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Disaster due to coal mines explosions

This paper deals with an account of occurrences and causes behind disaster due to explosions in Indian mines. Principal causes and mechanisms of explosion, and precautions against explosion are also discussed. The review indicates that although frequency of occurrence of explosion induced disasters have reduced over the years in coal mines of India, there is a need of implementation of modern technologies such as environmental tele-monitoring system in fire prone mines in general, and in degree II/III gassy mines in particular, to arrive at the zero-disaster regime. There is a need for an additional categorization of gassiness of seam such as degree IV gassy seam for the seam where rate of gas emissions is more than 20 m^3 per tonne of coal raised. Arrangement for methane drainage or coal seam degasification or coal bed methane recovery should be given top priority on degree III and proposed degree IV mines.

Introduction

Disaster in mines is defined as an accident where 10 or more fatalities take place. In coal mines, disasters occur due to explosion, fire, emission of toxic and combustible gases, inundation, roof fall etc. In the history of mine disasters, firedamp explosion has been the main cause in many of the cases. Among the disasters in coal mines, 42% were caused by firedamp explosions, leading to 41% of the total casualties (Singh et al., 2007). This paper gives an account of occurrences and causes of disaster due to explosions in Indian coal mines, principal causes of it, and precautions to be taken to guard against it.

Disaster due to explosion in indian mines

Out of 34 cases of explosions that have been recorded in Indian coal mines from 1901 to till date, 23 times (2/3rd) this has resulted in disaster. Explosions that resulted in disaster are summarized in Table 1.

It is revealed from the Table 1 that firedamp explosions are mainly responsible for such disaster.

Fig.1 depicts that prior to independence disaster due to explosion has steadily increased along with the rise of coal production. After independence there was huge need of coal mainly for power and steel projects that begun the industrialization of the Indian economy. However during this period of pre-nationalization of Indian coal mines fatalities due to explosion increased remarkably because there was less importance on safety mainly due to two reasons viz., there was no well framed legislation and most of the mines were run by private owners. After nationalization of Indian coal mines fatalities due to explosion led disaster has steadily gone down except the recent one in Bhatdih colliery, BCCL in 2006.

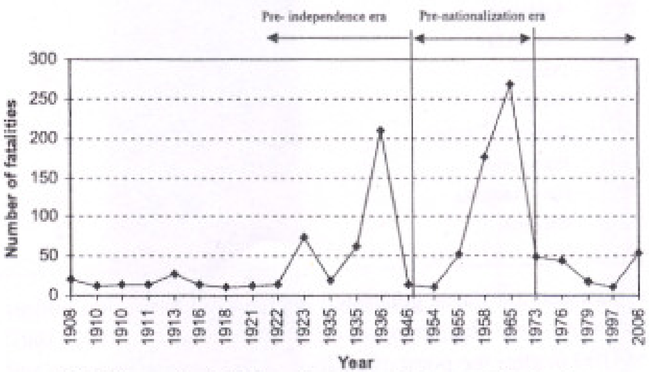

Fig.1 Year-wise fatalities due to explosion caused disaster

Mechanism and causes of mine explosions

Explosions are sudden combustion processes of great intensity which are accompanied by release of large quantities of heat energy and in which the original gas or solid coal substance is converted instantaneously into gaseous products. Firedamp accumulations are most likely to be found near the face and return airways. Therefore purely firedamp explosion occur on those places only. Firedamp explosion pressure varies from 700 to 1000 kPa. Naked flames, use of damaged safety lamps and their improper handling, electric sparks, mine fires, friction (between metal and metal, metal and rock or rock and rock), improper explosives and blasting techniques and lack of proper ventilation are the principal causes of firedamp explosions. For a coal dust explosion to take place in mines, two conditions must be fulfilled. The dust must be present as a thick cloud and there must be a source of ignition like naked flames, friction, and electric sparks, firedamp explosion etc. The exploding gas from firedamp explosion creates shock waves that disperse coal dust into

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TABLE 1: CHRONOLOGY OF DISASTER DUE TO EXPLOSIONS IN INDIAN MINES (KEJRIWAL, 2002; DGMS, 2004)

