CHAPTER VI  
COAL FIRES AND THE ENVIRONMENT  

6.1 INTRODUCTION  

Raniganj coal belt is one of the oldest coal mining regions of India and coal fires occur both on the surface and subsurface areas of this densely populated and urbanized region. These fires are of various extent and depth, and result in significant environmental degradation due to population and dereliction of land, and lead to operational difficulties in coal mining activities. Therefore, the research has immense operational and applied usefulness.

During the course of the research, mine fire areas were recognized from satellite data and mapped at 1:50,000 scale. The main limitation was that in nature of the data as Landsat 5 TM images were used for the study as they are in the thermal infrared band (10.42-12.50 µm). However, their ground resolution is so poor (120 metres) that such images are unable to locate smaller fires. Still, about 25 per cent of surface temperature anomaly points were surveyed for field verification. The survey areas were selected according to anomaly zones identified through laboratory work. Therefore, though the Raniganj township and surrounding areas had the largest occurrence of temperature anomalies, our survey points were spread over the entire region. In addition to satellite images, census and primary data were used for the purpose of characterizing the region. The coalfire problem was related to human security aspects through the calculation of village populations affected by such fires. Extensive field visits were undertaken at frequent intervals in different seasons to identify the causes of the mine fires. Finally, the means of control were researched from both technical and non-technical angles.

It was found that both surface and subsurface mine fires of the Raniganj region are closely related to the nature of socio-economic development of the region. Besides spontaneous combustion, unauthorized mining and a long history of void-related subsidence have enhanced the fire problem. These fires endanger human security, make mining operations difficult and lead to environmental degradation. Their means of control at present are mainly technical - dousing with sealant and water, and use of overburden material to stuff out the path of oxygen reaching the coal seams. It was suggested that the degradation of local environment and loss of livelihoods among local populations in association with a decaying agriculture and disappearing commons are at the root of the problem of unauthorized coal mining in the region. These human-induced factors increase
the spontaneous combustion of a highly inflammable material like coal. Therefore, along with technical measures, socio-economic planning will have to be taken by suitable implementing agencies. Such a holistic, region-specific approach to fire hazard will be able to control the problem in the Raniganj coalbelt.

6.2 OBJECTIVES
Keeping in view of the problems of the study area and the utility of remote sensing data analyzing techniques in conjunction with ground truth information, the present study has been aimed at the following objectives:

- to identify the locations of mine fires in the Raniganj coalbelt with the help of satellite data (Landsat TM thermal infra red data 10.42-12.5μm with temperature sensitivity);
- to identify the causes (both natural and human-induced) of fire in each case through extensive and intensive field surveys;
- to map the extent of these fires at 1:50,000 scale;
- to explore possible means of effective control of these mine fires; and
- to discuss about minefires impact on the environment.

6.3 METHODOLOGY AND DATABASE

6.3.1 Approach to the study
Two kinds of data sets were used in the study:

a. satellite data; and
b. ground information.

The methodological approach was to apply scientific and technological knowledge in solving practical problems of a specific nature. Satellite data was procured and processed at the departmental laboratory followed by ground truth checking and systematic field surveys, mapping and interpretation, and final report writing.

6.3.2 Data analysis
From a spaceborne or airborne sensor the amount of energy emitted by a object is possible to be measured. At absolute temperature T(K) the spectral radiance $L$ of an object on earth, detected by the $j$th TM band 6 sensor of on board satellite is:

$$L_j = \frac{1}{2} \sum B \left( \frac{\lambda_i + \lambda_{int}}{2} T \right) \times \left[ (\varphi_j(\lambda_i) + \varphi_j(\lambda_{int})) \right] \Delta \lambda$$

where,

$$\Delta \lambda = 0.01 \text{ μm} \quad \lambda_i = 10 \text{ μm} \quad \lambda_{300} = 13 \text{ μm}$$

$n = 300 \quad B = \text{Planck's function}$
\( \varphi_j(\lambda_i) \) = is the \( j \)th detector response function at wavelength and is normalized to unity, i.e.

\[
\varphi_j(\lambda_i) = \frac{\varphi_j(\lambda_i)}{\sum_{i=1}^{n} \varphi_j(\lambda_i) \Delta \lambda}
\]

(2)

Here \( \varphi_j(\lambda_i) \) is the relative spectral response. Using Planck’s radiation equation the temperature of the object can be estimated. The equation is:

\[
w_\lambda = \frac{2\pi h c^2}{\lambda^5 \left(e^{hc/\lambda kT} - 1\right)} \varepsilon_\lambda
\]

(3)

where,

- \( \lambda \) = Wavelength in meters
- \( h \) = Planck’s constant = \( 6.63 \times 10^{-34} \) Js
- \( k \) = Boltzmann’s constant = \( 1.38 \times 10^{-23} \) JK\(^{-1}\)
- \( c \) = Speed of light = \( 2.99 \times 10^8 \) m/s

Which can be written as:

\[
T = \frac{c_2}{\lambda \ln \left(\frac{e \lambda^5 \varepsilon_\lambda}{nL_\lambda} + 1\right)}
\]

(4)

or,

\[
T = \frac{C_2 \lambda^{-1}}{\ln \left[\frac{e \lambda^5 \varepsilon_\lambda}{nL_\lambda} + 1\right]}
\]

where,

- \( c_1 = 2\pi hc^2 = 3.74 \times 10^{-16} \) Wm\(^2\) = first radiation constant
- \( c_2 = hc/k = 0.0144 \) mK = second radiation constant

let,

- \( K_1 = \varepsilon C_1 \lambda^{-5}/\pi \)
- \( K_2 = C_2/\lambda \)

Then, equation become:

\[
T_R = \frac{K_2}{\ln \left(\frac{K_1}{L_\lambda} + 1\right)}
\]

(5)

where,

- \( T_R \) = Radiant temperature (°K)
- \( L_\lambda \) = Spectral radiance (mw cm\(^{-2}\) sert\(^{-1}\) \( \mu m^{-1}\))
If the emitted spectral radiance of an object is known, the temperature can be calculated using the equation 2. Sixth band of Landsat thematic mapper uses the 10.4-12.5μm region to measure the radiant temperature of a real body. Though its spatial resolution is poor (120 metres), but it is ideally most suitable for thermal measurement, because the peak of the emitted radiation occurs at about 9.6 μm for earth’s ambient temperature at 300°K. However, as per Planck’s equation, with the rise of temperature of ground objects, the intensity of emitted radiation also increases.

