-Crimes against property can also be extended to theft or breach of Intellectual Property. Some of the common forms of cyber-crimes against property are as follows:

a) ***Cyber Theft of IPR:*** Cyber theft of IP means stealing of copyrights, trade secrets, patents etc., using internet and computers. This would include illegal or unauthorized copying of digital content from websites which are protected by IPR.

b) ***Webjacking:*** This form of cyber-crime is often used in social media and websites where the attackers create a fake website and when the website opens it will redirect it to another website and harm the users' system.

c) ***Denial-of-Service attack (DoS attack):*** A denial-of-service attack (DoS attack) is a cyber-attack in which the perpetrator seeks to make a machine or network resource unavailable to its intended users by temporarily or indefinitely disrupting services of a host connected to the Internet**.** A DoS attack can result in complete crashing of the computer system.

iii. Cyber Crimes Against Organization

These forms of cyber-crimes are targeted against organizations as a whole and are often the result of business rivalry. These crimes may be targeted against organization(s) with an aim to steal confidential data or even defame the organization. Some common examples of this form of cyber-crime are as follows:

a) ***Cyber Espionage***: It is the act or practice of obtaining secrets from individuals, competitors, rivals. These acts are often carried out by means of Social engineering with the existing employees of the firms or by introducing malware into the computer systems of the firms.

b) ***Website Defacement:*** A website defacement is an attack on a website that changes the visual appearance of the site or a webpage.

In addition to the above-mentioned cyber-crimes, variants of cyber-crimes against individuals and against property may be targeted against organizations as well.

iv. Cyber Crimes Against Society

These forms of cyber-crimes are targeted against the society. These are often a combination of the afore-mentioned cyber-crimes. These crimes may involve spread of hate-speech against a race or religion through websites, online portals or the social media. A new form of crime that is emerging in this area is the sale of contrabands through online shopping and websites. These forms of cyber-crimes are being carried out in the Dark Net[1]

v. Cyber Crimes Against Nation

Cyber Terrorism is one distinct example of cybercrime against government. The growth of Internet has shown that the medium of cyberspace is being used by individuals and groups to threaten the governments as also to terrorize the citizens of a country. This crime manifests itself into terrorism when an individual or group of

individuals hack into a government or military maintained website**.** They may either steal sensitive and confidential information or may deface the website of the government organization or may even post derogatory and defamatory content on such websites.

Another form of cyber-crimes against nation is cyber-attacks against the critical infrastructure of the country. In the year 2010, the world witnessed the first cyber-attacks against the power grids in Iran. This attack was launched using a worm named as ‗Stuxnet'.

In addition to the above-mentioned common forms of cyber-crimes, the figure below is a illustration of several other forms of cyber-crimes. These crimes may be targeted against individuals, Society, organization and even nation.

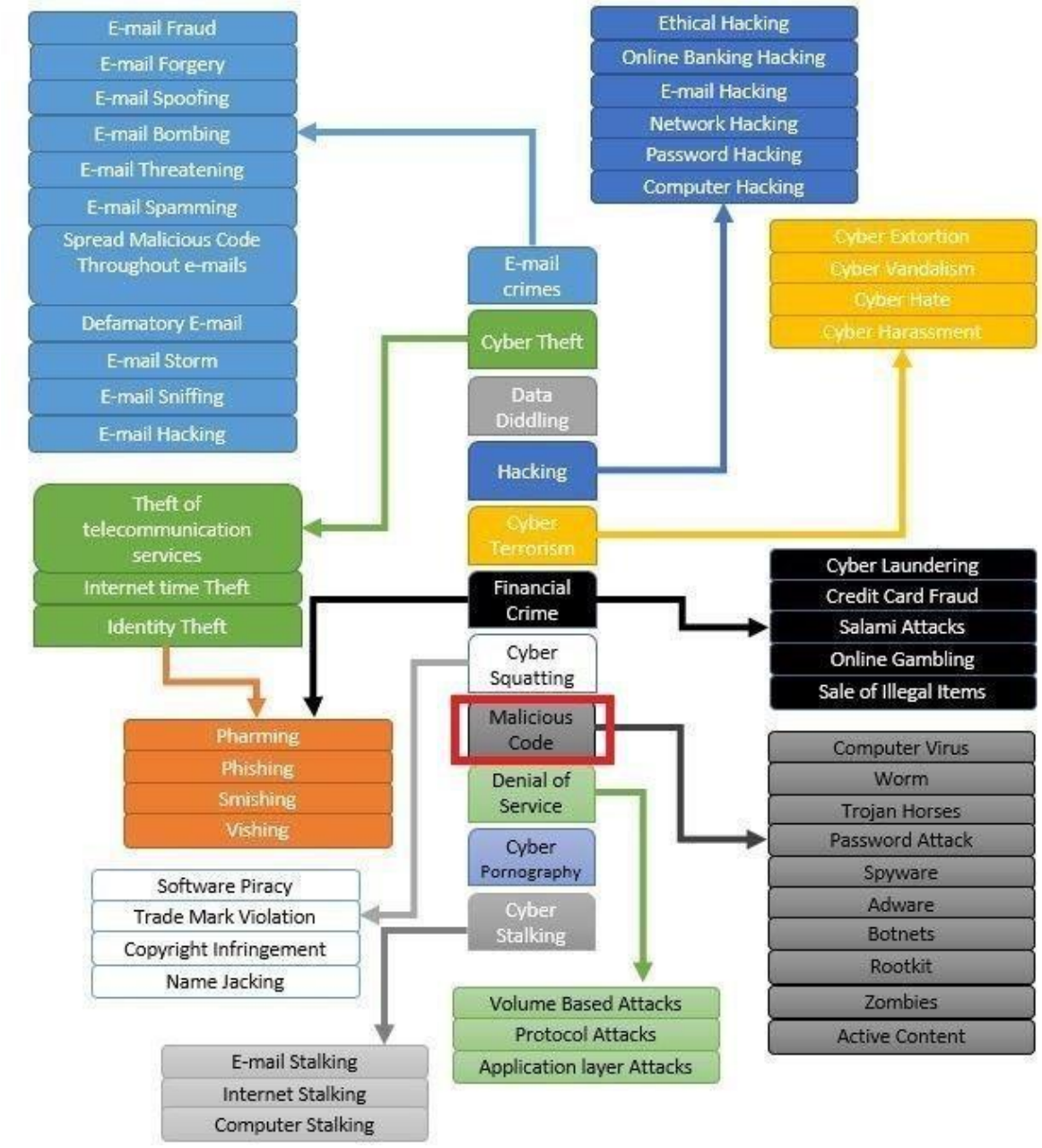


Figure 1: Different Forms of Cyber Crime

4.3 DIGITAL EVIDENCES

Crime, of any form, is associated with a criminal who perpetrates the attack, from a victim and from a crime scene connected to the incident. Evidence is the element which links any or all of these elements of crimes. The evidence may provide the link between the victim and the crime scene or may aid the investigation in eliminating innocent person(s) or identifying the *modus operandi* of the attacker.

Similar to a conventional crime scene, a cyber-crime scene will also contain evidences that may link the attacker or the victim to the crime. For example, if a computer has been compromised by means of Keylogger, the data contained in the hard disk would contain information which may indicate the presence of the keylogger or in some cases, the source from which the keylogger had been installed in the system. Such information form ***–digital evidence".***

Digital evidence may be defined as information and data of value to an investigation that is stored on, received or transmitted by an electronic device.

Digital evidence:

- ✓ Is latent (hidden), like fingerprints or DNA evidence
- ✓ May be in crosses jurisdictional borders
- ✓ Is quickly and easily can be altered, damaged or destroyed with little effort
- ✓ Can be time sensitive

This evidence can be acquired when electronic devices are seized and secured for examination. The specialized field related to the identification, collection and examination of digital evidences is known as **Digital Forensics**. With the advent of technology, the concept and scope of digital forensics has been expanded and the new term that is alternately used is **„Electronic Forensics".** The scope of digital forensics not only includes digital or electronic device, but even examination of files, in particular, multimedia files.

UNIT IV-B-CYBER FORENSICS

4.4 INTRODUCTION

Forensics is the use of science and technology to investigate and establish facts in criminal or civil courts of law. Computer Forensics is the scientific examination and analysis of data created, stored, modified or transmitted on computer storage media for the purposes of presentation in a court of law.

The field of digital forensics encompass research and incident response in addition to data recovery. It should be noted that Cyber Forensics is **different** from **Data Recovery.** Technically, both involve recovery of stored/active data or deleted data from a media like hard disk; however, in **Data Recovery,** the examiner is, in most cases, aware of what he is looking for. He may want to retrieve specific file(s) with either specific content or of specific format. Cyber forensics, on the other hand, is the task of recovering data that the users might have deleted or hidden or even transmitted through the suspected media. Often, the investigator is faced with a broad requirement and would have to use his skill, knowledge and experience to identify all possible sources of evidences from the suspected media. Cyber Forensics can be broadly classified into the following branches:

- Memory Forensics
- Mobile Phone Forensics
- Network Forensics
- Email Forensics
- Web Forensics
- File/Data Forensics
- Cloud Forensics
- Drone Forensics

The scope of Cyber Forensics (in any of the above-mentioned branches) may be defined as below:

- **Search**- identification of data/information that can be possible source of evidence
- **Seizure**- the Secure collection of the identified digital evidences
- **Analysis**-the examination of data to determine details such as origin and content
- **Presentation**- the collection and presentation of the information about computer data and computer systems to courts of law
- **Preservation**- protection of digital Data

A graphical representation of the above-mentioned steps is given in the figure below:

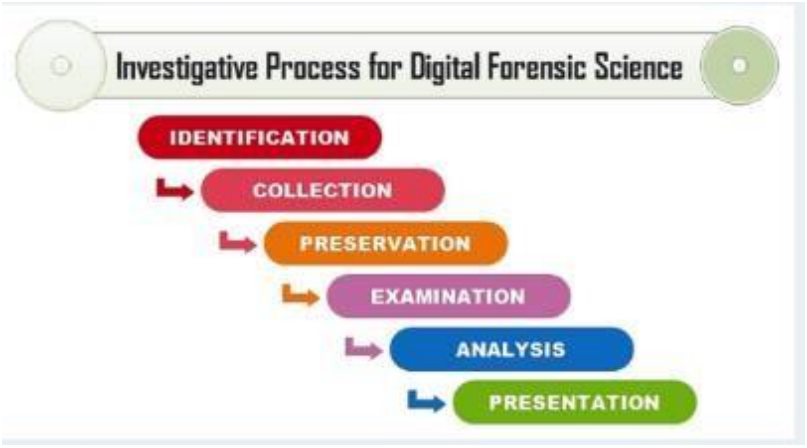


Figure 2: Steps in Digital Forensics[2]

4.5 MEMORY FORENSICS

Memory Forensics pertains to the branch of cyber forensics which primarily deals with forensic analysis of different forms of memory. In computer technology, there are two main types of Memory- **Volatile** and **Non-Volatile** memory. **Volatile memory** is computer storage that only maintains its data while the device is powered. Example: RAM of Computer Systems. **Non-volatile memory** is a type of computer memory that has the capability to hold saved data even if the power is turned off. Example: Hard Disks, Floppy Disks, etc.

Volatile Memory Analysis

At present, the forensic analysis of Volatile Memory like RAM is challenge and this is an emerging area in the field of digital forensics. Forensic analysis of Volatile Memory would broadly give information about the following:

a. Software /Applications that were active that are currently running the system
b. Details about Files that are open when the memory was captured
c. Users who are logged into the computer system

Note: The detailed study about Volatile Memory Analysis is out of the scope for the current course.

Non-Volatile Memory

There are different forms of Non-Volatile Memory. Some of the common forms are given below:

i. Hard Disk Drive
ii. Solid State Disk Drive
iii. Optical Drives- CD-R/CD-RW/DVD-R/DVD-RW/Blu-Ray
iv. Memory Cards/ Micro SD cards
v. Pen Drives/Flash Drives/USB Drives
vi. Floppy Diskettes

Note: As Floppy Disks are obsolete, digital forensic analysis of Floppy Disks is out of the scope of this course content.

Basics of Hard Disks

Hard Disk Analysis is one of the most common and perhaps the oldest known branch of digital forensics. The hard drive or hard disk of a computer is a device that stores all the software installed on a computer, as well as all the data files created and used by this software. Hard Disks can be broadly divided into the following types:

1. Parallel Advanced Technology Attachment (PATA) aka IDE Hard Disks
2. Serial ATA (SATA)
3. Small Computer System Interface (SCSI)

In general, all the above-mentioned types of hard disks consist of rotating disks known as **platters,** which are covered with magnetic media. These disks or **platters** are stack on a spindle. The read and write actions are performed on these platters by **actuator arms** which are also moving parts.

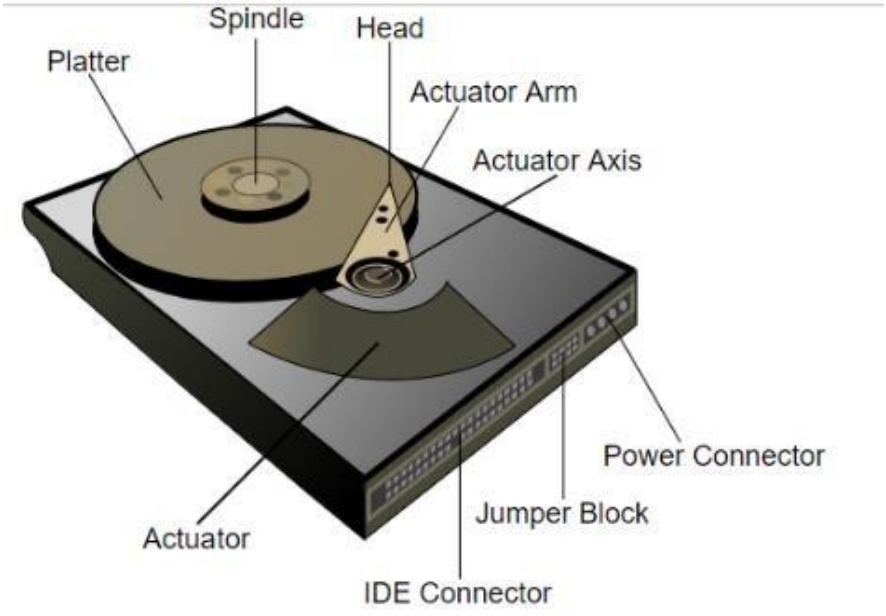


Figure 3: Hard Disk Structure[3]

How is Data stored in Hard Disks?

Data in the hard disks are stored in thin, concentric bands called **tracks.** Track numbers start at 0 and track 0 is the outermost track of the disk. The highest numbered track is next to the spindle. Typically, he highest numbered track would typically be 1023, i.e. there would a total of 1024 tracks (from 0-1023). Each track has a head position. A set of tracks having the same head position form a **cylinder.** Typically, a hard disk may have 1024 cylinders, numbered from 0 to 1023.

Each track is divided into sections called **sectors**. A sector is the smallest physical storage unit on the disk. The data size of a sector is always a power of two, and is almost always 512 bytes. Each track has the same number of sectors, which means that the sectors are packed much closer together on tracks near the center of the disk. The diagrammatic representation of sectors and tracks in a hard disk is shown in the figure below:

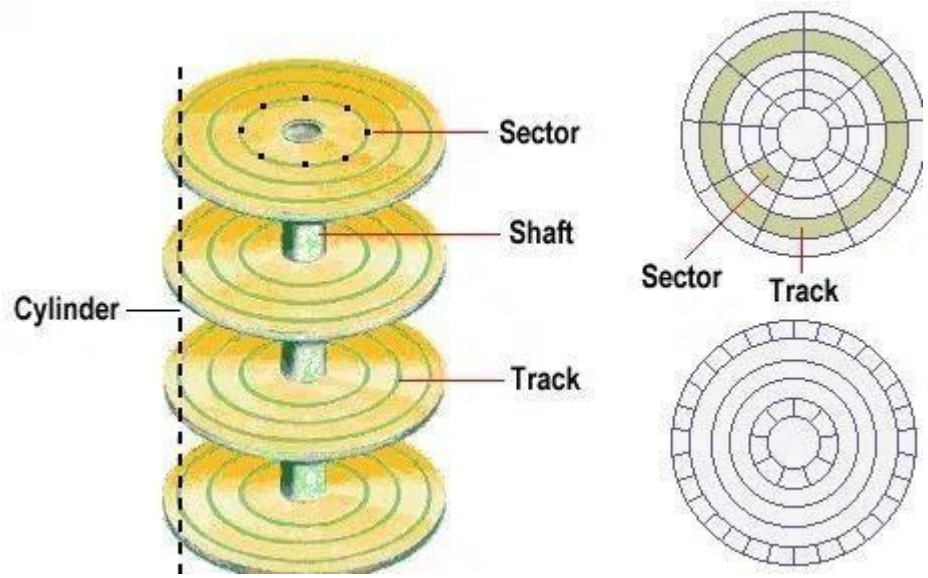


Figure 4: Sectors and tracks in a Hard Disk[4]

Data is stored in the sectors and tracks. A file may be stored across continuous sectors or may be fragmented across different sectors located on different tracks.

In order to stored data in a hard disk, it is first **partitioned** i.e. divided into logical compartments. This process is known as **Disk Partitioning.** A single physical hard disk may have more than one or two logical partitions. There are two types of partitions:

a. **Primary partition**: This type of partition holds information regarding the operating system and system area, as well as other information required for booting.

b. **Extended partition**: This partition holds the data and files that are stored on the disk.

The details of the logical partitions are stored in the **master boot record (MBR).** The master boot record (MBR) is the first sector of a hard disk.

When a computer system is powered on, a small computer program initializes the operating system. This process is known as **bootstrapping.** It is to be noted that the Operating System is a computer program that enables the user to interact with the computer through applications and software. The program used during the bootstrapping process is located in the hard disk itself and the location of this code is known as the **boot sector.** Details about the boot sector are also available in the **Master Boot Record.** Hence MBR is an important file.

Types of Data

Data stored in a hard disk can be broadly divided into the following types:

a. Active Data: This is the form of data that is currently available in the hard disk and can be accessed by any end user. This form of data may be user generated files, software or application files, operating system files, log files, etc.

b. Deleted Data: This form of data is not visible to a normal end user and can be viewed or retrieved using specialized forensic tools. This form of data may be user generated, software or application files, operating files, log files, etc. Data may be intentionally deleted by a user or could be result of automated computer process.

c. Data in Slack Space: When a file is stored in a hard disk, it is spread across sectors. There may be scenario where a file may occupy majority of the space in a

sector but not the complete sector and the remnant space in the sector may be left unoccupied. Such forms of unoccupied or waste spaces are known as **Slack Spaces.** A criminal, with adequate technical knowledge and skill, can use these slack spaces for data hiding. Slack spaces may also result when a file of smaller size overwrites a file of larger file. In such cases, fragments of the larger file may be recovered from the slack space.

d. Unallocated Clusters: When a file on a hard drive containing data is deleted, the data belonging to the file remains on the disk. This area is known as **unallocated clusters or unallocated space.** Data or fragments of data may be recovered from such unallocated clusters. In forensics, presence of data in unallocated clusters is an indicator of the fact that such data once existed on the hard disk and the same has been deleted.

How deleted data is retrieved?

When a data is created and stored in a hard disk, it is physically stored in it. Also, a reference of the data is stored in terms of its memory location is stored in a logical file. In Windows NTFS system, this file is known as **Master File Table or MFT.** When a file is deleted, only the reference of the file is deleted from the MFT, however, the file is still available in its physical location and would continue to remain there until a new file overwrites it. Hence deleted data may be recovered as it is still present in the hard disk.

In case, the data has been deleted and over-written, the chances of recovery of such deleted file may be less. In certain case, fragments of such deleted and overwritten files may be recovered.

Basics of Solid-State Disk Drives:

A solid-state drive (SSD) or Solid-state disk is a solid-state storage device that uses integrated circuit assemblies as memory to store data persistently. It differs from hard disks in the fact that solid-state disks do not have moving parts like cylinders or platters. As a result of this SSD are thinner and smaller in size when compared with HDD. The read and write speeds of SSD are higher when compared with those of HDD. The memory in it is flash memory and the data stored is in the form of blocks, not similar to HDD, hence deleted data recovery is not in the same pattern.

Forensically, the types of data that have been categorized in the previous section hold good for SSDs as well.

