CHAPTER I
CHAPTER 1

INTRODUCTION

Soil, as evidentiary clue plays vital role in arriving at significant forensic conclusions. It is almost impossible for any body to indulge in criminal activity without removing some particles of soil or dust from the scene of crime and carrying them on their clothing, shoes, vehicles and weapon of offence etc. For forensic purposes, the term soil is used in a wider sense related to earth material carried during the criminal offence accidentally or deliberately. The soil or earth material involved in the crime, thus, generally contains minerals and rock particles, plant and animal residues, micro- and macro-biological population and also a variety of man-made objects such as concrete, plasters, abrasions etc.

Soil (solum in Greek) may be defined in many ways. Commonly soil scientists define it as solid earth material that has been altered by physical, chemical and organic processes such that it can support rooted plant
life. Engineers define soil as any solid earth material that can be removed without blasting. Soil can be considered as an open system, a function of several variables including climate, topography, parent materials, time (maturity), and organic activity. Soil-forming processes tend to produce distinct soil layering, or horizons. Each horizon is defined on the basis of the process of formation or the type of materials present. Of particular importance are processes of leaching, oxidation, and accumulation of materials in various soil horizons. Vertical and horizontal movements of materials in soil systems provide a distinct soil layering, or soil profile, divided into zones. However, not all horizons may be present in a soil profile. Highly concentrated organic material is found in the O and A horizons—difference between the two reflecting the amount of organic matter present. E-horizon, if present, is highly light-colored horizon under the O or A that is leached of iron-bearing components—the colour is light because it contains less organic material than the upper horizon and presence of little colouring materials such as iron oxides. Below the O, A, or E-horizons and many other sub horizons / horizons have been identified, the B-horizon underlies. Probably the most important type of B-horizon is the argillic B (Bt).
which is enriched in clay minerals that have been translocated downward by soil forming processes. Depending upon the oxidation-reduction reactions, the soils show varying colours. Underlying the B-horizon is the C-horizon, directly over the unaltered parent rock material and consists of parent material partially altered by weathering processes. The D or R-horizon, the bottom part of the generalized soil profile consists of consolidated bedrock that underlies the soil development of the argillic B horizon, for example, depends on the translocation of clay minerals from upper to lower horizons, where they accumulate as oriented thin skins or plates of clay minerals surrounding soil grains and filling pore spaces between grains. Three properties of importance in descending soil are the colour, texture, and structure.

It can be noted from the afore-mentioned discussions that soils are essentially composed of organic matter, minerals, gaseous constituents, air and water. The main source of organic matter is plant residue consisting of lignin, oils, starch, sugar, cellulose etc. They decompose continuously and liberate gases of C, N, and P besides some sulphates, nitrogenous residues, and other compounds. Humus is formed when attacked by micro-organisms. Soils are often very rich in living organisms.
They contain insects, earthworms, rodents and various lower forms of plant life such as bacteria, algae and fungi. The organic matter thus influences the physical, chemical and biological properties of the soil.

The minerals in soil mostly come from rocks since it is the disintegrated product of the latter. The mineral matter may be subdivided into three basic categories: sand, silt and clay. Sand particles originate from quartz and to some extent from other minerals like mica, magnetite, etc. Silt particles originate mainly from quartz and feldspar minerals. The silt particles are very fine and the feel is like flour. Clay particles are derived mainly from feldspar minerals and are very small. During the process of soil formation, the soil disintegrates into coarse as well as fine particles which refer to as soil texture. Soil texture depends upon the relative proportions of sand, silt and clay-sized particles (Arakeri, Chalam, Satyanarayana, and Donahue, 1967). Clay particles have a diameter of less than 0.002 mm, silt is defined as particles with diameters ranging from 0.002 to 0.05 mm and sand consists of particles from 0.05 to 2.0 mm in diameter. There is no universally accepted definition of the term clay. Clays may occur as the principal constituents of a rock formation and soils. They are characterized by their small particle size.
Coarse, medium, and fine clays have size ranges \( \geq 2 - 0.5, 0.5 - 0.2, \) and below 0.2 \( \mu \text{m} \), respectively. Any material ground to less than a 0.2 -\( \mu \text{m} \) particle size becomes finer clay. Characterized by their chemical composition and crystal structure, a variety of minerals occur in clays. Clay minerals are principally silicates of Al, Fe, Mg and belong to the phyllosilicate (or layer silicate) family of minerals. Clay fractions in soils contain any fine-grained (\(< 2 \mu \text{m} \) diameter) minerals and materials produced on account of weathering and erosion processes, which disintegrate and decompose the parent rocks and materials. Thus, clays are not entirely composed of clay minerals but also the clayey fractions of any mineral and material (organic, inorganic etc.). It is evident that parent rocks and their sizes significantly influence the physical properties and chemical composition of the soil at any particular place to a great extent.

