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Anjan hill mine explosion: human failures resulting 14 fatalities

Energy is essential for development of a nation and its people. India is home to a large population and coal is dominant fuel for its growth. A sizeable coal reserve of the nation is at greater depth for which underground mining is feasible and economically viable technology. Underground coal mining is fraught with explosion hazard. Explosion in a mine is catastrophic and takes toll. Human factors are an important issue in coal mine accidents. In 2010, Anjan hill mine, an underground coal mine in Central India coalfields, experienced an explosion with multiple fatalities. Human factors analysis and classification system developed by Shappell and Weigman (2003) was used to identify human errors leading to the mishap. Human errors with higher level system deficiency were found to be causal factors. The study identified critical human errors which contributed explosion hazard in the coal mine.

Keywords: *Underground coal mine; explosion; human errors; human factor analysis and classification system (HFACS).*

1.0 Introduction

1.1 Background

India is home to 18% of the world population and it uses 6% of global primary energy mix (www.iea.org). The country is growing at a fast pace and energy is an important aspect of its phenomenal growth plan. India has modest crude oil reserve with a proven reserve of 5.7 billion barrel (www.eia.gov). Coal is the dominant fuel accounting for 55% of India’s energy consumption (www.coalindia.in) and it will remain central of India's energy mix for years to come (Prusty, B. K. and Patra, A. K., 2016). India's share of global coal production is 7.4% (www.bp.com). Coal resource of the nation is 306 billion tonnes out of which 30% reserve lies at a depth range of 300-600 m (www.cmpdi.in) for which underground mining is most suitable technology (Mandal, P. K. et. al., 2004) and industry may be forced to increase its future coal production by underground mining (Alam and Rai, 2016). As such future coal mining in India is by underground mining and in difficult underground conditions (Singh, A. K. et. al., 2009, Mangal, et. al. 2016).

Coal mining by underground technology is considered as one of the most hazardous industries (Mitchell et. al. 1998; Patterson and Shappell, 2010; Quanlong et. al. 2016). In comparison with other occupations underground coal miners are more exposed to hazards (Mahdevari et. al., 2014; Quanlong et. al. 2016). The inherent chemistry of coal makes it lethal (Prasad, 2003). Coal mining by underground method is the only industry where people have to work continuously in an explosive atmosphere (Pejic, L. M., et. al., 2013). Presence of CH_4 and coal dust generated during mining process makes underground environment liable to explosion.

1.2 Explosion in coal mines

First instance of colliery explosion was recorded nearly 300 years ago in Belgium (Belle, B. and Foulstone, A., 2015) and first occurrence of explosion in Indian coal mines dates back to 1899 in Khost coal mine (in Balochistan, now in Pakistan) killing 47 people (Naik and Basavraj, 2013). Explosion in underground coal mines have been a threat to miners since inception of coal mining and reasonable efforts have been made towards alleviation and prevention of the menace since early 19th century by framing and implementing suitable legislation (Huang, Q. and Honaker, R., 2016). Explosion remains one of the most serious challenges in coal mining industry (Zhang, B. et. al., 2014). Gas/coal dust explosion accounts for 90% of the fatalities in Chinese coal mines (Qifeng, N. et. al., 2012; Chunli, Y. et. al., 2014). 90 people lost their lives in 2010 in Raspadskaya coal mine in Russia in underground explosion (www.nytimes.com). Developed countries are also having the cases of explosion in their coal mines. The coal seam gas content in deeper regions are high due to multi-period geological processes (Liu, H. and Cheng, Y., 2015).

