Statistical Analysis of Workplace Accidents in Polish Mining Industry

Pawel Strzalkowski

Wroclaw University of Science and Technology, Faculty of Geoengineering, Mining and Geology, Wybrzeże Wyspiańskiego 27, 50-365 Wrocław, Poland

pawel.strzalkowski@pwr.edu.pl

Abstract. The publication presents a statistical analysis of workplace accidents in Polish mining in 2009-2017. Collecting and studying information on accidents at work is essential element necessary to improve the organization of work and to introduce preventive activities that will reduce the probability of the workplace accident. The analysis was based on the data of the Statistics Poland and the State Mining Authority. Based on the collected data, it has been shown that the number of workplace accidents and persons injured in these accidents in the studied years decreased and amount to 30% (according to the Statistics Poland) less in 2017 than in 2009. Whereas, the incidence rate of accidents at work (defined as the number of injured people per 1000 persons employed) in Polish mining ranges from 13.97 (in 2013) to 17.82 (in 2010) and is twice higher than the incidence rate of workplace accidents for all industries in Poland. The accidents at workplace in the mining industry in the analysed period occurred on average every 137.88-223.43 thousand Mg of mined minerals. Additionally, the causes of workplace accidents and the number of persons injured were analysed depending on the age of the persons injured, length of work seniority, specific physical activities performed by the persons injured at the moment of workplace accident and the type of injuries. The highest number of accidents at workplace is related to inappropriate behaviour of a person at work and workplace accidents were most often suffered by persons injured aged 20-49 years (89.47%), who performed different activities at the moment of an accident at workplace: movement (31.46% persons injured), handling of objects (20.22% persons injured), carrying by hand (19.91% persons injured) and working with hand-held tools (13.26% persons injured). The most frequent types of injuries suffered by persons injured at the moment of accident are wounds and wounds and superficial injuries (34.05%), fractures of bones (30.12%) and dislocations, sprains and strains (20.91%).

1. Introduction

Exploitation of mineral deposits performs a significant function in the world economy. Technological progress causes continuous demand for mineral raw materials, which are used in almost all branches of the national economy. The mine's life cycle begins at the time of mining activity planning and ends with the closure of the mining plant. In the whole process, employees are exposed to hazards during work, which can lead to workplace accidents [1, 2]. It should be emphasized that mining is one of the most dangerous industries in the world economy [3, 4, 5, 6, 7]. In addition, the variability of technologies, geological and mining conditions introduces a string of potentially dangerous situations. Therefore, there is a need to analyse hazards and accidents in order that introduce activities and measures that increase the level of employee safety [8]. Despite increasing awareness of health and safety in the workplace in many mining enterprises, marginal treatment of occupational health and safety is also
observed as a legal obligation, and not as a means to reduce the hazards and number of accidents at workplace. In addition, there is a confidence that implementing measures to reduce potential exposures to hazards and consequently to accidents at workplace is too expensive.

In the common sense, an accident is understood as a sudden, unpredictable event, which results in injuries and losses to people [9]. Accidents at workplace are a serious health, social and economic problem. Accidents are not only consequences of injuries to employees, but also, in the case of serious and fatal accidents, criminal liability and court proceedings, resulting in high financial penalties or imprisonment. Production suspend, the need to replace an injured worker, the repair or replacement of damaged machines or tools are not many economic losses, which can be caused by an accident at workplace even exceeding the costs of workplace accidents. The problem of understanding accident at workplace, as well as their causes and consequences, is an important element of planning and organizing work. Therefore, it seems important to review statistical data on accidents at work and indicate the areas in which these events occur most frequently in order to reduce the likelihood of their occurrence or even eliminate them through proper work organisation and introduction of preventive measures.

2. Hazards in the mining industry
Mining industry involves the exploitation of a very wide range of minerals. Depending on the mining method adopted, an employee is exposed to many dangerous hazards, defined as the possibility of a dangerous event. The analysis of these hazards is the basis for the assessment of occupational risks. During analysing the risk related to the production activity of the enterprise, it is necessary to consider the hazards occurring in connection with each other: human - technical object - environment. Based on this, natural, technical, organisational and human hazards can be mentioned in the mining industry [10]. The latter three are mentioned in many publications (e.g. [4, 8, 11]) as the main three pillars of occupational safety in all sectors of the economy. It should be emphasized that the groups of these hazards are not mutually exclusive and during analysing technical hazards, there is a need to consider the impact of factors belonging to other categories [10].

