Curbing Accidents on Mine Site

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Abstract: ***Mining accidents occur in the process of mining activities from machine operations and process application. Thousands of miners die from mining accidents each year, especially in the process of mining for minerals from rocks whether at the surface or underground. A review of specific cases was considered to buttress the need for complete and adequate safety against accidents. Generally speaking, surface mining is commonly less hazardous compared to underground mining; and large mines are prone to more accidents than smaller mines. This paper discusses accidents in mining operations, its causes, positions and ways to prevent its occurrence.***

Keyword: ***Accident, Mine, Injuries, Fatalities, Causes, Number, Coal, Year, Pattern, Surface mining, Underground mining.***

I. INTRODUCTION

Mining Accidents

The definition of a mining accident is depended on the legislation of a particular country.

1. In Australia : -

a) **Mining accident**: is an event(s), at a mine which causes injury to a person.
b) **Serious accident**: is an accident at a mine which causes a person to die, or to be admitted as a patient to a hospital for treatment of injury.

2. USA legislation : -

a) **Mining accident:** is an individual dying at a mine; an individual sustaining injury at

a mine which has potential to bring about death or an individual getting trapped for more than 30 minutes which has the capacity to cause death.

b) **High-potential incident:** is an event(s) that causes or has the capacity to cause a a high negative impact on the safety and health of a person (Amol, 2011).

The history of mining has been loaded with high level of accidents since it is a high-risk industry. The largest mining disaster occurred on the 6th of March, 1906; in European were dust explosion killed 1,099 miners at the Courrières mine in northern France. Also, 75 men were killed in northern Queensland after an explosion occurred at the Mount Mulligan mine in 1921. 299 men were disastrously killed at the Luisenthal mine in 1962 in Germany.

Other fatalities in history include the Moura Mine explosion which happened in Queensland in1994, killing 11 men (Hopkins, 2001); Mine explosion took place in Nanshan Colliery in northern China which killed 24 men in 2006 and the Sago mine explosion which came up in West Virginia, in 2006 where 12 miners met their death (Dao, 2006). Large scale accidents of this size draws great interest and attention from the press, foretelling that miner workers are seriously in conditions that could cause injuries or end their lives.

II. ACCIDENTS IN MINES AND THEIR ANALYSIS

Mining is a hazardous operation and consists of significant safety, health and environmental, risk to miners. A number of accidents have led to injury to lives, property damages, production downtime and losses due to unsafe conditions in mine: surface (Figures 1 - 5) or underground (Figures 6 - 10). The subsequent section highlights the various hazards experienced in surface and underground mines, stating their precautionary measures and details of accidents recorded in mines that are coal-based and non-coal-based.

III. HAZARDS AND CAUSES OF ACCIDENTS IN VARIOUS OPERATIONS AND PRECAUTIONS

(A) Surface Mine Working

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Table 1: The major hazards due to some mining activities and their prevention/control in surface mining.

Operational Hazard	Problem(s)	Solution(s)
Surveying	Fall from heights.	Use of good and properly constructed scaffolds.
	Thrown from overturning vehicle.	
Clearance	Struck by debris from demolition and falling tree.	Use trained operator.
	Use of power saw or other equipment for the removal of top soil.	Use full personal protection by operator
Laying Out	Falling while working at height.	Avoid driving at the edge of roadway under construction.
	Plant moving out of control.	Maintain plant and equipment.
	Struck by moving vehicle.	Trained workers signalling
Drilling	Falling from the edge of a bench.	- Training instructions on facing the open edge of the bench. - Erect portable rail fencing between the drilling operations and the edge of the mine. - Attach safety lines and harness to the drilling rig for the driller to wear. - Use water during the drilling operations. - Provide a ventilation system on drilling rig with dust filter.
	Inhalation of dust created during drilling operation.	
	Entrapment or being struck by a moving and revolving part of the drill equipment.	- Install guard devices - Trained and supervised operators.
Explosives	- Misfires - Early ignition - Fly rocks. - Poor fragmentation	- Plan for round of shots adequately surveyed, correctly drilled holes, proper logging, right explosive weight. - Use a trained person to carry out the blast design, charging and fire.
Face Stability	Rock fall, slide or collapse	- Regularly examine bench face remedially. - Do advance mine working in the direction of geology minding the stability of face and quarry side.
Loading	Rock fall on the driver.	Strengthen the cabin of operator.
Transporting	Electrocution in Draglines.	Properly install electrical supply to dragline with adequate earth continuity and protection for earth leakage.

	Draglines wire rope failure.	Examined suitability of wire rope periodically.
	- Failure of hydraulic system. - Fires	Position fire extinguishers.
	- Fall while accessing operator's cabin. - Plant toppling over because of uneven ground.	Positioned loaders very far from face edges.
	Rollover	- Provide edge protection is - Use seatbelt.
	- Brake failure - Vehicle movements particularly while reversing - Vibrations - Noise	Do regular testing and adequate maintenance.
Noise	Increased risks in older machines.	- Provide newer machines with cabins. - Provide operators with ear protection.
Processing Of Mineral		
Crushing	Blockages	Break up blockages Using hydraulic hammers.
	- High noise - Dust - Vibrations	Provide noise isolators and mechanical ventilation systems.
Grinding	- Noise - Dust	Provide noise isolation devices and air filtration system.
Screening	- Dust - Noise - Vibration	Protective equipment
	Fall from height during maintenance	Use harness

(Patterson, 2009).