2.0 Human errors

Stephen Pheasant (1991) proposed a binary definition of human error as simply “an incorrect belief or an incorrect action” (p. 181) whereas James Reason has defined human error as the failure of planned actions to achieve the desired events without the intervention of unforeseeable events (Reason, 1997). Errors when judged based on the outcome of

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TABLE 1: DETAILS OF THE SEAMS

	Name of the seam	Seam thickness in meters	Seam gradient	Parting between seams in meters	Reserve in MT as on 01.04.2009
1.	0 seam	3.0 - 5.33	1 in 30	Cover 138	Exhausted
2.	Local seam	1.71 - 1.90	1 in 30	13.40 - 13.85	0.171
3.	No. 1 seam	1.10 - 1.75	1 in 26	54.28 - 64.80	0.924
4.	No. 3 seam	7.63 - 10.35	1 in 45	29.05 - 29.55	5.828

the event, only then the performer could realize that an error was committed (Rasmussen, 1982).

Rasmussen (1982) classified human behaviour into three categories: skill based, rule based and knowledge based. Skill based behaviours are generally automated and take place at unconscious level. Rule based behaviours are result of application of learned rules such as policies and procedures through decision making. Rule based error happens when an individual applies the wrong rule or misapplies the right rule (Patterson, J., 2009). Knowledge based error occurs when there is high mental demand which may cause problem in unusual emergency situations and may be outcome of the lack of training or information.

Reason (1990; 1997) explains that errors and violations committed by an individual or individuals lead to adverse outcome/event. He termed them 'unsafe acts'. He further classified errors into slips/lapses and mistakes. Slips usually occur in highly automated task or situation and are the results of failure of attention, recognition, memory or selection. Mistake happens when a plan is executed as intended but the plan was not adequate to take stock of the situation. Mistakes arise when there are failure of intention. Violations are the willful disregards of established rules and set regulations (Patterson, J., 2009). These can be either routine or exceptional. Habitual bending of rules overlooked by management are routine violations. Isolated departures from the rules and regulations are exceptional violations and these are sporadic and very difficult to predict. Exceptional violations may or may not be condoned by the management.

Shappell and Wiegmann (2000; 2001) developed human factors and classification system (HFACS). HFACS is a four level framework and attributes of failures are unsafe acts, preconditions for unsafe acts, unsafe supervision and organizational influences. For mining industry outside factors also considered to cause accidents (Patterson, J., 2009).

3.0 Anjan hill mine

3.1 INTRODUCTION

Chirimiri collierry was started in 1928 with one opencast mine and another underground mine at the south east extremity of Chirimiri in Central India coalfields. The underground mine further divided into two mines in September 2002 namely Bartunga hill mine and Anjan hill mine. The latitude and longitude of Anjan hill mine are 23º09'24" to 23º09'00" (N) and 82º17'55" to 82º18'55" (E). At Anjan hill mine,

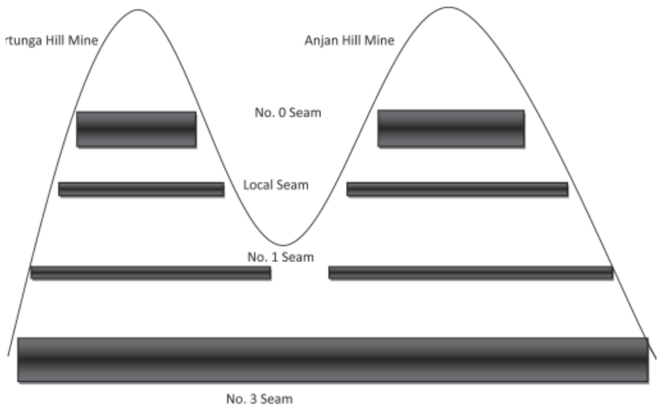

Fig.1 Vertical section showing the seams

on 6th May 2010 at about 11.30 am, an explosion occurred that took lives of 14 people and injured 31 others.

3.2 COAL SEAMS

There were four workable coal seams in Anjan hill mine leasehold area namely 0 seam, local seam, no.1 seam and no.3 seam and are depicted in Fig.1. No.3 seam was the bottom most seam where explosion took place.

3.3 CHARACTERISTICS OF NO.3 COAL SEAM

The characteristics of coal of no.3 seam was determined by Central Institute of Mining and Fuel Research (CIMFR), Dhanbad and are listed in Table 2.