There exists some space inside each soil granule and so also between the grains, known as pore space. The pores are made by plant roots, earth worms etc and are occupied by water and air in varying proportions. Some of the water in the soil is hygroscopic water and some portion of soil water is present as capillary water. The
pore space is occupied by air on evaporation of water. The soil air contains more of water vapors and more carbon dioxide but less oxygen. Depending upon the atmosphere, the composition of the soil air changes and so also its physical, biological and chemical properties.

Though soil itself varies over short distances both horizontally and vertically there is high probability that the earth sample of the same locality in the restricted sense will always exhibit similar chemical and physical properties. Thus it is possible to ascertain with a high degree of accuracy whether the two soil samples had a common source by comparing various physical and chemical parameters. However, instead of examining and comparing the physical and chemical properties separately for each soil sample, the examination of soil usually carried out in a forensic laboratory is restricted to comparison of the soil samples from the crime scene and from suspect person or soil contaminated articles (earth materials) by distribution of soil particles determined by density gradient method. The density gradient comparison is the only scientific evidence presented for comparison of soils (Kirk and Paul. 1974) which provides valuable corroborative evidence in establishing the place of scene of crime, the
Soil may undergo physical and chemical changes if subjected to high temperature.

It has been observed (Crampton, 1972) that a high temperature has marked influence on the soil materials such as removal of the organic material, destruction of some minerals, dehydration of the minerals including dehydroxylation of the clay minerals. The higher the temperature, the greater will be the changes. The organic material from the sandy soil has been found to be almost removed if the temperature is more than 850°C and is heated for 30 minutes. But with finer textured soil the removal of the organic material is accompanied by dehydration of clay minerals and also by destruction of calcite when present. It has been observed (Hartnup, and Jarvis, 1973) that the destruction of calcite required a temperature of 950°C for two hours.

Therefore soil samples collected before and after heating / explosion will vary in physical, mineralogical and chemical properties. The soil samples so obtained will indicate different sources if the
heating effect is not taken into account. It may be misleading in criminal cases. Ordinarily, in criminal cases the soil before and after the commission of crime is not expected to undergo a change in temperature of the order of 950°C to 1000°C to cause geochemical changes. Therefore, comparison of the soil samples collected from the crime scene with the soil collected from the apparel and other belongings of the suspect will exhibit similar distribution of the soil particles by density gradient method.

This becomes problematical if the soil of the crime scene during or after the occurrence of the crime is subjected to a high temperature of 1000°C or more. Such a situation arises in criminal cases involving explosives. The temperature in such cases is far more than 1000°C causing significant geochemical changes in the soil at the site of explosion. Valuable informations can be obtained by deciphering such changes and a comparison of such data accruing from the investigations of standard (control) soil sample (particularly B – horizon clayey fractions) and the explosive plus soil (clayey fractions) after the explosion. These data are conditioned by various factors discussed in sequel e.g. type of explosive, its composition, nature, targets, depth of crater, explosivity, temperature attained etc. Thus soil carried by the suspect
while planting the explosives will exhibit distinctly dissimilar physical and chemical properties with the soil collected from the same place after explosion. The phenomenon of change in physical and chemical properties of the soil may provide valuable clues in cases involving explosives especially if explosive residues are not detectable after considerable lapse of time or otherwise from the huge debris.

For a purposeful forensic study of the physical and chemical parameters of the soil samples before and after explosion, it needs to be discussed what happens when an explosion takes place.

**EXPLOSION:**

In criminal cases chemical explosives are used as the basic tool of explosion. These explosives when suitably activated have the following necessary and sufficient factors for creating a state of explosion (Yellop, 1980).

1. Rapid release of large quantity of gas.
2. Rapid release of large energy.
3. Self sustaining process.
In short the main function of the chemical explosive is to produce a large quantity of gas and heat in a very short time so that a high pressure is rapidly developed. The hot gas presses through the air that sets up the shock waves at very high pressure in the direction of detonation and perpendicular to this direction. A high pressure even higher than that developed in shock waves is developed. The mass of hot gases moving with high velocity and high pressure causes blast. Since the pressure is higher than the shock waves, a wave front at a very high peak pressure in the front is formed which can crush hard structures. The wave front acts as a powerful blow.