	Mine	Degree of gassiness	Number of fatalities	Reason	Date
1	Nadir Khan (Khost Colliery)	-	20	Firedamp explosion	16.06.1908
2	Dishergarh	-	11	Firedamp explosion	07.02.1910
3	Namdang	-	14	Firedamp explosion	26.11.1910
4	Kendawadih	-	14	Firedamp explosion	09.11.1911
5	Chowrasi	-	27	Firedamp explosion	22.10.1913
6	Dishergarh	-	14	Firedamp explosion	20.07.1916
7	Dishergarh	-	10	Firedamp explosion	18.11.1918
8	Amlabad	-	11	Firedamp explosion	28.02.1921
9	Khost Colliery	-	13	Firedamp explosion	09.03.1922
10	Parbelia	-	74	Firedamp explosion	04.01.1923
11	Bagdigi	-	19	Firedamp and coal dust explosion	29.06.1935
12	Kurhurbaree	-	62	Coal dust explosion	24.07.1935
13	Poidih	-	209	Firedamp explosion	18.12.1936
14	Begunia	-	13	Firedamp and coal dust explosion	19.03.1946
15	Damra	-	10	Firedamp explosion	14.03.1954
16	Amlabad	-	52	Firedamp explosion	05.02.1955
17	Chinakuri	-	176	Firedamp explosion	19.02.1958
18	Dhori	-	268	Coal-dust explosion	28.05.1965
19	Jeetpur	III	48	Explosion of gas/dust	18.03.1973
20	Sudamdih Shaft	III	43	Explosion of gas/dust	04.10.1976
21	Baragolai	III	16	Explosion of gas	22.01.1979
22	New Moghla	II	10	Firedamp explosion	03.03.1997
23	Bhatdih	III	54	Firedamp and coal dust explosion	06.09.2006

the air and the flame generated in firedamp explosion ignites the dust. Coal dust explosions propagate very slowly until 60-100 m after the point of ignition. The dynamic pressure and the flame speed increases with the distance from the ignition source. Even the weakest explosion has a flame speed of 30 m/s and a dynamic pressure of 1 kPa. In powerful explosions this can go up to 1000 m/s and 1700 kPa respectively. These coal dust explosions are often self-propagating and extremely violent, often affecting large sections of the mine or even the entire mine. However, in spite of coal dust explosions being more violent and extensive in its effect, firedamp explosion alone has been the major cause behind many disasters in mines as shown in Table 1.

Table 2 gives a summary of the disasters due to explosions from 1901 to till date in the descending order of fatalities.

Dealing with disaster

Each organization/mine authority has to keep a disaster handling procedures in place for emergencies. Procedure starts at the attendance cabin after information from worksite is received. As the information is received from attendance cabin, disaster management team swings into action and takes control of the situation from a control room set up for the purpose. Rescue and first aid teams of the colliery with their apparatus and accessories are mobilized. Locations of these teams are displayed prominently with duty chart. Mines Rescue Station and Directorate General of Mines Safety are informed as per severity of the situation. They are included in the disaster management team when the situation demands.

DISASTER MANAGEMENT COMMITTEE

Each area has a Disaster Management (DM) Committee headed by the general manager of the area, who is designated as the Director of the committee. He is the in-charge of all the disaster management activities in his area. In his absence, the deputy general manager takes his place. The Disaster Management Committee usually has the following members:

(i) Director - General Manager of the Area
(ii) Dy. Director - Dy. General Manager of the Area
(iii) Advisor - GM (Safety)
(iv) DDMS in-charge of the Area
(v) Superintendent of the Rescue Station
(vi) Area Safety Officer
(vii) Chief (HR) [Area Personnel Officer]
(viii) Chief Medical Officer
(ix) Chief Security Officer
(x) Senior Official of the largest trade union
(xi) Officer-in-charge of the local police station

TABLE 2: CAUSES BEHIND DISASTER DUE TO EXPLOSIONS IN INDIAN MINES (KEJRIWAL, 2002; DGMS, 1997)