Figure 1: Mining Accident (911metallurgist.com)

Figure 2: Coal Mine Indian Accident (industriall-union.org)

Figure 3: Two separate coal mine accident (clb.org.hk)

Figure 4: Chinese Rescue Race to save Workers (mining.com)

Figure 5: Some more men injuries fatally or trapped Mining Accident (amsj.com.au)

(B) Underground Mine Working

Table 2: The major hazards due to some mining activities and their prevention/control in underground mining.

Operational Hazard	Problem(s)	Solution(s)
Fall Of Roof and Sides	Falling of the roof and the sides	- Properly secure the roof and side of working. - Set support according to the rules of systematic support. - Provide fencing in unauthorised area. - Disallow workers from working under roof that is unsupported. - Provide temporary supports before clearing roof. - Collapse of pillar in coal mines - Ensure that the stocks left in depillaring is kept at comfortable sizes.
Air Blast		- Disallow the existence of the extensive area of un-collapsed roof. - Use seams that has strong and massive roof rocks and keep more number of entries open. - Provide shelters should be provided at suitable sites. - Install imminent air blast warning system.
Rope Haulage	Derailment, runaway and uncontrolled movement of tubs due to breakage of rope; failure of couplings/drawbars and failure of attachment to ropes.	Chose rope properly and maintain them cautiously.
	Journeying along roadway of haulage.	Strictly prohibit unauthorised travelling on haulage roadways.
	Failure of safety devices.	Do maintenance
	Poor construction of curves.	Adequately design and construct haulage curves.
Electrical Hazards	Electric shock and/or burn.	Inspect earthling point regularly.
	Ignition of firedamp or coal dust.	Use double wire armouring for cables.

	Fire arising from electric defects.	- Use safe apparatus with flameproof. - Regularly inspect equipment for the signs of mechanical damage, overheating and partial discharge.
Fire Hazards	Fire outbreaks	- Disallow the use of petrol power instrument. - Position hand-held extinguishers in different locations in the mine. - Reduce the storage of flammable Substances as much as possible. - Fit an automatic suppression system unto all underground equipment that contains above a hundred litres of flammable hydraulic fluid.
Inundation	Flood invasion	- Disallow mine work done vertically below water or reservoir depth. - Constructively position mine with its mouth not less than 1.5m above the highest flood level at selected point. - Locate shaft sites away from geological disturbances like faults and conformities.. - Fill all abandoned shaft and boreholes with sealing material like debris and broken rocks. - Properly plan mining into the bearing strata in case of highly water.
Ventilation	- Failing of cooling system. - Temperature and heat increase from rock and machines.	Repair and maintain ventilation systems.
Illumination	-Undue darkness	- Provide continuous lighting especially in hazardous locations. - Provide emergency light source at all locations where a hazard is high.

(Amol, 2011).

Figure 6: Mining accident (gettyimages.com)

Figure 7: Mine accident in Meghalaya (the hindu.com)

Figure 8: Mine Collapse (hurryetdailynews.com)

Figure 9: Mining Accident (istockphoto.com)

Figure 10: Mining Rescue Service (mining-technology.com)

Mining Acts

Some of the major provisions of the MINER Act include:

(i) Requires mine operators to make notify of all incidents or accidents which stand a sensible risk of death within 15 minutes.
(ii) Requires individual mine that is covered to develop and always update a written response plan of emergency.
(iii) Put on ground a competitive scholarship and training program for new safety technology in the mine and should be given by NIOSH (National Institute for Occupational Safety and Health).
(iv) Needs wireless transmission - feedback communications and an electronic tracker within the span of about three years, allowing those on the surface to find people trapped underground.
(v) Needs individual mine to have at least two professional rescue teams capable of an hour response time.
(vi) Put on ground a workable group to make available a formal means of sharing technologies that are government-based, and that would have link to mine safety.
(vii) Needs new safety standards associated to the closing of abandoned areas in underground mines, and advancing the needs for strength of the closure.
(viii) Put on ground a technical study committee for belt air to fact-find the utilization of air from conveyer belt of the mine entries to ventilate the mine face.
(ix) Lifting up the monetary punishment for safety incompliance.
(x) Put up an unalterable office of Mine Safety and Health in NIOSH, which helps to assure a sustainable and a long-term concentration on mining safety and health (Giirtunca, 2006).

IV. LITERATURE REVIEW

Even though issues of occupational health and safety in mining have been thoroughly dealt with in developed nations for about 20 years running, accidents are still being recorded at an alarming frequency (Komljenovic , Loiselle and Kumral 2017; Samantra, Datta and Mahapatra , 2016; Boudreau et al, 2014). The injury and accident file for 2016 through the Mine Safety and Health Administration (MSHA), U.S. was used to acknowledge the most usual types of injury and to ascertain the tasks that mine workers were working on when they sustained injury (NIOSH, 2017). Taking risk and breaking laid down rules are also related to work-prone injuries and accidents that differing cadres of the workforce can influence the potential of breaching of regulations (Laurence, 2011). It is obvious that unsafe conditions causing injuries during disbursement of duties continues to be a known challenge in countries (Baker et al., 1992). Monitoring equipment may be utilized as prompting signals for performance of safety (Payne, et al, 2010). Possibly some recorded figured and reported information grossly underestimate the actual counts of mine workers who got hurt during duties because so many injuries are hoarded or not reported (Miller, 1997). Injuries that are not reported results in decreased productivity, absence to work, illnesses and incurred costs of healthcare (Leigh, Marcin and Miller, 2004; Ruser, 2008; Boden and Ozonoff, 2008). Actually, in the United States, injuries are the major cause of death of people from the age of 44 and below (Baker, Conroy and Johnston, 1992). Despite significant reductions, the number of injuries and fatalities in mining remains high (Groves, Kecojeviv and Komljanovic, 2007). Many work accidents occur during its activities due to the adverse working conditions (Yasli and Bolat, 2019). It is required that any study concerning accidents are detailed and defined while venturing into why accidents (Khanzode, Maiti and Ray, 2011).Therefore, evaluating the terms of the situations of an event such as accident which represent a causal relationships is a major view (Fenton and Neil, 2012). Prusek et al.2017considerably studied the risk of falling roof in coal mines where comprehensive research was conducted to assess accidents in the mining sector using expert judgments to analyse the potential and possible consequences of the roof falling having applied the relevant conditions. Komljenovic, Loiselle and Kumral, 2017 looked into the organizational functions and the role that accidents play in the tradition of safety practices to providing safe-working locations in the mining industry. The most obvious accident sources are electrical failure, losing machine control, slipping or falling, unreliable moves and over-exertion performances (Yasli and Bolat, 2019).

