Accident investigation system in Indian mining industry: a case study

Even if the emphasis on safety in mining industry across the world is increasing, the accidents resulting in several injuries and fatalities are still taking place. Indian mining industry has suffered critically in the past from high rate of fatal and serious accidents. Accident statistics of Indian mines still shows very high rate of injuries and fatalities. The death rate per 1000 person employed in coal and non-coal mines in the year 2018 is 0.21 and 0.25 respectively. The serious injury rate in the current year is also very high. More disturbing is the fact that a few causes are repeated over the years for fatal and non-fatal serious accidents. Even though all the accidents are being investigated by different agencies and recommendations are made in each case, similar accidents are not prevented. Hence question mark is automatically put against the effectiveness of current investigation system.

In this paper one fatal mine accident investigation reports have been reviewed and analysed to understand the accident causation along with the status of accident investigation system in Indian mining industry.The review highlights certain deficiencies in current investigation methodology and the author has proposed for changing the focus of investigation from human error to system deficiency along with the lessons to be learnt.

Keywords: *Mining; accident; accidents analysis; accidents investigation; root causes*

1. Introduction

Occupational safety and health have always been sensitive issues in the mining industry, particularly considering its high accident and fatality rate. Safety in the mining industry has been considered a vital issue, with coal mine being one of the most dangerous industries all over the world. This is especially in India, where, safety is a major concern because of the high accident rate and fatality rate (Dash et al. 2016; DGMS, 2018). Although in recent years, the whole safety situation in terms of fatality rate of coal mines throughout the country tends to better. As per the DGMS records in the year 2018, there were 57, 42 and 2 fatal accidents involving 70, 48 and 2 fatalities in coal, metal and oil mines, respectively. The numbers of fatal accidents during the previous year i.e. 2017 were 56, 44 and 1 for coal; metal and oil mines respectively (DGMS, 2018). According to recent accident statistics, 279 major coal accidents occurred from 1901 to 2018 resulted in death of more than 3371 persons and serious injury to more than 278 persons. If we consider disaster (10 or more fatalities per accident) then Indian coal mining industry alone had experienced about 60 disasters resulting in more than 2223 fatalities since 1901. The alarming numbers indicate an urgent need for improving coal mine safety (Dash et al, 2015, Bhattacharjee et al., 2020).

Each and every incident/accident/disaster involves a unique set of events. It is not needed that every accident follows a common accident causation pathway. Tuner demonstrates that wrong information always plays a key role. Reason shows that all incident/accidents involve both active failure and latent failures (Reason, 1990, Reason, 1997). Kletz argues that all incidents/accidents can be traced back to organizational failures (management system failure) (Kletz, 1993; 1994). Perhaps it is not surprising that normally accidents have some common causes. However it would be more striking if accident could be shown to have particular causes in common. In Indian mining industry, it is observed that the disasters have been caused mainly due to explosion, inundation, fire, and ground movement. Similarly fatal accidents have also some common causes such as fall of sides, fall of roof, fall of person, explosives, dumpers, gas, dust etc. (Dash et al., 2016). It can be concluded that there are some common causes which are repeated every time because the learning process is handicapped due to the ineffective accident analysis and accident investigation process (Perrow, 1984; 1999; Lagadec, 1997). In this article an effort has been made to analyse some classic case studies of fatal accident in Indian mines and a way forward to improve the prevention strategy for Indian mining industry with some key lessons.