The digital values (DN) of satellite data can be converted to spectral radiance using the following equation (Markham and Barker, 1986):

\[
L_\lambda = L_{\text{min}(\lambda)} + \frac{L_{\text{max}(\lambda)} - L_{\text{min}(\lambda)}}{Q_{\text{cal}}/Q_{\text{cal} \text{max}}}
\]

where,

\(L_\lambda\) = Spectral radiance

\(L_{\text{min}(\lambda)}\) = Minimum detected spectral radiance for the scene (0.1238 mw cm\(^{-2}\) Sr\(^{-1}\) μm\(^{-1}\))

\(L_{\text{max}(\lambda)}\) = Maximum detected spectral radiance for the scene (1.56 mw cm\(^{-2}\) Sr\(^{-1}\) μm\(^{-1}\))

\(Q_{\text{cal}}\) = The grey level for analyzed pixel

\(Q_{\text{cal} \text{max}}\) = The maximum grey level

From the radiant temperature \(T_R\) will be converted into kinetic temperature using

\[
T_R = e^{\frac{\lambda}{\varepsilon}} T_K
\]

where,

\(T_R\) = Radiant temperature (°K)

\(\varepsilon\) = Spectral emissivity (0.95)

\(T_K\) = Kinetic temperature (°K)

The digital number (DN) value has been converted into kinetic temperature using the above equations. Then applying suitable corrections land surface temperature mapping and location of the mine fires are identified.
FIGURE 6.1

Methodology for Coalfire Zonation

Satellite data

Landsat TM

Georeferencing

TM 6 (Thermal)

Spectral Radiance Image

Radiant Temperature Image

Surface Temperature Image

Surface Temperature Anomalies

Coal Fire Zonation

Vulnerable village map

Ancillary data

SOI Toposheets

GPS

Thermopoint 80 Reading

Village map
6.3.3 Database
We have taken the following data to identify the fire locations are Landsat TM6. Toposheet, Census data, and Field data. For this chapter we have prepared some digital maps related to temperature estimated, emissivity, thermal band, false colour composite, surface temperature anomalies, and fire affected villages. In this chapter to going through all fires impacts on the environment.

6.4 IMPORTANCE OF REMOTE SENSING DATA FOR STUDYING COAL FIRES
The study of coal fires is a complex problem which involves the understanding and knowledge of many parameters, like the type, nature, movement, origin of fire, the structural setting of the area, that is, the fracture patterns, connectivities etc, the geological setting of the area, as well as the nature and property of the overlying material. Satellite remote sensing offers a powerful tool in this context, in view of special attributes such as multispectral approach, synoptic coverage and repetitive data. For detecting temperature anomalies, Landsat TM6, TM5 and TM7 have been used.

In geography, remote sensing is a well-established technique for spatial studies. We have used it in the case of a coal mining areas to identify the location extent and fire prone areas. We are able to draw the thermal anomalies map locating the abnormality of temperatures in mining areas of the RCB. Thus satellite data is able to aware the human being to protect themselves from adverse effect of mine fires. Mainly satellite data Landsat TM6, Liss III has been used to identify the fire locations in the RCB.

6.4.1 Justification for using TM6 for studying fires in the Raniganj coalbelt
The Earth surface temperatures are determined by the balance between the radiation received from the Sun and that re-radiated away to space by the earth. If the earth absorbed all wavelengths equally, this balance would result in an average surface temperature of about 270°K - rather cold for comfort. Radiation from the Sun, however, is predominantly at short wavelengths (visible and near-infrared spectral regions) corresponding to the peak of the Planck function for 6000°K whilst the Earth radiates longer wavelengths (the thermal infrared approximately 4-20 μm) corresponding to 300°K.
The thermal infrared (TIR) region of the electromagnetic spectrum applies to wavelengths from 3 to 14 microns. It is called the 'thermal region' because there is a significant amount of self-emitted radiation from materials at common temperatures. The earth's atmosphere in the wavelength ranges of 3 to 5, and 8 to 14 microns is relatively transparent. This means that for these regions (windows), thermal infrared radiation can propagate to a detector.

Following are the maps of the False Colour Composite and emissivity image of the Raniganj coalbelt prepared from satellite data (figure-6.2 and 6.3).

The thermal anomaly of coal fires: The thermal anomaly of a fire is the most important characteristic as regards survey. It can be used as an indicator for the fire's area extent and intensity and of the amount of coal loss. To establish the relation between thermal anomaly and coal loss, a calculation method for the thermal anomaly was developed. The thermal anomaly caused by the heat of combustion of the coal is a clear indicator of the existence and outline of a fire. This anomaly can be detected by satellite, airborne or handheld equipment.

The heat of combustion (ΔH) of an underground fire dissipates into the environment in several ways:

a) Conduction
b) Convective heat exchange
c) Radiation

Conduction: Conduction is the descriptive term for heat that is transported through solid-to-solid contact. The actual transport of heat is by the vibration of molecules against their neighbours. In general, this is a relatively slow process. The conductive heat transport plays an important role in the transport of heat within the intact rock of the fire area.

Convection: Convection is a term used for the physical transport of heat by the movement of gases. It plays a role in the transport of heat from the hot rock above a fire into the atmosphere. It is also the primary mechanism by which the exhaust gases transport away the heat of the combustion from the core of the fire. Due to the chimney effect, the hot gases move upward through the cracks and voids of the overburden into the atmosphere.
False Colour Composite
The Raniganj Coalbelt
Figure 6.3

Emissivity Image
The Raniganj Coalbelt
During the upward migration, the hot gases will exchange some of their heat with the surrounding rock, thus contributing to the thermal anomaly of the overburden.

**Radiation:** In the absence of solid matter, heat can be transported by radiation. This can be apparent in the combustion chamber of the coal fire and at the surface above the fire. The intensity of the radiation varies as a function of wavelength and temperature.

**Thermal expression of open fires:** Open fires radiate in the range from about 300 nm (1 nm = 10⁻⁹ m) until far into the thermal infrared (>12500 nm). Most energy is radiated in the thermal infrared. Open fires are seldom encountered in the field. The most common occurrences of open fires are during the loading-out of a subsurface fire and in opencast mines. The heat generated from open fires is dissipated mainly in the form of radiation and by the exhaust gases. The conductive heat transport will only give a small rim of heated rock around the fire because of the cooling by the atmosphere and the low thermal transport into the poorly conducting subsurface around the fire. This rim is unlikely to be more than a few meters wide.