Mine (persons killed, year)	Causes
Dhori, Bokaro & Ramgarh Ltd (268, 1965)	Up to the time of the explosion the mine was treated as non-gassy and therefore use of naked lights in mine was in practice. There was no mechanical ventilator, the air being circulated by natural ventilation only. There was an accumulation of firedamp within explosive limits and lack of proper ventilation was one of the contributory causes behind the disaster.
Poidih, Bengal Coal Co. Ltd. (209, 1936)	This was a violent explosion. Firedamp accumulated in the goaf of a depillaring district was expelled into the workings by a large roof fall in the goaf. Great violence of explosion indicates that it was not a single explosion, but a series of separate explosions. Source of ignition may be a defect in, or accidental damage to a safety lamp or flame of a match stick or other apparatus used for producing a light.
Chinakuri, Bengal Coal Co. (176, 1958)	Build up of inflammable gas took place in the mine from its natural make. Flame shooting out from the diesel loco inlet ignited the explosive mixture of methane and air. Outburst of methane was accompanied by certain quantity of small coal from the splinter seam and therefore coal dust explosion took place.
Parbelia, Bengal Coal Co. (74,1923)	Accident was caused by an explosion of coal dust due to a faultily placed shot which blew-through because of very little burden
Kurharbaree, Government of India (Dept. of Railways) (62, 1935)	Accident was due to ignition of coal dust by the flame from a blown-out shot of liquid oxygen explosive. The dust near the origin of the explosion was raised into the air by 3 shots which immediately preceded the blown out shot and the flame of the latter was projected into the cloud of fine dust so formed.
Bhatdih, BCCL (54, 2006)	The cause of accident is under investigation.
Amlabad, Bhowra-Kankanee Collieries Ltd. (52, 1955)	Miners were sent to work in the rise area where two galleries were driven. One gallery was driven up to a fault and the other gallery met a Jhama. The area was left unattended for two months. Owing to the absence of an attendant at the door behind an endless haulage, the door had been constantly kept open, thus allowing short-circuiting of intake air and adversely affecting the ventilation. This resulted in accumulation of firedamp in the rise area. The source of ignition may be spark from a non-flameproof 60 HP haulage.
Jeetpur, Indian Iron & Steel Co. Ltd. (48, 1973)	Fan was stopped from 14:10 hrs to 20:00 hrs when accident took place. Prior to it on the same day the fan was also stopped for another 3 hours i.e. from 10:30 hrs to 13:30 hrs due to cable laying operation. Gas was released due to stoppage of main mechanical ventilator. Electric spark produced from work on drill panel without cutting power supply was the probable source of ignition.
Sudamdih, Bharat Coking Coal Ltd. (43, 1976)	It occurred during Puja vacation. There was no proper check up of gas. Gas accumulation was high due to stoppage of auxiliary fans. Frictional heat generated by fall of roof rocks on metallic parts of the belt conveyor was possibly the source of ignition.
Chowrasi, Equitable Coal Co. (27, 1913)	This was the first occasion on which an outbreak of fire resulted in an explosion. The ignition source was a candle which the surveyor took with him to mark the centre line for extension of dip gallery. Two violent explosions and four small explosions with decreasing intensity took place within a span of 5 minutes.
Nadir Khan (Khost Colliery), North Western Railway, Beluchistan (20, 1908)	This was the first recorded mine explosion in India. The explosion was caused due to ignition of firedamp by a damaged flame safety. This was the time when unbonetted clanny flame safety lamps were in use in the mines.
Bagdigi, Anderson Wright & Co. (19, 1935)	Due to heavy rain on the day, a retaining wall protecting the mine from a large tank and a nallah collapsed. This resulted in a sudden inrush of water into the upper seam which was on fire. The water generated gases and caused reversal of air in the mine which in turn increased the concentration of inflammable gases in the mine. Naked lights, which were very much in use during that time, were the source of ignition.
Baragolai, North Eastern Coalfield (16, 1979)	There was accumulation of gas in a large cavity in the roof. This gas was pushed down by a further roof fall in the cavity. The source of ignition was an arc from the live electric cable which was cut by steel supports dislodged by roof fall. 4 persons died due to burn injuries and the rest 12 persons died due to asphyxiation.
Namdang, Assam Railways & Trading Co. (14, 1910)	A series of 4 explosions over a period of 10 hours took place due to ignition of inflammable gases by the fire in the old workings of the mine. Leaving aside the first explosion the remaining explosion occurred when a team went inside the mine to restore normal ventilation after the previous explosion.
Kendwadih, East India Coal Co. (14,1911)	Inflammable gas was produced as distillation product of a fire caused due to spontaneous heating that could not be controlled due to construction of inadequate stopping. The fire itself was the source of ignition of that explosion. This disaster prompted the need for formation of panels with substantial barrier between them so that active workings could be isolated from fires due to spontaneous heating in goaves.