2. Safety status of Indian coal mining industry

Accident statistics of Indian Mining industry indicates that, there had been significant reduction in the numbers of fatal accidents, fatalities and death rate per thousand persons

Dr. A. K. Dash, Assistant Professor, Department of Mining Engineering, National Institute of Technology, Raipur-492010, Chhattisgarh, India. Email: akdash.min@nitrr.ac.in

employed in coal and non-coal mines over the last 118 years since the first piece of mine safety legislation was enacted in 1901. For coal mines, a consistent decline is observed in the 10-yearly average number of accidents per year since the 1950s and in the 10-yearly average number of fatalities since the 1970s. The same trend continued for the last 10-yearly period 2001-2010. In last eight years, there is a slight decrease in the number. For non-coal mines, the average numbers of accidents and fatalities have remained more or less at the same level during the period from 1971-80 to 1991-2000. While the last ten yearly average during the period 2001-10 have declined in number of accidents and fatalities and the last eight-yearly average have fallen during the period 2015 from 0.40 to 0.25. Main factor behind this reduction in fatality rate in coal mines is shift of production technology from conventional underground to mechanises opencast, and reduction in underground manpower through introduction of intermediate mechanisation. However, the most disturbing fact is that we are not able to achieve zero accident yet.

According to Directorate General of Mine Safety records there were 1497 fatal accidents and 1802 fatalities in Indian coal mines between 2000 and 2018 (DGMS, 2019). Fig.1 represents the trend of fatal and serious accidents with number of fatalities in Indian coal mines since last 25 years. There was a sudden increase in number of both serious accident and injury in the year 2005 and after that it decreased gradually but not to an acceptable limit. Review of statistical data and literature related to Indian mining industry reveals that we still have high death rate, are not being able to prevent disasters, similar causes are repeated, process of hazard identification at workplaces and controls not yet been established, gross lack of effective mine emergency management system and general work environment is far below satisfactory level.

3. Method

This paper provides a critical examination of the current accident investigation system of Indian coal mining industry in order to understand how the mining accidents are investigated. A gap analysis of accident investigation system of Indian mining industry was done by reviewing a case study of fatal accident. The findings of the review are subsequently discussed to identify the gaps and weaknesses in the accident investigation system that failed to prevent similar types of accidents over the period. The primary focus of the gap analysis is to have a comprehensive understanding of the process of accident investigation and the recommendations made and why the recommendations could not prevent similar accidents. Efforts have been also made to find the root causes of these accidents by applying Root Cause Analysis (RCA) technique. The causes identified through the statutory inquiries conducted were compared to the causes identified through application of RCA techniques.Towards the end conclusion with some key lessons to change the Philosophy of Accident Investigation were suggested.

3.1. Case study

In this section a recent fatal accident is taken as a case study and reinvestigated. The investigation reports of the accident have been reviewed to understand the mechanism of accident causation. To give a clear view about the case study accident, brief description and identified causes of the