Basics of Optical Drives-C

A **compact disc (CD)** is a polycarbonate plastic disc with one or more metal layers that is used for storing digital data. CD can be broadly classified into the following types:

i. **CD-ROM (compact disc read-only memory):** This is the most basic type of optical disc used with computers. The most common CD-ROM format holds 700 MB of data. When a user purchases a CD-ROM, it already has the data on it. A user cannot write new data to the disc.
ii. **CD-R (compact disc–recordable):** This type of compact disc can be written to once. The user must have a CD recorder to write data to the disc.
iii. **CD-RW (compact disc–rewritable):** This type of disc can be written to many times. As with a CD-R, a user must have a CD recorder to write data to the disc.

A **DVD** is an abbreviation of **digital versatile disc.** It is a digital optical disc storage format invented and developed in 1995 and can store more data as compared with compact disks. DVD can be broadly classified into the following types

i. **DVD-ROM:** This is the most basic type of optical disc used with computers. When a user purchases a DVD-ROM, it already has the data on it. A user cannot write new data to the disc.
ii. **DVD-R/DVD+R:** This type of DVD can be written to once. The user must have a DVD recorder to write data to the disc.
iii. **DVD-RW/DVD+RW:** This type of disc can be written and erased many times.

Forensically, optical drives can be examined for presence of active and deleted files. The concepts of Slack Space and Unallocated clusters are uncommon for optical drives.

Basics of Memory Cards/ Micro SD cards

A **memory card** is a type of storage device that is used for storing media and data files. It provides a permanent and non-volatile medium to store data and files from the attached device. Memory cards are commonly used in small, portable devices, such as cameras and phones. A memory card is also known as a flash card or micro SD card. Forensically, memory cards can be examined for presence of active and deleted files. The concepts of Slack Space and Unallocated clusters are uncommon for optical drives.

Basics of Pen Drives/Flash Drives/USB Drives

Forensically, optical drives can be examined for presence of active and deleted files. The concepts of Slack Space and Unallocated clusters are uncommon for optical drives.

4.6 MOBILE PHONE FORENSICS

The advent of mobile technology has enabled more and more data to be stored and shared across devices and networks. Mobile Phones have become more popular as well as affordable when compared with computer systems and laptops. The popularity is as such that today, business is thriving on mobile phones and associated technology and their applications.

Mobile Forensics is a branch of Digital Forensics and it is about the acquisition and the analysis of mobile devices to recover digital evidences of investigative interest. It is not only limited to a mobile phone, but it also covers GPS, tablets, PDA, and other mobile devices. The detailed list of evidence on mobile devices will include the following:

- ✓ Subscriber and equipment identifiers
- ✓ Date/time, language, and other settings
- ✓ Phonebook/Contact information
- ✓ Calendar information
- ✓ Text messages
- ✓ Outgoing, incoming, and missed call logs
- ✓ Electronic mail
- ✓ Photos
- ✓ Audio and video recordings
- ✓ Multimedia messages
- ✓ Instant messaging

- ✓ Web browsing activities
- ✓ Electronic documents
- ✓ Social media related data
- ✓ Application related data
- ✓ Location information
- ✓ Geo-location data

The above-mentioned digital evidences from mobile devices have to be collected or seized and examined in a –Forensically Sound‖ manner so that they may be accepted as admissible evidence before a Court of law. By the term –Forensically Sound‖, we mean that the information should be collected in a manner that its original contents and attributes are not disturbed. However, with the advances in mobile technology, there may be scenarios where all parameters of a –Forensically Sound[5]‖ extraction of data may not be possible. In other words, there may be a requirement to access the boot loader of the mobile phone or even root the mobile phone in order to retrieve the necessary data or information. In certain scenario, we may have to downgrade applications in order to retrieve data or modify configurations enabling the forensic expert to bypass access controls like PIN/Password. All these actions are however, carried out under controlled environment and using specialized tools. Some of the methods of data extraction from mobile devices are illustrated below:

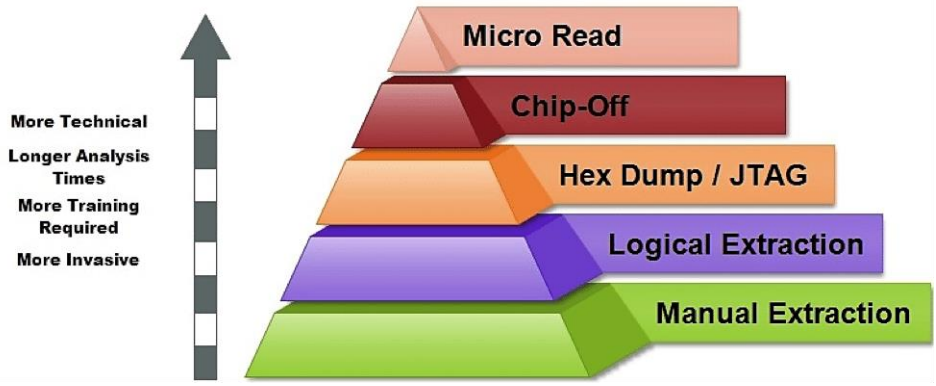


Figure 5: Methods of Extraction-Mobile Forensics

The above-mentioned methods are described below:

1. Manual Extraction

This is the most basic method of data extraction. The forensic examiner merely browses through the data using the mobile device‘s touch screen or keypad. Information of interest discovered on the phone is photographically documented. The photographic documentation can be in the form of screenshots which can be captured either by using the in-built feature of the device or using forensic software. This method is mostly used in circumstances where the available forensic tools and software may not be able to extract the data from the device. However, this method has the following shortcomings:

1. Deleted data cannot be retrieved.
2. This method cannot be used if the device is protected with access control like PIN/Password/Pattern Lock and the expert does not have access to this information.

3. This method cannot be used if the device is severely damaged.

Common tools which support this form of extraction **EDEC Eclipse, Projec-A-Phone and Fernico ZRT.** These are hardware bundled with suitable software to photographically capture or document the mobile evidence. These tools are more often employed by field forensic experts or investigators as compared against experts conducting lab-based examinations.

2. Logical Extraction

This approach involves instituting a connection between the mobile device and the forensic workstation using a USB cable, Bluetooth, Infrared or RJ-45 cable. The currently available forensic tools support this method of extraction. Both active and deleted data can be retrieved using this method. In certain cases, some forensic tools may install its agent or additional software in the mobile phone being examined.

3. Physical Extraction/Hex Dump/JTAG

Physical Extraction or Physical Acquisition is a method in which a bit-for-bit copy of an entire physical store or internal memory of the device is created and then analyzed. In some ways, it is similar to data extraction from hard disks. This method ideally involves the following two steps:

a. Imaging Process

The Imaging process is also referred to as dumping process and the resulting image is often referred to as –Dump‖ or –Physical Dump‖ or –Hex dump‖.

b. Data Extraction

This method involves the extraction of different forms of data from the afore-mentioned –Dump‖.

In cases, where software tools cannot be used for data extraction due to minor physical damages or the device is locked through access controls which cannot be bypassed using software tools, JTAG method of extraction is used. This method involves connecting to the Test Access Ports (TAPs) on a device and instructing the processor to transfer raw data stored on connected memory chips Physical Extraction/Hex Dump/ JTAG methods of extraction have proved to have high success rates in retrieving deleted data in addition to active data. This method is most commonly used by forensic experts in criminal cases as the attacker or criminal might have tampered or destroyed the evidences.

4. Chip-Off

In this method, data is obtained straight from the mobile device‘s memory chip. The chip from the mobile phone is detached and a chip reader or a second phone is used to extract data stored on the device under investigation. It should be noted that this method is technically challenging because of the wide variety of chip types existing on the mobile market and hence should be used only by trained experts and in cases where all the afore-mentioned methods have failed.

5. Micro Read

This method refers to manually taking an all-around view through the lenses of an electron microscope and analyzing data seen on the memory chip, more specifically the physical gates on the chip. In a nutshell, micro read is a method that demands

utmost level of expertise, it is costly and time-consuming, and is reserved for serious national security crises. This is the rarest form of forensic extraction.

4.7 NETWORK FORENSICS

Network forensics is a sub-branch of digital forensics relating to the monitoring and analysis of computer network traffic for the purposes of information gathering, legal evidence, or intrusion detection. [1] Unlike other areas of digital forensics, network investigations deal with volatile and dynamic information. It is often a pro-active form of digital forensics. The scope of network forensics includes the wired as well as the wireless and ad-hoc networks.

Network Forensics can be defined as capture, recording and analysis of network packets in order to determine the source of network security attacks. The goals of network forensics are as follows:

i. Collect digital evidences in the form of network packets
ii. Analyze network traffic data with respect to the content as well the forms of data or information being exchanged – PCAP analysis.
iii. Analyze network traffic data and identify signs of possible network attacks
iv. Development of Intrusion Detection and Intrusion Prevention Systems.

The steps involved in a generic network forensic examination are as follows:

Identification: recognizing and determining an incident based on network indicators. This step is significant since it has an impact in the following steps.

Preservation: securing and isolating the state of physical and logical evidences from being altered, such as, for example, protection from electromagnetic damage or interference.

Collection: Recording the physical scene and duplicating digital evidence using standardized methods and procedures.

Examination: in-depth systematic search of evidence relating to the network attack. This focuses on identifying and discovering potential evidence and building detailed documentation for analysis.

Analysis: determine significance, reconstruct packets of network traffic data and draw conclusions based on evidence found.

Presentation: summarize and provide explanation of drawn conclusions.

Incident Response: The response to attack or intrusion detected is initiated based on the information gathered to validate and assess the incident.

It can be seen that network forensics has an additional step of Incident Response when compared with other forms of digital forensics which often are restricted to the step of Presentation. This additional step of Incident Response adds the element of pro-active behavior in this form of digital forensics. The aim of network forensics is to develop models of defense to mitigate network attacks in future.

Methods of Network Forensics

There are two main techniques or models of network forensics:

“Catch-it-as-you-can”: All packets are sent through a traffic point where they are stored in a database. After that, analysis is performed on stored data. Analysis data is also stored in the database. The saved data can be saved for future analysis. It should be noted, though, that this type of system requires a large storage capacity

“Stop, look and listen” : This system is different from the –Catch-it-as-you-can system, since only data required for analysis is saved into database. The incoming

traffic is filtered and analyzed in real-time in memory, which means this system requires less storage but a much faster processor.

Challenges in Network Forensics

Network forensics analysis, like any other forensic investigation presents many challenges. Some of the challenges in Network forensics are:

i. ***Data Sniffing***: Data sniffing is the jargon for capturing network traffic data. The network forensic tool(s) deployed for network forensics may not capture all data. This may be on account of the manner in which the tool is deployed or the type of data that is being transmitted. For example, sniffing of data in encrypted or secure channels or mode of communication may not be possible.

ii. ***Voluminous nature of Evidence:*** The evidence in network forensics is in the form of network packets and hence is voluminous in nature. It is tedious task for an investigator to analyze the captured data. Also, due to the voluminous nature of evidence, storage and preservation of such data is a challenge as it calls for robust infrastructure.

iii. ***Source of Attack:*** It may not be always possible for the investigator to ascertain the actual source of a network attack. The attacker may employ anti-forensic techniques like multiple layers of traffic routing thereby making the tracing difficult and, in many cases, impossible.

Note: The discussion about the tools and techniques used for Network Forensics is out of the scope of this book.

4.8 EMAIL FORENSICS

Email has become one of the primary and most popular sources of communication. In fact, it is no longer just a medium of communication between peers, friends or family but has become one of the preferred modes of business, especially, trans-border business and e-commerce. This popularity has also resulted in miscreants exploiting this mode of communication.

For a forensic investigator, emails are an excellent source of evidence in a number of crimes like Defamatory or Obscene emails, Phishing emails and Email spoofing. Emails are also being increasingly used as corroborative evidences in both civil and criminal matters. Email Forensics may involve one or more of the following techniques:

Header Analysis: Email header analysis is the primary analytical technique. This involves analyzing metadata in the email header. It is evident that analyzing headers helps to identify the majority of email-related crimes. Email spoofing, phishing, spam, scams and even internal data leakages can be identified by analyzing the header. Some of the information that may be obtained from email header analysis are given below:

i. ***Genuineness of the Email***: Identify whether the email has been sent from a genuine account or is a spoofed email.

ii. ***Source of The Email:*** Identify the source (IP address) of the Sender, in certain cases. (With increasing concerns for privacy, many Service Providers are resorting to IP camouflaging or IP masking techniques in which the original IP address of the sender is obscured)

iii. ***Details of Attachments:*** Details of attachments received with an email can be obtained from email header analysis.

iv. ***Type of Email Communication:*** A skilled investigator can identify from the email headers, whether the associated email is received email or a sent email. Further, the header also gives information about whether the email is a forwarded email or has

been sent a reply to another email.
Some of the common fields in an email header are given in the table below:

Field Name	Description
From	E-mail address (sometimes names) of the author(s) of the e-mail
To	The e-mail address(es) (sometimes names) of the message recipient
Cc	Carbon Copy
Bcc	Blind Carbon Copy
Subject	A summary of the topic
Date	The local time and date when the message was written
Reply-to	Address that e-mail reply will redirected to
Message-ID	Globally unique message identification string generated when it is sent
References	Identifies other documents related to this message, such as other e-mail message
Received	Tracking information generated by mail servers that have previously handled a message, in reverse order

Table 1: Email Header fields[6]

Server Investigation: This involves investigating copies of delivered emails and server logs. In some organizations they provide separate email boxes for their employees by having internal mail servers. In this case, investigation involves the extraction of the entire email box related to the case and the server logs. This technique is often employed in combination with Header analysis, especially, cases of email crimes involving corporate and institutions.
Network Device Investigation: In some investigations, the investigator requires the logs maintained by the network devices such as routers, firewalls and switches to investigate the source of an email message. This is often a complex situation where the primary evidence is not present.

4.9 WEB FORENSICS

Web forensics relates to any sort of crime committed over the Internet, however, in general usage; this refers to forensic analysis of websites and web pages or URLs. Web forensics is often employed in cases involving pornographic contents including child pornography and cases involving website defacement. The techniques of web forensics are aimed at examining the date-time stamps of the web pages of a website. This may even involve Server Side examination wherein the hard disks of the web server may be examined. Web forensics may also involve examination of network devices like routers, firewalls, etc. in cases of website defacement. These techniques are aimed at identifying the IP address or source of the attack. In a way, web forensics is a combination of memory forensics and network forensics, as it involves examination of a memory storage device as well as of the network and peripheral devices attached with the web server system. A popular subset of web forensics is Social Media forensics which involves forensic examination of Social Media websites like Face book, Twitter, etc.
One of the common tools being used in web forensics is **FAW (Forensic Acquisition of Websites)[7]**: Some of the salient features of this tool are as follows:

a. Acquires the web pages including those present on the Dark web through TOR network.
b. Allows automatic as well as manual acquisition of web pages
c. Allows you to schedule the acquisition of a web page, so you can capture the

content at different times of the day.

d. Allows the investigator to search on websites with login-protected areas, such as the Social Network.

e. Captures entire Web sites in FTP and SFTP mode without modifying metadata of copied files

f. Creates a detailed report of all the activities carried out with the FAW suite importing all the acquisitions references in addition to regulatory references in Digital Forensics.

4.10 CLOUD FORENSICS

Cloud Forensics is cross-discipline between Cloud Computing and Digital Forensics. Cloud Forensics is actually an application within Digital Forensics which oversees the crime committed over the cloud and investigates on it. Cloud computing is based on huge network, which spreads globally and hence Cloud Forensics is a subset of Network Forensics. The basic techniques and principles of Cloud Forensics are similar to that of Network Forensics, however, there are three main dimensions in Cloud Forensics. These dimensions are :

i. ***Technical Dimension***: This involves data collection, live forensics, evidence segregation, virtualized environments and proactive measures. The data include the one stored in the infrastructure located at the providers end as well as the one stored at the customers end. The tools and procedures may be developed and may vary as per the cloud deployment and service model being used.

ii. ***Organizational Dimension:*** This dimension comes into being when two parties are involved: the cloud consumer and the Cloud Service Provider. The investigation widens when the Cloud Service Provider outsources their services.

iii. ***Legal Dimension:*** This requires development of regulations and agreement to ensure that the forensic activities do not breach laws and regulations in the jurisdictions where the data resides.

Cloud Forensics is a new branch of digital forensics and as Cloud computing is an upcoming technology in its nascent stages. These facts have resulted in some challenges in Cloud Forensics in terms of data collection and access to logs as there are currently, no agreements or guidelines for agreements between the Service Provider and the Customer with respect to access to data. On similar lines, the access to logs of the Cloud Server is a challenge for the customer. Recovery of deleted data from cloud is a grey area in digital forensics. Ensuring the integrity of digital evidence and maintaining the Chain of Custody are other areas where the investigator may face challenges in a cloud environment.

4.11 DRONE FORENSICS:

Drones in the Modern World Drones are now very popular; from recreational use by children, through to adoption by experienced criminals for the distribution of illegal items. Whether you are interested in using the technology or not, it is impossible to escape the continual presence of drones in our everyday lives - whether as a recreational pastime in the park, in mainstream media, footage on social media platforms, or on television and in films. There are regularly news stories, both positive and negative, about the use of drones, and the opportunities, risks and threats they can pose to leading industries as well as the general public. Changesin public perception, increases in manufacturers and available models, falling commoditised pricing, and rapidly advancing technology have all served to put drone devices in possession of many people around the globe. Whilst commonly and regularly referred to by the

public and mainstream media as 'drones', many law enforcement agencies around the globe use differing terms – i.e. unmanned aerial vehicle (UAV), unmanned aerial system (UAS), small unmanned aerial system (sUAS), and remotely piloted aircraft system (RPAS). This document will use the terms drone and UAV interchangeably. The combined increase of recreational and commercial UAV adoption around the globe highlights that interaction with these devices, and their owners and operators, will continue to become more common for police forces and law enforcement agencies in the coming years.

Drone Incidents Drones come in many shapes and sizes and can be used for a variety of operations, ranging from aerial photography and videos to transporting goods from one place to another. Drones have been increasing in availability and use by the public over the last few years. This, in turn, has led to utilization by criminals to aid in illicit acts such as: invasion of privacy, drug smuggling, terrorist operations, and the disruption of critical infrastructure. Common examples include: Transport contraband into prohibited areas such as prisons. Fly in restricted areas to take photographs or videos for personal use, or to gather intelligence. Use the drone as a menace to disrupt daily life such as flying a drone above or near an airport.

Crashed Drone with Drugs Payload Several drone incidents have transpired globally in the past few years. For example, a serious UAV incident occurred at Gatwick Airport, United Kingdom, in December, 2018, when an unauthorized UAV was flying on airport property and on the airport flight path. This incident disrupted airport operations for approximately three days, impacting thousands of people, and costing millions of pounds. Further, Singapore‘s Changi Airport experienced two drone incidents in one week in June 2019, disrupting the busy airport for several hours, affecting approximately 65 flights, and impacting numerous people. Additional drone incidents have affected numerous industries and people globally in recent years. For example, in the first 6 months of 2019 alone, reports of drone incidents affecting airports and prisons in the following countries were found in the media. Airports: Singapore, England, Ireland, Scotland, Canada, Germany, Italy, Dubai, USA, Mexico, New Zealand,and Norway. Prisons: USA, Italy, Scotland, Ireland, England, and Canada. However, while the above occurrences make regular headlines, the potential user cases for UAVs in both the commission and prevention of crime are almost endless. As UAV technology continues to develop and prices continue to diminish, adoption will increase and present new challenges for first responders, through to digital investigation subject matter experts, across the law enforcement community.

Categories of UAVs The sheer volume of UAVs available on the market, along with the drastic variations in pricing, can make it difficult to understand the different types of devices available. Our research has demonstrated that UAVs can be effectively summarised into three categories:

a) Recreational UAVs: Recreational UAVs are designed for use by amateur enthusiasts, hobbyists, and children, and tend to be low in price. Recreational UAVs start at the lower end of the specification spectrum, and can be purchased for less than £20. They are generally intended to be used outdoors, and possess a very limited battery life. UAVs are often classified as ‗recreational‘ when weighing under 250 grams. There are now thousands of recreational UAVs available in the marketplace from a range of technology stockists and toy stores, as well as endless online shops. Given that UAV legislation is governed by intended usage rather than the device capability, there is no limit on the upper end of recreational UAV specification. Hence some very expensive devices fall into this category; varying in price up into the thousands of pounds.

b) Commercial UAVs: Commercial UAVs are designed to be used in commercial practices. These UAV devices usually carry a payload depicting their usage purpose - such as a camera, used for professional photography, industrial inspection, or land survey. Like their recreational counterparts, commercial UAVs are not governed by device capability but by the intention of the user, thus even the cheapest device could be classified as ‗commercial' if an operator was to deploy the UAV with a commercial intention. Nonetheless, internationally there are many manufacturers of UAVs intended primarily for commercial rather than recreational use, and most commercially intended UAVs cost many thousands of pounds.

c) Bespoke UAVs: Bespoke UAVs are engineered by the owner using component parts that are purchased individually and then put together, rather than purchased as a complete off-the-shelf system. Whilst recreational and commercial UAVs offer great functionality in an 'off-the-shelf' combination of UAV and controlling software, the market for bespoke UAVs has expanded at a rapid rate in recent years as a wider selection of component parts have become available and commoditised, driving down costs. Bespoke UAVs enable a user or trader to purchase disparate component parts of a UAV from different sources, and then build and configure the device according to their individual requirements or available budget. These systems are only limited in capability by the capacity of available components and the knowledge and skill of the people building them, which are both increasing exponentially. Bespoke configurations can be built very cheaply as recreational UAVs designed as toys for children, but can conversely be designed, specified, and constructed by UAV enthusiasts and experts to compete in capability with even the leading commercial manufacturers, comprising component parts costing into the thousands of pounds.