**Coalfire and surface temperature:** The temperature of a surface depends on several factors. Those factors are not only inherent properties of a surface, but are also affected by the conditions of the surrounding area. In the case of a subsurface coalfire, the surface temperature also depends on rock and soil type, topography, local atmosphere, emissivity, crack or fissures on the surface, depth of fire, etc.

**Effect of local atmosphere on surface temperature:** Atmospheric factors that influence and decrease the surface temperature are evaporation and strong wind. Evaporation from a wet surface causes a strong decrease in surface temperature amplitude. It has been observed, if the surface is wet the overall heat transfer coefficient is larger than in the case of a dry surface (Rosema *et al.*, 1999). Strong winds cause a reasonable impact on surface temperature and decrease the temperature amplitude.

**Effect of ground material on surface temperature:** Most of the ground material is composed of sediments and rocks, these materials are related to the thermal conductivity and volumetric heat capacity. Together with these thermal properties, radiative properties also play a significant role in the temperature response of the surface to solar radiation.
Effect of terrain on surface temperature: Topography and earth cover type (that is, barren or vegetated, material type) of an area under investigation also has a significant effect on surface temperature. Slope and aspect play an important role with regard to surface temperature. Particularly during daytime, due to solar heating, the same surface has a different temperature compared to nighttime.

Effect of emissivity on surface temperature: Emissivity or emitting capability of a surface compared to a blackbody depends on the intrinsic properties of the surface. Emissivity depends on surface roughness, phase of matter and temperature of the body, it has a significant contribution towards the radiant temperature of a surface.

The detectable thermal anomaly at the surface is transported to the surface, through the overburden, by the exhaust gases as well as by conduction. The conductive transport is rather slow; it may take several weeks before a subsurface fire produces a detectable rise in temperature at the surface. The heat transport by the exhaust gas is fast; in the direct vicinity of the exhaust-gas outlet, an anomaly will soon occur after the fire develops. From field experience, it is known that subsurface coal fires spread at such a low speed that the conductive heat transport is significant. Through knowledge of the mechanisms of heat transport can give useful information about the size, intensity and depth of the fire by the examination of the anomaly.

6.5 RESULTS AND DISCUSSION

6.5.1 Detection of thermal anomalies and location of coalfires

Thermal band (figure-6.4) shows the Landsat-5 thematic mapper thermal band scene recorded on 30th April, 1997. There exists a good contrast between coalfire area and surroundings. Using the aforesaid methodology the surface temperature map was generated. The density sliced image (figure-6.5) of the study area displays the different zone of temperatures. In the image red coloured area represents 51°C-68°C and white, yellow, turquoise and blue represent 50-46, 45-41, 40-30, 29-15°C respectively. The red patches near Raniganj indicate the surface temperature anomalies due to surface and subsurface coalfires. The total area is grouped into three main categories:

1. areas of most intensive burnings – coloured in red;
2. areas of heat flow from active coalfires – coloured in white; and
3. areas of subsurface coalfires – coloured in yellow.
FIGURE - 6.4

Thermal Band
The Raniganj Coalbelt
Isothermal Zonation
The Raniganj Coalbelt

Temperature Zones:
- 68-51°C
- 50-46°C
- 45-41°C
- 40-31°C
- 30°C and less
Over water surface the temperature was found 12-22°C and the temperature over the vegetation was found to be in the range of 21-26°C including open and dense vegetation. because vegetation tries to be equilibrium with the air temperature (Metzier and Malia, 1985). The temperature of barren land and fallow was found in the range between 29-38°C. Over the settlement the temperature was found in the range of 28-34°C. The temperature over the overburden dump of the OCP was found 28-32°C and in the OCP it was 35-38°C. The maximum temperature was observed over the coal seams which extend from east to west. The temperature over the coal seams in some places more than 50°C. In some places the temperature was found 68°C.

It is known that the thermal infra red band of Landsat TM saturates at 68°C (Rothery et al., 1988). In this study the pixels with saturation temperature is assumed to be the surface coalfire. The possible other hotspots such as chimney of factories were identified during the ground truth survey and with help of Survey of India toposheet. Those were eliminated from further processing. The final surface temperature map shows the locations of surface coalfires (figure-6.6).

6.6 COAL FIRE AND ITS IMPACTS

6.6.1 Status of fire in Raniganj coalbelt

Like other countries India is also suffering from coalfires. The oldest and famous, Raniganj coalbelt is effected by surface fires as well as subsurface fire both. Reverent R. Everest has described fire affect coal seams as ‘Volcanic Eruptions’ in ‘Geological Observation’.

Coal fires problems have been started in the RCB in 1865. After that 140 fires incident occurred gradually up to 1967. Fires may extend with devastating form on the surface area and polluted the mining environment, due to proper management. At present fire incident have been occurred in nine places and damaged 640.8 hectares land. Among these are some old minefires, coal dump fires open cast fires. Coal fires create not only operational difficulties but also increase the lost of production or make existing operations uneconomical. Considerable economic and environmental problems are directly related to coalfires. Noxious gasesous like monoxide, nitrogen sulphar dioxide are polluted the mining environment continuously. Coal fire is increasing the local
Surface Coal Fires
The Raniganj Coalbelt

FIGURE - 6.6
temperature, and decrease the ground water table gradually. Different salt particuals and pollutent materials degrade the land fertility, and decrease the humidity in land. Land subsidence is a major environmental degradation due to fire has caused drying of the soil and vegetation also. Coal fire has adverse effects on human settlement surrounding in mining areas. Some affected villages are Sanctoria, Nimcha, Kajora, Nirsa, Amritnagar, Radhanagar and Seetalpur etc.

A brief description of nine fire places in the RCB are given below:

i) J.K. Nagare fire – Satgram area – total area 4.88 hectares fire excaved from cracks and hole fire depth 20 metres – 48 metres underground fire far away in from Eastern Railway. Now ECL trying to control it.

ii) Amritnagar fire – Kunustoria area – total area 39 hectares fire reached to eastern railway through voids and cracks.

iii) Dishergarh fire – Sodepur area – total area 86 hectares, depth, 27 metres. Now fire under controlled.

iv) Sactoria fire – Sodepur area – total area 3 hectors fire now controlled. This fire reached Sanctoria village and colony.

v) Khas Kajora fire – Kajora area – total area 16 hectares, surface fire and sub surface fire damaged the colliery nearly.

vi) Jambad fire – Kajora area – total area 4.7 hectares fire have damaged settlements adversely, now trying to control.

vii) Bonjumari open cast fire – Salanpur area – total area 3.6 hectares.

viii) Mohanpur colliery fire – Salanpur area – 8 and 9 number overburden in Mohanpur colliery are affected by fire about 3 hectors area. It trying to under control.

ix) Dasurbandh opencast fire – Pandaveswar area – total 4 hectors areas affected by coal fire.