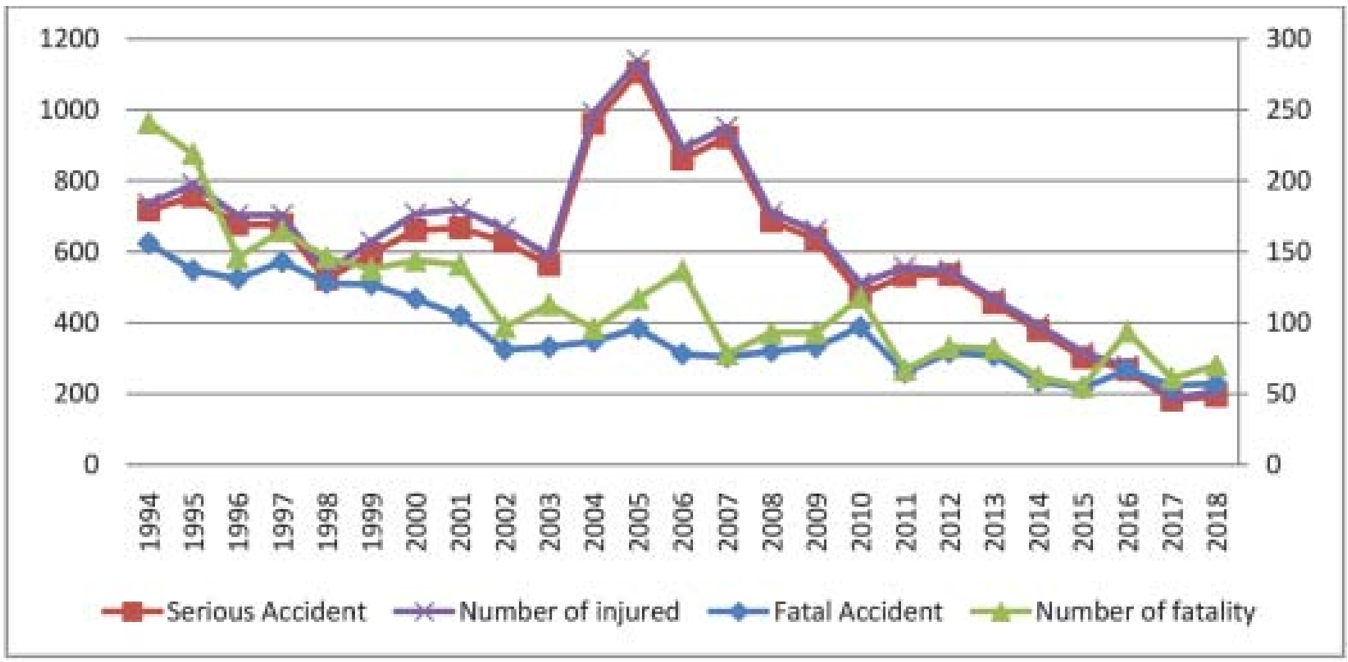


Fig.1: Trend of fatal, serious accidents and death rates and serious injury rates in coal mines from 1994 to 2018 (DGMS, 2019)

accident are provided as per the published reports. Then a gap analysis is conducted to identify the gaps in the current investigation system and lessons to be learnt from the past.

3.2. Brief description

The case study mine i.e. Jindal Power opencast mine is in Raigarh district of Chhattisgarh state in India. The Accident occuurred 2.30 P.M. on 01.04.2009, “while a mine worker was crossing a stationary belt conveyor in a coal handling plant, the conveyor started suddenly causing the worker to fall over the conveyor and he got carried away along four belt conveyors and three transfer points and finally fell in to a RCC bunker from a height of about 28m over loose coal, the worker succumbed to the injuries on the way to hospital after about four hours.”

3.3. Identified Causes (statutory inquiry)

The accident was investigated and the investigation identified the following causes leading to the accident

1. The worker (deceased) attempted to cross the belt from the place where he was not supposed to cross it.
2. The supervisor of coal handling plant was not able to remove the person’s presence in the vicinity of the belt conveyor before informing the control room to start it.
3. The site supervisor and the contractor employee fail to ensure that the person under his charge understood and carried out their duties properly in a safe way or not.

3.4. Gap analysis of the accident investigation

The investigation did not reveal the following and raised the following questions:

1. Why the worker tried to cross the belt without using the cross over bridge?
2. What was the level of skill, competency and experience of the worker?
3. Whether contractor’s workers had any safety induction training and were aware of the hazards of working around a moving belt or crossing over running belt?
4. Was it the usual practice or culture of the mine to cross over belt at any place? Had anybody ever been punished for such unsafe act?
5. Was there any suitable cross over bridge or any other arrangements for crossing the belt? What was the interval between such cross over bridges?
6. Whether the worker was in a hurry to complete the job?
7. Was there any pre-start warning system in the belt conveyor?
8. Was there any pre-start signal like start and stop of the conveyor before starting the belt?
9. Was there any pull cord arrangement along the conveyor?
10. Was there any procedure to check it regularly?
11. Whether the belt conveyor had any emergency stopping arrangement?
12. How the person was carried away so long (four belts and three transfer points) without being noticed by other operators?
13. Whether there was adequate supervision provided?

From the accident investigation, it could not be ascertained whether the above contributory factors were considered during the investigation. Rather, responsibilities were fixed based on their direct involvement, without investigating the root causes that led to the accident. To identify the root causes of the accident an accident causation tree is developed and presented in Fig.2.