In explosion, the substance is converted to the final products approximately proportional to the pressure. A detonator proceeds by the progress of a shock wave, which traverses the body of the substance. Explosion process of high speed, involving a sustained shock wave is termed as detonation. The rate of release of energy is very high and is of the order of microseconds. The velocity of the shock wave (detonation) is supersonic in respect of the reacted mass into which it is moving. This phenomenon generally occurs in case of explosion by high explosives.
1. A crater is formed. However, the crater may be absent if the detonation occurs at some height and so also in soft sand or earth.

2. At short ranges of explosion most building materials may be crushed into powder and small particles.

3. Punch holes may be caused in walls and other materials in the vicinity of the explosion.

4. Sympathetic detonation may be caused by the detonation waves in other explosives in the vicinity.

EXPLOSIVES:

The tremendous power of explosives has been used for causing considerable destruction. Till the 19th century only gunpowder was used as a high explosive. In 1866, the discovery by Nobel of the absorption of nitroglycerine with kieselguhr resulted in making of well-known dynamite, which had tremendous demolishing effect than the normal gunpowder. Later in the 20th century, the explosive properties of TNT were recognized. TNT has been used before the First World War and has been replaced by RDX and TNT mixtures between the two wars. The search for new explosive for different purposes resulted in the discovery of numerous military explosives. The basic explosive
compounds of interest are TNT, RDX, HMX, PETN, NG and Nitrocellulose etc.

1. TNT:

   It is the most widely used explosive both by itself and admixed with other substances such as Ammonium nitrate, RDX etc. Chemically this is the symmetrical isomer, 2,4,6-Trinitrotoluene, which is prepared by the continued action of nitric and sulfuric acids on toluene. It is stable and has low melting point, low sensitivity to impact, friction and high temperature. The molecular formula is $C_7H_5N_3O_6$ and structural formula is given below (Yinon and Zitrin. 1993).
2. RDX:

This substance is chemically known as cyclotrimethylene-trinitramine, hexogen or cyclonite. It is one of the most important military explosives. It has greater explosive power than that of TNT. It is considerably more susceptible to shock detonation than the TNT. It has high chemical stability lower than that of TNT. The molecular formula is C\textsubscript{3}H\textsubscript{5}N\textsubscript{6}O\textsubscript{6} and structural formula is given below (Yinon and Zitrin. 1993).
Due to high sensitivity, RDX has to be desensitized for general use as bursting charge. One of the commonest methods used by terrorists operating in the country is by mixing RDX with plastic desensitizers of oily nature. TNT is also mixed with RDX in different proportions for desensitizing RDX.

3. HMX:

It is chemically known as cyclotetramethylene-tetranitramine or octagon. It is used as a burster charge for artillery shells in military. Its molecular formula is $C_4H_8N_8O_8$ and the structural formula is given below (Yinon and Zitrin. 1993).

![Structural formula of HMX](image)

1,3,5,7- Tetranitro-1, 3,5,7-tetraza-cyclooctane.
4. PETN:

The chemical name of PETN is Pentaerythritol Tetranitrate. It is used as a base charge in blasting caps and detonators, as core explosive in detonating cord and as an ingredient in mixtures with other explosives (e.g. TNT and RDX). It has relatively high sensitivity to impact. Generally, it is used after using additives such as wax. Though it is not so sensitive to friction but it is highly sensitive to initiation by explosion. Its molecular formula is: C₅H₈N₄O₁₂ and the structural formula is given below (Yinon and Zitrin. 1993). No toxic effect has been reported.

\[
\begin{align*}
\text{O}_2\text{N-O-CH}_2 & \quad \text{C} \quad \text{CH}_2\text{-O-NO}_2 \\
\text{O}_2\text{N-O-CH}_2 & \quad \text{O}_2\text{N-O-CH}_2 \\
\text{CH}_2\text{-O-NO}_2 & \quad \text{CH}_2\text{-O-NO}_2
\end{align*}
\]

5. Nitroglycerine:

It was discovered in 1847 by Ascanio Sobrero in Italy who called it 'pyroglycerine'. Its sensitivity was decreased by mixing it with Kieselgur and was known as Dynamite. It is sensitive to shock, impact and friction and is used only
when desensitized or mixed with Nitrocellulose. Its molecular formula is $\text{C}_3\text{H}_5\text{N}_3\text{O}_9$ and the structural formula is given below (Yallop, J. 1980).

\[
\begin{align*}
\text{CH}_2\text{ONO}_2 \\
\text{CHONO}_2 \\
\text{CH}_2\text{ONO}_2
\end{align*}
\]

6. Nitrocellulose:

It is the nitrate ester of cellulose. It is used primarily as propellant. It is also used in dynamite and in non explosive applications. It burns at a relatively slow rate and burning rate can be varied by mixing it with Nitroglycerine (Yinon and Zitrin, 1993).