According to CMPDIL report of ECL the surface fire affected areas and their remedies have been given in a table-6.1.
TABLE 6.1: Surface fire areas in Raniganj coalbelt

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Area</th>
<th>Location</th>
<th>Affected area in hectare</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodepur</td>
<td>Sanctoria colliery</td>
<td>86</td>
<td>Sand blanketing done</td>
</tr>
<tr>
<td>2</td>
<td>Kunustoria</td>
<td>Amritnagar colliery</td>
<td>39</td>
<td>Surface blanketing being done</td>
</tr>
<tr>
<td>3</td>
<td>Satgram</td>
<td>Jay Kay Nagar colliery/ Nimcha colliery</td>
<td>4.88</td>
<td>0.50 M.Cu.m. of search spread for blanketing the area/trench cutting</td>
</tr>
<tr>
<td>4</td>
<td>Kajora</td>
<td>Jambad colliery</td>
<td>4.7</td>
<td>0.70 M.Cu.m blanketing done</td>
</tr>
<tr>
<td>5</td>
<td>Bankola</td>
<td>Shankarpur colliery</td>
<td>16</td>
<td>Controlled by excavation</td>
</tr>
<tr>
<td>6</td>
<td>Pandaveswar</td>
<td>Dalurbandh colliery</td>
<td>4</td>
<td>Blanketed with alluvium</td>
</tr>
<tr>
<td>7</td>
<td>Salanpur</td>
<td>Bonjumari OCP</td>
<td>3.1</td>
<td>Blanketed with overburden</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>640.8</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: CMPDIL

ECL authority now trying to control such fire and they blamed previous mine-owners of pre nationalization. But the real situation does not support it. Because after nationalization ECL authority does not take proper secured policy against fire, and fires are go on in this way. It is clear that from a survey report that 223 fire incident have been happened from 1973-1980 even after coal mine nationalization (table-6.2).


<table>
<thead>
<tr>
<th>Year</th>
<th>Numbers of hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>29</td>
</tr>
<tr>
<td>1974</td>
<td>23</td>
</tr>
<tr>
<td>1975</td>
<td>25</td>
</tr>
<tr>
<td>1976</td>
<td>35</td>
</tr>
<tr>
<td>1977</td>
<td>39</td>
</tr>
<tr>
<td>1978</td>
<td>32</td>
</tr>
<tr>
<td>1979</td>
<td>15</td>
</tr>
<tr>
<td>1980</td>
<td>25</td>
</tr>
</tbody>
</table>
It is proved clearly that mining authority is indifferent about mine security in respect of fire hazards during 1973-'80. Area wise fire incident has given below.

i) Kajora area – 105 times
ii) Sripur area – 41 times
iii) Dishergarh area – 12 times
iv) Satgram area – 65 times

6.6.2 Main causes

Both surface and subsurface coal fires are found in the Raniganj coalbelt. Surface fires are relatively small in their areal extent and are controlled efficiently. On the other hand, subsurface fires are extensive and widespread and are marked by wider surface thermal anomalies. Spontaneous combustion is the major cause of fires in most coalfields, and takes place whenever a coal seam comes in contact with oxygen in the air. Air may pass through cracks, fractures, vents etc. to reach the coal seams. Abandoned mines and mine refuse dumps are very prone to fires, which can spread to the adjoining working mines. Extraction of coal from the subsurface without completely filling the empty spaces or goafs with sand has caused widespread subsidence and has also left the area prone to subsidence in the future. Besides damaging the infrastructure above and near the subsided area, blocking the coal reserves and causing damage to the environment, land subsidence may cost the lives of mineworkers if it occurs during mining operation. The cracks and fissures associated with subsidence provide greater access to air and moisture, increasing the problem of underground coalfires. Increased extraction of coal from the underground to meet the ever-expanding resource demand is bound to aggravate the problem of land subsidence.

Negligence on the part of mine workers may also start a subsurface coalfire. A few fires are entirely ignited by humans such as by an external heat source setting fire to the coal. One example would be the fires caused by the illegal distillation of alcohol (Sinha, 1986) and illegal mining (Lahiri-Dutt, 1999) in Indian coal mines.

The origins of subsurface fires in coal mines cannot be identified accurately. The subsurface fires spread continuously from their points of origin, and turn a huge land into void by burning the coal into ash. Such fires lead to the occurrence of large-scale subsidences and ground collapse in the coal mining regions. Thus, there is clearly a nexus between the phenomena of fire-void-subsidence. The breathing of oxygen into the coal...
seam may be triggered in many ways but in the RCB, it mostly occurs through one or another factor in this nexus. Subsurface fires fundamentally damage land, which is a great loss to the economy of a nation like India where land is the main resource. Consequently, they lead to erosion of the subsistence base of the livelihoods of local communities.

Conditions that influence the development of coal fires are:

- The type of coal. Its vulnerability to spontaneous combustion decreases with the maturity of the coal.
- The presence of mining works or faults and fissures in the geological formations, which facilitate the exchange of oxygen and exhaust gasses with the atmosphere.

The burning coal outcrops cover substantial areas. There is geological evidence that coal fires have existed since prehistoric times. It is believed, however, that their number has increased substantially since mining activities started.

The main causes of fire are the following:

1. Spontaneous combustion.
2. Travel of fires to neighbouring mines.
3. Direct contact of the hot ashes/heated quarry debris with coal outcrops.
4. Negligent acts on the part of mine workers and others, which may also start a surface or subsurface coal fire. and
5. Presence of mine refuse dumps and abandoned mines which are very prone to fires.

However, spontaneous combustion is the most important cause of fires. Spontaneous combustion takes place whenever a coal seam comes in contact with oxygen in the air. Air may reach the coal seams through cracks, fractures, vents etc., which are very common in mining areas. The incident related above serves as an excellent case study of a spontaneous combustion of coal fire. It illustrated some major causes of such fires as well as the problems of fighting them effectively and safety. The following general factors have been mentioned as contributing causes:

- Coal handling procedures allowed for long-time retention of coal, which increases the possibility of heating.
- New coal added on top of old coal created segregation of particle sizes, which is a major cause of heating.
Too few temperature probes installed in the coal bunker resulted in an excessive period of time before the fire was detected.