TABLE 2

Crossing point temperature	136ºC
Ignition point temperature	145ºC
Grade of coal	Steam grade "B" and slack grade "C"
Gassiness of seam	Degree I
Moisture (M)	5.42
Ash (A)	15.02
Volatile matter (VM)	30.08
Fixed carbon (FC)	49.48

3.4 METHOD OF WORKINGS

As shown in Fig.1 there were four working coal seams in the mine. No. 0 seam was extracted by continuous miner and then exhausted. Local seam and no.1 seam were developed by bord and pillar method and were being depillared by slicing with caving using SDLs (Shetty, Justice P. V., 2011). No.3 seam was developed by bord and pillar and was being depillared by blasting gallery (BG) method with remote control LHD and jumbo drills (Bhowmick, B. C., et. al. 2010).

3.5 Ventilation of the mine

The underground workings of the mine were ventilated by exhaust system of ventilation. The mine was equipped with two exhaust fans at its air-shaft, one main fan and other as standby with the details (Bhowmick, B. C., et. al. 2010) in Table 3.

Table 3: Specifications of main fan and standby fan

	Specification	Main fan	Standby fan
1.	Capacity (m^3/min)	10,000	2,000
2.	Current drawn (A)	37	20
3.	Fan pressure (mm water gauge)	80	20
4.	Discharge velocity (m/min)	500	500
5.	Fan efficiency	62%	

Independent ventilation circuits were provided for all the three working seams viz. seam no. 1, local seam and seam no. 3. Adit A and adit B were acting as intake airways while air-shaft was working as main return of the mine. Regulators were used to control the air in seam no. 1 and local seam.

3.6 Events/circumstances leading to the explosion

Datewise worth mentioning happenings (Bhowmick, B. C., et. al. 2010) prior to the explosion are summarized below:

1st May '2010

It was national holiday on Labourer's Day. No production work. The main fan was under maintenance. Electrical shutdown was reported from 6.00 am to 5.00 pm.

2nd May '2010

Production activities resumed. Two air samples were collected from 62 dip/94 level (return of workings of A2 panel) and 56 dip/81 level (sealed off A1 panel) at 12 noon and 12.15 pm respectively. The samples were analyzed by gas chromatograph.

3rd May '2010

Gas analysis report of above samples received by mine management. Reports indicated presence of CO in sealed off panel A1 and return airway of A2 panel. Analysis report of sealed off A1 panel revealed CO as 0.1262%, CH_4 as 0.245% and CO_2 as 1.18% while O_2 as 16.93%. Alarmed by CO presence, mine authority initiated action to check all the isolation stoppings of A1 panels followed by their repairing and strengthening. Fresh air base (FAB) for rescue team was established at 45 dip/59 level. In 3rd relay, production work in A2 panel of seam no. 3 was suspended and only persons required for monitoring of the environment and repairing of isolation stoppings were deployed thereat. CO inside the A1 panel behind the isolation stopping of 56 dip/ 81 level was measured to be more than 2000 part per million (ppm) and in general body of air it was measured up to 200 ppm. CH_4 was noticed near stopping of 82 level. Repairing of the stoppings brought down CO level in general body of air to 20 ppm.

4th May '2010

Decision was taken to construct additional row of isolation stoppings against sealed off A1 panel. Work was started under rescue cover and under supervision of senior officials. The level of 650 ppm to more than 2000 ppm CO was recorded behind different isolation stoppings of A1 panel. Production work resumed in 2nd relay.

5th May '2010

Normal production activities continued in 1st relay. Induced blasting in the roof was carried out in A2 panel to bring down the hanging roof. At about 4.20 pm a gust of air raising coal dust was felt at adit B. Persons working in A2 panel heard the sound, felt the gust of air but did not observe any dust cloud. Mine management comprehended it as air-blast out of goaf fall. However, after the incident goaf edge of A2 panel was checked by the officials present in the panel but fall of goaf was not noticed. CO in the general body of A2 panel was observed to be varying between 10-15 ppm.