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According to working conditions, underground mines mostly have potential difficulties like rock mass movement and geotechnical situations which leads to a lot of major and minor or accidents (Prusek et al., 2017).

V. MATERIAL AND METHODS

This study focuses and discusses accidents in some selected mines and suggesting ways of curtailing it. The method of review was adopted in this article.

VI. DATA MINING AND METHODOLOGY

Data Collection

Data about accidents in then mine were extracted from the internet: a US underground coal mines and Obukhovskaya mine in Ukraine.

Data Review and Analysis

Data were analysed using Microsoft Excel. Data and information were sourced from the internet.

Table 3: Using data from Obukhovskaya mine (underground coal mines) in Ukraine to study the pattern of accidents in Coal - Based Mines in US – (2001-07).

Number of Fatal Accidents							
Causes of Accidents	**Year**						
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fall of Roof	30	23	18	26	18	13	11
Fall of Sides	9	11	5	8	7	4	2
Dumpers, Trucks, etc.	19	14	21	22	21	18	11
Explosives	2	4	3	5	2	1	1
Winding in Shafts	2	0	1	0	0	3	0
Other Ground Movements	0	1	1	0	0	1	0
Rope Haulage	15	6	10	5	12	8	6
Non-Transportation Machinery	10	9	11	7	15	9	8
Other Transportation Machinery	1	2	2	3	4	5	2
Fall of Objects	2	2	1	0	6	6	3
Fall of Persons	7	4	5	3	7	3	7
Electricity	4	4	1	4	4	3	4
Gas, Dust, Fire, etc.	0	0	2	2	0	4	1
Other Causes	4	1	2	2	3	8	12
Total	105	81	83	87	96	79	81

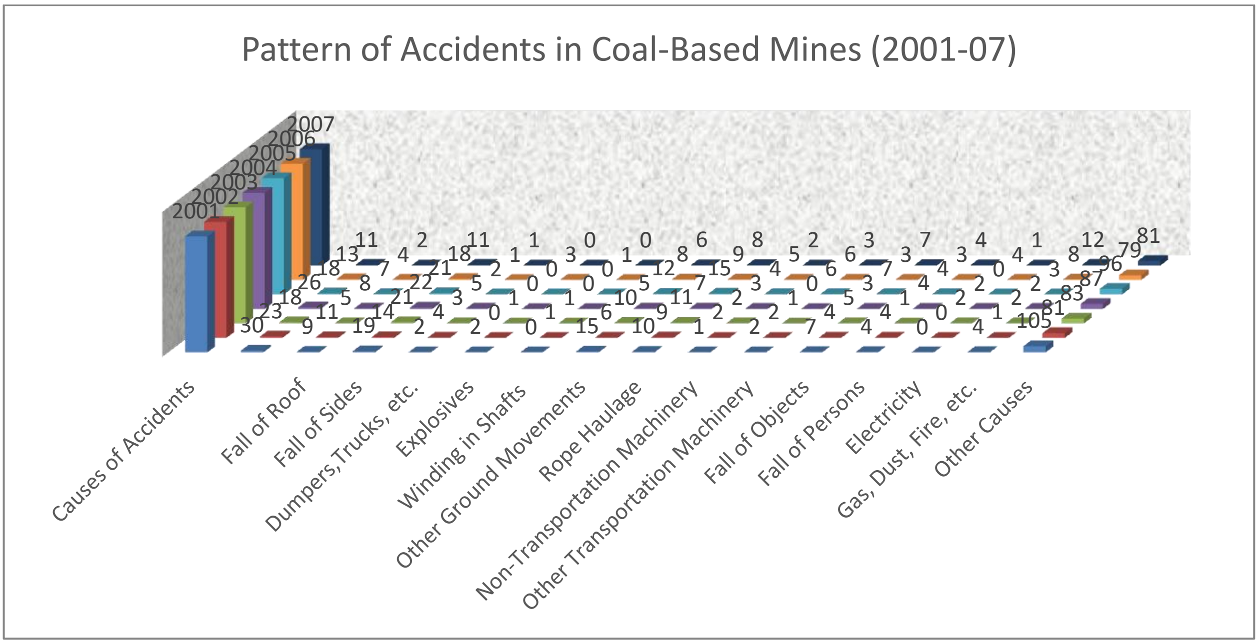

Figure 11: Pattern of Accidents in Non-Coal Based Mines in US (2001- 07)

Table 4: Using data from Obukhovskaya mine (underground coal mines) in Ukraine to study the pattern of accidents in Non-Coal Based Mines in US – (2001-07).