Failure of equipment needed to fight the fire (drag chain conveyer).

Ineffective capability and use of carbon dioxide fire suppression system.

Delay in the application of water.

Inadequate policies, procedures, and training of personnel prevented proper decision making, including the required knowledge to immediately attack the fire.

Failure to learn lessons from two previous coal bunker fires at the same installation.

**Mode of fires in the RCB:** Coal fires can be classified into four groups according to the place of occurrence:

i) Underground mine fire,

ii) Coal seam fire (coal field fire),

iii) Coal refuse fire, and

iv) Coal-stack fire.

Underground mine fires, restricted to the mines, are detectable by remote sensing techniques only if they are less than 30 meters in depth (Greene and Moxham, 1969). In areas where there are no cracks or fractures to lead the underground heat to the surface. This study mainly concentrated on coal seam fires (coal field fires). Coal field fires normally start from the spontaneous combustion of a coal seam at the outcrop of the coal seams or at a shallow depth until the ground water is reached and then spread along both directions of the strike and dip of the coal seam. They can also develop from underground coal mine fires spreading to the surface.

An open coal fire is defined as a coal fire that burns in direct contact with the atmosphere. Much research has been done on the ignition of these fires. Because of their low rate of occurrence (if any), not much research was put into the burning of open fires or into the transformation of a just-ignited open fire into a subsurface fire. Open fires are seldom encountered in the field. The most common occurrence of these is where it has been decided to load-out an active fire, or when mining takes place where the fire was already a problem. Open fires in (abandoned) underground mines are probably even more rare;
Surface Fire - Jambad OCP

Sub-surface Fire - Khaerabad
Fire in spoil dump - Parasia abandoned OCP

Smoke coming out of subsidence
soon after ignition the overburden will start to collapse. As started before, this type of fire only occurs over a short period of time and the area affected is relatively small. Therefore, these fires are unlikely to be detected by remote sensing.

The combustion rate is, in general, dependent on the oxygen supply to the coal. In the case of subsurface combustion, the oxygen required enters the fire via cracks or fissures in the rock or coal, or via old mine shafts or tunnels. The permeability of the adjacent rock is controlled by the collapse of the overburden as a consequence of the reaction to the disappearance of the coal. Subsidence occurring during and after mining has be same influence.

Heat generated by the coal fire is dissipated in several ways:
- Heat is transported to the surface by the exhaust gases.
- Heat is conducted through the rock.
- Heat is used for the vaporisation of volatiles.
- Heat changes the mineralogy of the rock (baking).

Surface fires are unlikely to exist for a long period of time and are likely to evolve quickly into subsurface fires. Due to the good oxygen supply, open fires burn vividly as long as enough fuel is available. However, due to the high fuel consumption at the surface, this type of fire soon runs out of fuel at the surface, this type of fire soon runs out of fuel. The possible available subsurface coal, if not already on fire, will then be the only direction in which the fire can spread. Compared to weathered coal, fresh coal has a higher calorific value and contains more volatiles. Because of the insulating effect of the overburden, the heat of combustion can dissipate less easily into the subsurface.

In most cases, a balance between the surface and subsurface situations will be maintained. The result is a subsurface fire that spreads along the outcrop strike direction. It has been stated that the fire spreads towards the point from which the oxygen is entering (Banerjee, 1985). Subsurface combustion relatively slow compared to surface combustion. For this reason, the subsurface type of fires will burn for the longer time.
6.7 HAZARDS DUE TO FIRES IN THE RANIGANJ COALBELT

The environmental effects of the coal mine fires can also be felt at both local and global levels. Noxious gases often affect the immediate surroundings of an active subsurface coal fires. As well as being unpleasant, this pollution especially that caused by carbon monoxide, can have fatal consequences. The general degradation of the land results as plants in the area are killed by the heat or are poisoned by the gases. The fire-affected villages face another major problem - that is land subsidence. Mining induced subsidence, on the other hand, cause horizontal and vertical movements in the land surface and open cracks and fissures that serve as inlets for oxygen, which in turn aggravates the problem of coal fires. In case of underground fire-related subsidence, the land does not recover to its pre-existing condition even if careful rehabilitation measures are undertaken. Thus it is lost forever to humankind as a resource. In the Raniganj region, such fires and subsidence have significantly affected agricultural activity in a negative way. Thus both the human and natural resources of the region are endangered.

Heating due to subsurface fires has caused drying of the soil. The dryness of the soil has increased its reflectance and also rendered it locally unfit to support vegetation over the subsurface fire areas. Thus, the thermally anomalous regions are notably barren. Dry and barren higher temperature areas can be easily identified on satellite sensor images and these may serve as indicators of the presence of subsurface fires (Prakash and Gupta, 1998).

Dry barren lands are not cultivable. An old mining area like the Raniganj coalbelt is now endangered in many ways. Subsurface fires in this region have grossly affected both the lives of human beings and their living environment. In the old colliery areas, underground voids of unknown locations and depths, subsidence, and unauthorized coal mining are the main responsible factors leading to subsurface fires.

The major hazards related to coal fires in the RCB are as follows:

(1) They consume the precious, non-renewable natural energy resources.
(2) Fires hinder economic exploitation of coal.
(3) Fires pose danger to man and machine in the mines.
(4) Fires threaten to many surface features like.
   (a) Residential areas – houses are either damaged or are threatened which are required to be vacant for the safety of the inhabitants.
(b) *Jhor* (tributaries of River Damodar) beds which may collapse, leading to flooding of underground mine workings.

(c) Railway stations/sidings around Raniganj is threatened by Amritnagar fire.

(d) Roads/National Highways is threatened by Jay Kay Nagar fire.

(5) Fires lead to environmental pollution due to emission of huge quantities of smoke and toxic gases into the atmosphere, mainly the oxides of carbon, sulphur and nitrogen. The level of air pollution is more surrounding one kilometres.

(6) Fires along with the gaseous emissions cause general warming in the local climate.

(7) Fires cause water pollution. Increased temperature of water near fire areas cause increase in total soluble salts and decrease in the content of dissolved oxygen making the water unsuitable for agriculture and fishery.

(8) Fires cause damage to the soil by lowering the water table, causing upward migration of salts and sterilisation of soils because of high temperatures.

(9) Consumption of coal and disintegration of adjacent material due to fire leads to land subsidence and degradation of land resource. and

(10) Safety and health risks for the miners and local population (Rosema et al., 1999).