At about 7.15 pm, second incident of gust of air with coal dust cloud was felt, of course with lesser intensity, which was again attributed to the result of goaf fall.

Third incidence of gust of air laden with coal dust was felt at about 10.10 pm at adit B and underground workings of seam no. 3. It was also understood by the mine management to be the result of major roof fall in the goaf. Meanwhile one sample analysis by gas chromatograph indicated presence of 5521 ppm of CO in main return airway which impelled the management to withdraw all the persons from the mine. Spot samples from return airway of seam 0, local seam and seam no. 1 checked and were found normal. Presence of high quantity of CO observed in return of seam no. 3 signified presence of fire at someplace between A2 panel return and return drift of seam no. 3. It was also thought that the fire might be in old workings.

At about 2 am a team was sent to inspect surface area near outcrop where potholes existed. The team revealed that one pothole was completely filled up, one over 74 level/80 dip was partially filled and another was having sign of burnt ash inside. One pothole over 70 level/80 dip was found to be with blazing fire. This led the management to comprehend that fire was in old workings.

At about 4.30 am one rescue team was sent to collect air sample from main return of seam no. 3. While the team was on the way a gust of air with coal dust observed at adit B. The rescue team came out of the mine thereafter covered with coal dust. They could not perform their assignment.

6th May ’2010

At about 5.30 am two rescue team each comprising 6 rescue trained persons (RTP) sent to underground for environmental monitoring of A2 panel. The teams performed their tasks. One team stayed at fresh air base (FAB) and another returned to surface at 8.30 am.

At about 10.30 am two persons were sent below ground to collect the samples and to hand over breakfast to RTPs. Two RTPs left the FAB after getting their breakfast and came to surface. The samplers went further to seam no. 3 return airway to collect the air sample.

At about 11.45 am a shock wave with huge cloud of dust and smoke blew out from the mine opening that killed 14 persons and injured 31 persons. Fatalities were caused to 6 persons who were below ground and 8 persons who were gathered in front of adit B. All injured persons were present near the adit.

4.0 Method

To inquire into the causes and circumstances for attending the explosion on 06.05.2010 at Anjan hill mine one expert committee was constituted by the national coal company comprising persons from reputed institutions followed by Court of Inquiry appointed by Government of India. The findings are revelation of many a facts which are helpful in preventing such accidents in future.

To further examine human failures that led to explosion, authors visited the inquiry reports submitted by Expert Committee and Court of Inquiry, permission order issued by Directorate General of Mines Safety (DGMS) for Blasting Gallery (BG) panel A2 and gas analysis reports. Statements of 121 persons recorded by Expert Committee were examined thoroughly. Authors interacted with one survivor of the accident and one captain of a rescue team who carried out rescue operation after the explosion. In order to figure out role of different human factors, conditions that led to explosion were analyzed on human factor analysis and classification system (HFACS) developed by Shappell and Weigmann (2003) and customized by Jessica Patterson (2009) for analysis of mining industry.

5.0 Results and discussion

5.1 Unsafe/inappropriate acts

5.1.1 Skill based errors

It is also termed as routine disruption errors (Patterson, J., Shappell, S., 2009) and occur with little conscious effort. Skill based errors are susceptible to memory failure or attention failure. While negotiating a curve, driver does not reduce speed of the vehicle and gets into accident is an example of skill based error.

5.1.1.1 Anjan hill mine was being worked in a thick seam (no. 3 seam) with blasting gallery (BG) method. Surface of the mine was hilly terrain and forest area. BG panel A1 was worked near outcrop and sealed off on 15.01.2010 after exhaustion. At some of the places depth of the seam was up to 7.0 m only and after depillaring, potholes formed above some of the junctions. It has been observed that filling up of potholes and blanketing of subsided area were not carried out to prevent leakage of air through surface cracks/potholes.

5.1.1.2 Old workings of seam no. 3 was being ventilated by return air of A2 panel which created confusion in detecting seat of the fire. Old workings and working panel should have separate ventilation system.