Number of Fatal Accidents							
	Year						
Causes of Accidents	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fall of Roof	2	1	1	2	1	0	2
Fall of Sides	8	10	7	12	6	10	6
Dumpers, Trucks, etc.	22	10	13	18	12	18	15
Explosives	6	8	5	3	4	3	1
Winding in Shafts	2	0	1	0	0	3	0
Other Ground Movements	0	1	1	0	0	1	0
Rope Haulage	15	6	10	5	12	8	6
Non-Transportation Machinery	10	9	11	7	15	9	8
Other Transportation Machinery	1	2	2	3	4	5	2
Fall of Objects	2	2	3	3	2	7	1
Fall of Persons	11	10	11	6	13	14	2
Electricity	1	1	3	2	0	0	1
Gas, Dust, Fire, etc.	3	0	1	0	0	0	0
Other Causes	5	1	0	2	1	1	1
Total	**71**	**52**	**52**	**57**	**48**	**59**	**36**

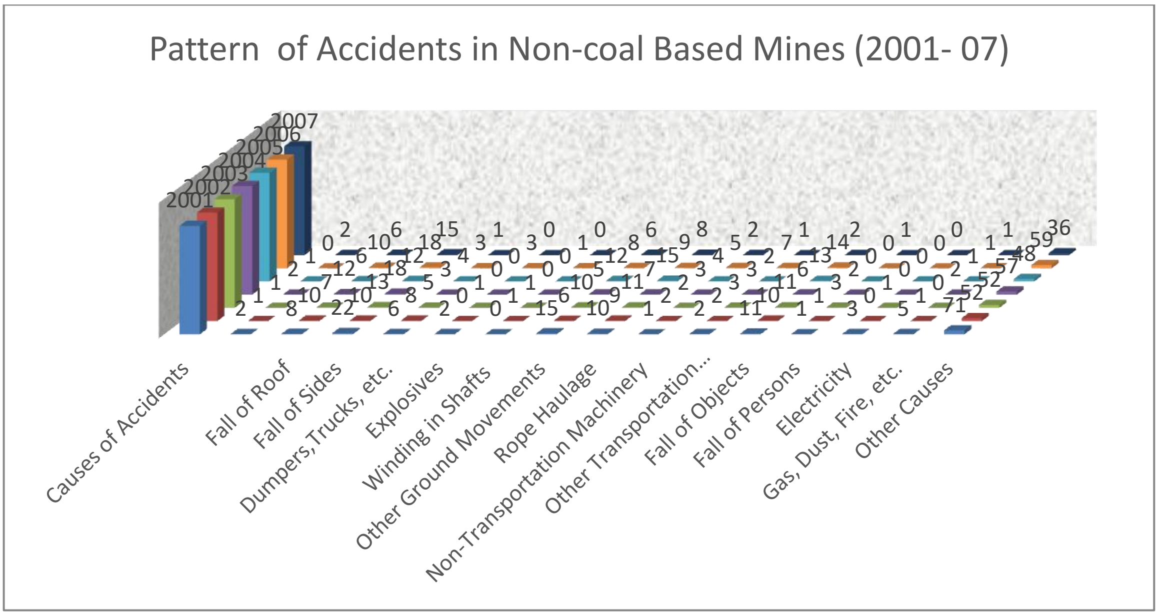

Figure 12: Trend of Accidents in Non-Coal Based Mines in US (2001- 07)

Table 5: Using data from Andrei and Anni, 2017 for industrial injury record in 2014 and 2015.

Indicator	**2014**	**2015**
Number of accidents	27	17
Number of fatalities	11	10
Coal mining (million tons)	119	105
Fatality index per 1 million tons of coal produced	0.95	0.84