The explosive power of PETN is much greater than that of RDX and the explosive power of RDX is much greater than that of TNT. For classifying explosives on the basis of explosive power a Relative Effectiveness Factor (REF) is worked out, taking TNT as base or value 1. Explosion properties are compared with TNT and a comparison
value is determined. The REF values of different explosives, with respect to TNT, are as under.

1. TNT 1.00
2. PETN 1.66
3. RDX 1.50
4. Composition -B 1.35
(Mixture of RDX and TNT)
5. Black Powder 0.55

The explosive power also depends upon the loading density. The velocity of detonation is directly proportional to the loading density. The increase in loading density in respect of TNT is as follows:

<table>
<thead>
<tr>
<th>Loading density</th>
<th>Velocity of detonation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>5600 m/s</td>
</tr>
<tr>
<td>1.4</td>
<td>6300 m/s</td>
</tr>
<tr>
<td>1.6</td>
<td>5600 m/s</td>
</tr>
</tbody>
</table>
Higher the explosive power higher is the velocity of detonation. The velocity of detonation of the following explosives has been tabulated below: (Meyer, 1987).

<table>
<thead>
<tr>
<th>Sr.No:</th>
<th>Explosives</th>
<th>Velocity of detonation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TNT</td>
<td>6900 m/s</td>
</tr>
<tr>
<td>2</td>
<td>RDX</td>
<td>8700 m/s</td>
</tr>
<tr>
<td>3</td>
<td>PETN</td>
<td>8400 m/s</td>
</tr>
</tbody>
</table>

Explosives having velocity of explosion exceeding 1000 m/second is said to detonate and they fall in the category of high explosives. High explosives can be subdivided into the following three categories:

A. **INITIATORS**: (Primary or Initiation explosives)

Initiators are extremely sensitive to detonation by heat, shock, friction and impact. Commonly used primary explosives are lead azide, mercury fulminate and lead styphnate (Urbansaki, 1964). Commonly used initiators to initiate an explosion are

a) Blasting caps:

   i Electric/ Electronic/ Remote
ii Non electric /Chemical

b) Detonating cord (explosive)
c) Detonator (metal)
d) Priming charge

B. INTERMEDIARIES:

An intermediary picks up readily weak impulse from the initiator and transmits in a much-amplified form to the main filling charge to cause it to detonate. Commonly used intermediary is Tetryl known as CE (Composition exploding). Chemically it is 2,4,6 Trinitrophenyl-methylnitramine. PETN /wax and RDX /wax have also been used as intermediaries especially by Germans. Intermediaries are not used as main bursting charge.

C. MAIN CHARGE OR BUSTERS:

TNT, RDX, PETN, NG etc are high explosives that are used as main charge for explosion. An explosion leaves the following significant effect on the surroundings /targets.

1) Heat effect:
At the site of explosion a very high temperature between 3000°C to 4000°C is attained for a very short time. The objects at the site may burn or char due to the high heat of explosion.

2) Formation of crater:

High explosives cause craters at the point of explosion. The diameter of the crater is approximately given by the ratio \( d = K W^{1/3} \), where \( d \) is the diameter of the crater and \( W \) is the weight of the explosive in lbs. The constant \( K \) depends upon the nature of the ground on which explosion takes place. Its value is smallest in sand or soft earth (clay) and greatest in friable rocks. The depth of crater is approximately half the diameter of the crater.

Explosives when buried under ground, on explosion generally create a crater of volume equal to four times the weight of explosive in lbs. If the detonation is above the ground then the crater will be either very small or non-existent.

3) Blast effect:
On explosion, very hot expanding gases are produced within 1/10,000th of a second which exert a pressure of 700 tones / sq. inch on the atmosphere surrounding the point of explosion. The gases rush away from the point of explosion, compressing the surrounding air, at a very high supersonic velocity upto 30,000 miles / hr. This sharp front of high pressure creates the vacuum behind, thereby causing a negative pressure or a backward pull on the target after the shock wave has crossed over. This is known as blast pressure wave. Considerable damage can be caused by the blast pressure wave on any object in its path.

Blast pressure wave in case of detonation in the open will lose its power and velocity quickly. If the blast wave strikes on surrounding reflective surfaces then the reflection may cause scattering or focusing of the wave, like sound or light waves and may cause considerable effect. If a charge in the open looses its power within 100 meters from the point of detonation then the same charge if placed inside a large diameter sewer pipe or in the long way then the blast pressure effect may be effective even up to 200 meters or more. This is obviously due to reinforcing the original wave by reflection. If the blast pressure wave strikes on an immovable object in its path like solid concrete post, then the object will absorb
and shield the pressure wave. Entire structure of a building may be blown by detonation inside the building due to reflection or shielding of pressure waves. The blast waves in the open may also be reflected at great distances by natural obstacles such as hills, clouds etc.