5.1.1.3 At about 6.00 am on 06.05.2010, prior to the explosion, it was found by an inspection team that pothole above developed workings of 76 level/80 dip was oozing grey and blackish smoke. Another pothole nearby was observed to be having blazing fire. The observation confirmed the fire in old workings of seam no. 3. Initially, it was not identified and not thought over and whole concentration of recovery work was carried out with apprehension that there was spontaneous heating at sealed off A1 panel.

5.1.1.4 After each of first two gust of air, A2 panel was inspected by mine officials for goaf fall but no such event was reported to have taken place. Instead of such confirmation by the inspecting officials, steps were not taken to find out other probable cause of gust of mine air.

5.1.1.5 The gust of air was felt four times which were outcome of explosion but these were misconstrued as air-blast out of goaf fall.

5.1.2 Decision errors

Decision errors are also known as honest mistakes and are consequences of poorly executed procedures, inadequate job knowledge or poor choice. These also correspond to intentional actions that progress as planned but the plan proves inappropriate or inadequate or not enough for the circumstances. Inadequate safety inspection of the mine by supervisory official, failure to take appropriate action against known hazard and failure to recognize hazardous condition are examples of decision errors in Indian coal mines (Suman, S. C., Pathak, P., 2017).

5.1.2.1 On 05.05.2010 during 2nd and 3rd shifts gust of air laden with coal dust were experienced at 4.30 pm, 7.30 pm, 10.15 pm and 1.30 am at an interval of approximately 3 hours and was informed to senior officials. The officials reckoned them result of air-blast in A2 panel whereas the underground officials entrusted with inspecting A2 panel denied such happenings.

5.1.2.2 Though the air sample, collected in first shift of 05.05.2010 from fan drift, confirmed presence of 5441 ppm of carbon-mono-oxide, officials failed to realize the severity of hazardous condition and did not take adequate remedial measures.

5.1.2.3 An inspecting team observed two potholes over depillared area (76 level/80 rise and 74 level/80 rise) with sign of burnt ash and smoke. A third pothole at 70 level/80 rise was detected with blazing fire. Such conditions were results of failure to take adequate action against known hazards.

5.1.2.4 Risk assessment was not carried out after detection of spontaneous heating/fire belowground. Such incidence comes under principal hazard and requires formal risk assessment.

5.1.3 Violations

Violations are usually not following the rules, regulations or orders meant for the safe operations (Shappell and Weigmann, 2000). Based on their etiology violations can be labelled as routine violations or exceptional violations. Routine violations are habitual by nature and usually tolerated by management for such departures from the rule (Reason, 1990). Exceptional violations are isolated departures of authority and not overlooked by management (Weigmann and Shappell, 2001). These are regarded as exceptional because these are neither condoned by authority nor typical by individual. Following violations deciphered to be the causal factors that led to the explosion in Anjan hill mine.

5.1.3.1 Indian Coal Mines Regulation (CMR), 1957 stipulates panel system workings with independent ventilation system while developing any coal seam through underground mining. Where development has already been made, panel should be created by construction of sectionalization stoppings. At Anjan hill mine neither development was made through panel system nor stoppings were constructed to form panels with independent ventilation network.

5.1.3.2 Depillaring permission of A2 panel required regular measurement of reduced level of surface over depillaring area and its monitoring to notice any ground movement/cracks/ subsidence due to depillaring. Any crack/subsidence over depillared area was required to be suitably filled and blanketed with soil/earth to prevent any leakage of air below ground through these cracks/subsidence. In absence of such inspection and monitoring cracks/surface subsidence with symptoms of spontaneous heating and blazing fire remained unnoticed and were reported during fire dealing operation.

5.1.3.3 Standard code of practice was not followed while dealing with fire.

5.1.3.4 Local management did not bring into notice of DGMS or Internal Safety Organization (ISO) regarding the incidence of spontaneous heating and incidence of gust of air and coal dust. Presence and expertise of officials of DGMS and ISO could have made the difference in dealing with the fire and could have averted the accident.