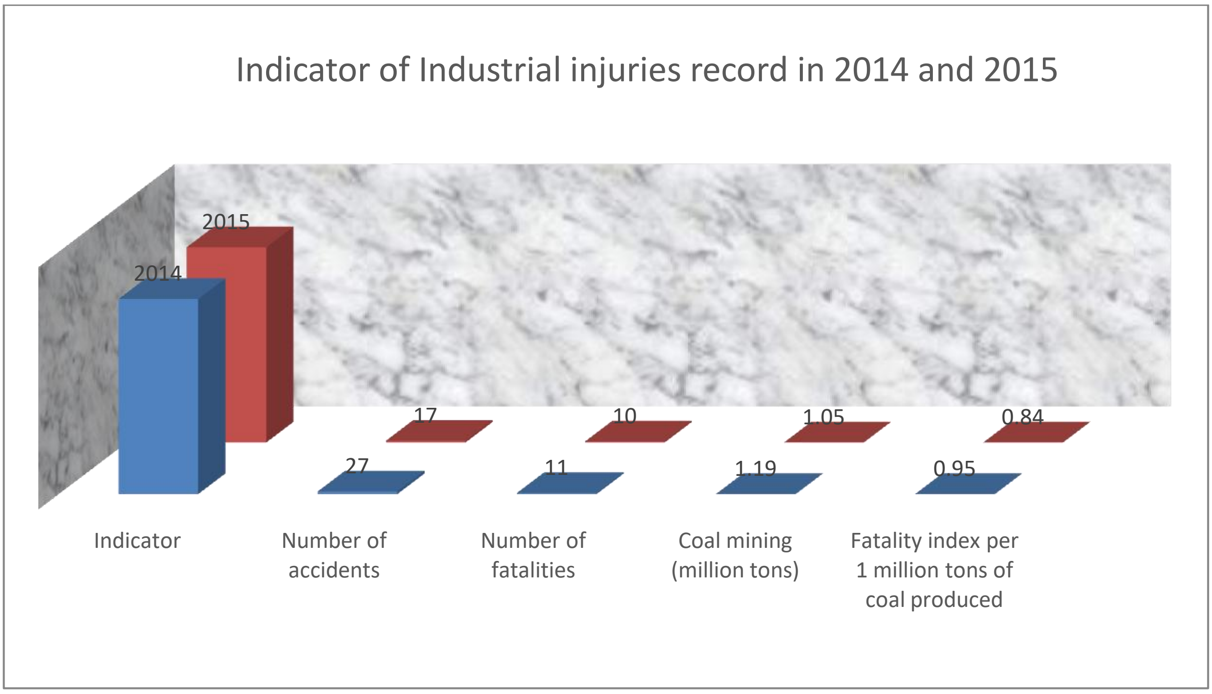

Figure 13: Record of Industrial injuries in 2014 and 2015

Table 6: Using Giirtunca and Breslin, 2006 in underground coal mine explosion fatalities and injuries in1980.

Year	**Fatalities**	**Injuries**
1980	5	6
1981	37	13
1982	7.5	13
1983	8	8
1984	7.5	11
1985	2.5	15
1986	2.5	15
1987	1.5	6
1988	1.5	3
1989	0	4
1990	4	7
1991	0	23
1992	3.5	13.5
1993	12.5	13
1994	1.5	5
1995	2.5	0
1996	0	0
1997	0	0
1998	0	5
1999	0	2
2000	0	1
2001	1	8
2002	2.5	4
2003	8	0
2004	0	3
2005	3.5	1
2006	0	5
2007	13	1
R^2	**0.3103**	**0.3273**
Equation	**$y = 0.0566x^2 - 225.82x + 225375$**	**y = -0.0042x2 + 16.314x - 15846**

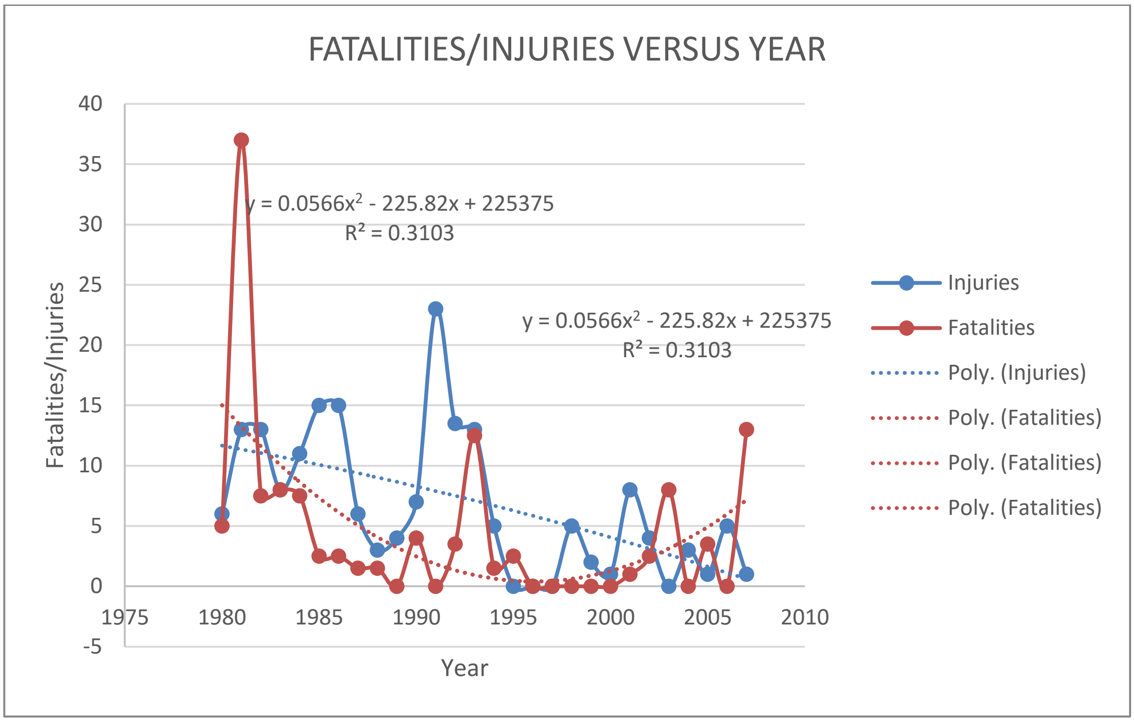

Figure 14: Underground Coal Mine Explosion Fatalities and Injuries 1980.

Table 7: Using data from Paithankar, 2010 pattern in accidents and fatality in coal mines (1951 - 2007)

Year Range	Average Accidents	Accident Rate	Average Killed	Death Rate
1951-1960	222	0.61	295	0.82
1961-1970	202	0.48	260	0.62
1971-1980	187	0.4	264	0.55
1981-1990	162	0.3	185	0.34
1991-2000	140	0.27	170	0.33
2001-2007	87	0.22	112	0.28