4) Earth and water shock:

An explosive charge buried in the earth or placed under water, on detonation will also produce gases, heat, shock and loud noise. But the detonation in the earth (under ground) is less violent and the energy released is similar to that of the detonation in the open air because earth is more difficult to compress as compared to air, but the damage is in larger area. The blast wave is transmitted through the earth in the form of a shock wave similar to a short and powerful earthquake. This shock wave travelling through earth is capable of causing damage to structures and buildings as earthquake does. Windows may shatter, walls may crack, objects may fall from the shelves and doors may be jammed.

If a detonation occurs under water the damage is in large area because water can-not be compressed at all.
5) **Fragmentation:**

Bomb containers, on explosion, fragment and are projected. The fragmentation of thick metal casing bomb is projected at a very high velocity of about 3000 to 4000 ft/ per second. Fragments of medium and thin casing are projected with an average velocity of 6000 ft / sec.

When large fragments of bombs hit concrete structures, roofs etc., heavy damage may be caused. They may even destroy the structure and crush the objects. The cracks radiate from the point of impact.

Small fragment is capable of penetrating objects around e.g. brick work and masonry work etc. The small fragments may also be effective on human targets as well as on steel plates depending upon the striking velocity at the time of impact. Fragments striking on an object, on disintegration may, cause secondary fragmentation.

6) **Directional effect:**
A hole in a metal or hard surface similar to the shape of explosive can be punched or created by the detonation wave in the explosive material. If explosive is placed on some metal and detonated, it will cut the metal.

**FORENSIC USE OF SOIL:**

In view of the aforementioned potentialities of high explosives, the terrorists have resorted to destructive activities by using high explosives. It has become the terrorist’s weapon of choice to intimidate and kill or to indulge in mass destruction of life and property.

It can be seen from the details mentioned in the preceding pages that an explosion is accompanied with rapid release of gases, development of high temperature and pressure, production of a sustained shock wave transversing through the earth and every thing in the vicinity. Besides heat, other effects of explosion may also contribute to the geochemical changes in the soil to a great extent. A detailed study of the geochemical changes in the soil after explosion will obviously help in ascertaining whether or not the soil was subjected to explosion i.e. site of explosion. It will serve as a
positive tool in the identification if residues of explosives are not detectable by known methods, due to considerable lapse of time or improper soil samples collected from wild huge debris. In addition, the nature of geochemical changes may also provide valuable clues in ascertaining the type of explosives used because of marked variation in heat, pressure, blast effect etc., along with the type and quantity of explosive used. These aspects of great forensic significance have remained unexplored. In the present scenario of ever increasing use of explosives in criminal/terrorist cases it is warranted that a detailed study of geochemical changes in the soil is made for arriving at significant forensic conclusions and finger printing.

With this in view the present work has been undertaken. For a meaningful study of the problem in hand, it is necessary to identify the area of investigation. Accordingly following aspects were addressed:

i) Type of explosives to be chosen for the present study.

ii) Type of soil to be chosen for experimentation.

iii) Type of targets to be chosen for experimentation.

iv) Nature of examination for the detection of explosive.
V) Identification of geochemical changes by examining and comparing physical and chemical properties of pre and post blast soils.

i) Type of explosives to be chosen for the present study:

In the present day of worldwide terrorism, chemical explosives are the choicest weapons for mass destruction of life and property. Almost all criminal cases involving explosives are related to terrorist acts. Increased threat of terrorist's acts is now an issue of national and international importance. Therefore, it has to be tackled at all fronts and in this context the role of forensic scientist has become vital. For proper forensic investigation, it was considered appropriate to choose those explosives for the present study which are most often used by the terrorists throughout the world. With this aim, the literature (restricted manual or otherwise) on terrorism with special reference to the use of explosives was reviewed from different possible sources including information available on the internet and so also from
available terrorist cases of the region/country including those examined by the author as an explosive expert.

Terrorists of all nationalities adopt similar tactics. They commit heinous acts to fulfill their cause and aims. They compel an individual, group or authority to adopt a particular disposition or accept the imposed demands under conditions of fear created by violence. They fully exploit the fact that the threat of death, incapacitation or torture and media attention can pay greater dividend than the actual killing of the victim. Their aim is not as much to cause violence in order to perpetuate the fear of it and to drive the Government into a state of hysteria and panic, disrupt its control over the citizenry and cripple the bureaucratic machinery, installing the fear of death. In today's terrorism, the outside powers and their agencies are playing a significant role by providing highly skilled leadership and ideological motivation to the terrorists. In addition, they provide finance, training, equipment, intelligence, sophisticated electronic devices etc. Any terrorist group can easily get sophisticated weapons and explosives from the open or from the gray market provided it has the financial resources.