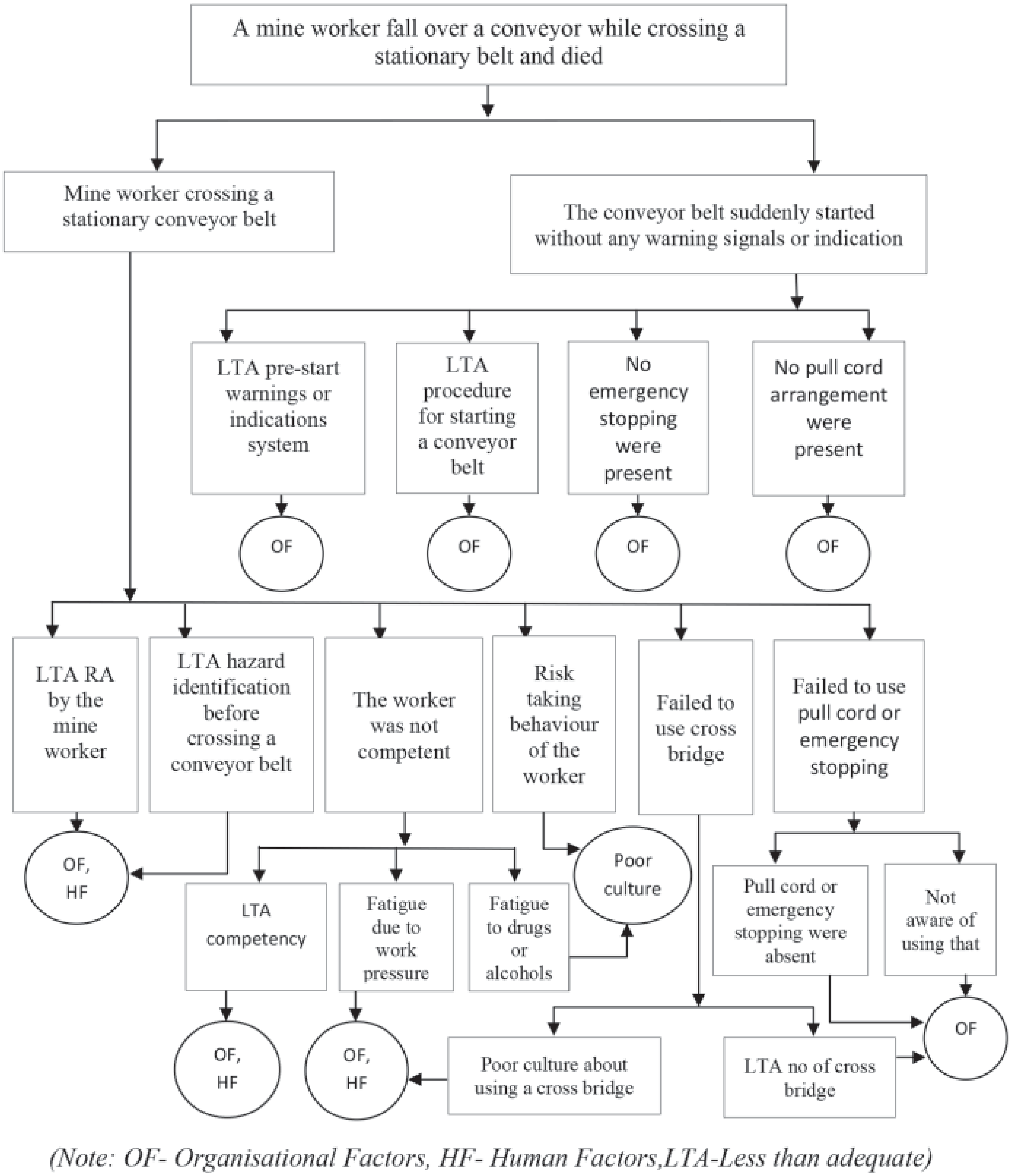
A comparison between the causes identified by the statutory inquiry and the possible/potential causes identified through application of RCA technique like accident causation tree reveals that