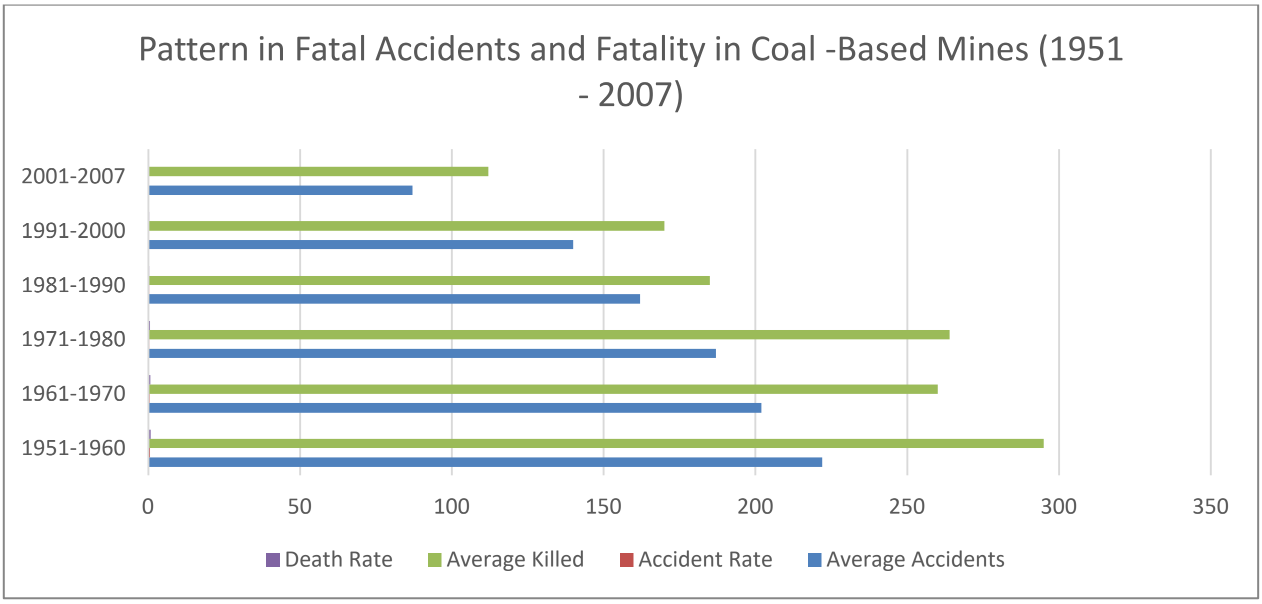

Figure 15: Pattern of Accidents and Fatality in Coal Mines (1951 - 2007).

Table 8: Using data from Paithankar, 2010 pattern in accidents and fatality in non- coal mines (1951 - 2007)

Year Range	Average Accidents	Accident Rate	Average Killed	Death Rate
1951-1960	64	0.27	81	0.34
1961-1970	72	0.28	0.28	0.33
1971-1980	66	0.27	74	0.3
1981-1990	65	0.27	73	0.31
1991-2000	65	0.31	77	0.36
2001-2007	54	0.34	62	0.4

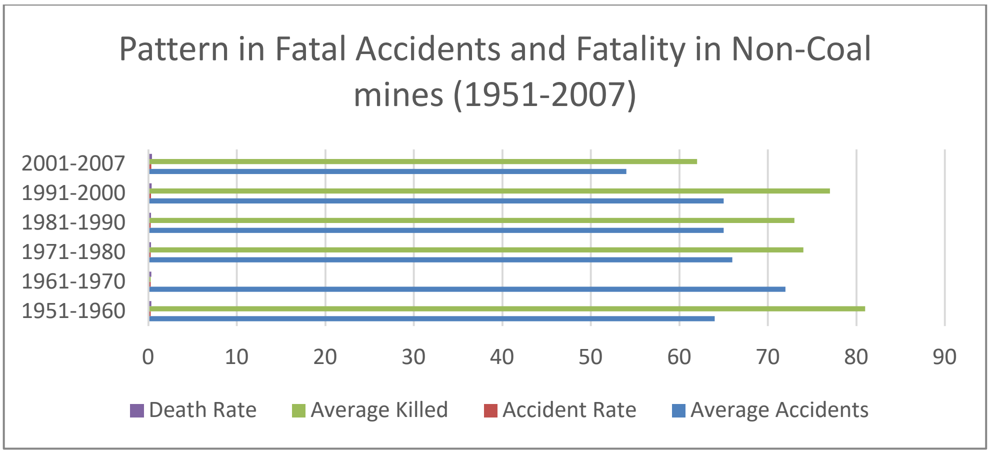

Figure 16: Pattern in Fatal Accidents and Fatality in Non-Coal mines (1951-2007)

Table 9: Using data from Clarence, 1907 for Number of men killed for each 1000 miners employed averages for five years.

Country	Five Year Range Count	Number of men Killed
France	1901-1905	91
Belgium	1902-1906	100
Great Britain	1902-1906	128
Russia	1900-1904	206
United States	1902-1906	339