5.2 Preconditions for unsafe act

According to Reason (1997), humans usually forget to fear the things which rarely occur in particular where production and productivity are important. Preconditions for unsafe acts generally explain the reasons behind such unsafe acts. They are latent system failures that lay dormant for extended period before contributing to a mishap or unwarranted event (Patterson, 2009). Shappell and Weigmann, 2001 elucidate preconditions for unsafe acts as understanding the reasons of a disease. As such knowing the preconditions for unsafe act create awareness about the symptoms which may cause mishap.

5.2.1 Analysis of coal seam of Anjan hill mine indicated in Table 2 demonstrates low crossing point temperature (136ºC) and high volatile matter (30.08%) which points to its high susceptibility to spontaneous combustion (Bhowmick, B. C., et. al. 2010; Shetty, Justice P. V., 2011) and may be considered to be highly prone to explosion (Bhowmick, B. C., et. al., 2010).

5.2.2 Quantity of air entering through the main intake was 6,255 m^3/min and quantity of air leaving the mine was 7,533 m^3/min.. Difference in air quantity of main intake and main return was 1,278 m^3/min which was approximately 20% of main intake. Being a mine of degree-I gassiness, such excess quantity in main return could be attributed to leakages from surface through potholes and cracks (Bhowmick, B. C., et. al. 2010).

5.2.3 The mine was having three parallel ventilation circuits. Considering high susceptibility to spontaneous heating of the coal seam, the fan pressure of 80 mm water gauge was unfavourable. A 40-50 mm water gauge is usually ideal fan pressure for such mine to control leakages of air.

5.2.4 Major portion of old workings towards outcrop of seam no. 3 was neither sectionalized nor properly ventilated. To prevent spontaneous heating in old workings of developed area either these should have been adequately ventilated or should have been isolated from air.

5.2.5 Development and depillaring of coal seams extended to low cover zone as a result potholes formed at 76 level and 79 level in 2006. These potholes were being used for ventilation purpose. Potholes and cracks allow breathing of air into the mine and facilitate spontaneous combustion.

5.2.6 It was pointed out that thick layer of coal dust existed in mine, particularly in return airways and old workings. Presence of such coal dust intensifies any explosion.

5.3 Unsafe leadership

Unsafe leadership deals with the actions and decision of management which may cause accident. Shappell and Weigmann (2000) classify unsafe leadership into four categories: inadequate leadership, planned inappropriate operations, failure to correct known problems, and leadership violations.

5.3.1 Effective and periodical inspection of unused workings of the mine could not be ensured by competent person for early detection of spontaneous heating therein.

5.3.2 In recent past similar incidents of spontaneous heating had occurred in Kunustoria collierry (Eastern Coalfields Ltd) and New Majari collierry (Western Coalfields Ltd) but mine management was unaware of such incidents. Lack of awareness have deterred the learning from the mistakes of others (Bhowmick, B. C., et. al. 2010). Dissemination of knowledge empowers mine management to take precautions and mitigation measures.

5.3.3 It was pointed out that emergency action plan was not made operational and officials and key personnel were not thoroughly instructed in emergency to avoid contradictory orders and confusion.

5.3.4 Information of blazing fire from surface pothole at 70 level/80 rise should have prompted complete withdrawal of persons from below ground workings. Air sample should have been collected from fan drift instead of sending persons below ground for collecting air sample to assess the mine atmosphere.

5.3.5 In spite of four incidents of gust of air and coal dust felt, reasons thereof could not be ascertained and due precautions against explosion were not taken. An understanding of symptoms of explosion could have saved the lives and the mine.

5.4 Organizational influences

In substantial and unsound decisions taken by higher level management directly affect supervisory practices (Shappell; S. A., Weigmann; D. A., 2000). Unfortunately, clandestine conditions at higher managerial order usually get unnoticed during accident investigation (Patterson, J.,Shappell S., 2009). These factors are difficult to find during accident investigation because of unwillingness of management to take the responsibility and liability. Shappell and Weigmann (2000) has categorized them into resource management, organizational climate and organizational process.