The social and economic impact of these hazards is high. The coal fire problem can not be solved easily. Much attention should be paid to coal fire detection, prevention and fighting techniques.

### 6.8 ENVIRONMENT PROBLEMS CAUSES BY MINE FIRES

Coal fires cause considerable economic and environmental problems. The environmental effects of the fires are also serious and can be felt at both the local and global levels. The immediate surroundings of an active coal fire are often affected by noxious gases such as sulphur dioxide, nitrogen oxides and carbon monoxide (Bhattacharya and Reddy, 1994). As well as being unpleasant, this pollution, especially that caused by carbon monoxide, can have fatal consequences (Slavecki, 1964). Smoke and wind-blown ash can also plague the areas around fires. Added to this, there is the general degradation of the land as plants in the area are killed by the heat or are poisoned by the gases. In some areas this may encourage desertification.

Widespread cracking and slumping of the land surface is another associated problem. As the burned coal turns to ash, often the rock overburden can no longer be supported and
deep cracks open up. Eventually, the surface collapses, causing extensive damage to infrastructure such as buildings, roads, railways, etc.

Coal fires are a major source of pollution both locally and globally. Coal fires also emit some noxious gases such as $\text{SO}_2$, $\text{H}_2\text{S}$, $\text{NO}$, $\text{CO}$, etc. Other problems caused by coal fires include: 1) Blockage and devaluation of coal resources in the seam below, above, and around the coal fires; 2) Damage to coal mining infrastructures; 3) Land subsidence and land slides are also the consequences of coal fires; 4) Parching the vegetation of the surface and damage to the ecological system; 5) Risk to surface structures such as railway lines, roads, oil pipelines etc.; and 6) Hazardous working conditions for coal miners.

Field investigations revealed that the areas lying directly above subsurface coal fire are almost barren due to prevailing dry condition of soil and cracks. The carbon monoxide ($\text{CO}$) and other toxic gases, coming from cracks of the surface, develop hazardous conditions in environment. Due to subsurface fires the land surface temperature increases and this leads to increase of the temperature of the local area.

Another associated problem is widespread cracking and slumping of land surface. As the burned coal turns into ash, often the rock overburden can no longer be supported and deep cracks open up. Eventually, the surface collapses causing extensive damage to agricultural land, buildings, transport network etc.

Occurrence of natural vegetation at any place is the result of interaction of all favorable environmental components. Temperature, moisture and air play their profound roles for germination and sustainability of a particular type of vegetation in addition to other physical parameters. The surface and subsurface coal fires with or without smoke plumes have their direct impact on the required amount of availability of such components. In addition, the flying ash and smoke plumes cover the entire vegetative communities of the layer on the surface of green leaves. As a result of such conditions the green vegetation can not prepare the required quantity of food for its sustenance. Subsequently growth is retarded and many plant species start towards mortality.

It was also noticed during the field survey that the underground water discharged by the mines was poor in quality in many ways. In respect of colour, which has a direct impact
on the vegetation community, it was especially poor. The following table shows that water quality is not suitable for most plant species.

As the burned coal turns into ash, huge voids are created underground and from the nearby water layer the water passes through the cracks to lower levels. With other reasons like less rainfall, extensive urbanization and hence increase water demand – it has a strong impact on ground water table. As the temperature of the surface increase over the subsurface coalfires, the microorganisms, which live in the soil and recycle the biodegradable matters may extinct. And in the case of nitro fixing bacteria, may cause degradation of soil quality and turn towards desertification. The effects of coal-burning waste products on air, rain, surface water, plants, soil, and aquatic organisms

6.8.1 Adverse effects of mine fires

In India, in coal producing regions like Raniganj and Jharia, coalfires are quite common. In the present study, we have studied only the Raniganj region where some of them have been burning for several years now. In places the fires are on the surface and are visible, whereas in other they are subsurface in-seam fires and can not be detected quite easily. The fires create severe environmental hazards such as:

- Wastage of valuable non-renewable energy resources of the country.
- Air pollution, and warming of local climate.
- Destruction of agriculture
- Desiccation of natural vegetation.
- Degradation of land, and land subsidence.
- Changes and disruption in natural drainage and surface water regime
- Changes in settlement pattern, and
- Endanger human security in a densely built up and highly urbanized region.

**Wastage of valuable non-renewable energy resources of the country:** Economic losses, loss of mining productivity and increasing safety risk as a result of coalfires are major factors which decrease substantially coal output.

**Air pollution, lowering of water table and warming of local climate:** Air pollution The production of CO$_2$ by these coalfires is estimated to be 2-3 per cent of the total CO$_2$
Cracked and burnt surface

Subsidence due to surface fire - Amritnagar OCP
PLATE - 4

Subsidence due to illegal mining - Lalbandh

Subsidence at Parasia OCP
production of the world and as such do contribute significantly to the Greenhouse effect. Other harmful gases (SO₂, NO, CO) resulting from coalfires are produced as well.

**Destruction of agriculture:** This is caused by outflow and spreading of infertile loose soils from waste dumps to fertile land and also spreading of solid waste disposal from settling ponds of washeries to agricultural land. Finally use of polluted water contaminated with very high dose of particles (fine coal) and toxic trace metals resulting in infertility of land.

Continuous degradation of land quality is detrimental to agricultural economy resulting in socio-economic disparity and also causing more people to look for their livelihood in industry oriented jobs. But jobs being less, people indulge themselves in antisocial work and may become nuisance to society.

**Desiccation of natural vegetation:** Which is caused by (i) meeting the requirement of fresh land for mining and related activities by removing forest, (ii) as a consequence of increase in mining, new settlement centres and associated communication lines come up for which fresh land is develop by cutting forest, (iii) burning of underground in-seam coal – fire results in charring of vegetation in the area, (iv) release of dust, smoke and obnoxious gases from mines, washeries, thermal plants and coke plants result in subsequent degeneration and may lead to ultimate loss of vegetation.

Loss of vegetation cover may drastically change the climatic conditions like rainfall, temperature, humidity and thus making the area derelict of flora and fauna and may even result in the death of wild animals and birds living in that forest. This also causes soil erosion and land instability etc.

**Degradation of land and land subsidence:** Which is caused by (i) goafing or subsidence as a result of underground mining, (ii) voids left after removal of over-burden and coal in opencast mining area, (iii) formation of parallel ridges or mounds by irregular dumping of mined materials, (iv) coal dump fire and near surface in-seam fire.