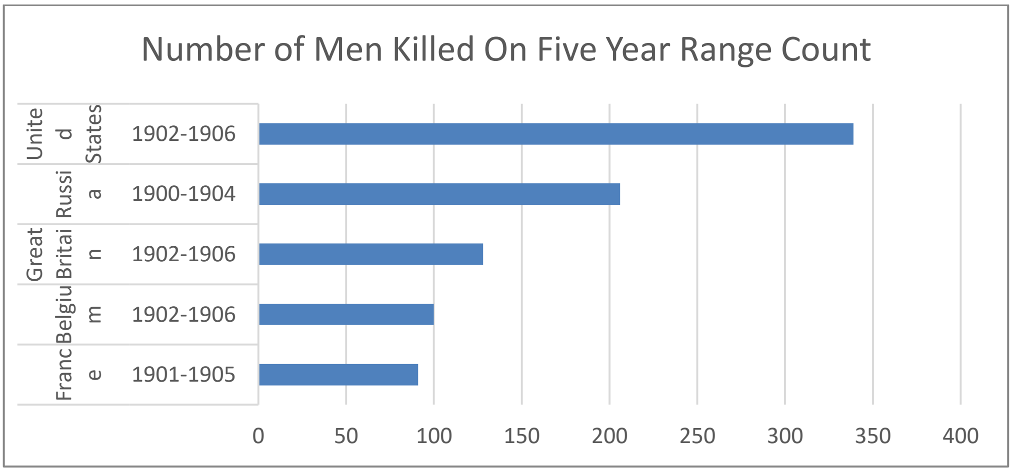

Figure 17: Number of Miners Killed On Five Year Range Count

In 1906 the causes of the fatal and nonfatal accidents in the coal mines of the United States were as follows:

Table 10: Using data from Clarence, 1907 for Coal-Based Mine accidents in the United States, 1906.

Accidents Due To -	**Killed**	**Injured**
Gas and Dust Explosion	228	307
Powder Explosion	80	215
Falls of roof and coal	1008	1863
Other Causes	732	2,192

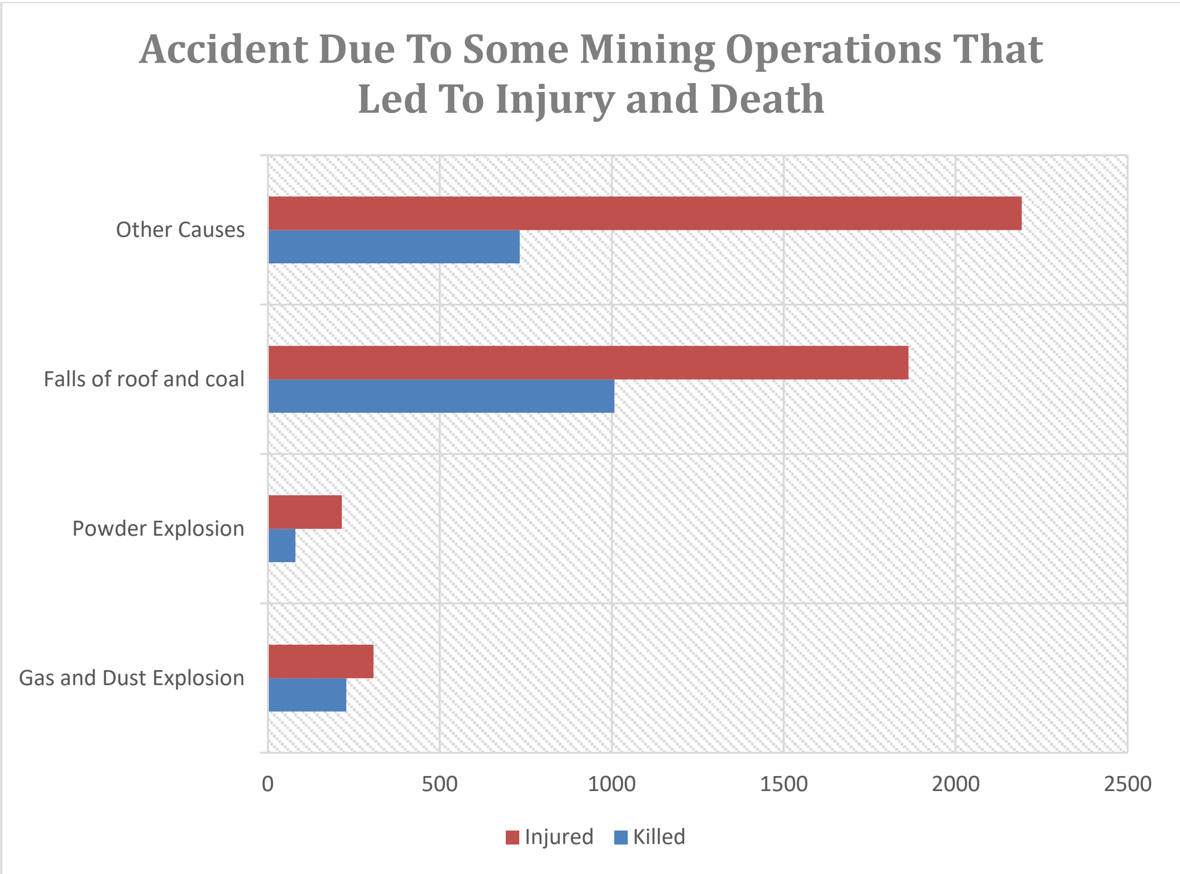

Figure 18: Accident Due To Some Mining Operations That Led To Injury and Death

Table 11: Using data from Clarence, 1907 of recorded deaths from falls of roof and coal per 1000 miners employed.