UAV Components

Any UAV will consist of the following two types of components:

Physical Components: The physical components of any UAV which make up the body and flight mechanisms can be broken down into the following categories. Not each and every UAV encountered will contain all outlined component parts, but each element on any UAV can be identified as one of the following:

i) Drone Body The core fuselage of the UAV used to house all other components.

ii) Flight Controller Used to control flight. This device will stabilize the UAV and generally accept navigation input from a radio control device. In more sophisticated systems the flight controller can both be controlled remotely in real time and be pre-programmed for autonomous flight.

iii) Motors, Rotors/Propellers/Wings, and Speed Controllers These component parts combined provide the lift and propulsion for the UAV. Different designs exist, for example, specializing in increased speed or flight duration.

iv) Protective Casing This protection securely encases the motors and propellers (the most vulnerable component of any UAV) to prevent collision and loss of control, and subsequent damage to the system.

v) GPS Receiver Not essential in all UAVs, but common in the leading solutions. This component is used to effectively manage UAV position, return to home functionally, and autonomous flight routes.

vi) Radio Receiver (RX) Used to receive control input signals received from the ground based transmitter.

vii) Transmitter (TX) Transmits manual input from the operator on the ground to the UAV.

viii) LED Lights Some UAVs come equipped with LED lights (usually green and red) which can be used to aid the pilot of the orientation of the drone, and help other airspace users to identify the drone.

Software All UAVs include an application or software that is used to control the system when it is operational. While each recreational or commercially intended UAV will tend to come with its own configured software or control solution, for bespoke UAVs the responsibility is on the person constructing the device to build or integrate a component which works effectively. In support of this model, there are now many open source flight control and ground control applications available online that can be freely downloaded and easily modified to perform any number of tasks. No matter which system is used or how the software components are configured, UAV software solutions can be classified into two core categories:

a) Flight Management Software This software is uploaded to the flight controller within the UAV at one end, and also within the remote control of the user at the other end. When operational, it is used to control the UAV during takeoff, flight, and landing. Typical functions which are controlled by the flight management software solution include UAV flight, device stabilization, and manual navigation input.

b) Ground Control Software This software is used to control pre-determined navigation and effectively plan flight schedules, and is best used by a pilot when the UAV is grounded in planning and preparation for flight. Ground control software additionally facilitates enhanced live monitoring to remote users other than the pilot when the UAV is in flight - either directly to their computers or smart devices such as a tablets or mobile phones. Whilst offering significant innovation and supporting technical development of skills, consideration should be given to the fact that bespoke UAVs may potentially propose increased risks and more dangerous use, as they are likely to be configured with convenience and cost, rather than safety, in mind. This may result in them lacking core safety features and functionality that are built into many of the leading commercial off the shelf (COTS) systems, such as restricted area control, obstacle avoidance, and fail-safe management. These features lessen risk to persons and property in the event of a pilot error or a system failure. Whilst some of these proposed categorisations of UAVs can become blurred, for example – in cases where wealthy recreational users purchase higher end UAVs that are intended for commercial purposes, this categorization approach is recommended when defining UAVs and considering their respective capabilities.

Drone Payloads There are many payloads available at different price points that can be carried by commercial UAVs. These typically fall in to one of the following categories.

a) Camera and Video Payloads Whilst most UAVs are designed to carry some sort of camera, commercial UAVs will carry far more sophisticated imaging devices with enhanced features that could include: first person view (FPV), 4K video, optical zoom for commercial inspection applications, and GPS tagging for 3D mapping. More sophisticated camera systems may have camera gimbals which hold the camera in a level and stabilised position, eliminating any flight movement to produce a superior stabilised image and video output.

b) Thermal, Infrared (IR), and Forward-looking Infrared (FLIR) Payloads Traditionally reserved for higher end systems, thermal imaging can be employed in a variety of user cases, including: agricultural surveying, health and safety, law enforcement, and digital search and rescue applications. Infrared payloads can be particularly useful for effective operation of UAVs during dark or night time flying conditions. FLIR uses a thermographic camera that senses the slightest of variances in

infrared radiation. FLIR can see different frequency ranges, and hence can detect chemical compounds using light detection and ranging (LiDAR) to capture the exact location and distance between objects.

c) Delivery Payloads The use of UAVs to provide timely and efficient deliveries has become an ever-increasing area of investment in recent years, with Amazon most notably making headlines for their Prime Air service. While commercial and retail deliveries provide one opportunity for mainstream adoption, radio deployment and delivery technology could also significantly enhance other sectors, such as healthcare, with UAVs able to transport time-critical services including defibrillators on demand. However, the use of UAVs for delivery also offers opportunities to criminals, providing them with innovative solutions for transporting drugs, weapons, and other items. This tactic has been encountered in prisons internationally.

d) Weapon Payloads UAVs possess the ability to transport weapons for distribution, or to conduct attacks using the UAV itself. This is now seen regularly in military user cases where devices are chosen as the attack method due to the increased precision and reduced risk of loss of life posed in comparison to traditional human-led combat methods. To equate the risk in an operational user case, a medium specification UAV has the capability to carry a payload of 3kg for 16 minutes at 16 meters/second. This could equate to an autonomous vehicle that can effectively carry and deploy 3kg of explosives to a range of 16 kilometres.

e) Communications Payloads Communications payloads are not yet commonly used, but may become more common with the introduction of 5G networks. UAVs can carry communications payloads that might be used to monitor, interrupt or mimic legitimate private wireless communications – for example, through spoofing cell towers or wireless access points.

Understanding Drones and Other Associated Evidence Sources Drones, unlike many other electronic devices, require supporting devices for appropriate operational capability. These associated devices could include the following components:

a) Remote Controller These are used to control the drone remotely. Figure 5: Drone Remote Controllers b) Mobile/Tablet Device These devices are used to view the camera/video feed from the drone. Drone Remote Controllers with Phones/Tablets Attached

c) First Person View (FPV) Goggles FPV goggles are used to view the camera/video feed of the drone, and may also control the drone by head movements or associated controls. First Person View (FPV) Goggles

d) Memory Cards Removable media may be utilized to hold pictures and videos taken using the drone. They may also contain flight path data, as well as geotagging of photographs by using exchangeable image file (EXIF) data within the photographs.

e) Cloud Storage The drone may utilize the associated mobile handset to store photographs or video in cloud storage services such as iCloud or Google Photos.

f) Wet Evidence Like any other piece of physical evidence, a drone and its associated devices may hold wet evidence such as fingerprints, DNA etc. Figure 10: Fingerprint While the drone will be the primary source of evidence, it is vital that secondary sources of evidence such as the controller, mobile phone/tablet, and memory cards are secured to ensure that the most comprehensive picture of the event and associated intelligence is collated. When responding to a drone incident, it is important to capture as much information on the incident and the associated events, such as identifying key witnesses, locations and environmental conditions. Some of these identifiers may seem superfluous at first, but as the investigation unfolds it may become a critical factor.

Drone Data Like all other digital solutions and devices, the use of a UAV will inevitably result in a digital footprint with the creation and storage of data - whether intended by the user as part of the core service capability or as a by-product of the use of the UAV, such as historical usage logs.

Types of Data There are various types of data which assist the investigation of drone incidents. These include:

a) Audio Visual Content In most cases, the primary and largest source of data stored by either recreational or commercial UAVs will consist of digital imagery or video footage. Most operators now strive to record the highest quality of footage possible to give them a unique selling point and business advantage over their competitors, which can result in significant volumes of data and required storage capacity, even in short bursts of filming or capturing imagery.

b) Flight Schedules Where the UAV control system offers the capability to plan advanced flight schedules and offers a degree of autonomy to the user, this data is regularly retained and can be revisited by the user to review previous activity, repeat an existing flight schedule, or amend previous flight schedules.

Often, data that is captured during flight and retrospectively downloaded into a control system or flight schedule review platform will also be intentionally retained by the user for an audit and review of usage overlaid with mapping, so users can track the UAV‘s activity and progress.

a) Other Payload Created Content Where other payloads are integrated into a UAV, these too are very likely to capture and record their own data sources and present them back to a user or organisation. The type of data will vary depending on the payload in question, but one example is UAVs that are used as delivery assets. These will be required to audit times, locations, and results of their respective missions.

b) Automated Usage Logs UAVs are no different to most other digital devices in that when in use they routinely create and retain digital data that helps them continue to function as intended. While this data is not intended to be read by the user, and in fact will be unbeknown to most, some UAVs will routinely create and store usage logs that can include details such as mission details, time and date of operations, and navigational waypoints during use. This data will generally consist of GPS positions, motor speeds, altitude, and directional information.

Accessing Different Data Storage Mediums Multiple devices/evidence sources present significant opportunities to investigators who, if required to do so, may have the opportunity to access vast volumes of rich data about an owner or user's usage of a device from multiple data storage sources. Our research has demonstrated that the storage and retention of data change dramatically depending on the manufacturer and specification of the UAV in question. This can range from very little, if any, digital recovery opportunities available from low-end recreational devices, right up to vast volumes of complex data that can be accessed from commercial and bespoke UAV configurations. In addition to varying volumes of data, the location of data can also vary significantly depending on the specifications of the device, and the chosen configuration of the user. It is therefore crucial when considering data from UAVs that the principle of Digital Profiling is adopted to review: the wider technical profile and digital competency of the user, the specification of the UAV in question, any payloads in use, and the flight control configuration in place for the specific UAV. Once each of these factors has been considered, then an informed assessment can be made as to where the relevant data relating to an enquiry may be retained. There are several locations that data may reside during an investigation. These include:

a) On-board Data Storage Some UAV devices will store and retain information within memory and processors built into the UAV frame or flight controller. Depending on the specifications of the UAV and its associated ports, the method of extracting this data may vary from relatively simple methods such as _plug and play‘, to advanced destructive forensics techniques such as _chip off‘.
b) Removable Storage Devices Given the size of the associated files, most UAVs designed to capture high resolution images and video will offer the capability to integrate a removable storage device. Given micro SD cards are now available with up to 2 TB in storage, this range offers the most value and capacity while taking up little space, and is the leading data storage solution in UAVs. It should be taken into consideration that while the primary purpose of external storage may be to retain multimedia files, other types of data may also be available on the device.
c) Mobile Devices and Applications Many UAVs offer the ability to fully or partially control the device or payload via a web connection or native application on a smart device. This should not be overlooked as a potential source of UAV data. When conducting digital profiling, consider which applications the subject has on their mobile device, and what the presence of a UAV-related application may offer to the investigation.
d) Remote Controllers Most drones require a specific remote controller. This remote controller may hold residual data that may assist in helping identify the drone it is paired with, as well as any phones or tablets used to view the drone‘s footage.
e) Ground Stations Control systems that have a ground link for route planning, FPV, or visual monitoring can also record their data or live footage onto a local storage device such as a computer hard drive. Access to this rich data can be obtained through the use of integrated software to view the data in its intended source or, if this is not available, through computer triage or traditional digital forensic techniques.
f) Cloud-Based Data Platforms The continual commoditisation of and increased access to cloud-based storage means that it cannot be overlooked as a potential source of UAV data. Cloud data could be intended by the user to reduce local storage demand, or a by-product of a UAV cloud-hosted platform which retains data on behalf of its customers.
g) Network Packet Data Wireless controllers often issue commands to the drone and communicate through wireless networks. This network packet data is an additional source of forensic evidence. The introduction of 5G will likely lead to an increase in drone control over cellular networks, making cellular network data a potentially invaluable evidentiary source.
Common Tools Used in Drone Forensics The market for drone forensics tools is in its infancy and a majority of commercial tools for drone forensics are part of a bigger suite of tools for mobile or computer forensics. The capability of these tools can change month to month so when selecting the right software tool to extract drone data you should always check the manufacturers supported devices list alongside what data types they extract from that supported device.
Cellebrite/MSAB XRY/Oxygen/CFID Capable of mounting and parsing data extracted from drones. Supports a limited number of drones• but this should be utilised where appropriate as this simplifies the processing of drones and the associated data. It should be considered to use at least two tools to ensure that data verification is made over the extracted data.
CsvView and DatCon [http://datfile.net/] DatCon is an open source tool capable of parsing and converting DJI .dat files into various formats• such as .kml, .csv. It also has the ability to strip out certain data into a separate log file, such as configuration

and event logs. CsvView is a similar tool, by the same developer, that can be used for parsing log data. Despite the• name, it is not limited to CSV files and can accept original .dat logs. Although both tools are similar they have different capabilities and features.

DRone Open source Parser (DROP) [https://github.com/unhcfreg/] DROP Developed by Devon Clark with the UNH Cyber Forensics Research• & Education Group. This open source tool can be used for parsing and converting flight logs from DJI Phantom 3 drones. The program also includes an incomplete breakdown of the data structure within logs, reversed engineered from DatCon.

Google Earth Pro [https://www.google.co.uk/earth/versions/#download-pro] May transmit data online. This mapping tool can be used for viewing flight data extracted from logs.• It was successfully tested with both CSV and KML files.

ST2Dash and Dashware [https://github.com/ajpierson/st2dash ; http://www.dashware.net/] May transmit data online.• ST2Dash is an open source tool designed for converting ST10+ controller and Q500 flight logs in to a• format usable by Dashware. Dashware is a free editing suite for overlaying telemetry data on to video footage. In testing it seemed impractical for forensic use as synchronising the data was time consuming and it did not provide information that was not already available. But it be useful under some circumstances.

DJI Assistant This may be used to acquire data held on a DJI drone, and will also parse recovered flight logs into• csv files.

FTK Imager This can be used to create images of SD cards for analysis. Note: a media write blocker should be• used.

VLC Player A multifunctional multimedia player that supports multiple video formats and codecs. This can be• used to view the multimedia generated by the drone being examined. Since both internal and external SD cards can be either FAT32 or exFAT, they can be easily examined• with forensic suites such as FTK and Autopsy. Useful Web Resources There are many websites that demonstrate or highlight drones and the associated forensic process. Below are some useful sites for reference that will aid you in understanding the issue and challenges in drones.

Drone Forensics [https://www.droneforensics.com/] The Drone Forensics program seeks to identify digital forensic data on consumer and professional drones to aid law enforcement and government in investigations. The program is run by VTO Inc. of Broomfield, Colorado, USA. Forensic Focus [https://www.forensicfocus.com/] This is a website that has very active forums discussing digital forensics as well as informing you of the latest developments in digital forensics. RPAS Forensic Validation Analysis Towards a Technical Investigation Process: A Case Study of Yuneec Typhoon H (https://www.mdpi.com/1424-8220/19/15/3246) Analyse drone images using the Computer Forensics Reference Datasets (CFReDS) and present results for the Typhoon H aerial vehicle manufactured by Yuneec, Inc. Furthermore, this paper explores the availability and value of digital evidence that would allow a more practical digital investigation to be able to build an evidence-based experience National Civil Aviation Agencies (https://www.icao.int/pages/links.aspx) This directory contains details of all national aviation agencies. These agencies may be useful to contact when dealing with a drone incident.

Data and information that need to be extracted from a drone/remote controller depends on the type of case.

a) Pictures and Videos

To conduct analysis on pictures and videos, the examiner first needs to have a clear idea from the requester of what to look for. Is the investigator looking for multimedia created on the device, or indication by analysing the pictures and videos for a criminal act? Reviewing the stored pictures and video will assist the examiner in understanding the nature of use of the drone, and also the areas that the drone has been operating in. Analysis of pictures typically starts with signature analysis. Next, the examiner may sift through pictures in the gallery by using the thumbnail view. For video analysis, some software offers the feature of extracting still pictures from videos. For example, Y pictures, in every X second/minute. These extracted pictures can then also be viewed in a gallery view. This allows for the much more efficient previewing of video files. In cases where location or production details of pictures and video files are important, the examiner should consider extracting the metadata of those files. Metadata are sets of data that describe and give information about other data, for example, GPS coordinates where the picture was taken, creation date and time, as well as the device used to capture the picture. If the multimedia was taken on the drone, then there will be geo tags as this would automatically be initiated by the drone unless the user has changed the configuration of the drone. Some exhibits may have thousands of photos and videos, and it is impossible for the examiner to sift through and locate one specific video or pictures file. The best way of doing this is by extracting all pictures and then passing them to the requester. Also, there may be multiple copies of the same video or photograph on the drone, as these may be used to enhance user experience by utilising thumbnails and compressed videos of the original footage. The simple task of viewing the contents of the pictures/videos does not require any digital forensic expertise and hence could be carried out by the requester. When the relevant photos/videos have been 67 identified, further analysis can be conducted by the examiner to extract more meaningful data, such as GPS coordinates and creation or modification data.

b) Flight Logs Drone flight logs are of evidential value in many cases. They typically contain the following artifacts:

- GPS position
- Time and date
- Data parameters (i.e. rotor speed, altitude, and direction)
- Drone telematics
- Diagnostic error codes
- Associated media logs Analysing drone flight log artifacts can be important for suggesting purpose or intent.

An example is the position of the drone at a certain point, which could illustrate the drone user‘s intent to enter a restricted or protected airspace. Most analysis forensic software offers flight log parsing. However, due to evolving technology where some drones are frequently being updated, some forensic software may take some time to update their database. Therefore, it is important for examiners to understand the underlying structure of flight logs. Since most drones utilise SQLite database or CSV files, the examiner may consider parsing the artifact manually by using appropriate software to display the data. This not only allows examiners to be independent of a particular software, but also allows them to crosscheck the results of the software against the flight logs.

c) Applications/Software Although there are no standard procedures for how to analyse all artefacts due to their diversity, analysis is commonly done by conducting information gathering on reliable and trusted sources on the software artifacts or application installed. The findings can then be verified by conducting a simulation or installing the application on a test device and conducting tests to understand the functionality and data collection of the application. This will also give the examiner a better understanding of the user rights of the applications and if what registration data is required to use the app.
d) User Activity The drone operating system tracks user activity at many different places. Examples include:
● Drone power on and shutdown times
● Drone settings
● Device usage
● User logins/accounts
● Wi-Fi/device connections
● Telematic Logs
Analysing this user activity helps to get a better understanding of the user‘s behavior and can even prove evidential activities. Depending on the operating system, the arte-facts are stored in various files and locations
e) Unallocated Space unallocated areas can contain arte-facts of all of the types of evidence mentioned above. Searching and extracting certain file types in unallocated areas can be automated by using carving software. The Examiner should specify what kind of files they are searching for because data carving is a very time consuming task. Data carving does not work well on fragmented files. Most of the time data found in unallocated areas cannot be an associated with a certain user, time stamps, or even a location within a folder structure.
f) Cloud and Remote Storage When an Examiner discovers traces of cloud services in a drone, it could indicate either of the following: Data is stored locally on the drone and remotely on the cloud; or
- Data is stored fully on the cloud. The drone may not contain any data at all
- In fact, the data that are stored remotely may not just be stored on a single server, but can be stored on multiple servers in the cloud.

Most of the time, even the provider of a cloud service cannot tell on which particular server, data-centre or in which country certain parts of the data are stored. Although technically it is easy to make a forensic copy of the virtual machine which resides in the cloud, there are some legal matters that need to be considered. Depending on the applicable legislation, identifying and obtaining the appropriate legal authorization for intercepting such data may pose an issue. It may also be challenging to ensure that the data have been acquired in compliance with the legal procedures in the requesting country. Another disadvantage is that there is likely to be far less recoverable data to be extracted. Indeed, if a suspect created a temporary virtual machine to commit his or her crimes and then deleted that machine, there may be no evidence at all to recover. The possibility of acquiring and analysing remotely stored data is dependent on the legislation and jurisdiction. In some jurisdictions, for example, under certain circumstances the Examiner is allowed to connect to the remote storage using the suspect's credentials from the drone in order to acquire the data. Other jurisdictions may not accept such an acquisition. In these cases, official channels can be used to request preservation and access to the data from the provider.

