Much of India’s energy needs are met by coal. According to the Coal India Limited (CIL), around 53% of India’s energy is met by coal and about 70% electricity is coal based. Coal is thus, a major source of energy and a significant player in the country’s economic growth.

Coal, or any rock, exists naturally in large and wide seams. These seams may be 3 to 4 kilometres wide. Hence, it is not possible to extract it directly. It needs to be broken or fragmented into small pieces. There are several means to fragment any rock. Of these methods, blasting occupies a primary position, chiefly due to its cost-effectiveness.

Blasting occurs by the controlled use of explosives. The principal factors that influence blasting results are the properties of the explosives being used, their distribution and initiation sequence in the blast, the overall blasting geometry, and rock structure and other properties.

Despite the use of the best quality explosives and most modern blasting technology and equipment, it is a fact that only 15-30% energy released is utilised for actual rock fragmentation. Rest of the energy is used up in creating unwanted and possibly harmful environmental problems such as (1) Ground Vibration, (2) Noise and Air over Pressure, (3) Gas and Fumes, (4) Dust and (5) Flyrock.

Ground Vibration: The blasting in any coal mining area is short-term, usually taking place for one or two hours in the afternoon. However, it is known to cause a lot of annoyance to the people living in the peripheries of the area.

When an explosive charge is detonated inside a blasthole, the explosive is converted into a gas at high temperature and pressure. A wave of high amplitude travels into the rock and crushes it to roughly a radius which is twice the original blasthole. In certain rock types, a cavity having four times the original volume of the original hole is formed around the charge. As a consequence of blasting, a large of number of radial cracks start developing. However, only a few cracks become dominant and the rest do not grow much. The expanding gases move the rock upward and outward.

Beyond the perimeter of the damage rock zone, the pulses are called elastic waves or seismic waves. Such waves do not cause any further damage to the rock as the stress generated is within the elastic limits of the rock. These waves travel in all directions leading to ground vibration.

In India, the Directorate General of Mines Safety (DGMS) has prescribed permissible limits for different kind of structures (Table 1).

Noise and Air Overpressure: Noise is the sound of the gasses venting from the blast area, and rocks collapsing into the muck pile. Noise is part of the pressure wave so it occurs at the same time as overpressure. It may be augmented by the rattling of windows, etc. which can be caused by the overpressure or by the structure shaking in response to the ground vibration event. Equipment is now available to determine whether noise caused by the structural response of a building is the result of ground vibration or air overpressure (the air blast). This needs to be identified if the effects are to be minimized.

Gas and Fumes: Gas and fumes generated during the detonation of explosives are another major environmental hazard. Ideally, when an explosive is detonated, only Carbon Dioxide and Nitrogen should be emitted. However, in practical mining activities, Carbon Monoxide,

<table>
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<th>Table 1. DGMS Prescribed Permissible Limits for Ground Vibrations</th>
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<tbody>
<tr>
<td>Type of Structure</td>
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<tr>
<td>A. Buildings/structures not belonging to the user</td>
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<tr>
<td>1. Domestic houses/structures (Kuchcha, brick &amp; cement)</td>
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<tr>
<td>2. Industrial buildings</td>
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<tr>
<td>3. Objects of historical importance and sensitive structures</td>
</tr>
<tr>
<td>B. Buildings belonging to owner with limited span of life</td>
</tr>
<tr>
<td>1. Domestic houses/structures</td>
</tr>
<tr>
<td>2. Industrial buildings</td>
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Nitrogen Dioxide and Nitric Oxide are also released. In underground mines, mine ventilation ensures that these gases are ventilated out. However, opencast mining, which is mining done at the surface, relies upon natural ventilation for the release of such gases.

During detonation of explosives, there exist two possibilities, one, the trapping of the gases in the muckpile or alternatively, their release into the atmosphere. Any process that results in a decrease in temperature during detonation leads to gas and fume generation. If these gases are trapped in the muckpile, they can cause several health problems, which are at times, quite severe.

Carbon Monoxide is a highly toxic and hazardous gas. It can cause illness and death as a result of asphyxiation, i.e. lack of oxygen. In fact, this gas on mixing with haemoglobin forms a complex carboxyhaemoglobin, which is 250 times more stable than the complex that oxygen forms with haemoglobin, i.e. oxyhaemoglobin. As a result, it hampers the transport of oxygen in our body.

Nitrogen Dioxide is a brown gas possessing pungent odour. It is a highly corrosive gas. It can cause burns to the skin, eyes and lungs. Higher exposure levels result in headache, nausea, shortness of breath and vomiting. Nitric oxide is an odourless gas. It can cause redness of the eye, coughing, and abdominal pain.

**Dust:** Coal dust is a primary problem of any mining area, especially an opencast one. This comprises of Suspended particulate matter (SPM) and Respiratory particulate matter (RPM). Dust generation and its dispersion have been found to be of major concern in air quality modelling of any mining area, especially an opencast mining area. Dust generation is caused from various mining activities apart from blasting. These include handling, processing, storage and transportation of coal. Dust is so instantaneous that its estimation is very difficult.

In huge amounts the dust is a cause for several health and safety hazards such as damage of lung tissues, black lung disease, poor visibility, failure of mining equipment, increased maintenance cost etc. which ultimately lowers the productivity of the miners as well as the machinery.

**Flyrock:** Flyrock usually refers to the rock impelled beyond the blasting area. It is the most hazardous impact of blasting as it may lead to severe injuries and even death instantaneously. Hence, flyrock is not only a cause of concern for the environment, it is more so for the health of the miners and that of the people living in the adjoining regions. A study of Indian coal mining accidents by Singh et al in 1989 indicated that more than 40% fatal and 20% serious accidents resulting from blasting were caused by Flyrock.

**Mitigation**

Several measures are taken to mitigate the fall-outs of blasting. For instance, to reduce ground vibration, premature release of explosive energy is avoided by measures such as carefully designing blast delay and hole spacing, avoiding excessive sub-drilling and using low energy detonating cords – Nonel.

Similarly, to control flyrock, if blasting is being done within 200 m of any structure, then muffle blasting should be done, a suitable hole diameter should be selected, heavy loading in the blast hole should be avoided, and all loose pieces of rock from the blasting site should be cleared before charging.

One of the most common ways to reduce dust generation is spraying of water before explosion. In addition, some plant species such as Anthocephalus cadamba, Butea monosperma and Spathodea campanulata can be grown in the mining area to lessen the impact of dust on human beings.

To reduce noise, experts suggest the use of 150 mm thick cover of sand or drill cuttings a dn use of electric detonators. It is also suggested that blasting should be carried out in mid-day, and should be avoided in cloudy weather and while strong winds are blowing towards the residences.

To minimize any hazardous exposure from the gases produced by outdoor blasting, it is essential to excavate blasted material as soon as possible after blasting. Excavation should start as close to the underground enclosed space as possible in order to provide for venting of any entrapped gases. Possible problem areas can be monitored to determine if any gases have migrated from the blasting operation, for example, by drilling monitoring holes between the blasting operation and inhabited buildings.

Blasting remains the most economic way of fragmenting of rocks. However, the harmful impacts it creates for the environment must be carefully understood and tackled. Geology and other factors of a region must be understood before carrying out blasting in a region to avoid hazards.

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