Dishergarh, Equitable Coal Co. (14, 1916)	Inflammable gas from the goaf entered into the mine workings due to a roof fall in the goaf. Naked light, which was prohibited in depillaring district due to an earlier accident in the same mine previous year, was the source of ignition.
Khost Colliery, North Western Railway, Beluchistan (13, 1922)	The mine was mostly naturally ventilated. Inadequate ventilation by a hand-operated blowing fan with air-pipes in a longwall face was responsible for accumulation of inflammable gas. A defective safety lamp was the source of ignition.
Begunia, Oriental Coal Co. (13, 1946)	Auxiliary fans in rise galleries and stone drifts remained stopped for a considerable length of time due to presence of no miners in the area on a festival day. This resulted in accumulation of inflammable gas to a dangerous proportion. The source of ignition was either a defective safety lamp or smoking materials.
Dishergarh, Equitable Coal Co. (11, 1910)	Inflammable gas was found from time to time in the working seams, viz., Hatnol and Sanctoria seams of the mine. The disaster occurred in Hatnol seam where flame safety lamp was made mandatory. The most probable source of ignition was either a naked light carried by a miner or use of a defective safety lamp.
Amlabad, Eastern Coal Co. (11, 1921)	A firedamp explosion occurred in sinking of a pit. Blasting done before the explosion caused an accumulation of gas in the strata. Gases were gradually diluted by air to come within the explosive range. The explosive mixture was ignited by the lighted match-stick of one of the victims.
Dishergarh, Equitable Coal Co. (10, 1918)	The mine had a history of explosion that time, because of which use of flame safety lamps was made mandatory. In January 1918, at the request of Manager, Agent sanctioned the lighting of whole sanctoria seam with naked lights except advance drivages where safety lamps were to be used. Firedamp explosion occurred in a goaf where accumulated gas got ignited by naked lamps of some persons who were engaged in building of two ventilation stoppings near goaf.
Damra, Kaliphari Coal Co. (10, 1954)	The firedamp explosion occurred in a dip gallery while installing an electric pump over there. There was an accumulation of firedamp near the roof of the gallery that got ignited by persons smoking there.
New Moghla, Jammu & Kashmir Minerals Ltd. (10, 1997)	Explosion of inflammable gas occurred to a second degree gassy mine near the auxiliary fan. The deaths were due to burn injuries from explosion and due to asphyxiation of persons who got trapped in blind galleries inbye by a roof fall that was triggered by explosion.

This committee meets at the interval of two months at different mines in the area to discuss the respective task and to check the disaster management preparedness of the mine, where the meeting is being held.

Prevention of disaster due to explosions

FIREDAMP EXPLOSION

Many authors (Kejriwal, 2002; Ramlu, 1975; Ray et al, 2008) have suggested several precautions and safety measures to be taken to reduce the occurrence of firedamp explosion. Some are very well practiced (use of permitted explosives in blasting, use of well maintained safety lamps and adequate ventilation arrangements especially to areas where firedamp accumulation takes place and where normal ventilation fail to reach, use of intrinsically safe and flame-proof equipment, etc.) in mines whereas some (use of firedamp drainage system in degree III gassy mines, etc.) are not frequently adopted.