UNIT IV-C-MULTIMEDIA FORENSICS

4.12 INTRODUCTION

Multimedia Forensics, include a set of scientific techniques proposed for the analysis of multimedia signals (audio, videos, images) in order to recover probative evidences from them. In particular, such technologies aim to reveal the history of digital contents in terms of the following aspects:

1. Identifying the acquisition device or the original device that produced the data,
2. Validating the integrity of the contents,
3. Retrieving information from multimedia signals.

With the growing popularity of Internet and associated technologies, the Legal and Justice system is facing, increase in the number of forged or fake evidences and a large number of fabricated evidences are either in the form of audio-visuals or in the form of digital images and pictures. Hence it has become pertinent that the authenticity of digital and electronic multimedia evidences are vetted before they are adduced as evidence before a Court of law or similar institution. Multimedia Forensics, applies scientific methods for the analysis of the contents of the multimedia files. In addition to ascertaining and establishing the veracity of multimedia evidence, this branch of forensics also, exploits a number of signal enhancement procedures such as noise suppression or distortion compensation, in order to attain a higher degree of intelligibility of the data. This book, broadly covers, the following branches of Multimedia Forensics:

1. Image and Photograph Forensics
2. Audio Forensics
3. Video Forensics

4.13 IMAGE AND PHOTOGRAPH FORENSICS

Images and photographs, unlike text, represent an effective and natural communication media for humans, due to their immediacy and the easy way to understand the image content. Historically and traditionally, there has been confidence in the integrity of visual data, such that a picture printed in a newspaper is commonly accepted as a certification of the truthfulness of the news, or video surveillance recordings are proposed as probationary material in front of a court of law. However, with the advent of newer technologies, the veracity of such pictorial representations is being questioned as the available and upcoming technologies aid in creation of fake or fraudulent images or photographs. Such fake photographs or images are known as Morphed Images.

Image forensics or photograph forensics is a branch of Multimedia Forensics which aim to ascertain the genuineness of a digital image or photograph.

Methods of Image or Photograph Forensics

Images and/or Photographs can be examined in the following methods to ascertain their authenticity, both in the form of **Comparative studies and Identification studies**:

1. Visual Analysis

This is the most basic and required form of examination wherein the forensic expert undertakes an examination of the images or photograph with naked eye as well as under magnification through Stereo Microscopes.

2. Perspective Analysis

This examination is aimed at ascertaining information about the nature of images or photographs with respect to the synchronization between the different regions of the image or photograph In addition to this, perspective

3. Exif Data Analysis

Definition of: **EXIF**. **EXIF**. (EXchangeable Image Format) Descriptive **data** (meta-**data**) in an image file that include the date the photo was taken, resolution, shutter speed, focal length and other camera settings. Developed in 1995 by JEIDA for JPEG images, **EXIF data** was later added to TIFF, RAW and other formats.

Viewing **EXIF data** in Windows is easy. Just right-click on the photo in question and select ‑Properties‖. Click on the ‑Details‖ tab and scroll down—you'll see all kinds of information about the camera used, and the settings the photo was taken with.

Editing is now possible with wide range of tools, for metadata of that image from the camera model to the shooting date to copyright information and more Finally,

if **you** want to **change** the **Exif data** in tons of photographs, **you can edit** them all in **one** go using a dedicated **Exif** editors like Geosetter or Microsoft Pro Photo. If the computer is analysed with which it is edited it can be forensically identified.

In cases of generic/ public photos, it can be verified when it is seen in public domain for the first time.

4. RGB Histogram Analysis;

In an image processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. This histogram is a graph showing the number of pixels in an image at each different intensity value found in that image. For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values. Histograms can also be taken of color images --- either individual histogram of red, green and blue channels can be taken, or a 3-D histogram can be produced, with the three axes representing the red, blue and green channels, and brightness at each point representing the pixel count. The exact output from the operation depends upon the implementation, it may simply be a picture of the required histogram in a suitable image format, or it may be a data file of some sort representing the histogram statistics. Histograms have many uses. One of the more common is to decide what value of threshold to use when converting a grayscale image to a binary one by thresholding. If the image is suitable for thresholding then the histogram will be *bi-modal* --- *i.e.* the pixel intensities will be clustered around two well-separated values. A suitable threshold for separating these two groups will be found somewhere in between the two peaks in the histogram. If the distribution is not like this then it is unlikely that a good segmentation can be produced by thresholding.

5. Pixel Level Analysis

Faced with an image scanned into the computer, the first group of processes deal with pixel-level transformations.

- Thresholding is the determination of whether a particular pixel position is to be treated as white or black, given that it is actually perceived as some level of color or gray: We don't address this task in our programs, relying instead on the scanner (perhaps with its low-level software) appropriately adjusted, to come up with the (binary level) image. While such an arrangement can be fooled by inverse-color

printing, printing on top of halftone, etc., it is found that the scanners used can be adjusted satisfactorily to produce 2-level images. This decision to leave well enough alone could be re-examined

- Noise reduction. This can include a host of transformations attempting to modify or filter the shapes represented, including morphological processing and ``kFill" filters.
- Thinning/skeletonization This is a kind of higher-level morphological concept that can be applied to images which is especially useful in images that are graphs, maps, etc. Thinning for the purpose of text recognition appears less appropriate.
- Chain coding and vectorization, though run-length encoding on a row-by-row basis serves some of the same needs: it is easier to compute connectivity, and it is potentially far more compact.
- Region detection/ connected components

6. Error Level Analysis

Error Level Analysis is a forensic method to identify portions of an image with a different level of compression. The technique could be used to determine if a picture has been digitally modified. To better understand the techniques, it‘s necessary to deepen the JPEG compression technique.JPEG (Joint Photographic Experts Group) is a method of lossy compression for digital images. It‘s a data encoding algorithm that compresses data by discarding (losing) some of it. The level of compression could be chosen as a reasonable compromise between picture size and image quality. A JPEG compression scale is usually 10:1.The JPEG algorithm works on image grids, compressed independently, having a size of 8×8 pixels. The 8X8 dimension was chosen after numerous experiments with other sizes, any matrices of sizes greater than 8 X 8 are harder to be mathematically manipulated or not supported by hardware, mean while any matrices of sizes less than 8 X 8 don‘t have enough information. They result in poor quality compressed images. For images not digitally modified, all 8×8 grids should have a similar error level, resaving the picture. Each square should degrade at approximately the same rate, due to the introduction of a homogeneous amount of errors across the entire image. In a modified image, the altered grid should be at a higher error potential in respect to remaining part of the image.

The principle behind ELA

Error Level Analysis evaluates the quality level for grids squared within the images. They present an increased degree of error during successive resave operations. The phenomenon is obvious if images aren‘t optimized for a specified camera quality level. Subsequent resaves reduce the error level potential, producing a darker ELA. After a number of resaves, the grid square reaches its minimum error level.

The Image Error Level Analyzer

The Image Error Level Analyzer in an online tool that implements an ELA algorithm. By using it, it‘s possible to rapidly discover image manipulation. The web tool is based on the Python Image Library and the libjpeg library (v6.2.0-822.2). The verification process consists of successive resaves of the image at a predefined quality. The resulting picture is compared with the original one.

If an image hasn‘t been manipulated, all its parts have been saved the same number of times, images are composed by a portion of other sources, or have been simply been manipulated, will show different level of errors visible in the ELA representation with different colors.

With the ELA method, it‘s possible to discover image modification by establishing a chronological order of changes of various parts of the image. The lighter parts have been edited most recently, the most opaque have been saved several times.

The test

The first step is the generation of an ELA image. Upload an image on http://fotoforensics.com, or simply provide its URL.

Figure – ELA web tool

After pressing the ‒Process‖ button, users are redirected to a page containing the original image and the ELA. Let‘s start with the original image:

Figure – Original Image

Then modify it by introducing a stack of coins and changing the aspect of the toad:

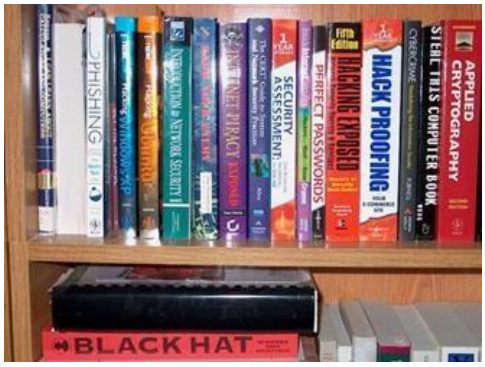
Figure – Altered image

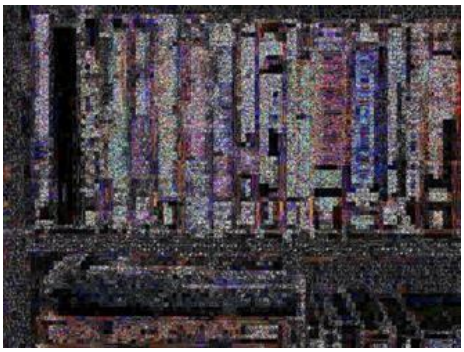
At this point, let‘s submit the picture to the online service to generate the following ELA representation.

Figure – ELA image

The sections that are black correspond to the parts that usually aren‘t manipulated. Solid white blocks usually represent the same. Solid colors present a good level of compression with minimal error levels, displayed as darker areas in the image. ELA highlights the altered portions of the image that represent higher ELA values, and a bright white color. Note that in the outline of objects in high frequency areas, they usually have higher ELA values than the rest of the image. In the following image, the text of the books stands out because the contrast creates a high frequency edge.
“In general, you should compare edges with edges and surfaces with surfaces. If all surfaces except one have similar ELA values, then the outlier should be suspect.”

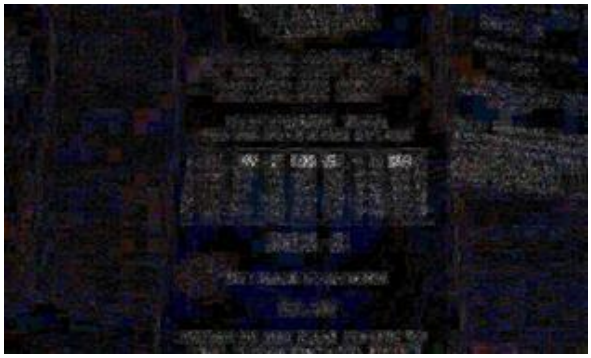
Image **ELA**





Another interesting example is provided by the Hacker Factor Blog[8] this time an allegedly winning lottery ticket is under analysis. ELA shows that the image has been modified, the digit ‒4‖ has been inserted in the ‒04‖ and ‒46‖, and both ‒23‖ values were altered.

Image **ELA**



The tool could provide false-negative results when different portions of the image have been resaved the same number of times. In this case, all the areas present same degree of error.

There are some limitations to consider when conducting an ELA analysis. The technique operates on JPEG images based on a grid, changes to a portion of a grid to affect the entire grid square. That makes it impossible to identify the pixel modified.

ELA can‘t detect single pixel modification or minor color adjustment. Scaling and recoloring the picture impacts the entire image, introducing a greater error level potential.

Another element of noise for ELA is represented by the presence of high contrast colors within the same grid, for example black and white colors, which generate high ELA values. This anomaly is attributable to the fact that JPEG uses the YUV color space representation.

Thanks to ELA analysis, it‘s possible to discover if the image was the result of a conversion from another format. For example, if a non-JPEG image contains visible grid lines (1-pixel wide in 8×8 squares), it means the picture was originally a JPEG that was later converted to a non-JPEG format.

Another interesting case in ELA literature is that in an image converted from the PNG format to JPEG, ELA analysis produces very high levels of error in edges and textures. That appears as a prevalence of dark or black coloring. A conversion from JPEG to PNG is lossless, and will retain JPEG artifacts.

The rainbowing technique

Rainbowing indicates the visible separation between the luminance and chrominance channels, as blue, purple and red. Rainbowing evaluation is possible because JPEG separates colors into luminance and chrominance channels. The *luminance* is the gray-scale intensity of the image, while the *chrominance-red* and *chrominance-blue* components identify the amount of coloring, independent of the full color‘s intensity.

Photoshop, Adobe products, and other third party software companies like FilterGrade introduce a large amount of rainbowing when they adjust images. This is vastly different from other tools such as Microsoft Paint, which do not do this. Picture modification with commercial tools such as Photoshop or Gimp can introduce distinct

rainbowing pattern surfaces that have near-uniform coloring. High-quality camera photos may also include a rainbowing effect along uniformly colored surfaces.

Beware that the presence of rainbowing may only mean that an Adobe product, like Photoshop or Light room, was used to save the image. It may not represent proof of intentional image alteration.

7. Noise Pattern Analysis

Noise is a topic in photography that seems made to cause confusion. However, it is crucial to understand it if you want to maximize image quality. In this article, we will go into detail about the two types of noise that affect your photos, shot noise and digital noise, and what you can do to minimize them. We will also explain the connection between things like your camera‘s ISO and the amount of noise in your photos. So, what is noise in photography, and what can you do to reduce it? Several years before I bought my first DSLR, I had a point-and-shoot that I really wanted to learn how to use – but I was clueless about photography. When I read online that a high ISO setting ‒adds more noise‖ to a photo, naturally, I started thinking that a camera *actually grows louder* at those settings. I tested this theory by taking two photos at different ISO values, and – I could have sworn it! – the camera‘s shutter was significantly louder at the higher ISO. For an embarrassingly long time afterwards, I went around thinking that high ISO values were fine to use, except in museums or cathedrals where silence was required. I doubt that many other people have been so hopelessly misguided about noise, but there still are several aspects of noise that even advanced photographers often misunderstand.

Technically, some amount of noise will *always* be in every photo. There is nothing you can do to prevent this; it is a physical property of light and photography. There are two broad types of noise in your photographs: **shot noise and digital noise**. Although they come from different sources, shot noise and digital noise are typically hard to distinguish from one another when you look at the final photo, since they generally lead to the same result: pixels that are randomly too bright, too dark, or discolored.

Shot Noise

Shot noise, or photon noise, is randomness due to photons in the scene you are photographing, which are discreet and random. Light emits and reflects off everything you can see, but it does not happen in a fixed pattern, and graininess is the result. For example, a very dim lightbulb may emit an average of 1000 photons per second, but each individual second will be a bit different — 986 photons, 1028 photons, 966 photons, 981 photons, 1039 photons, and so on. If you‘re taking a one-second long picture of this lightbulb, you won‘t get exactly the same result each time. This is what photographers call **“shot noise”** in an image.

Digital Noise

Digital noise, or electronic noise, is randomness caused by your camera sensor and internal electronics, which introduce imperfections to an image. Sometimes, digital will have a clearly visible pattern, although it depends upon the camera. Both shot noise and digital noise are important in digital photography. Shot noise typically has a

greater effect on your photos, but digital noise is the reason why a lens-cap photo isn‘t completely black. Each makes a difference.

Photographs with high amounts of noise, digital or shot noise, are ones where random imperfections are overwhelming. Your camera isn‘t actually any louder, but it might be angry that the real details of your photo aren‘t strong enough to drown out the noise backdrop.

It‘s not hard to use this knowledge to take better images. Just *increase the real data* you‘re capturing whenever possible (with a longer shutter speed, a larger aperture, or a more luminous scene). If you have hit the reasonable limit for those three variables, your remaining options aren‘t great. Raise your ISO to reduce digital noise (preferable), or brighten the photo via post-processing software (not as good – unless you‘re at an invariant ISO setting). Either way, it always is better to capture more light in the first place.

Digital noise and shot noise are both randomness, and the way to overwhelm randomness is with real data. If you remember that, you will be able to minimize noise in your photography and take the highest quality pictures.

8. Clone Detection

Photographs were considered to be the most powerful and trustworthy media of expression and were accepted as proves of evidences in a number of fields such as forensic investigations, investigation of insurance claims, scientific research and publications, crime detection and legal proceedings, etc. But with the availability of easy to use and cheap image editing software, photo manipulations became a common practice. Now it has become almost impossible to distinguish between a genuine camera output and a tampered version of it and as a result of this, photographs have almost lost their reliability and place as proves of evidences in all fields. This is why digital image tamper detection has emerged as an important research area to separate the tampered digital photographs from their genuine counterparts and to establish the authenticity of this popular media Images are manipulated for a number of reasons and all manipulations may not be called tampering or forging. According to Oxford dictionary, the literary meaning of –tampering" is interfering with something so as to make unauthorized alterations or damages to it. Therefore, when images are manipulated to fake a fact and mislead a viewer to misbelieve the truth behind a scene by hiding an important component of it or by adding new components to it, it is called a tampering; not the simple manipulations involving enhancements of contrast, color or brightness.

Active Vs Passive Detection Techniques

Active tampering detection techniques such as semi-fragile and robust watermarking techniques require some predefined signature or watermark to be embedded at the time of image creation whereas, the passive methods neither require any prior information about the image nor necessitate the pre-embedding of any watermark or digital signature into the image. Hence the passive techniques are more preferred over the active methods. Though a carefully performed tampering does not leave any visual clue of alteration; it is bound to alter the statistical properties of

the image and the passive tamper detection techniques try to detect digital tampering in the absence the original photograph as well as without any pre inserted watermark just by studying the statistical variations of the images.

Passive-Blind Detection Techniques again can be guided or blind depending upon whether the original copy of the image is available for comparison or not. Most of the time, it has been seen that once an image is manipulated to fake some fact, the original image is generally deleted to destroy the evidence. In situations where neither the original image is available nor the image was created with a watermark embedded to it; tamper detection and image authentication becomes a challenging problem. In such cases, passive-blind tamper detection methods can be used to detect possible tampering. In this paper we concentrate on passive-blind methods of cloning detection.

Types of Tampering

Based on whether the manipulation is performed to the visible surface of the image or to invisible planes, the manipulation techniques can be classified broadly classified into two types: **tampering and Steganography**. Again, based on whether the tampering is performed by making changes to the context of the scene elements or without the change of the context, tampering can be classified as context based and content based tampering. In the second case, the recipient is duped to believe that the objects in an image are something else from what they really are but the image itself is not altered. The context-based image tampering is generally achieved by copy-pasting scene elements of an image into itself or to other and hence called the copy-move forgery. If an image tampering is performed by copy-pasting a part of an image to itself so as to conceal some object or recreate more instances of the objects in the scene then the process is called cloning. On the other hand, if the forged image is created by copy-pasting a part of one image into another then the process is known as splicing.

Image Splicing

In image splicing, a part of an image copied and pasted onto another image without performing any post-processing smoothing operation. By Image tampering, it generally means splicing followed by the post-processing operations so as to make the manipulation imperceptible to human vision.

Techniques of Clone Detection

1. Exhaustive Search Method

Given an image, the task here is to determine if it contains duplicated regions of unknown location and shape. In an exhaustive search approach, it is required to compare every possible pairs of regions with each other to locate duplicate regions, if any. Though this is the simplest approach for
detecting clones in a digital image, the computational time is very high so as to be effective for large size images.

2. Block Matching Procedures

In this method, the test image of size (M x N) is first segmented into (M-b+1) x (N-b+1) overlapping blocks by sliding a window size (b x b) along the image from top-left corner to right and down by one pixel. Then the blocks are compared for matches. Problems associated with this method are:

i. **Compare large number of blocks:** Though, this method requires less number of steps to detect the clones in comparison to the exhaustive search still, the time complexity remains large.
ii. **Optimal Block Size:** What should be the optimal block size? The experiments to detect clone blocks in images are performed with multiple block sizes. It is clear from the experimental results that smaller the block sizes, more better the detection of duplicate regions. But if the block size becomes very small then some false matches are also obtained as in case of the false matches detected. Therefore, a good clone detection algorithm should be able to detect a duplicate region even if it is of very small size and at the same time should minimize both the number of false positives as well as computation time. It has been seen that selection of an appropriate block size can help recognizing smaller duplicate regions and by careful design of the block matching step and dimension reduction, the computational efficiency of the algorithm can be improved.
iii. **Elimination of False Positives** by Measuring Block Shift distances The false positives can be eliminated by considering image blocks that are at a constant distance, instead of looking for whole duplicated regions as all the blocks of two duplicate regions are likely to be shifted by a fixed distance. Therefore, the tampering decision can be made calculating the shift distances for all matched blocks and then seeing if there are more than a certain number of similar image blocks within the same distance

4.14 AUDIO FORENSICS

Audio forensics can be defined as the field of forensic science relating to the acquisition, analysis, and evaluation of sound recordings that may ultimately be presented as admissible evidence in a court of law or some other official venue. Audio forensic evidence may come from a criminal investigation by law enforcement or as part of an official inquiry into an accident, fraud, accusation of slander, or some other offence. The primary aspects of audio forensics are establishing the authenticity of audio evidence, performing enhancement of audio recordings to improve speech intelligibility and the audibility of low-level sounds, and interpreting and documenting sonic evidence, such as identifying talkers, transcribing dialog, and reconstructing crime or accident scenes and timelines. Modern audio forensics makes extensive use of digital signal processing, with the former use of analog filters now being obsolete. Techniques such as adaptive filtering and discrete Fourier transforms are used extensively.