Further as degraded land can not be used for any practical purposes by the human being, this results in degradation of quality of life and general ecology of the region.
Settlement and Colliery - Khaerbadi

Abandoned Village due to subsurface coal fires - Parasia OCP
Water table lowering due to subsidence - Nimcha village

Sand blanketing, prevent to surface fires
Changes and disruption in natural drainage and surface water regime: Which is caused by (i) mining operation, dumping of coal and wastes, solid waste disposals, construction of communication network like road/railway/rope ways and installation of heavy industry and colonies, (ii) excavation of sand from river beds and tanks.

The main effects are: (i) Disappearance of lower order streams, (ii) shallowing of river bed/tank/pond resulting in lowering of water carrying and storing capacity, (iii) flooding and water logging of areas during rainy season. These all result in unhealthy environment.

Changes in settlement pattern: With the requirement of more land for increasing mining and related industry, pre-existing settlements are compelled to be abandoned or shifted to safer region. Cultivable land, forest and pasture land are also often lost due to such operations which necessitate abandoning or shifting of villages and settlements. On the other hand new colonies, roads, railways, ropeways, factories etc. have developed in the region.

The following impacts are: (a) change in Demographic pattern and landscape of a region (b) change in geo-environmental condition of landscape (c) influx of labourers required to man mining and other related industry – causes social imbalance resulting in social unrest.

Endanger human security in a densely built up and highly urbanized region: In the Raniganj region, subsurface mine fires have made significant numbers of villagers vulnerable to the hazard. Surface fires (in coal dumps, mainly) are often visible and easily located. Subsurface fires, on the other hand, are more difficult to locate as they are not visible or felt immediately. These fires are also of a more permanent nature and offer far greater potential risk than surface fires. Such risks may be both direct and indirect to human communities.

6.9 HUMAN SECURITY
Ensuring or increasing the security of humans from environmental hazards has been a significant agenda for sustainable development practitioners in recent years. Hazards that are visible immediately no doubt pose considerable risks to human security. However, some hazards are not visible and are of a more or less semi-permanent or permanent
nature such as subsurface fires in coal-mining regions. These fires have tremendous risk potential in terms of endangering human security both directly and indirectly.

This chapter draws the links between subsurface fire hazard and human security. For this purpose, we have calculated the populations of the coal fire affected villages from latest available census data. Their occupational characteristics have been outlined to identify the areas more vulnerable to fire risks. Finally, we have provided some recommendations for improving human security in this fire-prone old coal-mining region of India. The objective is to identify the affected or more vulnerable human populations. For this, we have combined the use of Landsat thermal data with available census data on village populations. As the buried hot features are identified and located in this densely populated mining-urban belt, we attempt to make a risk assessment for this oldest mining region of India.

6.9.1 Human security and fire hazard

The rate and scale of socio-economic, technological and environmental changes in today’s world are without precedent. The security of human populations is increasingly being influenced by these large-scale changes that include, amongst others, climate change, stratospheric ozone depletion, loss of biodiversity, emergence of genetic resistance, the increasing gap between rich and poor, widespread air pollution, worldwide urbanization, and mass migration of people due to war or natural disasters. The earth’s environment and habitability are now, as never before, affected by human activities which are inequitable, unsustainable and probably unstable (IHDP, 2001). Thus, human security is affected in many ways making populations more vulnerable to what they perceive as hazardous to their well-being.

In the Raniganj region, subsurface mine fires have made significant numbers of villagers vulnerable to the hazard (figure-6.7). Surface fires (in coal dumps, mainly) are often visible and easily located. Subsurface fires, on the other hand, are more difficult to locate as they are not visible or felt immediately. These fires are also of a more permanent nature and offer far greater potential risk than surface fires. Such risks may be both direct and indirect to human communities.
FIGURE - 6.7

SOME MINING VILLAGES
THE RANIGANJ COALBELT

RANIGANJ
BARABANI
KHERBAD
DHARAPUR
MUCHIDI
SALANPUR
KULTI
ASANSOL
HIRAPUR
BANKURA
PURULIA

0 5 10 km.

86°150'E 87°10'E 87°10'E
6.9.2 Locating the vulnerable settlements

The vulnerable villages were identified on the basis of their higher surface temperature than the average temperature (40°C) of the RCB, and were detected from satellite data (figure-6.8 and 6.9). At the time of Ground Truth Survey, they were physically inspected to verify the origin of the heat. In the next step, textual data (from census) were combined to calculate the population totals affected by such fires. Also, the field surveys provided important insights into the chain effect of fires on the local ecology and environment.

Most of the villages vulnerable to subsurface fires are located in the middle part of the Raniganj coalbelt closer to the Grand Trunk Road and the main railway line of Eastern Railways. In the first step of the study forty villages were identified. Some of these fire-affected villages are:

- Khairul, Sripur, Satpukuria, Kankhaya, Joba, Ninga, Tapasi, Jemari, East Nimcha, Sonachora, Jambad, Mahira, Harispur, Amritnagar, Damagoria, RaghunathChak, Kunustoria, Fatakduar, Ballavpur, Beniyadidanga, Kashinathpur, Banshra, Khas-Kajoara, Ratibati, Chota Dhemo, Sodepur, Nimcha, Parasia, Dhandardihi, Kuldanga, Jitpur, Shitalpur, Sanktoria, Dishergarh, Bilpahari, Khottadih, Binodbandh, Sanbant, Chinakuri, Shawrarpur, Mukundapur, Siduli etc. (figure-6.10).

The coalfire phenomena may render a mining area unfit for human habitation and make the commercial exploitation of coal nearly impossible. Fire affected villages are potentially risky for humans because voids occur under the ground, which may collapse and endanger human lives. Fire-related problems of the environment do not only affect the land, but also affect the inhabitants of that region. (figure - 6.11, 6.12).

6.9.3 Fire-affected villages

Subsurface fires have endangered more than 15 villages along with their physical and economic resources. The total population of these vulnerable villages in the Raniganj Coal belt is about 44,000. Among them 26 per cent is working population. These people are engaged in many other occupations such as cultivation, livestock, forestry, fishing and quarrying, manufacturing and processing in household industries, construction, trade and commerce, transport, storage and communication etc. besides coal mining. Most of the workers are engaged in the primary sector activities like mining and quarrying. Mining, however, is the
Surface Temperature Anomalies over the Coalesces: The Raniganj Coalbelt
FIGURE - 6.9

Surface Temperature Anomalies over the Coalesces: The Raniganj Coalbelt

- Coal seams
Some Fire Affected Villages
The Raniganj Coalbelt, India
dominant occupation of the region: about 60 per cent of the workers are employed in mining activities in RCB making it the second largest coal producing area in India.