Past experiences indicate that degree II/III mines account for about the majority of the explosions. Table 1 indicates that since the coal mines of India are classified into different degree of gassiness in 1967 (Kejriwal, 2002; Ray et al, 2005), all the disasters have taken place either in degree II or III mines. Disasters prior to 1967 had also taken place in mines which would mostly fall in degree II or III mines had the degree of classification existed at that time. Examples include Amlabad, Chinakuri, Bagdigi, etc. For example, the rate of emission of CH_4 in Chinakuri is 20-35 m^3/t. Table 3 shows that

TABLE 3: UNDERGROUND WORKING MINES HAVING DIFFERENT DEGREE OF GASSY SEAM AS ON 2004

Owner	Degree I only	Degree II only	Degree III only	Degree I & II	Degree II & III	Total
BCCL	52	17	4	-	-	73
CCL	13	13	-	2	2	30
ECL	41	46	6	5	-	98
MCL	5	5	-	-	-	10
NEC	1	-	2	-	-	3
SECL	74	1	-	-	-	75
WCL	34	12	-	-	-	46
IISCO	1	-	2	-	-	3
J&K Min.	1	2	-	-	-	3
SCCL	50	2	-	-	-	52
TISCO	-	4	-	-	1	5
All India	272	102	14	7	3	398

as on 2004, India has about 126 degree II/III coal mines, nearly 1/3rd of the total coal mines. Therefore it is high time that in a gassy mine of degree II/III or degree III only, where it is not possible to effectively dilute the gas by normal ventilation, coal seam degasification or coalbed methane recovery procedure must be adopted. This will not only reduce the methane concentration in the face thereby ruling out the possibility of firedamp explosion, but also ensure methane utilization which otherwise would have been wasted (Thakur, 1996).

COAL DUST EXPLOSION

This can be prevented by following precautions (Mishra, 1986; Kejriwal, 2002; Ray et al, 2008):

Reducing the formation of coal dust

Various aspects of coal winning machine, drilling and blasting operation should be looked into to reduce the dust production. Sharper picks of coal winning machines, selected cutting speed of the machine to fit into suitable geo-mining conditions are some steps in this regard. Water should be used during drilling operation. In blasting water ampules may be used for stemming. Water stemming produces 50-70% less dust than in that of clay stemming. Shot holes should not be overcharged or undercharged. Pulsed infusion shot firing reduces the dust production. Selecting correct air velocities to prevent the raising of coal dust is also important.

Preventing the dust getting air-borne

Dust produced during cutting and drilling operation should be suppressed by wetting it with water. At the coal face to allay dust from mining machines arrangements for water spraying on the machine should be there. Water-sprays and mist at transfer and loading points effectively suppress the dust.

Rendering the dust non-inflammable

Coal dust is treated with water or stone dust to make it non-combustible. Water treatment is restricted to areas close to working faces generally up to a distance of 60 m from the face. Complete rock-dusting (dusting with incombustible material like limestone, gypsum) should be done on all open areas i.e. on sides, roof and floor of all mine workings except those within 10 m or less of all working faces. Stone dusting may not be adequate where coal dust production is high. Paste methods ($Cacl_2$ or common salt) can be effective if applied properly but they are very corrosive.

Reducing the hazard of coal dust ignition

Generally coal dust explosions are initiated by firedamp explosions. So measures taken against firedamp explosion are also important. Good ventilation practices, firedamp drainage system, intrinsically safe and flameproof enclosures for equipment are mandatory.

Stopping the propagation of an explosion

This can be achieved by installing explosion barriers. Explosion barriers are the last line of defence. Although they cannot eliminate the initial explosion, they can prevent the explosion from becoming larger and more violent, and can keep it from propagating into other areas of a mine.

Conclusions

Although post nationalization India has witnessed comparatively less disaster than earlier periods, the Indian coal mining industry should strive towards zero disaster regimes. Several precautions that need to be taken include increased vigilance during and after the periods of national holidays, proper design of explosion barriers, firedamp drainage system in degree III gassy mines, environmental tele-monitoring system in fire prone areas in general and degree II/III mines in particular, etc.

Present categorization puts all the mines where rate of gas emissions is more than 10 m^3 per tonne of coal raised in degree III caterogy. However there exists mine (e.g., Chinakuri, Amlabad and Bhatdih) where the rate of emission of gas is in the range of 20 – 35 m^3/t. Certainly, the occurrence of hazard due to gas in these mines are more than in mines where the gas emission marginally exceeds 10 m^3/t. Therefore, there is a need for categorization of degree IV gassy seam. If rate of gas emissions is more than 20 m^3 per tonne of coal raised it should be termed as Degree IV gassy seam. Arrangement for methane drainage or coal seam degasification or coal bed methane recovery should be given top priority in these mines.

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