- As per the statutory inquiry, the accident took place because, (1) the worker (deceased) attempted to cross the belt from the place where he was not supposed to cross it, (2) the supervisor of coal handling plant was not able to remove the person’s presence in the vicinity of the belt conveyor before informing the control room to start it.
- However, the possible/potential causes identified by application of RCA technique are:
  (1) Wrong decision of the mine worker for crossing a stationary conveyor belt due to lack of hazard perception and LTA risk assessment before crossing a conveyor belt, poor culture of risk taking behaviour of the worker due to poor management culture of tolerating unsafe act for long period of time, poor culture of not using a cross-over bridge, and inappropriate location of cross over bridges;
  (2) LTA pre-start warnings or indications system, LTA procedure for starting a conveyor belt led to the starting of conveyor belt suddenly;
  (3) LTA system of emergency stop in conveyor belt like pull-chord, Emergency stop switches.

4. Summary of the findings of the gap analysis

The summary of the findings on the gap analysis of the case study are as follows:

- The accidents are of very common and repetitive in nature.
- In most of the cases, human behaviour or unsafe act was identified as main cause and persons who were directly involved in the accidents, including the deceased, were held responsible for the accidents.
- The direct causes were identified to be the causes for accidents and no efforts were made to identify the latent, indirect or underlying causes
- The organizational factors like task condition, supervision, risk assessment and development of safe work procedure,



(Note: OF - organisational factors, HF- human factors, LTA - less than adequate)

Fig.2: Accident causation tree of case study accident

ensuring competency for performing a job etc. were not examined while identifying causes of the accidents.

- The basic theory of causation of any accident as unplanned and uncontrolled energy was overlooked.
- Risk assessment was not carried out before all the routine or non-routine types of activities and adequate controls were not identified or in place before undertaking such job.
- Lack of skill, competency and fitness for duty of the operators or work persons was not examined.
- Human error or non-compliance of statutory provisions was identified as causes of accidents in most of the cases. But what led to human error or non-compliance were not examined.
- The real objective of accident investigation through identification of root causes and implementation of corrective measures could not be achieved through such superficial accident investigation.
- There is a strong need to review the effectiveness of current accident investigation methodology and introduce the concept of objective assessment of latent causes for unsafe act or behaviour.

5. Discussion and lesson learnt

The above analysis of the accident through root cause analysis techniques helps in identifying suitable corrective actions against all these causal factors including the root causes. It is expected that implementation of the above recommendations will reduce major accidents from explosion to a great extent.

Further analyses of the above case studies show that the root causes of the accident can be attributed to one or more of the following basic factors (Dash et al., 2015a; Dash et al., 2016, Dash et al., 2017):

I. Poor culture of risk assessment: LTA risk assessment before any safety critical job.

II. Unsafe practice: Poor culture about risk taking behaviour without any assessment.

III. Culture of denial: Poor safety culture of taking credit in getting some extra production through unsafe means ignoring proper hazard identification and risk assessment.

IV. Ineffective supervision: Management failure resulting in shortage of statutory manpower and key operators, ineffective safety organization, absence of improper system of reporting, etc.

V. Safe/standard operating procedure (SOP): Lack of adequate and effective Standard Operating Procedure (SOP) for different machines, equipment, tools etc., working in hazardous conditions.

VI. Ineffective accident investigation system: LTA investigation system in Indian mining industry.

Though a number of accidents occurred due to lack of proper risk assessment, we have not learnt from them. It is necessary to convince workers, at all levels that risk assessment should be done before, during and after every safety critical job and that it is not an optional extra, something that can be neglected or put to one side under pressure of work (Bhattcharjee et al., 2014; Bhattcharjee and Dash, 2016, Dash et al., 2016). Now it is made mandatory in our law (CMR, 2017) and management system also (CMR, 2017).