FIGURE 6.11: Void-subsidence-coalfire Nexus

The Raniganj coalbelt

Underground Coal Mining

Legal / Illegal Mining

Void

Subsurface Coalfire

Subsidence
Most of the working age group people in the village of Ninga are engaged in mining activities. Mining is the main occupation also of other fire-affected villages such as Sripur, Satpukuria, Joba, Jemari, Tapasi, Kankhaya, Sonachora, Mahira, Harishpur. The Remote Sensing data (Landsat TM-6, 1997) recorded high temperatures (35°–48°C) in these areas. The surrounding areas show comparatively lower temperatures (28°–35°C).

The existing landuse has been analyzed taking into account the developed land in each category. In a coal mining region, the landuse pattern responds first to economic changes;
even underground mining is liable to change the surface landuse through transport linkages, warehouses, subsided areas and dumping grounds for trilling and removed overburden. The vast cultivated tracts often become interspersed with abundant quarry depressions, large heaps of ash and soils, overburdens, mine head gears and the usual characteristic components of the working collieries. A recent survey has revealed that cultivable land in Jamuria no.1, Asansol, and Kulti blocks of the Raniganj coalbelt has decreased by 97 per cent, 17.44 per cent, 3.2 per cent respectively between 1978-'93.

Besides extensive urbanization, a major part of this land is lying fallow with large number of surface cracks, caves in and abandoned mine openings. According to RoyChowdhury and Roy (1989) different types of anthropogenic landforms such as mine pits, spoil tips and subsided lands have developed on a flat to gently rolling pediplain area of the RCB.

Mining operations have already made Raniganj, Bahula, Jamuria, Uhsagram and number of villages and bustees ‘unsafe’ due to the existence of goafs underneath as per DGMS notification. In addition, several ‘fire zones’ are known to exist in this region as noted during the survey of Amritnagar, and Jay Kay Nagar areas. The changes of landuse pattern as well as in the environment are clearly due to opencast and underground mining. In future, a marked increase of mining activity is likely to further aggravate the environmental deterioration (Lahiri-Dutt, 1995).

The villagers suffer from surface and subsurface fires in the case of land subsidence, where land is the main occupational source. The loss of productive land affects more or less every sector of occupation. The village workers contribute to the national economy in many ways, and a decline in agriculture means erosion of the alternative occupation base in this mining region. The following table-6.3 shows the distribution of occupation groups to the total population of the fire-affected villages of RCB.
TABLE 6.3: Occupational categories of populations, the Raniganj coalbelt, 1991

<table>
<thead>
<tr>
<th>Different kinds of occupation in RCB</th>
<th>Percentage in respect to total working population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cultivators</td>
<td>7.60</td>
</tr>
<tr>
<td>2. Agricultural labourers</td>
<td>11.90</td>
</tr>
<tr>
<td>3. Livestock forestry fishing etc.</td>
<td>0.78</td>
</tr>
<tr>
<td>and allied activities workers</td>
<td></td>
</tr>
<tr>
<td>4. Mining and quarrying workers</td>
<td>59.58</td>
</tr>
<tr>
<td>5. Manufacturing and processing in</td>
<td></td>
</tr>
<tr>
<td>household industry worker</td>
<td>1.60</td>
</tr>
<tr>
<td>6. Manufacturing and processing in</td>
<td></td>
</tr>
<tr>
<td>other than household industry</td>
<td>2.87</td>
</tr>
<tr>
<td>worker</td>
<td></td>
</tr>
<tr>
<td>7. Construction worker</td>
<td>10.08</td>
</tr>
<tr>
<td>8. Trade and commerce workers</td>
<td>6.92</td>
</tr>
<tr>
<td>9. Trans storage and communication</td>
<td>1.85</td>
</tr>
<tr>
<td>workers</td>
<td></td>
</tr>
<tr>
<td>10. Other services workers</td>
<td>5.63</td>
</tr>
</tbody>
</table>

6.10 RISK ASSESSMENT

Traditional risk assessment methods use a qualitative matrix for classifying risk levels depending on: (i) the probability of occurrence, and (ii) the relative severity of an adverse effect (Basu, 1998). In general such methods use three risk levels low, medium and high. The score for probability of effect is based on the percentage of total population that is likely to be exposed to a hazard. The score for severity effect reflects the severity of consequences that in the investigator's judgment are most likely to occur based mainly on prior laboratory and final field assessments. The total score assigned to the environmental risk is the sum of the scores for likelihood of effect and severity of effect.

The summary table of Comparative Risk Assessment of the mining activities in the Raniganj coalfield area has been presented in the table-6.4.

TABLE 6.4: Summary table of risk assessment

<table>
<thead>
<tr>
<th>Problem area</th>
<th>Total mining area (sq. km.)</th>
<th>Total affected area (sq. km.)</th>
<th>% of area affected</th>
<th>Total exposed pop.</th>
<th>Actual pop. affected</th>
<th>% of pop. affected</th>
<th>Severity score</th>
<th>Exposure score</th>
<th>Final score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidence</td>
<td>256</td>
<td>50</td>
<td>19.5</td>
<td>1781164</td>
<td>665996</td>
<td>37.39</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>degradation</td>
<td>256</td>
<td>2</td>
<td>8</td>
<td>1781164</td>
<td>156470</td>
<td>8.78</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Depletion</td>
<td></td>
<td>12.45</td>
<td>5</td>
<td>1781164</td>
<td>156470</td>
<td>8.78</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>of ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water table</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine fire</td>
<td>256</td>
<td>6.37</td>
<td>2.5</td>
<td>1781164</td>
<td>174055</td>
<td>9.77</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>
The above table shows that the problem of subsidence in the coal mining area is of great importance. The mining activity here is responsible for putting human lives at risk, and for making properties and the economic utilization of land as also social viability of the region vulnerable. This problem is closely followed by the problem of ground water depletion. Mine fire is another risk that is assessed to be of significance as it is liable to endanger human life and property.

Solid fuels (that is, coal) burn slowly at first with a steady rise of temperature when its vapours are distilled. At this state, with fresh onrush of air, there may be sudden bursting out of flames all over, resulting in a fast spread of fire known as flashover stage. Delayed action in combating any fire makes it very difficult to deal with.

An underground fire is much more hazardous to deal with than those are at the surface. An immediate danger arises from the evolution of toxic fumes, particularly from CO, affecting even far off places in the return end of the mine.