5.4.1 Neither workings of seam no. 3 was developed in panel system nor artificial panels were created in old workings to seal off the area having fallen coal to prevent spontaneous heating. Same factor was discussed in violation also. It means working with such violations had become the organizational climate for that mine and it appeared to be normal.

5.4.2 Risk management plan for principal hazards was not formulated in the mine.

5.4.3 Formal risk assessment of recovery operation after detection of spontaneous heating was not undertaken. As such consequences and probability of the outcomes could not be deliberated.

5.5 Outside factors

Organizations do not work in isolation, rather they are regulated by government policies and regulations. Inspecting authority plays a role. Society influences the organization. Political pressure contributes in different activities. However, authors kept analysis of the accident under these factors out of their scope.

6.0 Limitations

Analysis of human factors contributed to the disastrous accident was carried out by scrutinizing statements recorded by the Expert Committee. Inquiry reports prepared by the court of inquiry and the expert committee are the basis of identification of human errors. It is also submitted that study was carried out for one mine so findings may be used with caution.

7.0 Conclusion

It is well-known that human errors play imperative role in catastrophic accidents (Reason, J. 1990), the explicit types of human error had not been identified for Anjan hill mine accident. The study illustrates that the tragic accident at Anjan hill mine was result of many human errors and caused loss of lives and properties. In particular, decision errors, violations, precondition for unsafe acts and unsafe leadership were the key contributory factors associated with higher level system deficiencies. Precondition for unsafe acts and violations kept on accumulating fire hazard in the mine. Because of decision errors and unsafe leadership, administration failed to understand the dangerous atmospheric condition prevailed after spontaneous combustion detected on 02.05.2010. As a result, the circumstances further worsened due to inability to comprehend the hazardous condition (presence of 5441 ppm of CO on 05.05.2010). Human failures made the prevailing underground atmosphere fraught with explosion hazard that led to such disastrous conclusion on 06.5.2010.

The study demonstrates that HFACS framework can be used to systematically make out causal human factors in coal mine explosions. Using HFACS for identification of human factors can facilitate safety intervention to avoid such accident in future. The study underlines critical areas of human factors which call for attention in formulating underground coal mining safety programme. The results presented in the study may be taken up to address the human error related issues in underground coal mines to prevent explosion.

8.0 Acknowledgement

Authors are thankful to the management of coal mining company for providing information and other details of Anjan hill mine.

9.0 Disclaimer

The opinions expressed in the study are of the authors and may not be of the organizations they belong.