Though terrorism had always been a problem yet it took a serious turn in mid-sixties. The
terrorists in Ireland used commercially available high explosives for a series of explosions in 1968. (Marshall, 1976). The Japanese red army militants indulged in indiscriminate shooting of innocent passengers at Lord (Israel) airport in 1972. Indiscriminate shooting in the Munich Olympic village killed eleven Israeli sportsmen. The Scotland yard had to take special measures in London post office due to a spate of plastic bomb incidents in 1972. A Japanese airline plane was blown up in Libya in 1973. There was an explosion at the office of the Kuwait oil company in London in 1980 (Feraday, 1993). A bomb exploded at the Inglis barracks, the Army postal sorting unit in London (Feraday, 1993). On 21 December 1988, PANAM flight 103 was blown over Scotland, which killed 270 people (Feraday, 1993). The recent bombing in 1995 of a Saudi military building in Riyadh in which the entire front side of the three-stories building was blown away. Seven people were killed including five U.S. advisers (Web links U.S.state, 1997).

Our country is no exception. The act of terrorism has engulfed various states of the country especially the states of J& K, Punjab and Northeast. The year 1991 was the year of important blasts. On 21 May 1991, a human bomb was used against Shri Rajiv Gandhi, the then Prime minister of
the country (Sharma, 1994). An explosion occurred on 2.2.91 at Ludhiana in which Shri Mangat, the then D.G.P Punjab and his security officer were injured (Sharma, 1994). An explosion occurred on 7.6.91, in the heap of stone pieces kept on the roadside. It was aimed at ex Minister of State for Home, Shri S. K. Sahay by using RDX a high explosive. A car parked on the roadside was blown on 29.8.91. This was aimed to target at the vehicle of the S.S.P. Chandigarh which was passing through that road (Sharma, 1994). In the year 1992, an explosion occurred in the office of the Director General of Police, Jammu & Kashmir at Srinagar. On 11\textsuperscript{th} Sept. 1993, one of the cars parked in the parking area outside the building of the youth congress at New Delhi was blown when the youth congress President, Shri M. S. Bitta, after addressing a meeting, was going out from the said building. Eight to ten Kg of explosives was planted inside the car, at two places. Two craters of diameter approximately 1 ft 5" and 1 ft 8" and depth of 40 cms and 43 cms respectively were found on the ground. A series of eleven explosions of various magnitudes occurred in various places in Bombay on 12 March 1993. A vehicle bomb having 30 to 40 Kg of explosives was used for explosion at Bombay stock exchange. A car bomb using 35 to 45 Kg of explosives was used for the explosion in Air India building. On the
Republic Day 1995, there was a loud blast at Jammu stadium, where General Rao was delivering Republic day speech. There were three explosions one after the other and they formed craters of approximately 2 to 5 ft. in diameter and 2 ½ to 3 ft deep (The Tribune, 28th January, 1995). There are many more instances. In 1995, a bomb blast at Punjab civil secretariat Chandigarh which took 15 lives including Shri Beant Singh, the then Chief Minister Punjab (Indian Express, and The Tribune, 1st September, 1995). In the capital alone, 32 explosions took place one after the other in 1997-98 including blast at ITO, Karol bagh, Lalkilla, ISBT and in blue and red line buses. Earlier this year (2000) a human bomb tried to kill Kumar Tunga, the Prime Minister of Sri Lanka. She was injured badly but survived. In May, 2k. militants detonated a landmine, killing Jammu and Kashmir minister Sh. G.H. Bhat and four others, in Anantnag. 25 feet deep crater was found at the site of explosion (The Tribune, MAY, 2000). Within an hour of this explosion, a BSF vehicle was blown in south Kashmir, which took two lives.