ACQUISITION

The acquisition of digital audio recordings MUST be done in accordance with the acceptable protocols within the scientific community. These protocols have been established by an organization called SWGDE. The acquisition of digital audio recordings is broken up into three categories; establish/examine the chain of custody, request the original, retrieve the recordings using acceptable methods.

EXAMINE THE CHAIN OF CUSTODY:

First, examine the chain of custody. What type of equipment was used to create the evidence? How was the evidence handled from the time of its creation to the delivery to the courtroom, as well as investigators and experts? Are there authentic chain of custody documents and reports that outline the chain of custody? Sometimes a chain of custody log from law enforcement will be included, which will strengthen the

authenticity of the audio evidence. If the investigation of the chain of custody reveals inconsistencies, more often than not that recording is determined to lack authenticity and integrity.

ESTABLISH THE CHAIN OF CUSTODY:
If the expert is able to retrieve the evidence from the original source, in most cases that will automatically create and establish an authentic chain of custody, IF DONE PROPERLY. This retrieval process must be documented through video recording or images in order to provide an accurate record of what the expert did during the retrieval process. If it isn‘t possible to retrieve the recording(s), then the forensic expert must carefully go through all of the documents and reports that arrived with the evidence. But if the chain of custody cannot be established, the forensic expert must rely on other techniques as well as their own expertise to determine the authenticity of the chain of custody, such as request of the original.

REQUEST FOR THE ORIGINAL:
–As a general rule, a forensic audio laboratory should request the original recording or the earliest generation available. An original recording is the first manifestation of sound in a recoverable stored format. If the original recording is on analog media, playback and duplication rely on physical processes that introduce noise and degrade the signal, even if slightly. A copy of an analog recording can never be an exact duplicate. An original digital recording is a bit stream from which the acoustic audio signal can be generated. Exact copies of that bit stream can be made. With digital evidence, each stage of copying can be exact with no loss of quality between generations. The exactness can be tested and confirmed through the use of a hash function. Therefore, a bit stream duplicate of a recorded file is equivalent to the original

RETRIEVAL METHODS:
–Means of securing the recorded evidence must be evaluated based on their effect on the recorded signal, and the available method of transfer preserving the evidence in a condition as close to the original as possible should be chosen. Use multiple means of collection if it is not apparent which available means will produce the highest quality.‖
Appropriate retrieval methods are as follows:

- The original recorder/recording system
- A forensic image of the original storage medium
- A forensic image of the original file(s)
- A file transfer of the data from the original storage medium
- Other; analog transfer, digital signal transfer, copy, etc.

ANALYSIS
ENHANCEMENT/CLARIFICATION
One of the most common audio issues that I address during an enhancement is noise and other extraneous _unwanted‘ sounds. The noise floor is usually consistent throughout the recording and can be removed to varying degrees by using noise reduction software. The most complicated issues are the extraneous sounds that are not continuous. These sounds could include anything from a plane flying overhead to someone whistling while people talk. These sounds are difficult to pinpoint with standard tools like noise reduction and equalization, but they can be identified using a spectrogram.

A spectrogram shows both the frequency content of a recording and the level of those frequencies over time. It may be the most helpful tool to an Audio Forensic Expert because it visually presents everything that is happening throughout the audio in one window. Using this, the expert can both identify and address individual harmful noises in the recording. With the right software, these individual sounds can be selected and removed without affecting any other part of the recording. It is important to remember that there is a right and a wrong way to do this, which is why only a trained Audio Forensic Expert should be hired to complete an enhancement for use in court.

When processing audio, it can be easy to introduce artifacts to the recording. Artifacts are unwanted noise that is produced from various processing and compression techniques. Considering the goal of an audio enhancement is to eliminate extraneous noise, introducing artifacts is the exact opposite of what you want when working with a recording. Many things can introduce artifacts, but the simplest way to describe the cause is over processing. By over processing, I mean using extreme settings within individual audio tools.

When adjusting individual ranges of frequencies on the spectrogram, it is very important to be aware of artifacts. Being able to recognize artifacts and know the limitations of what processing can be done is what makes an Audio Forensic Expert necessary. When isolated portions are processed with a trained ear and the right knowledge, noise can be eliminated and voices can be brought out without introducing any artifacts.

AUTHENTICATION/INTEGRITY VERIFICATION

The authentication process determines with scientific certainty the authenticity of the events that are represented, as well as the integrity of the recording and ultimately whether or not the audio recording in question has been tampered with. In this age of digital audio, edits can be made and covered up very easily. There are free versions of audio editing software – such as Audacity – which are available online and can make edits that alter the events or conversation that originally occurred in digital audio recordings.

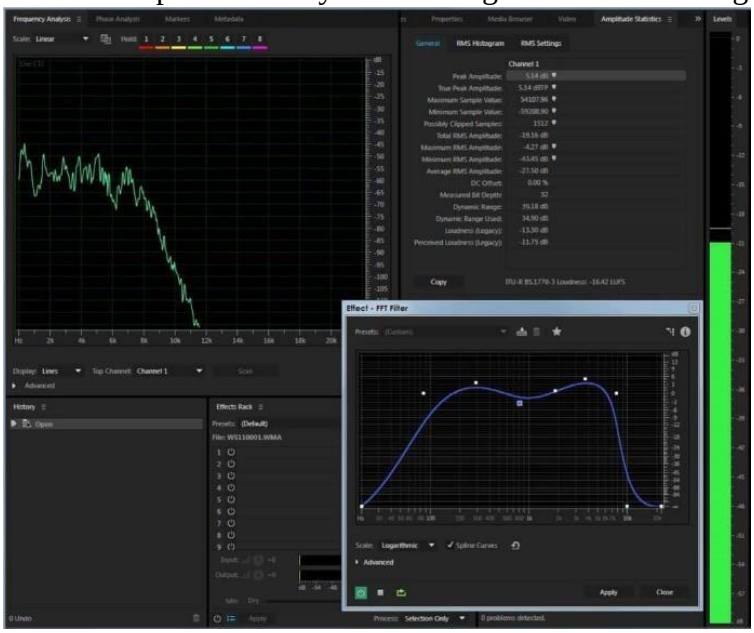
When one of the parties in a litigation believes that an audio recording was tampered with or edited, an audio forensic expert is brought in to investigate the recording. When we authenticate a audio recording, the first step is to establish chain of custody. While it is the first step, chain of custody does not, in and of itself, establish a recording as being authentic. I have witnessed audio evidence that was not authentic and was stored in a digital audio recorder. So, what does the authentication process look like?

CRITICAL LISTENING

Critical listening must be the first step to become familiar with the audio evidence. If an edit is discovered during the critical listening phase, they are usually in the form of abrupt changes. Detecting these changes is not easy and comes with experience.

It‘s important for the forensic expert to put themselves in a quiet, isolated room during critical listening so as to avoid any outside disturbances. The quiet environment enhances the critical listening focus. High quality, professional grade monitoring

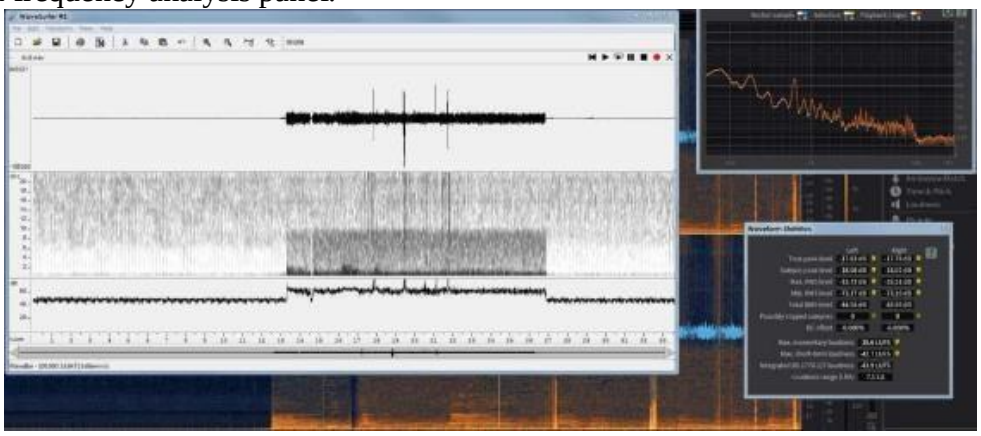
headphones and high quality studio monitors (speakers) are best for critical listening analysis of digital audio recordings. Professional quality headphones and speakers will have the flattest frequency response, which means they produce neutral and natural sound. This is very important for the forensic expert because subtle boosts and cuts in frequencies can impact the analysis of the digital audio recording.



ELECTRONIC MEASUREMENT

After critical listening, the forensic expert must use electronic measurement to examine the audio evidence. This is done by noting the prominent frequencies in the voices or other sound source and the noise floor. The levels of the recording and of the different frequencies can be measured as well. Tools such as spectrograms, frequency analysis windows and level meters are very helpful for observing and collecting this information. The expert should note the frequency range of the overall recording, the voices or conversation and the noise floor or extraneous sounds in the recording.

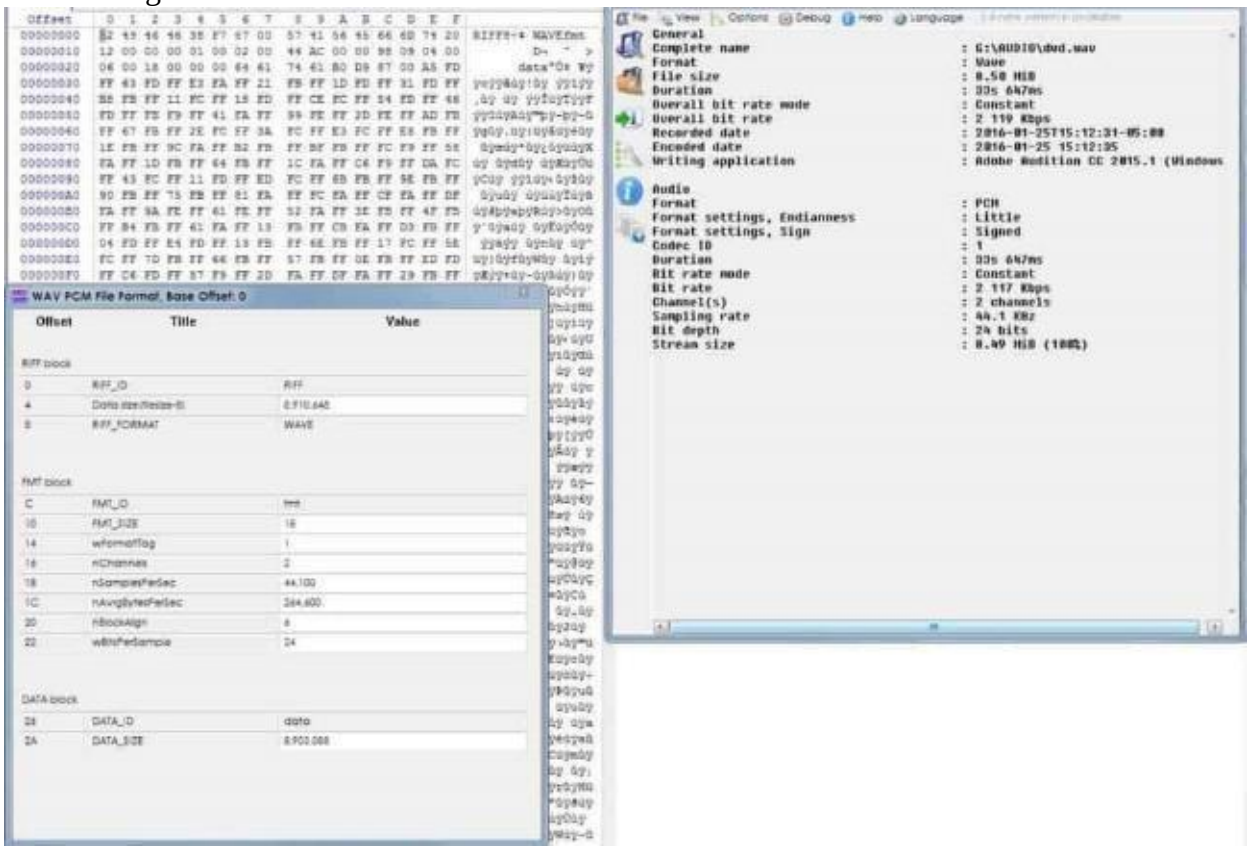
If the frequency range of a voice suddenly becomes larger or smaller or shifts in frequency range, that can be a sign of an edit. Sudden, unexplained changes in the noise floor level as well as the sudden presence of another background noise can also be a sign of an edit. As I mentioned before, I have come across recordings in which I could hear two noise floors. This can often be measured and seen in a spectrogram and a frequency analysis panel.



VISUAL INSPECTION

Visually inspecting the audio wave form and spectrogram is the next step in authenticating the audio. This goes hand in hand with the electronic measurement as the forensic expert analyzes the physical wave properties and frequency information. Waveforms are continuous and smooth when examined very closely. Even a quick, loud sound like a clap will have a smooth, continuous wave. If there are sudden breaks in the waveform of a recording, these are signs of editing. The expert should also pay close attention to the phasing of the waveform. This can also been seen when visually zooming in to the waveform. If the waveform of the recording is suddenly inverted, this can also mean an edit was made.

The spectrogram will show the full frequency spectrum with warmer or colder colors representing the strength of that frequency. The noise floor can be seen very clearly in this view, helping to identify breaks in the sound. All recordings have some noise floor, even if they are almost inaudible. When viewing the spectrogram, any breaks in the noise floor may be signs of an edit. Changes in the volume of the noise floor can also be a sign of an edit.



ANALYZING METADATA IN DIGITAL AUDIO EVIDENCE

Digital audio recordings contain metadata which reveals information about how the recording was made and the type of equipment that created the recording. If a recording was loaded into a software program capable of performing edits, there will often be a footprint left in the recording HEX information showing what software was used.

When examining the digital information, it is necessary to create an exemplar recording to compare the metadata with the original. An exemplar is a recording that

is made in conditions that are as close to the original recording as possible. The exemplar is made on the same kind of audio recorder and, if possible, the same environment. Using this exemplar, the forensic expert can compare the metadata and HEX information of the two files. If there are inconsistencies in the data, that can also be a sign of tampering.

FORENSIC SPEAKER IDENTIFICATION

Forensic speaker identification is the application of science to solve the problems related to identification of the unknown speaker in criminal investigation. A voice is much more than just a string of words. Speaker identification is less complicated and leads to a more definite opinion when the expert has to deal with the normal or ideal voice recognition. The problem arises when the cases of disguised voice samples, involving both accidental as well as attempted disguise, comes for the purpose of identification. There is another aspect that makes the achievement of this goal of speaker identification a bit difficult i.e. the case of almost similar sounding speakers, sharing the same sex, age and dialect.

Speech is the vocalization form of human communication. The principle behind Speaker Identification are as follows:

i. Speech is unique to a person as it is dependent on the physiological parameters of the person.
ii. Even the same utterance by the same person within the shortest span of time will not be exactly identical in terms of speech parameters like Speech rate, waveforms, etc.

Hence, from an expert perspective, the opinion of a voice matching or speaker identification **cannot** yield the result as **identical** and the expert would offer his/her opinion as **similar voices.**

As a corollary to the afore-mentioned Point (ii), it is a fact that the voice of a person would have variations and also there would be variations between the speech uttered by different speakers. Hence, variation in speech can be broadly classified into two categories:

i. Inter-Speaker Variation

Inter-speaker variation refers to the differences in the speech patterns of two different individuals.

ii. Intra-Speaker Variation

Intra-Speaker Variation refers to the differences in the speech patterns within the speech by the same speaker. This type of variation is commonly referred to as _Natural Variations‘.

Methods used in Speaker Identification

The following are the methods used in Forensic Speaker Identification:

1. Auditory Analysis

This method involves critical listening of the speech uttered by the speaker(s) and identifying common utterances between the disputed recording(s) and the exemplar or admitted or specimen recording(s), studying the linguistic features like nasal accents, stylish pronunciations, etc, studying articulatory features like speech rate, etc. This is a preliminary examination and is often followed by Instrumental or Spectrographic Analysis or Feature extraction methods.

2. Instrumental or Spectrographic Analysis

In this method, voice spectrograms, also known as Voiceprints, are generated and their patterns are studied. In this method, the clue words are selected from the questioned and the specimen samples on the basis of auditory analysis. These are then selected for voice spectrographic analysis. A trained examiner may be able to give an opinion about the similarity between the two samples on the basis of the following characteristics:

a. Fundamental Frequency
b. Spectrogram Patterns
c. Formants and Formant distribution patterns
d. LPC (Linear Predictive Coding) graphs
e. Pitch and Energy Contours.

3. Computerized or Feature Extraction Method

In this method the parameters of the signals are extracted by means of spectrum analyzer and recognition is made by means of computer system on the basis of stored data in respect of controlled samples of the speakers.

4.15 VIDEO FORENSICS

The camera cannot lie, but it can be an accessory to the truth/untruth"
- Harold Evans

Forensic Video Analysis is the scientific examination, comparison and/or evaluation of video in legal matters. For a video or audio recording to be used in a legal proceeding it must first be validated to ensure that the evidence is authentic and suitable for court purposes. A video forensics analyst must also determine which facts or pieces of evidence might be relevant to the case. Knowledge of evidence handling and technical expertise isn't enough. This field also requires a high level of critical thinking. There are number of jobs titles you will see in the Video Forensics field. The most common titles are *Forensic Video Analyst* & *Forensic Video Expert*.

Why is Video Forensics Important?

Have you ever heard the expression the ‑The camera cannot lie‖? Well, the reality is the way video and images are captured can have a dramatic impact on how people interpret what they see – and often leading to incorrect conclusions. This is why video forensic analysts are essential when any videos (or images) are submitted as evidence during a trial. There are a tremendous number of camera makes and models on the market today, including dedicated digital photography cameras, action cameras (ie. Go-Pro), smartphones, and of course security system cameras. File formats can vary, as well as settings for recording video, such as frames per second (fps) or video resolution. These can all factor into how and what video information is stored. A forensic video analyst must understand all of this to prevent a misinterpretation of what a video appears to show, such as colors or perhaps the speed of events unfolding in the video. In a criminal case, where a video could be very important to proving someone's innocence or guilt, these factors can be very important.

VIDEO ANALYSIS/AUTHENTICATION

Forensic video analysis and authentication is the scientific processes performed by a trained video forensic expert in order to determine events that occurred at the time of the video recording. The available digital technology enables digital videos to be edited or altered. Hence, it has become pertinent to establish the authenticity or

integrity of a video recording before it is considered as an evidence. Video authentication techniques can be broadly classified into the following categories:

a. Digital Signature or Digital Watermark Techniques

Digital videos can be watermarked or digitally signed using specialized software. In these techniques, the forensic expert should be aware of the hash digest or digital signature or the watermark that a particular class of video is supposed to have. With this knowledge, he can verify whether the recording submitted to him for analysis is the original video or is duplicate. This method is most commonly used in detecting video piracy.

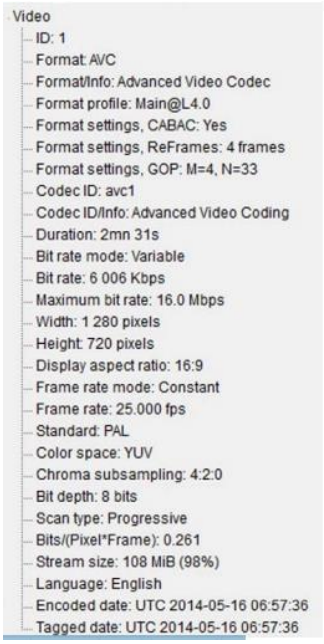
b. Visual Content Examination

Video content examination could be categorized into macroscopic and microscopic examinations. In the macroscopic examination, one video was considered as a unit, and was played by using corresponding players in the examination. Experts watched the video carefully in the visual inspection, analyzed and evaluated its continuity, rationality and consistency. Video examination consisted of the inspection both in semantic and imaging levels. In the continuity examination, one intact video usually had a progressive story and the steady intra-frame and inter-frame changes. Any abnormal interruption or discontinuity may indicate forgery. Rationality inspection mainly focused on the feasibility and possibility of video imaging and contents. Moreover, since the resolution and shooting performances of videos were largely depended on used camcorders, the image quality of questioned videos should be matched with the alleged recording devices. Any illogical event presented in questioned videos might mean artificial modification. Macroscopic examinations are also referred to as **„Visual Examination" or Visual Inspection**

In the microscopic examination, questioned videos were further disassembled into frames. The basic unit in the examination was the video frames. The general steps in the microscopic examination included frame acquisition and frame-based image forensic authentication. Some image enhancement operations could be used, such as image super-resolution, alignment of image intensity, etc. The pattern recognition methods, such as copy-move detection, could also be applied to find abnormities. Microscopic examinations are also referred to as **„Frame-by-Frame" analysis.**

c. Video Meta data examination

Video Meta data examination or examination of technical specifications of video coding involves examination of meta data like frame rate, format and encoding, frame rate mode, colour space, compression, etc. A typical video attribute data of a given video recording was shown in figure 2. Figure .