References

1. Alam, S. and Rai, P. (2016.): "An innovative technique for improved production from depillaring panel in an underground coal mine." *Journal of Mines, Metals & Fuels*, Vol. 64, Nos. 1 & 2, P 3-13.
2. Barry, E. (2010): Putin Suggests Human Error in Mine Disaster. The New York Times, May 11, 2010. www.nytimes.com.
3. Bell, B. and Foulstone, A. (2015): "Explosion Prevention in Coal Mine TBM Drifts - An Operational Safety Knowledge Share." *Procedia Earth and Planetary Science*, 11, 15-28.
4. Bhowmik, B. C., et. al. (2010): Interim Report of the Enquiry Committee on Anjan Hill Mine Accident Dated 6th May, 2010 of Chirimiri Area, South Eastern Coalfields Limited. Camp Indian School of Mines, Dhanbad.
5. BP Statistical Review. www.bp.com.
6. Chunli, Y., et. al. (2014): "Statistical analysis and countermeasures of gas explosion accident in coal mines." *Procedia Engineering*, 84, 166-171.
7. Coal India - About us, www.coalindia.in.
8. Huang, Q. and Honaker, R. (2016): "Optimized reagent dosage effect on rock dust dispersion and explosion mitigation in underground coal mines." *Powder Technology*, 301, 1193-1200.
9. India Energy Outlook, www.iea.org.
10. Inventory of coal resources of India as on 01.04.2015, www.cmpdi.in.
11. Liu, H. and Cheng, Y. (2015): "The elimination of coal and gas outburst disasters by long distance lower protective seam mining combined with stress relief gas extraction in Huaibei coal mine area." *Journal of Natural Gas Science and Engineering*, 27, 346-353.
12. Mahdevari, S., et. al. (2014): "Human health and safety risks management in underground coal mines using fuzzy TOPSIS." *Sci. Total Environment*, 488 (1), 85-89.
13. Mandal, et. al. (2004): "Strata Behavior Investigations of India's First Depillaring Face with Continuous Miner and Shuttle Car," *Minetech*, Vol. 25, No. 6, P 3-12.
14. Mangal, et. al. (2016): Role of convergence behavior for superior recovery of thick coal seams in underground mines by blasting gallery. *Journal of Mines, Metals & Fuels*, Vol. 64, No. 4, P 63-73.
15. Patterson, J. (2009): Human error in mining: A multivariable analysis of mining accidents/incidents in Queensland, Australia, and the United States of America using the human factors analysis and classification system framework. Clemson University.
16. Patterson, J. and Shappell, S. (2009): Analysis of mining incidents and accidents in Queensland, Australia from 2004-2008 using the HFACS-MI framework.
17. Patterson, J. and Shappell, S. A. (2010): "Operator error and system deficiencies: Analysis of 508 mining incidents and accidents from Queensland, Australia using HFACS." *Accident Analysis and Prevention* 42 (2010), 1379-1385.
18. Pejic, L. M. (2013): "A new simple methodology for evaluation of explosion risk in underground coal mines." *Journal of Loss Prevention in the Process Industries*, 26, 1524-29.
19. Prusty, B. K. and Patra, A. K. (2016): "CO_2 sequestration in underground coal mines." *Journal of Mines, Metals & Fuels*, Vol. 64, No. 3, P 43-47.
20. Qifang, N., et. al. (2012): "Research and application of safety assessment method of gas explosion accident in coal mine based on GRA-ANP-FCE." *Procedia Engineering*, 45, 106-111.
21. Rasmussen, J. (1982): "Human Errors: A taxonomy for describing human malfunction in industrial installations." *Journal of Occupational Accidents*, 4, 311-333.
22. Reason, J. (1990): Human Error, New York: Cambridge University Press.
23. Reason, J. (1997): Managing the Risks of Organizational Accidents. Ashgate Publishing Company. Burlington, VT.
24. Shappell, S. A. and Weigmann, D. A. (2000): Human Factor Analysis and Classification System - HFACS, US Department of Transport.
25. Shetty, Justice P. V. (2011): "Report of the Court of Inquiry into the major accident involving 14 persons at Anjan Hill Mine of M/s South Eastern Coalfields Limited on 06-05-2010." *Gazette of India*, No. 2441, New Delhi, December 30, 2011.
26. Singh, A. K., et. al. (2009): "Rock mechanics challenges of depillaring at deep cover." *Journal of Mines, Metals & Fuels*.
27. Suman, S. C. and Pathak, P. (2017): "Human Errors: Analysis of 96 Serious Accidents of an Indian Coal Company using Human Factors Analysis and Classification System (HFACS)." *Journal of Mines, Metals & Fuels*, in press, March 2017.
28. Stephen Pheasant (1991): Ergonomics, Work and Health. Macmillan Press, Basingstoke.
29. US Energy Information Administration. www.eia.gov.
30. Weigmann, D. A. and Shappell, S. A. (2001): A Human Error Analysis of Commercial Aviation Accidents Using the Human Factors Analysis and Classification System (HFACS), US Department of Transport.
31. Zhang, B., et. al. (2014): "Pressure characteristics and dynamic response of coal mine refuge chamber with underground coal explosion." *Journal of Loss Prevention in the Process Industries*, 30, 37-46.