The act of terrorism over the last two decades in the country and abroad has one thing in common that they resort to explosions by chemical explosives. The following
are the little common high explosive used by the terrorists in this country (Yinon, and Zitrin, 1981).

a. Amatol
b. Composition -B - mixture of RDX and TNT
c. Composition C3 demolition block
d. Composition C4 Plastic explosives
e. PETN
f. TNT
g. Tetrytol
h. RDX- (cyclonite)

But the terrorists of today make use of those high explosives, which preferably satisfy the following criteria:

1. Easy to use.
2. Safe to handle
3. Immense destruction power
4. Easily available either commercially or by preparing in the laboratory from easily available cheap materials.
5. Capable of being molded to a desirable shape.
7. And above all not easily detectable by the conventional detectors during transportation.
The choicest explosives, which fulfil all the criteria, are the two powerful explosives: RDX (cyclonite) and PETN (Pentaerythritol Tetranitrate) and their combinations known as semtex. A few kilograms of this carry immense destructive power. The choicest explosive, extensively used by all the terrorist organizations worldwide is RDX. Many versions of RDX explosives are commercially produced. Only a small quantity is required for creating a shattering explosion. RDX can easily be made malleable and safe by the addition of mineral oil. The malleable explosive can be molded to a desirable shape and can be planted at any place. So much so that the detonator can also be inserted in the soft explosives for initiation. Semtex is a combination of RDX and PETN, both powerful explosives in their own right. Today semtex is the most powerful plastic explosive in the world. Most of the well-organized and well-known terrorist groups/organizations in the world make use of Semtex. The IRA alleged to possess more than 3 metric tons of Semtex. It is also alleged that the recent U.S. Embassy bombings in Kenya and Tanzania, Semtex was used by Islamic terrorists. Plastic explosive can conveniently be used being light in weight. They have high shattering effects in comparison to their volume. These
explosives are relatively harmless and can be easily handled. The most significant property of RDX, PETN and Semtex are that they have very low vapor pressures and are not easily detectable during transportation. The presently available explosive detectors mainly work on thin vapor analysis system almost like that used in gas chromatography. Explosives having low vapor pressure like plastic explosives, RDX, PETN and Semtex etc. are almost non-detectable by these instruments. It is also difficult to detect by using electron chemical sniffers. Their weak odour is very seldom detected by dogs. They are also often overlooked by X-ray machines at the airports. In view of fulfillment of all the aforementioned criteria, the choice worldwide is that of a plastic explosive i.e. RDX, PETN, SEMTEX etc.

In India, these explosives are often used after addition of suitable additives to give them a deceptive look. Some of the commonly encountered deceptive explosives in our country are mentioned below:

1. **Black colored RDX** (Sharma, 1994).

White coloured pure RDX is turned black by adding carbon and mineral oil. The common composition is:
2. White coloured PETN: (Sharma, 1994)

The yellow colour of PETN is changed to white by the addition of plasticisers. The composition of white coloured PETN is usually:

PETN -------------- 85 %
Plasticisers--------- 15 %

3. The other common composition is a mixture of RDX and PETN:

RDX + PETN
70 + 30

In view of the aforesaid universally accepted choice of plastic explosives by the world wide terrorists, the
explosives chosen for the present study were RDX, PETN. In addition, the mother explosive TNT and their mixtures, were also chosen for the study. Pure explosives were taken for explosion and experimentation.

**ii) Type of soil to be chosen for experimentation:**

Unlike other criminal cases the soils from deeper layers of the earth are also involved in cases of explosion. On explosion, the soils from the under layers of the earth are thrown out in vicinity of explosion from the crater formed by the explosive material. Depending upon the explosive charge and nature of soil (physical characteristics), the crater will be deeper or shallow. Though depth of crater is dependent on the quantity and type of explosives, it is the fine textured soil at the horizon B level that is almost always affected by the absorption and adsorption of volatile and nonvolatile organic constituents of explosive substances and their combustion products. It is almost certain that usually encountered criminal/terrorist cases of explosions, one would come across the fine textured soils i.e., clay soil. Under laboratory conditions of experimentation it may not be possible to get desired crater for detailed study
obviously because of limitations of quantity of explosive, simulation of targets and above all the safety factor. Therefore, it was considered appropriate to choose clay soil itself for explosion experiments which would necessarily help in making extensive study on all aspects irrespective of the depth of the crater. Accordingly the clay soil area of the city Chandigarh was chosen for experimentation. Instead of using a small quantity of soil and explosive for explosion experiments in the laboratory, it was considered appropriate to carry out explosion experiments in the open ground to simulate the practical situation as far as practicable.

iii) Type of targets to be chosen for experimentation:

The militants in our country, are our countrymen as well as foreign missionaries from the neighboring countries. Militants of foreign origin begin their activities at the border and the line of control itself. In addition to usual explosions to terrorise people in the country, the cross border militants of today adopt various means of explosions to perform the following acts (Sappers Field Engineering manual part 1, 1988).