VIDEO ENHACEMENT

In some case, it may be required that the video recording(s) need to be enhanced in order to study details or elicit details that may be relevant to the case. Some of the techniques used in Video Enhancement are as follows:

Sharpening – Makes edges of images in the recording become more clear and distinct.

Video stabilization – Reduces the amount of movement in the video, producing the smoothest possible playback.

Masking – Covers the face or areas of the video that may protect a witness, victim or law enforcement officer. Sharpening – Makes edges of images in the recording become more clear and distinct.

Video stabilization – Reduces the amount of movement in the video, producing the smoothest possible playback.

Interlacing – In an analog system, interlaced scanning is used to record images (a technique of combining two television fields in order to produce a full frame of video). A process called de-interlacing may be used to retrieve the information in both fields of video.

Demultiplexing – Allows for isolation of each camera. In CCTV systems, a device called a multiplexer is used to combine multiple video signals into a single signal or separate a combined signal. These devices are frequently used in security and law enforcement applications for

In addition to the above-mentioned Digital Forensics and Multimedia Forensic, new area of forensics knowns as Biometric Forensics is emerging, however, the description of the same is outside the scope of this course.

LEARNING OUTCOME

After studying this unit you should be able to:

1. Various Cyber Crimes.
2. Digital Evidence.
3. Memory Forensics.
4. Types of Hard disks.
5. Different types of Data.

GLOSSARY

1. Cyberspace
2. Hacking
3. Defamation
4. Web
5. E-mail
6. Drone
7. Cloud
8. Retreive

SUGGESTED READINGS

1. Digital Forensics with open source tools- Cory Altheide and Harlan Carvey.
2. Guide to Computer Forensics and Investigation- Amelia Philips, Bill Nelson and Christopher Steuart.

UNIT V

LEARNING OBJECTIVES:

In this unit you will be introduced to:

1. Expert Witness and its Impact.
2. Quality Assurance and Quality System.
3. Investigative Psychology.
4. Lie-Detector.
5. Polygraph Examination and their Procedures.

UNIT V-A-Expert Testimony

5.0 INTRODUCTION

Expert testimony plays an important role in forensic science. An expert‘s scientific findings, no matter how important, have no real meaning in law until they are presented to the judge or jury. The expert evidence is covered mainly under the section 45 of the Indian Evidence Act, 1872 and section 293 of The Criminal Procedure Code, 1974.
Section 45 states that: -

Opinions of experts - When the Court has to form an opinion upon a point of foreign law, or of science, or art, or as to identity of hand writing or finger- impressions, the opinions upon that point of persons specially skilled in such foreign law, science or art, or in questions as to identity of handwriting or finger impressions, are relevant facts. Such person called experts.
The expert performs the required analysis, makes observations, collect the necessary data and draw certain conclusions based on the analysis. The presentation is usually in the form of a written report.

5.0.1 WHY EXPERT WITNESSES ARE REQUIRED

1) When required by law, in cases involving the negligence (malpractice) of a professional.
2) When required by facts, in cases concerning complex technological issues where the subject is sufficiently beyond common experience.
3) To assist the courts, where the opinion of an expert may be of some assistance to the judges and lawyers.

5.0.2 IMPACT OF EXPERT WITNESSES

1) The expert explains the logic of the mechanism involved, be it a technique, echanical or medical procedure.

2) The expert gives an authoritative opinion as to causation and fault, if any.

3) Expert witnesses not only conclude based on the facts in the case, but also help shed light on the general practices about certain issues.

5.0.3 ADMISSIBILITY OF EVIDENCE

Admission of evidence requires a foundation. Through the use of witness‘s testimony, the validity of the physical evidence can be established. The typical process involves the labeling of an item as an exhibit and foundation being laid by the expert witness through a process of verification so that the exhibit can be accepted as evidence.
Admissibility is based on a two-step analysis in which the court determines

1) Whether the proffered expert opinion reflects scientific knowledge,

2) Whether the findings are derived by the scientific method and whether the work amounts to good science (reliability), and
3) Whether the proffered expert opinion is relevant to the task at hand (relevance).

For the first step in this admissibility analysis, the Supreme Court provided a list of nonexclusive factors, which it characterized as „general observations, which a court should analyze in determining the reliability of scientific evidence:

1. Whether the scientific theory or technique on which the testimony is based are centered upon a testable hypothesis.
2. Whether the scientific theory or technique has been subjected to peer review and publication.
3. The known or potential rate of error associated with this method.
4. The existence and maintenance of standards controlling the technique‘soperation
5. General acceptance in the relevant scientific community.

5.1 EXPERT WITNESSES

The chief performer in the presentation of the expert evidence is the expert. An expert should be proficient in his field. Qualifications, education, training and experience determine the expertise of an individual.

5.1.1 QUALIFICATIONS

The judge determines whether the witness is qualified to render an opinion as an expert on the basis of knowledge, skill, training, experience or education. The judge may consider the expert‘s educational background, work experience, publications, awards, teaching or training positions, licenses or certification, prior expert witness testimony and membership of professional associations to help decide whether the person giving evidence is a qualified expert or not. The detailed nature of the training and the work done during it by the expert should be scrutinized. The length of the training is also important. Often the expert may have to educate the attorney proffering the expert regarding the significance of particular experience, achievements and certifications to ensure that they receive the appropriate emphasis. An expert must be prepared to explain board certification and licensure in detail.

5.1.2 EXPERIENCE

Quantitative experience paired with qualitative experience is necessary. This is achieved in the professional forensic science laboratories where the experts examine the cases relating to his expertise only. The experts are aware of the latest developments and contribute to the progress. Thus a high degree of specialization is achieved. The expert also needs to keep researching and publishing literature as well as continuing education and joining professional societies.

The believability and credibility of an expert witness are tested in the courtroom and in other legal proceedings. Direct examination and cross examination are a true test of an individual‘s knowledge of the materials presented. A good cross examination attempts to test and disprove the assertions that are brought out in the direct examination. The expert must prepare adequately to present the information clearly in the most persuasive manner possible as his professional expertise, thoroughness, accuracy and honesty are tested. Experts are allowed to give opinion testimony based on availability of evidence, evaluation of facts, information from texts and journals etc., used in forming their opinion.

5.2 REPORT

An expert‘s report is issued on a standard pattern. The report should be concise and intelligible to prove the conclusions arrived at, convincingly. As the reports are to be utilized by the non-technical laymen in most of the cases, in the absence of experts, under section 293 of the Code of Criminal Procedure, 1974, they are expressed in simple language. The wording of the inference should be standardized to increase clarity and obviate chances of misinterpretation. The reports should be illustrated with the experimental data, photographs, and illustrations and with sketches whenever possible and necessary. The conclusions which form the most important part of the report can either be definite or indefinite based only on the probability figures. However the inconclusive reports are probed to ascertain their probative values and are given due weight-age accordingly. Expert evidence is verifiable and leaves no room for bias.

5.3 THE COURT

The court is the ultimate authority to evaluate and utilize the expert evidence. The scrutiny of expert evidence by the court is necessary in the dissemination of justice. The scientific methods in the detection of the crime are daily improving and are becoming accurate, sensitive and specific. It should be made sure that the expert evidence produced is relevant, intelligible, properly demonstrated and explained and conforms to the standards in the specialty.

UNIT V-B-Quality Assurance

5.4 INTRODUCTION

Forensic science laboratories have a particular responsibility with regard to quality. The results of their work have far-reaching consequences and the nature of the materials that they examine makes quality control much more difficult than in most instances of application of scientific analyses.

5.4.1 DEFINITION

The quality of forensic science service is measured by its fitness for the intended purpose. The necessary elements to ensure quality make up the quality system. The quality system is the total of policies, practices and procedures which form the basis for good laboratory practice.

The laboratory puts the quality system in place through its quality manual and an internal audit program. The proof that it is implementing its quality system is shown by third-party assessment for accreditation which examines the appropriateness of the quality system and compliance with it.

Quality assurance is all activities and functions concerned with the attainment of quality in the laboratory, including method development and selection, calibration, staff, procurement, reviews and audits and sub-contracting.

Quality control is the operational techniques and activities that sustain the product or service quality to the specified requirements. In the laboratory it includes method evaluation, control of standards, materials and reagents, calibration, proficiency tests and QC samples.

5.5 THE QUALITY SYSTEM

An effective quality system is based on three components: People, Technical and Documentation.

5.5.1 PEOPLE

People‘s quality depends on job descriptions, recruitment, education, training, competency, supervision and evaluations.

Job description: The purpose of job description is to capture a definition of the job and to communicate that definition. The content of a typical job description includes:

- An understandable, meaningful title
- Responsibilities and accountabilities
- Job outcomes
- Key tasks to achieve outcomes
- Competencies required to perform the tasks successfully
- Education, training and experience standards to confirm the competencies
- Performance goals

Recruitment: The job description provides the framework within which recruitment can take place. There are two main concerns in regard to quality: whether to recruit to promoted posts from within or hire new candidates. All candidates can be measured against the elements of the job description and select the ideal one.

Education, training and competency: It deals with the ability of people to do the tasks assigned to them. Education provides a platform of theoretical and practical knowledge. Training provides continuous development of the candidate‘s knowledge at a personal level after appointment to cope up with the requirements. Competency is a measure of the overall capability of the person, arising from education, training and the on-job experience.

Supervision: Good quality requires appropriate supervision. Supervision should have two parts to it: coaching and responsibility/accountability. The coaching role works best when coupled with the responsibility/accountability role. The supervisor has to make clear what the responsibilities of the staff are and how they will be held accountable for their performance.

Evaluations: The performance of people has to be measured and used to further performance. Building performance evaluations into the laboratory quality system provides a way to meet the quality needs of the forensic science operations.

5.5.2 TECHNICAL

The technical overall aspects of a laboratory are the methods and instrumentation which contribute to quality.

Methods: Forensic science operations make substantial and sometimes conflicting demands on methods used. The requirements for method selection are mostly conservative. Methods should be either well established or thoroughly validated. One of the problems of general acceptability is that the method may be outdated and better methods available. Validation can be defined as a process by which a procedure is evaluated to determine its efficacy and reliability for forensic casework analysis including: Developmental validation, which is the acquisition of test data and determination of conditions and limitations of a new or novel methodology for use on forensic samples; and Internal validation which is the accumulation of test data within the laboratory to demonstrate that established methods and procedures perform as expected in the laboratory. The normal approaches of analytical chemistry can be used. Accuracy, precision and recovery studies, evaluated by standard statistical techniques are important characteristics. A range of substrates/matrices should be tested and aging and environmental effects must be studied.

Instruments: The nature of the use to which results are put, together with the nature of samples tested and the need to be able to select an approach best suited to the overall case conditions, means that instrument calibration and maintenance must be of the highest order. An inventory of all equipment is maintained which is linked to a calibration and maintenance program, whose performance can affect analytical accuracy. Accuracy and linearity of a range of standard masses is to be checked periodically. Annual routine preventative maintenance by the manufacturer with complete recalibration and certification is also performed.

5.5.3 DOCUMENTATION

A quality system cannot exist without proper documentation. The best way to write the quality manual is to begin by recording what the laboratory actually does. The language is kept simple and at a high level. It is important to avoid wholesale adoption of another laboratory‘s manuals. The policies and procedures of the laboratory are

noted and to make sure they are being followed is through the use of proformas which record all vital steps. The policies or procedures are improved and updated while beingexperimented.

5.6 THE QUALITY MANUAL

The quality manual covers policy, procedures and practices for quality assurance and quality control. The quality manual must address the following:

- A quality policy statement including objectives and commitments by management.
- The organization and management structure of the laboratory, its place in any parent organisation, relevant organizational charts.
- The relationships and responsibilities of management, technical operations and support services in implementing the quality system.
- Job descriptions, education and up-to-date training records and procedure manuals.
- The laboratory‘s procedures for ensuring that measurements are traceable to appropriate standards, where available.
- The type and extent of examinations conducted by the laboratory.
- Validation and verification of test procedures used.
- Handling evidence items.
- An inventory of equipment, the performance of which affects the quality of the laboratory product.
- Reference measurement standards used.
- Calibration and maintenance of equipment.
- Physical environment control (such as access, temperature, lighting).
- Verification practices for ensuring continuing competence of examiners, including inter-laboratory comparisons, proficiency testing programs and internal quality control schemes (e.g. technical peer review).
- Gaining feedback and taking corrective action whenever analytical discrepancies are detected.
- Monitoring court testimony to ensure the reporting of scientific findings in an unbiased and effective manner.
- Laboratory protocol permitting departures from documented policies and procedures.
- Dealing with complaints.
- Disclosure of information and confidentiality.
- Audits, reviews and updates to the quality system.
- Health and safety.
- Accreditations and policy on subcontracting.

The quality manual is completed by the laboratory methods manual. The methods must show the requirements for sampling, equipment, reagents, safety, controls and

standards, possible sources of error and a step-by-step description of the procedures. Each policy or procedure must declare the title, date of issue, authorization, version number or other identification of prevalence of the policy or procedure. The quality manual is therefore a living document which gives realistic, authoritative, up-to-date appropriate guidance.

5.7 INTERNAL AUDIT PROGRAM

The internal audit program has two goals:

- To demonstrate compliance with the quality system;
- To provide a basis for improvement of the quality system.

An audit is defined as a planned and documented activity performed to determine by investigation, examination or evaluation of objective evidence, the adequacy of and compliance with established procedures, and the effectiveness of implementation.

The usual form is the vertical audit, in which all activities in a section are audited at the same time. A less common alternative is the horizontal audit, in which all instances of a specific activity are audited throughout the laboratory at the same time. The conduct of an audit is the same whether it is a compliance or quality improvement audit, and whether it is a vertical or horizontal audit.

Planning the audit requires attention to:

- Dates when the audit will take place, advising team members and those being audited;
- Team members should be independent of the area being audited and have had training in auditing;
- Scope what is being looked at;
- Documents what documentation is needed (policies, procedures, records).

Conducting the audit requires that the auditors obtain objective information about compliance with the quality system. This is achieved by:

- Questioning staff
- Observing methods and procedures
- Examining facilities, documents, records
- Reviewing the information Corrective actions

If the audit produces objective evidence of non conformance, the laboratory must deal with these through a corrective action program. A non conformance should always be described in words of the quality system standard or procedure. Non conformances should be recorded as corrective action reports (CARs). The CAR should describe the non conformance and initiate a sequence designed to produce an effective rectification, thus:

- Request for rectification by audit team leader.
- Responsibility for rectification assigned by management.
- Root cause investigated by problem-solving team involving front-line staff.

- Corrective action required identified by team and reviewed by management.

- Verification of effectiveness of corrective action assessed by follow up audit.

5.8 ACCREDITATION

Accreditation in the crime laboratory

The objective proof that the laboratory has an adequate quality system and is following it is achieved through accreditation, which is defined as the formal assessment and recognition by an impartial competent and authority that a laboratory is capable of meeting and maintaining defined standards of performance, competence and professionalism. The strength of accreditation lies in the involvement of the third party competent authority to assess the performance of the laboratory.

A technical committee appointed by Chairman, National Accreditation board for Testing and Calibration Laboratories (NABL), developed NABL Specific guideline document on accreditation of Forensic Laboratories in June 1998.

Aims and objectives of NABL are:

1. To promote, coordinate, guide, implement and maintain accreditation system for laboratories suitable for the country in accordance with the relevant national and international standards and guides.

2. To ensure that all measurements either during calibration or testing by accredited laboratories are traceable to appropriate national or international standards maintained at National Physical Laboratory (NPL) and at Bhabha Atomic Research Centre (BARC) through an unbroken chain of comparisons.

3. To encourage proficiency tests or inter-laboratory comparisons in order to ensure accuracy, reliability and reproducibility of test results.

4. To ensure that the accredited laboratories adhere to all the conditions of accreditation, by periodic surveillance.

5. To organise Awareness programmes on all aspects of laboratory accreditation for the laboratories by various means including seminars, workshops and laboratory-industry-accreditation body meets etc.

NABL is a signatory to ILAC (International Laboratory Accreditation Conference) Arrangements as well as APLAC (Asia Pacific Laboratory Accreditation Cooperation) Mutual Recognition Arrangements (MRA). Such international arrangements facilitate acceptance of test / calibration results between countries to which MRA partners represent.

NABL has established its Accreditation System in accordance with ISO/IEC 17011:2004, which is followed internationally. NABL also complies with the requirement of APLAC MR001 for the fulfillment of APLAC MRA and ILAC Arrangements.

Laboratories can be checked and certified for their compliance to international management system standards such as ISO 9000. This involves the auditing of an organization‘s quality management system. Proper technical evaluation requires the use of technical experts who can assess the laboratory against internationally accepted criteria. These criteria are embraced globally in a document called ISO/IEC 17025.

Accreditation bodies may also apply additional technical requirements for evaluating a laboratory, as per requirements of different technical fields.

Laboratory accreditation against the standard ISO/IEC 17025 does, however also covers the quality management elements of ISO 9000. So laboratory accreditation, which is based on ISO/IEC 17025 is a measure of both technical competence and quality management and is the most appropriate process.

BENEFITS OF ACCREDITATION

- Better control of laboratory operations and feed back to laboratories as to whether they have sound Quality Assurance System and are technically competent.
- Increase of confidence in testing/calibration data and personnel performing work.
- Customers can search and identify the laboratories accredited by NABL for their specific requirements from the Directory of Accredited Laboratories.
- Users of accredited laboratories will enjoy greater access for their products, in both domestic and international markets, when tested by accreditedlaboratories.

UNIT V-C-Forensic Psychology

5.9 INTRODUCTION

Most criminal investigators today regard the concept of modus operandi as too simplistic to be of much practical use. But far from obsolete is the idea that offenders motivated by certain emotional drives, offenders shaped by certain elements in their current life and in their background, leave a recognizable signature on the crimes they commit. In contemporary criminal investigation, the modus operandi concept appears as the much more sophisticated and refined process of criminal profiling, which we‘ll discuss in this chapter.

5.10 PSYCHOLOGY GETS A NEW BRANCH

In a German courtroom in 1896, physician Albert von Schrenk-Notzing testified in the sensational case of a man accused murdering three women. Citing research into memory and suggestibility, Schrenk-Notzing argued that pre-trial publicity had made it impossible for witnesses to distinguish between what they actually saw and what they read in newspapers. This instance of expert psychological testimony is generally considered the birth of *forensic psychology* – the application of psychological principles and knowledge in the legal sphere.

Today, forensic psychologists (generally persons holding a doctorate in clinical psychology who have devoted special study to forensic psychology) and forensic psychiatrists (medical doctors specializing in psychiatry who have focused on forensic matters) study and testify about matters of criminality, criminal responsibility, a defendant‘s competency to stand trial, sentencing, and assessment of future risk (is a convicted person likely to offend again?).

Some forensic psychologists and psychiatrists help to process crime scenes from a psychological point of view in an effort to determine what the nature of the crime indicates about the personality – and likely identity – of the perpetrator. Such forensic psychologists attempt to define and classify the range of criminal behavior and are often referred to as criminal profilers.

Today, criminal profiling is the most widely familiar specialty in forensic psychology; however, most of today's profilers are not psychologists by profession, but specially trained criminal investigators with knowledge of certain principles of psychology and, when necessary, a willingness to consult with forensic psychologists and forensic psychiatrists.