Country	**Number of Men Killed**
Belgium	40
France	47
Great Britain	64
Germany	92
United States	170

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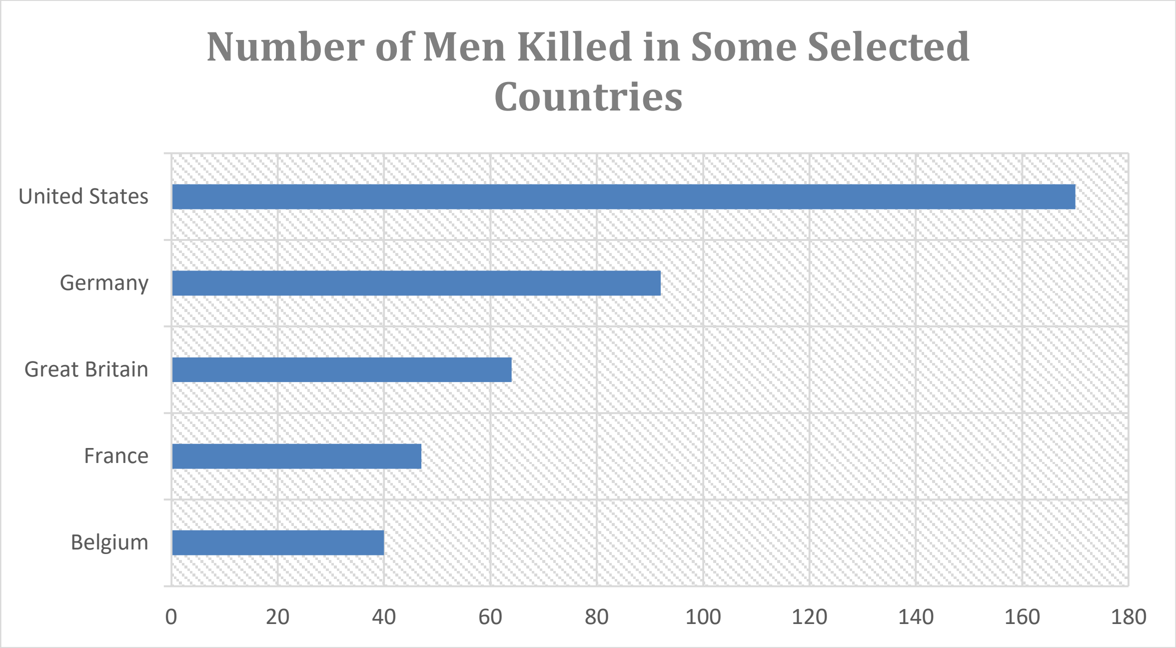

Figure 19: Number of Men Killed in Some Selected Countries

VII. RESULTS AND DISCUSSION

In Figure 11, the trend of the different causes of accidents from coal-based mining operation reported from 2001 to 2007. The accidents made at the maximum year record(s) were as follows:

Fall of roof – 2001; fall of sides – 2002; dumpers/trucks, etc. – 2003; explosive accidents – 2004; winding in shafts – 2001; ground movement accidents – 2002 and 2003; rope haulage – 2001; non-transport machinery – 2005; other transport machinery – 2006; fall of object – 2005 and 2006; fall of persons – 2001, 2005 and 2007; electricity – 2001, 2002, 2004, 2005 and 2007; gas/dust/fire, etc. – 2006.

In Figure 12, the trend of the different causes of accidents from non-coal based mining operation reported from 2001 to 2007. The accidents made at the maximum year record(s) were as follows:

Fall of roof – 2001, 2004and 2007; fall of sides – 2004; dumpers/trucks, etc – 2001; explosive accidents – 2002; winding in shafts – 2006; ground movement accidents – 2002 2003 and 2006; rope haulage – 2001; non-transport machinery – 2005; other transport machinery – 2006; fall of object – 2006; fall of persons – 2006; electricity – 2003; gas/dust/fire, etc. – 2001.

In Figure 13, the indicators for the cumulative number of accidents, fatalities were reported from underground Obukhovskaya mines in Ukraine for 2014 and 2015. The peak of mining accidents and fatalities occurred in 2004, in which the quantity of coal mining went up to 119 million tonnes of production.

In Figure 14, Giirtunca and Breslin, 2006 reported underground coal mine explosion fatalities and injuries that happened in 1980. Using mathematical polynomial correlations, I derived that the fatalities and injuries recorded were about 31% and 33% of the cumulative accidents that occurred that year.

In figure 15, Paithankar, 2010 reported the trend of accidents and fatalities in coal mines for 1951 to 2007, in the range of ten years basis.

For the coal mine, the highest average accidents are recorded between 1951 to 1960 with 295 as the number of workers killed. It is noted also that accidents and death rates has been on the decrease continuously.

For the non-coal mine, the highest average accident was reported between 1961 to 1970 with 72 as the number of miners that died. It is further observed that death and accident rate has been on decline from peak records made.

In Figure 17, Clarence 1907 reported the number of men killed from each 1000 employed in five different countries on five years basis. The highest number killed was recorded as 339 from the United States with France as the least country.

In Figure 18, Clarence, 1907 further reported the accidents that happened in the United States in 1906 for some mining operation-based risks. The worst operation that got people injured and killed was ‘the fall of roof and coal’ which recorded 1008 and 1863.

In Figure 19, Clarence, 1907 buttressed on the risk of ‘the fall of roof and coal’ against the number of miners killed out of 1000 workers employed, using five countries. The highest number killed occurred in the United States with 170 people, while France recorded the least, as 40 people.

VIII. CONCLUSION AND RECOMMENDATION

In mining operations, accidents are bound to happen. The accidents causes injuries and losses to lives and damages to properties in the mines that spans through various areas of mining activities like: surveying, clearance, laying out, drilling, noise, explosives, face stability, loading, transporting and processing of minerals. Accidents can also occur in underground mining like: fall of roof and sides, airblast, rock burst and bumps, rope haulage, electrical hazards, fire hazards, ventilation, inundations, illumination issues.

Solutions will be drawn from the mining acts stated previously like notify of all incidents or accidents; developing and updating response plan of emergency; instituting training programs; using feedback communications and an electronic tracker; following safety standards, especially those of NIOSH.

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