1. To clear obstacle of RC wall
2. To destroy bridges at strategic position and bending of iron bars / beam.

3. To destroy roads and to make crater in airfields to make it non-operational and for mass killing.

4. To destroy wire fencing at the border for entry into the country or elsewhere.

5. To make hole on concrete and masonry floor, to cut steel etc.

6. To effectively cut steel, wood or masonry wall for entering into or escaping from desired locations.

7. To destroy roads and to make craters.

8. Direct explosion by using PETN.

In addition to usual experiments of explosions carried out in the open ground on clay soil in the lake area of Chandigarh, it was necessary to simulate aforementioned target arrangements for a meaningful study of explosive effect in actual criminal cases as far as practicable. But elaborate and appropriate arrangement of desired simulation of targets was a difficult task in the city. Besides, it could not be made possible to carry out experiments with a sufficiently large quantity of explosives in the city due to security and safety reasons. Therefore, it was necessary to carry out experiments in Government
organisation where facilities for desired simulation of targets were either available or possible. It was found during the course of author's visit / training in different institutes that the National Security Guard at Manesar area, a training institute for Bomb squad and explosive experts of the country did have the requisite facilities for simulation of targets for the desired experimentation. Incidentally a study of the soil samples also revealed that the area had also clayey / loamy soil. Therefore it was considered appropriate to carry out explosion experiments with the available / possible simulation of targets in National Security Guard in addition to the initial simple experiment on open ground on clayey soil in the Sukhna Lake area of the city. To make the study broad based and of practical forensic utility explosion experiments were carried out to simulate all the aforementioned varied targets likely to encounter in actual cross border terrorism.

iv) Nature of examination undertaken for the detection of explosive.

The detection of explosives is significant both before and after the blast. The pre-blast detection of explosive is of importance to restrict the
trafficking of explosive substances from one place to another especially cross-country, using different modes of transport. Technologies available today for screening baggage at the airport for hidden explosives include conventional X-Ray machines, an electromagnetic system and trace detection devices. Various methods are available that can be employed for detection of explosives such as dual-energy X-rays, back scattered X-ray,. X-ray diffraction, axial tomography, thermal neutron analysis, quadrupole resonance radio frequency pulse probes etc. (Web link). Because of high operational cost very few airports are equipped with these modern detection methods. Sniffer dogs are also used for the detection of explosives. Plantation of explosives can be detected by explosive detectors, sniffer dogs etc. Once the unexploded explosives is seized, it becomes a simple task to detect type of explosives by known laboratory methods obviously because of availability of large quantity of explosives for testing purposes. It becomes somewhat difficult after the blast because the explosive residues are distributed in a very large area of explosion site. The usual procedures of identifying explosives from the soil samples collected from the explosion site are well known. They are by chemical spot tests, TLC and other techniques. In addition modern
sophisticated instruments such as TEA, HPLC, IR/FTIR, ICP, XRF etc. are employed for precise identification. Since the present work relates to the study of geochemical changes in post blast soils, the identification of explosives has a limited role as branded explosives have been used for the study. Following methods have been chosen for identifying explosives from the post blast soils.

a) chemical spot tests.
b) chemical confirmatory tests
c) Thin layer chromatography
d) FTIR analysis

v) Identification of geochemical changes by examining and comparing physical and chemical properties of pre and post blast soils.

The identification of soil depends mainly on the mineral analysis because mineral grains form the bulk of almost all soils. The identification of mineral in rocks found in soil offer greatest potential for distinguishing between two soil samples obviously because of large number of mineral kinds and diversity of minerals from one place to the other as a result of geological process. A detailed
mineralogical analysis is thus called for to study the geochemical changes in forensic work. Therefore, specific mineral identifications of the constituent grains of the soil samples and allied chemical study of the intergrain space were undertaken to investigate geochemical changes. The following examinations were considered appropriate for the present work.

e) pH of the soil.
f) Colour of the soil.
g) Density distribution.
h) Ignition percentage
i) Mineralogical analysis by X-ray diffraction (XRD) technique.
j) Mineralogical analysis by FTIR (Fourier Transformation Infrared spectroscopy).
k) Chemical analysis by ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry).

After conducting explosion experiments soil samples were collected from the site of explosion. Explosive residues were detected. Geochemical changes between the pre and the post soil samples were studied by
comparing various physical, chemical and mineralogical properties.

The second chapter describes the explosion experimental details of simulation of targets, collection and preparation of soil samples.

The third chapter deals with the methodology adopted for the present investigation.

In the fourth chapter presentation of data has been done.

The fifth chapter deals with "Mineralogy of soil" pre-and post-explosion.

The sixth chapter deals with the "Geochemistry of soil" pre-and post-explosion.

The seventh chapter deals with conclusion of the present work and its Applications.