5.11 CRIMINAL PROFILING: FACTS VS. FICTION

Let‘s get the inevitable pun out of the way fast: these days, *criminal profiling* is a high profile investigative technique. The public is fascinated by it and sees TV new magazine stories about it, watches movies about it (such as the 1999 Denzel Washington vehicle, *The Bone Collector;* or Morgan Freeman in *Kiss the Girls, 1997;* and *Along Came a Spider, 2001)* and TV cop shows built around it (aired from 1996 to 2000, *Profiler,* for example, was about a sexy forensic psychiatrist, haunted by the murder of her husband, but possessing an uncanny knack for nailing „the criminal mind‰). Even more recently, the CBS television series *Criminal Minds* focuses on the FBIÊs Behavioral Analysis Unit.

Definition

Criminal profiling uses crime scene evidence and other (mainly psychological) data to indicate the type of person likely to have committed a crime under investigation.

5.11.1 WELCOME TO HOLLYWOOD

As portrayed in popular fiction, film, and TV, detectives are cops who operate on (invariably brilliant) hunches, while profiles are detectives whose hunches are raised to the *n*th degree by a combination of nerdy scientific savvy and paranormal psychic ability. They arrive at a crime scene, slip on the latex gloves, pick up a few pieces of evidence, stand back and survey the scene, frown, grimace, then raise their eyebrows and declare, The doer is a white guy, early twenties, brown hair, brown eyes, and a fan of Seinfeld reruns. Let‘s go get him! (See Chapter 20 for more on psychic detectives.). And if it‘s never quite this simple on the more sophisticated shows, well, the loose ends are nevertheless almost always tied up before the last commercial break.

5.11.2 A DOSE OF REALITY

In reality, however, profiling is first and foremost painstaking detective work, which begins with a by-the-book analysis of physical evidence at individual crime scenes in the light of certain principles of psychology. By inductive reasoning – that is, reasoning that uses specific physical facts to build generalizations – the criminal profiler begins to identify the tendencies and typologies that characterize various classes of offender.

It is only after carefully analyzing many crime scenes that the criminal profiler can, with some confidence, attempt to reconstruct the behavior of a perpetrator at a particular crime scene and, from this reconstruction, draw inferences about his motivation.

No reputable criminal profiler believes in the old-time definition of MO, that a certain type of criminal behavior is always and inevitably the result of the same motivation. On the contrary, it is assumed that a given behavior may have resulted from any number of motives. Say an investigator finds a body with its eyes covered by a cloth. Does this reveal a significant psychological kink in the offender? Or does it mean that the offender know the victim and didn‘t want to be recognized?

Usually, the most that can be expected from real-life criminal profiling is a narrowing of the range of suspects. Although this is no investigative silver bullet, it is a valuable tool, because it allows police agencies to focus their limited resources more efficiently. If the perpetrator is likely to possess characteristics A, B, and C, detectives don‘t have to hunt for suspects who partake of the rest of the alphabet.

Sworn Statement:

The criminal profiler should have (some) understanding of psychology: The study of individual behavior; sociology: the study of group behavior, groups being comprised of individuals; criminalistics: a general term for the scientific study of recognition, collection and preservation of physical evidence as it is related to the law; forensic pathology: a branch of medicine that applies the principles and knowledge of the medical sciences to problems in the field of law: Anyone without specific training from qualified experts, or experience in at least the above fields is not, in my opinion, capable of the complex processes involved in rendering a criminal profile.
- Brent E. Turvey, M.S., in „What Is Criminal Profiling?

5.12 A SHORT HISTORY OF CRIMINAL PROFILING

Ask most law enforcement professionals who invented criminal profiling, and the credit will probably be given to the Behavioral Sciences Unit (BSU) of the Federal Bureau of Investigation, based at the FBI Academy in Quantico, Virginia. While it is true that a number of FBI special agents, including Roy Hazelwood and Robert Ressler, among others, have pioneered contemporary profiling, the idea of creating criminal profiles was born long before the FBI even came into existence.

Sworn Statement:

In each case the mutilation was inflicted by a person who had no scientific nor anatomical knowledge. In my opinion he does not even possess the technical knowledge of a butcher or horse slaughterer or any person accustomed to cut up dead animals.
- London Metropolitan Police surgeon Dr. Thomas Bond, in reference to the work of Jack the Ripper.

5.12.1 LOOKING FOR THE RIPPER

The most famous early historical example of profiling is the work of London Metropolitan Police surgeon Dr. Thomas Bond, who in 1888 performed the autopsy of Mary Kelly, the last victim of Jack the Ripper. Bond‘s autopsy led to the conclusion that, contrary to what many believed, the Ripper had no knowledge of surgical technique. But Bond went beyond this to reconstruct certain aspects of the crime and, based on wound patterns and the use of a sheet to cover the victim‘s face, he advised police to seek a quiet and inoffensive-looking man, neatly dressed, and in his middle age.

Based on his examination of all of the Ripper‘s victims, Bond concluded that the crimes were the work of the same perpetrator, a man of „great coolness and daring.

This 1888 cartoon from the British humor magazine Punch *is titled Blind Man’s Buff and depicts what the public perceived as the utter confusion of the police in their failed pursuit of Fack the Ripper.*

While Bond‘s analysis was though-provoking, it did not assist police in tracking the Ripper. He was never brought to justice.

5.12.2 A PROFILE OF DER FUHRER

Something very like modern profiling was employed in the study of another infamous murderer, Adolf Hitler. During World War II, the precursor agency to the CIA, the Office of Strategic Services (OSS), called on psychiatrist Walter Langer to profile Hitler in an attempt to gain a strategic edge against German forces. If Hitler is running the show, OSS officials asked Langer, what kind of person is he?

What are his ambitions? We want to know about his psychological make-up the things that make him tick. In addition, we ought to know what he might do if things begin to go against him.

Langer made a number of fascinating speculations, the most intriguing of which involved predicting what would happen to Hitler in the end. Langer believed that Hitler was too healthy to die of natural causes (recently discovered evidence suggests that he actually suffered from Parkinson‘s disease and other ailments). While he did not rule out the possibility of assassination, he did conclude that Hitler, in defeat, would never seek refuge in another country, because the dictator was convinced that he was the savior of Germany. Langer predicted that Hitler would commit suicide if defeat seemed inevitable. This, of course, is precisely what Der Fuhrer did.

5.12.3 MAD BOMBER OF NEW YORK

On November 16, 1940, someone walked unseen into the 64th Street offices of Consolidated Edison, New York City‘s electric power generating company, dropped his toolbox, and walked out again. Workers opened the toolbox and discovered an unexploded pipe bomb with a note wrapped around it: Con Edison crooks, this is for you. The NYPD Bomb Squad was summoned but, finding no fingerprints or other evidence, let the matter lie.

One year later, an unexploded alarm clock bomb was found in a gutter just outside another Con Ed building, this one on 14th Street. Three months after this, the police received a letter: „I will made no more bomb units for the duration of the War – My patriotic feelings have made me decide this – Later I will bring the Con Edison to justice

– they must pay for their dastardly deeds.

True to his word, the perpetrator the press dubbed the Mad Bomber planted no more bombs during World War II, but he did continue to send letters (each signed F.P., for Fair Play) to various individuals, newspapers, movie theaters, Con Edison, and the police. Then, on March 29, 1950, a bomb was discovered in Grand Central Station. During the next half-dozen years, 30 more were found, in phone booths, in the public library, in subway stations, and in movie theaters (here the Mad Bomber would slit a seat, tuck in a bomb, then disappear through a fire exit). Up to this point, none of the Mad

Bomber‘s devices had actually exploded, but on December 2, 1956, the detonation of one in a Brooklyn movie house injured six people, three critically. At last the police were driven to take unconventional action. They called on Dr. James Brussel, a Manhattan forensic psychiatrist.

Brussel intensively reviewed the massive 16-years case file on the made Bomber, including his many letters. After some deliberation, Brussel delivered a remarkably detained and specific criminal profile: the Mad Bomber was a middle-age man, heavyset but meticulous in grooming, self-educated, and of Slavic, Roman Catholic background. Brussel believed that he was single and living with a brother or sister in Connecticut. He suffered from an *Oedipus complex*. Brussel also concluded that the bomber had worked for Consolidated Edison or one of its subsidiaries.

Dr. Brussel had some pointed recommendations for the detectives. He told them not to keep the profile confidential, but to publicize it widely so that the bomber, antagonized, would be lured out of cover. In addition, he urged them to search Con Ed

files pertaining to former employees. Just as the detectives were leaving with their marching orders, Brussel added: One more thing. When you catch him, and I have no doubt you will, he'll be wearing a double-breasted suit. And it will be buttoned.

Definition

In psychoanalytic theory, an **Oedipus complex** is the unconscious sexual desire in a child, especially a boy, for the parent of the opposite sex. Unresolved, the Oedipus complex may result in an adult

The police reluctantly followed Brussel's recommendation about publicizing the profile and, as the doctor had predicted, the stories to irked the Mad Bomber that he revealed himself by sending to a newspaper a detailed account of his motive: an accident he had suffered while working for Con Ed and what he alleged was the company's plot to cheat him out of workmen's compensation.

The police consulted Con Ed files and arrested George Metesky, a heavyset bachelor living in Waterbury, Connecticut. At the time of his arrest, he was wearing a double- breasted suit. It was buttoned. Committed to an asylum, Metesky was released in 1974 and returned to Waterbury, where he lived quietly until his death, at age 90, in 1994.

5.12.4 BOSTON STRANGLER

In Boston, on June 14, 1962, the body of Anna Slesers, age 55, was discovered by her son. She had been strangled with her own belt. Before the end of June, three other Boston women – ages 85, 68, and 65 – were discovered strangled to death.

The press began referring to the unknown assailant as the Boston Strangler, and police called in a team of forensic psychiatrists to create a profile of the killer. The psychiatrists concluded, among other things, that the murders was acting out a hatred of his mother, and his next two murders, during August 1962, both of elderly women (75 and 67), seed to bear this out. But on December 5, 20-year-old Sohie Clark was found strangled and, on the 31st, the body of Patricia Bissette, 23, was found.

Stymied, police again called on Dr. Brussel. Whereas the earlier profilers had concluded that the serial killer was between 18 and 40 and suffered from delusions of persecution and a hatred of his mother, Brussel believed that the murderer was about 30, of strong build and average height, clean shaven, with thick dark hair. He was, Brussel thought, of Spanish or Italian heritage and a paranoid schizophrenic.

Despite possessing this profile, the police turned up nothing as five more women, ranging in age from 19 to 69, were found strangled in Boston. The break in the case came not from the profile, but from the perpetrator himself.

On October 27, 1964, posing as a detective, Albert DeSalvo entered a young woman's home. He bound her and began to assault her sexually. Then, as suddenly as he had attacked her, he stopped, said I am sorry, and left. The woman subsequently described him to police, and he was soon identified by other rape victims. He was apprehended for the rapes, but he was not suspected of being the Boston Strangler

until he voluntarily confessed. The police were impressed not only by the detailed nature of his confession, but by how well he fit Brussel‘s profile.

Because there was no evidence to corroborate his confession, DeSalvo was never tried for the strangling, but he was tried for robbery and rape and sent to prison for life in 1967. Six years later, he was murdered in his cell by a fellow inmate.

Although he fit the forensic psychiatrist‘s profile to a tee, nobody personally acquainted with DeSalvo ever believed he was the Boston Strangler – not his wife, his former employers, his lawyer, his prison psychiatrist, and not even police officers who knew him as a small-time burglar. Furthermore, no physical evidence connected him to any of the murders, and there were no eyewitnesses to place him anywhere near any of the crime scenes.

Some experts now believe that the murders were perpetrated by more than one person. But why would DeSalvo have confessed to horrendous crimes he didn‘t commit? Some point out that he believed the rape convictions would send him to prison for life in any event. By confessing to the sensational Boston Strangler crimes, he could sell his story to support his family financially. Besides, the high-profile strangling were a „step up‰ for a petty criminal.

5.13 FBI CRIME SCENE ANALYSIS

In the 1960s, Howard Teten, an investigator with the San Leandro (California) Police department, worked with the School of Criminology of the University of California to develop a systematic approach to profiling. In 1970, after Teten became an FBI special agent, he initiated what would become the bureau‘s famous profiling program, working in conjunction with Pat Mullany, a specialist in abnormal psychology. The FBI‘s profiling methods were further refined in the late 1970s by John Douglas and Robert Ressler, who introduced the organized/disorganized method, still a cornerstone of the FBI profiling procedure.

FBI Crime Scene Analysis begins by distinguishing between an organized and disorganizedcrime scene. Organized offender characteristics include:

- Average to above average intelligence
- Adequate level of social competence
- Prefers skilled work
- Sexually competent
- High birth-order status
- Father had/has stable work
- Childhood discipline inconsistent
- Mood was controlled during the crime
- Used alcohol in connection with the crime
- Situational stress precipitated crime
- Lives with partner
- Is mobile; owns a car in good condition
- Follows crime in the news media
- May change jobs or leave town after the crime

Disorganized offender characteristics include:

- Below average intelligence
- Socially inadequate
- Works at unskilled labor
- Sexually incompetent
- Low birth-order status
- Father has/had unstable work
- Received harsh discipline as a child
- Mood was anxious during the crime
- Minimal use of alcohol in connection with the crime
- Situational stress played little role in precipitating the crime
- Lives alone
- Lives or works near the crime scene
- Not interested in following the crime in the news media
- Significant behavior change follows the crime; may resort to drug or alcohol use

Between 1979 and 1983, agents from the FBIÊs Behavioral Sciences Unit interviewed incarcerated offenders about their backgrounds, crimes, crime scene, and their victims. They supplemented the interviews with reviews of court transcripts, police reports, and psychiatric and criminal records. Using this data, they developed a six-step „Crime Scene Analysis procedure for building a suspect profile:

1. Inputs. The first step is collecting and assessing materials relating to the case under investigation, including crime scene and victim photographs, a thorough background check of the victim, autopsy reports, and other forensic data.
2. Models. The modeling phase requires arranging the data gathered in the input stage into a logical, coherent pattern for analysis.
3. Assessment. Using the sorted and arranged data, the profiler attempts to reconstruct the sequence of events and the behaviors of the perpetrator as well as the victim. The object is to determine the role each played in the crime.
4. Profile. Based on the reconstruction of the crime, a list of background, physical, and behavioral characteristics is prepared. This is the profile of the perpetrator. The profiler tries to advise police officials on how to identify, apprehend, and then interview the suspect.
5. Investigation. In this stage, the profile is fully integrated into the investigation of the crime. If the profile fails to turn up suspects – or if new evidence comes to light – it is reevaluated and, possibly, modified.
6. Apprehension. Any suspects who are apprehended are cross-checked against the profile to assess how closely the suspect‘s characteristics correspond with it.

5.14 INVESTIGATIVE PSYCHOLOGY: THE CANTER APPROACH

David Canter is a British psychologist long associated with the University of Surrey, where, under the auspices of Scotland Yard, he developed a leading method of psychological profiling designed especially to identify serial rapists and murders.

Canter is best known for his work in nailing John Duffy, England‘s railway rapist, during the 1980s. By identifying certain features of Duffy‘s crimes – location, timing, method – Canter established that the offender had a troubled, childless marriage, that he was interested in martial arts, and that he was employed as a semiskilled laborer. Using this and other information, police were able to pick Duffy out of a field of 1,999 suspects .

Definition

> The five-factor model is the basis of the criminal profiling method developed by David Canter. It evaluates evidence of interpersonal coherence, the significance of the time and place of the crime, criminal characteristics, criminal career, and the offenderís forensic

Canter‘s method is based on what he calls the *five-factor model*, analysis of five key aspects of the interaction between the victim and the offender: interpersonal coherence, significance of time and place, criminal characteristics, criminal career, and forensic awareness. Let‘s take a closer look at each.

Interpersonal Coherence

Canter believes that features of an offender‘s criminal activity relate to features of his activity in non-criminal situations. For example, the most infamous serial killer of the 1970s, Ted Bundy, apparently selected victims who somehow resembled a former girlfriend. Canter makes the assumption that offenders deal with their victims in ways that are similar to how they deal with people in their everyday lives.

Significance of Time and Place

Because the offender chooses the time and place of the crime, this information may reveal information about the perpetrator‘s mobility and where he lives or works. The choice of time and place may also suggest how the offender views his surroundings and may say something about the offender‘s usual schedule: when he is (legitimately) at work, for example.

Criminal Characteristics

This is a catchall category in which the investigator may list characteristics that seem significant and compare these to the evidence found at the crime scene. The FBI‘s organized/disorganized categories are examples of criminal characteristics that might be considered.

Criminal Career

Based on the crime scene evidence, does it seem likely or unlikely that the offender has committed other crimes? Is he a career criminal? A serial offender?

Forensic Awareness

This is strongly related to the „criminal career‰ category. The investigator looks for signs of the perpetrator‘s awareness of police techniques relating to the collection of evidence. Such awareness strongly suggests a serial offender as opposed to someone who committed an isolated or random crime on impulse or because of opportunity.

Behavioral Evidence Analysis: The Turvey Approach

Brent E. Turvey is a California-based private criminal profiler who has extensively interviewed convicted sex offenders and serial killers in an effort to understand characteristics common among them. He developed Behavioral Evidence Analysis (BEA), a four-step profiling method. It begins with a new concept called equivocal forensic analysis, the assumption that any given piece of evidence may suggest more than one interpretation, then narrows this down and proceeds through analysis of victimology, crime scene characteristics, and offender characteristics.

Equivocal Forensic Analysis

Turvey assumes that physical evidence found at a crime scene is typically equivocal in nature; that is, any given piece of evidence may suggest more than one interpretation. Therefore, the first step in analysis is to list the possible interpretations and assess the most likely one.

Victimology

After thoroughly evaluating evidence related to the crime scene, Turvey turns next to the victim, profiling him or her in much the same way and with the same thoroughness as the perpetrator is profiled. Assessing how, where, when, and why a victim was chosen suggests a wealth of information about the offender. For instance, the physical build of the victim implies much about the physique and strength of the offender and whether or not he worked alone or with others. The presence or absence of signs of struggle may suggest whether or not the victim and offender were acquainted with one another.

Offender Characteristics

Using data and conclusions derived from the first three steps, the investigator now attempts to create a picture of the characteristics of the offender. The features that make up this picture typically include the following:

- Physical build and other characteristics
- Gender
- Presence and type of vehicle used
- Offender‘s residence or workplace in relation to the crime scene
- Level of skill
- Criminal history, repeat or serial offender

- Aggressiveness
- Medical history
- Marital status
- Race or ethnic origin

Profiling Scorecard

Because criminal profiling is almost always just one element in any criminal investigation, it is difficult to assess how effective or ineffective it is in bringing about an arrest. Moreover, the quality of the profiling depends on the quality of the crime scene and crime scene investigation. The skill, knowledge, experience – and, yes, luck – of investigators also vary widely.

Case in point

The FBI musters a few agents who specialize in criminal profiling. A number of private investigators market themselves as criminal profilers and are hired on a case-by-case basis by local police departments. In large urban departments, some detectives receive training as

Nevertheless, research conducted in the early 1990s strongly suggests that trained profilers provide more useful and more valid criminal profiles than general clinical psychologists or even detectives do. While it is clear that criminal profiling does not magically deliver the offender into police custody, profiling often significantly improves the odds of making an arrest and doing so with less time and less wasted effort than would be the case without the profiling information, especially when the perpetrator is a repeat or serial offender.

The Least You Need to Know

- Criminal profiling employs meticulous analysis of crime scenes in order to reconstruct offender and victim behavior and draw conclusions about the characteristics and identity of the perpetrator.
- Although the FBI Behavioral Sciences Unit brought profiling to a high level of sophistication in the 1970s, the technique was used at least as early as 1888 in the case of Jack the Ripper.
- Alternatives to „FBI Crime Scene Analysis include the Canter method of investigative psychology and Brent Turvey‘s Behavioral Evidence Analysis approach.
- Criminal investigation involves too many variables to permit an unambiguous assessment of the effectiveness of profiling, but most experts believe that, especially in serial cases, criminal profiling is a significant aid to investigation.

5.15 POLYGRAPH/LIE-DETECTOR

5.15.1 INTRODUCTION

The science of lie detection / truth verification has its roots in two sciences i.e. psychology & physiology. The technique of the detection of deception/truth verification is based on the principle of psychosomatic interaction within an individual i.e. psychologically a change in the person's consciously held feeling produces a defense reaction in the form of physiological change in blood pressure, pulse rate, respiration and electro-dermal responses. The physiological functions (i.e. respiration, blood pressure, pulse rate and galvanic skin response) which are taken into consideration for the polygraph examination are not under the voluntary control of the individual but are being controlled by the Autonomic Nervous System. The fear of detection and entrapment induces the physiological reactions when an individual consciously attempts to deceive in order to protect his well being.