6. Conclusion

From the analysis of the accident case studies, it is revealed that the accident investigation in Indian mines is mainly focused at human error or non-compliance of statutory provisions. Though the causes identified were very common in nature and had been repeatedly pointed out in the past, the coal mining industry did not take any lessons from it. Identification of the root causes along with all possible causes through proper accident investigation is needed to prevent the repetition of similar types of incidents/accidents/disasters in future. The lessons learnt will not be effective, had the causes been identified by root causes analysis not been brought into the recommendation and implemented accordingly. In most of the cases only the direct causes have been identified to fix responsibilities and making recommendations. This approach is proved to be grossly ineffective because of the fact the system deficiencies still remain undetected or unidentified during such investigations and the recommended actions may not suitably address the root causes (Rasmussen, 1990; 1997; Leveson, 2004; Dash et al., 2015b, Bhattacharjee et al., 2018; Dash, 2019). That is why similar accidents are repeated. It is time to focus on systems approach instead of human error or unsafe act only. The systems approach takes into account the dynamics of systems that interact within the overall safety programme. It concludes that accidents are considered defects in the system. People are only one part of a complex system composed of many complicated processes (more than we realize). Accidents are the result of multiple causes or defects in the system. It becomes the investigator's job to uncover the root causes (defects) in the system. Fixing the system, not the employee, is the heart of the investigation. To prevent accidents, the system must work more safely. This thinking results in long-term fixes: Less expensive to implement and maintain (Dekker, 2007; Bhattacharjee et al., 2014).

From the case study described or similar accident/incident/dangerous occurrences, there is much more to be learnt from accidents than we usually learn, not because we are not aware of the facts but because we do not consider them deeply enough (Kletz et al., 1999). Identify and assess the risk systematically before, during and after every routine or non-routine job to make sure that the safe method or practice (SOP) has been followed (Dash et al., 2015a, 2015b). Most importantly, poor safety culture like, taking undue risk without risk assessment, culture of denial, normalization of abnormal conditions etc. should be completely eliminated from the system.

Acknowledgements

The author would like to express his sincere gratitude and acknowledgement to the Department of Mining Engineering, National Institute of Technology, Raipur for their help and support, and to Directorate General of Mines Safety (DGMS) for their kind co-operation during the course of the study.

References

1. Bhattacharjee, R. M., Dash, A. K. and Paul, P. S., (2020). "A Root Cause Failure Analysis of Coal Dust Explosion Disaster - Gaps and Lessons Learnt", *International Journal of Engineering Failure Analysis*, Elsevier Science, doi.org/10.1016/j.engfailanal. 2019.10422.
2. Bhattacharjee, R. M., Dash, A. K., Panigrahi D. C., (2018): "Lessons Learnt from Bhatdee Coal Mine Explosion Disaster in India using Root Cause Analysis Technique", Proceedings of the 11th International Mine Ventilation Congress, Science Press and Springer Nature Singapore Pte Ltd. 2019, pp. 439-446, ISBN 978-981-13-1420-9; DOI: 10.1007/978-981-13-1420-9_37.
3. Bhattcharjee, R. M., Dash, A. K., (2016): "Zero Harm: A Novel Mission towards Accident Prevention" Proceedings of the National Seminar on Eco Friendly Surface Mining-Technology, Challenges & Way forward" at Neyveli during 12th & 13th November-2016, Organized by Neyveli Lignite Corporation Limited, pp. 80-86.
4. Bhattcharjee, R. M., Dash, A. K., and Paul, P. S., (2014): "Changing Philosophy of Accident Investigation In Indian Mines – Need for Shifting Focus from Human Error to System Error", Surface Mining, Pages: 321-333. ISBN No. 978-93-5156-1866.
5. Dash A. K., Paul, P. S. and Bhattcharjee, R. M., (2014): "Accident Analysis of Indian Non-coal Mines- Need for Change in Focus of Accident Investigation". The *Indian Mineral Industry Journal*, Vol. II, No.2/Q2, pp.47-51.
6. Dash A. K., Paul, P. S. and Bhattcharjee, R. M., (2015): "Need of an Accident Investigation Model for Indian Mines - An Approach" *The Indian Mineral Industry Journal*, Vol. 3, No.2, pp. 93-98.
7. Dash, A. K., (2019). "Analysis of Accidents due to Slope Failure in Indian Opencast Coal Mines" *Current Science*, Vol. 117, NO. 2, pp. 304-308.
8. Dash, A. K., Bhattacharjee, R. M. and Ahmad A. (2016): "Case Study of Accidents Related to Fall from Height in Indian Coal Mining Industry: An Analysis" *International Journal of Scientific & Engineering Research*, Volume 7, Issue 9, September 2016, ISSN 2229-5518, pp. 387-392.
9. Dash, A. K., Bhattacharjee, R. M. and Ahmad A., (2016): "Case Study of Accidents Related to Fall from Height in Indian Coal Mining Industry: An Analysis" *International Journal of Scientific & Engineering Research,* Volume 7, Issue 9, September 2016, ISSN 2229-5518, pp. 387-392.
10. Dash, A. K., Bhattacharjee, R. M. and Paul, P. S. (2015a): "Gap Analysis of Accident Investigation Methodology in the Indian Mining Industry - an Application of Swiss Cheese Model and 5-Why Model", *IAMURE International Journal of Ecology and Conservation,* Philippines, Vol.15, No.1.
11. Dash, A. K., Bhattacharjee, R. M. and Paul, P. S. (2016): "Lessons Learned from Indian Inundation Disasters: An Analysis of Case Studies", *International Journal of Disaster Risk Reduction*, Elsevier Science, vol.20, pp.93-102.
12. Dash, A. K., Bhattacharjee, R. M., (2017): "A Decision can be a Disaster: A Descriptive Analysis of a Case Study" *International Journal of Applied Environmental Science* (IJAES), Volume 12, Number 10, pp.1803-1820.
13. Dash, A. K., Bhattacharjee, R. M., Paul, P. S., Tikader, M. (2015b): "Study and Analysis of Accidents Due to Wheeled Trackless Transportation Machinery in Indian Coal Mines – Identification of Gap in Current Investigation System", Procedia Earth and Planetary Science, Elsevier Science, USA, vol. 11, pp. 539-547.
14. Dekker, Sidney (2007): Just Culture: Balancing Safety and Accountability, Ashgate.
15. DGMS, Directorate General of Mines Safety, "The Accident Investigation Report", Dhanbad, India, (2018).
16. DGMS, Directorate General of Mines Safety, "The Accident Investigation Report", Dhanbad, India, (2017).
17. Kletz, T.A., (1993): Lessons from Disaster. How Organizations have no Memory and Accidents Recur Gulf Professional Publishing, Rugby, UK.
18. Kletz, T.A., Hazop and Hazan (1999): Identifying and Assessing Process Industry Hazards, fourth ed. Taylor & Francis, Philadelphia.
19. Lagadec, P., (1997): Learning Processes for Crisis Management in Complex Organizations. *Journal of Contingencies and Crisis Management* 5 (1), pp. 24-31.
20. Leveson, N. (2004): A new accident model for engineering safer systems. *Safety Science*, 42, pp. 237-270.
21. Perrow, C. (1984): Normal Accidents: Living with High-Risk Technologies, Basic Books. New York, NY.
22. Perrow, C., (1999): Normal Accidents. Princeton University Press, Princeton, NJ.
23. Rasmussen, J. (1990): Human error and the problem of causality in analaysis of accidents. Paper presented at the Human Factors in Hazardous Situations. Proceedings of a Royal Society Discussion Meeting.
24. Rasmussen, J., (1997): Risk management in a dynamic society: A modelling problem. *Safety Science*, 27(2-3), pp.183-213.
25. Reason, J., (1990): Human Error, Cambridge, Cambridge University Press.
26. Reason, J., (1997): Managing the risk of organizational accidents, Aldershot, Ashgate.
27. The coal Mine Regulations (2017).