The equipment which is used for the purpose of truth verification / lie-detection is the polygraph means many writings simultaneously. As the name indicates the equipment can simultaneously record more than one physiological response and the changes therein. Detection of deception/truth verification technique with the help of polygraph since its development is being extensively used in criminal investigation in America, Japan, Israel, Canada and several other countries. In India the technology was introduced in year 1972- 73 at Central Forensic Science Laboratory, CBI, New Delhi. Other Central and State Forensic Science Laboratories followed suit subsequently. Since the technique is popularly known as lie-detection technique, this terminology shall be used through out the text but it is a technique of truth verification as well.

5.15.2 SCOPE & OBJECTIVES

Scope: In India, the technique is being used only in the field of crime investigation as a scientific aid.

Objectives:

- To verify the veracity of the statement of suspect, witness and complainant in all types of crime
- To replace the third degree method of interrogation in a scientific manner;
- To examine white-collar criminals, economic offenders, cyber criminals and other offenders;
- To economize the process of investigation by screening large number of suspects by differentiating between the guilty and the innocent.
- To corroborate or to refute the findings of the investigation.

5.15.3 GUIDELINES TO THE INVESTIGATING OFFICERS FOR FORWARDING THE CASES FOR

POLYGRAPH (LIE-DETECTION/TRUTH VERIFICATION) EXAMINATION

1. Preliminary Investigation by the Investigating Officer is pre-requisite for forwarding the case for Lie-Detection examination.
2. Request for appointment along with the name of the subject (s), justification for subjecting the individual (s) to Polygraph examination may be sent to the Director, Forensic Science Laboratory/Institute.
3. Presentation of the case by I.O. after appointment has been fixed by the laboratory, the investigating officer should present the case to the polygraph expert

prior to the beginning of the polygraph examination. The investigating officer who initially attended the crime scene and most familiar with the details of the case/investigation should be preferably present during discussion of the case.

4. It is mandatory for the current investigating officer to be present for the discussion, before the polygraph test of the subject (s) in his case is initiated.
5. The following materials be made available to the laboratory well in advance of the date of the examination in all the cases:
(i) A copy of the FIR
(ii) Investigating reports including facts, names, places, times, dates, crime scene diagrams (if applicable and available), photographs etc.

(iii) Statements/interrogation reports of suspect (s), complainant(s) witness(s) including alibi witness(s).
(iv) In cases of serious injury, violent or suspicious deaths, sex offence, a copy of the attending physician‘s or medico-legal report and postmortem report has to be furnished.
(v)In cases of alleged sex offences such as intercourse with a female child, forcible rape, indecent liberties or perversion, it is important that the victim, as well as the accused, be made available for interview and polygraph examination. It is essential that the polygraph examiner gets a first hand detailed statement from the victim, and the interview of the victim precedes that of the suspect(s) or witness(s).
(vi) It is desirable that in order to have proper understanding of the scene of crime, formulation of the issues for polygraph examination and helping the investigation in meaningful manner, the polygraph examiner also visits the scene ofcrime.

5.15.4 RECEIPT OF CASES

1. Receipt of case files in the division.

2. Maintenance of record details viz. entry in case registers regarding FIR/RC No., name(s) of subject(s), date of receipt, name of examiner, date of examination date of report can be entered after disposal of the case.
3. Check if following documents have been sent along with the requisition:

(i) Copy of FIR

(ii) Brief facts of the case

(iii) Statements of subjects concerned

(iv) PMR/MLC incase of violent crime

(v)Crime scene sketch and photographs (if available)

(vi) Justification for subjecting the individual to polygraph examination.

(vii) Issues to be probed

(viii) Any other relevant material/document to facilitate the understanding of the case.

4. Fixing of appointment for the case – personally, telephonically or by a letter. In case appointment is fixed by a letter, preparation of appointment letter, submission of letter / file to competent authority in the laboratory for information and onward transmission to the concerned requisitioning / forwarding authority (format of appointment letter at Appendix-I).

5. Study of case file and marking the important points for discussion with the

investigating officer during his presentation.

6.

5.15.5 POLYGRAPH EXAMINATION PROCEDURE

The polygraph examination is conducted in following phases:

1. Discussion with the investigating officer in detail and finalizing the issues for conducting the polygraph examination. Subject to information form is to be filled-up by the investigating officer. (Appendix-II).

2. Pre-test Interview: The pre-test interview is an integral pat of a polygraph test situation. It helps to bring the subject into a proper psychological set, enables the expert to assess the holistic personality of the subject and prepares him for the lie-detection test. The objective of pre-test interview is to establish rapport between the examiner and examinee in order to:

(i) Remove unfounded fears from the mind of the examinee which might have cropped up due to misinformation;

(ii) Know the willingness of the subject. In normal circumstances the polygraph examination will be conducted only with voluntary consent which has to be given in the form of informed consent (Appendix-III-A). However, the legal and constitutional rights to refuse to undergo the test have to be explained prior to the subject signs the informed consent form to take the polygraph examination. Refusal generally should be in the form of informed refusal (Appendix-III-B). In case, the subject is not willing to either give the consent or refusal in writing the polygraph expert will make a note of it and report accordingly to the forwarding authority. In case, the subject refuses to take the test, his/her test will not be conducted.

(iii) Know the version of the subject about the allegations leveled against him as to why he is being implicated;

(iv) Find out if there is any gap in information provided by the subject and the

I.O. which may be bridged by another discussion with the I.O.;

(v)Find out if there is any abnormal situation which may affect his test records;

(vi) Assess his personality, general nervousness, and conscious efforts to lie in the first instance or showing over confidence;

(vii) Assess any past or present physical or mental abnormality that might have an impact on actual polygraph examination records;

(viii) Test the memory of the subject-such as find out if he is leaving any major details of his statement while narrating his story to the expert and to assess if the concealment is intentional or due to lapse of memory with time or due to false recording of statement.

(ix) Ascertain if a person‘s revelation of some information such as name and facts of crime have some genuine ground or is baseless with the intention to mislead the investigation.

(x)Build up a proper psychological set both in the guilty as well as innocent subject so as to get an accurate picture on the recordings during the polygraph examination.

(xi) Ascertain that the conversation between examiner and examinee goes on properly. This is foremost condition for a successful polygraph examination. This helps the examiner to decide the language to be used for formulating the questionnaire, and

(xii) Ascertain if some new issue evolves out of the pre-test interview of the subject which require to be included in the issues to be probed.

3. The background information form (appendix-V) and the non-verbal clue form

(appendix-VI) are filled-up in order to collect information from the subject regarding his medical, psychological, personal history, and crime record.

4. Preparation of the questionnaire: For formulating the questionnaire to conduct the polygraph examination Control comparison Question Technique is utilized.

Three types of questions are included in the control/comparison question techniques.

(i) Irrelevant questions: Irrelevant questions are (not related to crime under investigation or any other crime) included because the answers to the questions are admitted truth.

(ii) Control/Comparison questions: Questions capable of provoking emotion, which are about an act of wrong doing of the same general nature as the main issue under investigation, but are not related to the crime under investigation. They are less serious in nature and in all probability the examinee will lie or his answer will be of dubious validity in his own mind. (this is known as probable lie question).

A recent development in the questioning technique is the use of questions (on which the subject is directed to tell lie) as a control/comparison question. This reveals the pattern of physiological response when a person tells a lie (directed lie question).

(iii) Relevant questions: Questions pertaining to the crime under investigation based on the facts of the case.

5. The various control/comparison question techniques are detailed below:

(i) Reid control question technique (RCQT)/Modified General Question Technique (MGQT).

(ii) Guilty Knowledge Test (GKT)

(iii) Zone Comparison Test (ZCT)

(iv) Peak of Tension Test (POT)

(v)Guilt Complex Test (GCT)

(vi) Revised Affirmative Test (RAT)

(vii) Mixed General Question Test (MGQT)

(viii) Silent Answer Test (SAT)

Note-1: Silent Answer Test is the altered mode of response and may be used in conjunction with verbal answer tests applying any of the above mentioned techniques.

Note-2: If the narration is given in writing by the examinee, the revised affirmative test may be administered to verify the narration.

Note-3: The technique(s) appropriate to the case is selected depending on the nature of the case, and the issue(s) required to be examined. If needed, more than one technique may be applied for the sameexaminee.

Note-4: Guilt Complex Test and Mixed General Question Test are used in specific circumstances like if a person is reacting equally on control and relevant question then Guilt Complex Test (GCT) is applied. The Mixed General Question Test (MGQT) is used for re-examination purpose.

6. Precautions to be taken while formulating the questionnaire.

(i) The questionnaire should be in the language the examinee is conversant with/familiar with/comfortable with. In case, the examiner is not familiar with the language of the examinee, the services of an interpreter with knowledge of both the languages may be taken. However, in selecting an interpreter the following points should be considered.

- The interpreter must not be a member from the investigating team.
- The interpreter must be very intelligent and have thorough knowledge of both the languages i.e. of the examinee and examiner.
- As far as possible, efforts may be made to get professional interpreters but at times the services of some employee from the organization may also be utilized, who is well-versed in both the languages.
- Before the test begins, the expert explains the principles, theory and purpose of the polygraph test and his/her role in conducting the polygraph examination to the subject and interpreter.
- To check the competence of the interpreter in both the languages – the questions are formulated by the examiner; the interpreter is asked to write it in the language of the examinee. Afterwards he/she is asked to read the questions in the language of the examinee and give simultaneous translation of the same in the language of the examiner.
- The interpreter is given brief instruction regarding the principles involved in conducting the examination like all the questions have to be asked in the same tone throughout the test, the subject should not be charged emotionally at any point of time. He/she should only convey the questions asked by the examiner to the examinee and the answers given by the examinee to the examiners.

(ii) Words used in formulating the questionnaire should be direct the simple without carrying any double meaning.
(iii) Single question should be formulated avoiding the use of connecting words.
(iv) Leading questions should be framed to elicit a yes or no answers only.

(v) One questionnaire should include only 10-12 questions. The number of questionnaire for examination of one person shall depend upon the number of issues / queries involved in the case.

7. Polygraph Equipment: Computerized polygraph equipment and/or manual instrument capable of producing simultaneous recordings of physiological parameters may be used as the basis for the application of a reliable technique for detecting truth or deception. For the said purpose, the polygraph equipment shall be able to record following physiological parameters (minimum requirement) and the changes therein.

(i) Pneumograph: To record respiration, partially inflated rubber tube is fastened around thoracic and/ or abdominal region of the examinee.
(ii) Sphygmomanograph: A Blood Pressure cuff (of the type used by physicians) is fastened around the right arm in such a way as to ensure that the rubber portion of the cuff is placed over the brachial artery for a satisfactory recording of blood pressure and pulse rate. If the blood pressure pulse rate cannot be recorded satisfactorily with the arm cuff, a plethysmograph may be used.
(iii) Galvanograph: Electrodes are attached to the index finger and the ring finger of the left hand for recording the galvanic skin resistance

Besides the above principal requirements, the optional physical parameters like Activity monitor Sensor and the latest available additions may also be used.

8. Examination Proper: The examination of the subject on polygraph equipment is conducted in following steps:

(i) Familiarize the examinee with the examination room, polygraph equipment and its attachments.
(ii) Instruct the examinee about the manner in which he has to sit during the examination.

(iii) Attach the sensors on the examinee.

(iv) Record the normal physiological parameters after the sensors are attached to the examinee.

(v) Instruct the examinee regarding the administration of the questionnaire.

(vi) Review of the questionnaire with the examinee: Before administering the questionnaires, the same has to be reviewed with the examinee. The objectives are as follows:

a. Questionnaires are reviewed with the examinee to ensure that the examinee has understood the questions properly.

b. To familiarize the examinee with the questionnaire and placements of relevant and control questions.

c. If any anticipatory reaction or response is elicited in terms of maneuvering, the questions may be framed again.

d. Proper framing of the control questions to elicit probable/directed deceptive reactions.

e. Finalize the questionnaire after review with the examinee.

f. To rewrite the questionnaire which require modifications after review with the examinee.

(vii) Pre-test recording is done after the introduction and review of the questionnaire to the examinee in order to see the impact of the introduction of the questionnaire.

(viii) Administration of the questionnaire: Each questionnaire is administered minimum three times except in stimulation test or POT where only one run is sufficient. While asking the questions on the equipment, each question is asked after a gap of 25 seconds. This gap is allowed in order to activate and normalize the sympathetic and parasympathetic components of the autonomic nervous system. Marking should be made on the chart at the time of starting of question and end of the question and also indicate the responses of the subject on chart.

Note: The examiner should record the artifacts like swallowing, coughing, movement, external factor and other non-verbal clues observed on the chart during the polygraph examination.

9. Card Test/Stimulation Test: The subject is asked to select one number/name/object from a set, write it on a piece of paper and keep it with him/her. After that he/she is directed to say no to all questions, when the examiner asks „Whether he/her is keeping – with him/her. In the process, he/she tells one lie on the number/name/object which ever he/she with him/her and the lie is detected instantly. Card test/stimulation test helps to enhance the guilt complex in the guilty person and to normalize the innocent person by instant detection of deception. Examiner at his/her discretion can use the card test even prior to administration of test questionnaire. The card test may not be conducted if the subject does not agree.

10. Post-test recording is done after administration of all the questionnaire(s).

11. Post-Test Session:

(i) Getting the signature or thumb impression of the examinee on the polygraph charts/polygrams and questionnaires.

(ii) Post Test Interview: An opportunity is given to the examinee to account for the deceptions evidenced on his graph if the reactions are indicative of guilt. This helps the examinee to understand the meaning and consequences of the polygraph examination results.

(iii) If there is a need, polygraph examination may be repeated by administering the

same and or modified/added questionnaire.

5.15.6 ANALYSIS AND SCORING OF POLYGRAPH CHARTS

1. Analysis of Polygraph charts/polygrams: -

(i) Steps followed in analyzing the charts are as follows:

Drawing the lines on polygrams at the beginning of each question i.e. question time and when the examinee reply the question i.e. reaction time. (Applicable only for Manual Electronic Polygraphs).

(ii) Observe the patterns of normal recordings in all the four parameters.

(iii) Polygraph chart tracing is divided into four tracing segments for the purposes of analysis, i.e.

a. Average-tracing segments: Tracing interpreted as normal tracing without stress.

b. Reaction-tracing segment: Tracing interpreted as having observable physiological changes while answering the relevant questions.

c. Relief-tracing segment: Tracing interpreted as having relief reaction after answering relevant questions.

d. Distorted-tracing segment: Tracings not arising out of deception but occurs because of other factors.

(iv) Sequential analysis: After deciding the tracing segments, sequential analysis is carried out in following steps.

a. Observing the normal recordings of physiological parameters i.e. respiration, blood pressure, pulse rate and galvanic skin response.

b. Comparing the recordings of each physiological parameter on each relevant question with respect to normal recordings, pretest recordings, recordings on control/comparison questions and recordings on irrelevant question.

c. Marking the reactions on each and every question on all the polygrams.

(v)Sequential analysis is done for each run separately and the final conclusion is based on the average score of all the runs.

2. Following are some of the deception criteria:

(i) Respiration – deception criteria:

a. Staircase suppression

b. Rise in baseline

c. Ordinary suppression

d. Respiration cycle change (slow/fast/heavy breathing)

e. Erratic specific respiration

f. Generally erratic respiration

g. Post deception respiration relief

(ii) Blood-pressure pulse rate deception criteria:

a. Rise in base level of tracing with reduction/increase in pulse amplitude

b. Rise on base level of tracing without reduction / increase in pulse amplitude.

c. High level of blood pressure before asking the relevant question and dropping of blood pressure level after relevant question.

d. Exceeding slow / fast pulse rate.

e. Roller coaster shape of blood pressure pulse response.

(iii) Galvanic skin resistance: To be judged from the pen excursion in the reaction tracing, (three times) in proportion to the normal tracing zone. A plunging GSR tracing within time frame of a question or within five seconds following the answer to a relevant question is a deception criterion.

3. Scoring and Reporting:

(i) Writing the analysis chart for all polygrams in tabular form (Appendix-

VII) in terms of qualitative analysis and assigning respective numerical – responses observed on polygraph chart to be scored on a seven point scale (i.e. ranging from NR+ to nr for non-deceptive and R+ to r for deceptive and ? for responses arising out of external factors) and its corresponding numerical values (i.e. +3 to +1 for non deceptive, -3 to -1 deceptive, 0 for responses arising out of external factors) – scoring manual (Appendix – VIII).

(ii) Matching the analysis with questionnaire for writing the report.

5.15.7 REPORT FORMAT

1. Title of the report (polygraph examination report).

2. Name & address of the laboratory and if different from the address of the location where the test performed.

3. Unique identification of the report.

4. Date of issue of the report.

5. Page No. & total No. of pages on each page.

6. Name & address of the forwarding authority.

7. Description, unambiguous identification, date of receipt of requisition.

8. Date(s) of performance of test/examination.

9. Identification of test methods or procedures i.e. polygraph test, psychological tests.

10. Examination results:

(i) Deception is reported as: Analysis and evaluations of polygrams reveal deceptive responses. According to test and analysis X is deceptive in his answers on issues number_____to_____.

(ii) No deception is reported as: Analysis and evaluations of polygrams do not reveal deceptive responses. According to test and analysis. X appear is truthful in his answers on issues number to .

(iii) No opinion is reported as: No significant inference could be drawn on the basis of test and analysis. No opinion, therefore, could be furnished in respect of X on issues No._____to_____.

11. Name, designation, qualification, experience and signature, or equivalent identification of person authorized to release the report.

5.15.8 ESSENTIAL CONDITION FOR SUCCESSFUL POLYGRAPH OPERATION

Apart from basic condition that the polygraph instrument should be very sensitive and accurate to record the physiological changes during Polygraph examination, other prerequisites for accurate recordings are the examiner, the examinee, polygraph examination room and privacy.

1. The Examiner: A high degree of accuracy in conducting Polygraph examination depends upon the educational background, personality, integrity, objectivity, impartiality and experience of the examiner. The educational qualification of the examiner should be Post-graduate degree in Psychology preferably Ph.D. Only a gazette officer should be authorized to release the report of polygraph examination. There are various factors due to which misleading responses similar to deception can appear on the chart, which can easily mislead an inexperienced examiner. A skilled examiner can differentiate such false responses and can successfully identify deception whenever it occurs.

2. The Examinee: It is very important in polygraph examination to ensure that examinee is in good mental and physical condition. Before conducting the test, the examiner should ensure that the examinee is,

(i) Not exhausted from intensive interrogation, kept hungry or made to suffer because of third degree treatment.

(ii) Not under the influence of alcohol, drugs etc., and

(iii) Has no grave physical or mental abnormalities which may interfere with his understanding of the purpose of the test, his legal rights regarding the test and consequences of the test results.

3. Polygraph Examination Room: Condition of examination room also plays an important role in achieving high degree of accuracy and reliability in Polygraph examination. The room should preferably be semi sound proof and air- conditioned. No wall decorations to divert the attention of the examinee. Examination room should give the examinee an impression of absolute privacy with comfortable and peaceful surroundings. If possible the provision of one way mirror and or CCTV and recording system should be introduced for providing transparency in conducting the Polygraph examination.

4. Privacy: Polygraph Examination is always conducted in absolute privacy. In the examination room; none else except the examiner and the examinee are present. Police officer, counsel and any outsider are never allowed inside the room during the examination. If need be, only assistant of the examiner or interpreter (in case of language barrier) is allowed inside the room during the examination. If required by legal, provision the counsel, police officer and others may watch from outside through one way mirror or CCTV monitor.

5.15.9 LIMITATIONS OF THE POLYGRAPH EXAMINATION

There are some limitations of Polygraph examination for which precautions have to be taken by the examiner, in order to avoid wrong opinion formation:

(i) Mental tension of the subject e.g. extreme nervousness, fear of feeling of guilt due to offences committed earlier.

(ii) Unresponsiveness of the subject.

(iii) Some unobserved muscular movements.

(iv) Physiological defects like hearing impairment, neurological impairment etc.,

which can interfere in proper administration of the Polygraph examination procedure.
(v)Mental abnormalities.

These limitations, nevertheless, can be eliminated by strictly following the conditions essential for successful operation of the polygraph examinations explained above.

Note: Criminal profiling, personality test, psychological test etc., should be carried out in cases whenever required.

LEARNING OUTCOME

After studying this unit you should be able to:

1. Explain the importance of Expert Witness and its Impact.
2. Quality Assurance and Quality System.
3. Investigative Psychology.
4. Lie-Detector.
5. Polygraph Examination and their Procedures.

GLOSSARY

1. Audit
2. Accreditation
3. Offender
4. Stimulation

SUGGESTED READINGS

1. Expert Testimony- Grif Stockley.
2. Successful Expert Testimony- Christine Funk, Harold A. Feder, and Max M Houck