Natural hazards arise independently of humans. They are the result of the impact of energy located in the natural environment. Natural hazards include, among others, landslides of excavations slopes, rockburst or methane hazards in underground mining. It should be emphasized that most of these hazards may lead to mining disasters and most often lead to serious or fatal accidents at workplace [12].

Technical hazards are associated with the presence of a material factor and the most common source of their occurrence is improper operation of equipment. The most common technical hazards include: lack or improper selection and poor technical condition of protective devices, improper selection or poor technical condition of control systems and devices signalling the occurrence of hazard or insufficient durability of the material factor. Matuszewski [13] emphasises that the technical factor in mining industry as a cause of accidents at workplace is very rare and is not always properly identified.

Inappropriate organization of workstation causes organizational hazards, because it is connected with, among others, lack of qualifications of managing staff, tolerating by supervision deviations from the rules allowing for safe performance of work, or admission to work of people without proper training.

The last group of threats are human hazards, which are related to the behaviour of a person, his uncontrolled movements and the effects of muscle strength and body weight. It should be emphasized that the human factor is the most common cause of accidents at the workplace. Human hazards include, among others, dangerous actions taken by employees or insufficient concentration at work. Post-accident prevention should include a detailed analysis of the human factor as a direct and indirect cause of the accident.
3. Analysis of workplace accidents in the Polish mining

The analysis of workplace accidents in the Polish mining industry was repeatedly conducted by many authors, e.g. [1, 7, 14, 15, 16, 17] and included short periods of time. This publication attempts to analyse accidents at workplace in the Polish mining industry in the period 2009-2017 on the basis of published data from the Statistics Poland (SP) and the State Mining Authority (SMA). The Statistics Poland data present statistical values of accidents for the whole mining area with distinction of hard coal mining. On the other hand, SMA data present statistical data for the whole mining industry divided into hard coal mining, copper ore mining, surface mining, borehole mining, geological works and other mining (data from 2010 to 2017).

In the domestic mining industry, employment ranged from 138618 (in 2017) with output of 484.18 million Mg to 1777761 (in 2011) with output of 567.56 million Mg. This largest number of employees was caused by the very high development of construction related to the preparation of Poland for the European Football Championship (Euro 2012), which in turn resulted in a much higher demand for minerals. Since 2011, there has been a declining trend in employment in the Polish mining industry, which is related to a decrease in demand for minerals. Despite this decline, the output per employee was variable in 2009-2017 and currently has an increasing trend, as shown in Figure 1. Based on output data and the number of accidents, it can be estimated that accidents at workplace occurred every 137.88-223.43 thousand Mg of mined mineral. This may be due to technological progress, better organization of work and increased employee awareness of occupational safety.

![Mining output (in thousand Mg.) per accidents frequency and 1 employee](image)

**Figure 1.** Mining output (in thousand Mg.) per accidents frequency and 1 employee (own study based on [18, 19]).

Exploitation of deposits is connected with accidents occurring in the process of work. In the analysed period of time, there were 25901 workplace accidents (including 233 collective workplace accidents), with a total of 26378 persons injured (including 710 persons injured of collective workplace accidents). The incidence rate of accidents at workplace (defined as the number of injured people per 1000 persons employed) in particular years was variable and amounted from 14 to 18 (the average incidence rate of workplace accidents in the analysed period was 15.61). Compared to the incidence rate of workplace accidents in all sectors in Poland (average 7.52 for the analysed period), the incidence rate of workplace accidents in mining is more than twice as high. Figure 2 presents the number of accidents at workplace
and persons injured of such accidents and the incidence rate of workplace accidents in the years 2009-2016 on the basis of SP data.

![Figure 2](image)

**Figure 2.** The number of workplace accidents, persons injured of these accidents and the incidence rate of workplace accidents in the years 2009-2017 (own study based on [18]).

The SMA data show 20296 accidents at workplace (including 102 collective workplace accidents), in which there were 20703 persons injured (including 509 persons injured of collective workplace accidents). The difference in the recorded number of accidents at workplace and persons injured of these accidents by SP and SMA is presented in Figure 3. Despite a large difference in data of SP and SMA, the trend in the number of workplace accidents and persons injured is decreasing. Differences between the data result from different classification of accidents for statistical purposes.

![Figure 3](image)

**Figure 3.** Number of workplace accidents, persons injured of these accidents in the years 2009-2017 on the basis of data from SP and SMA (own study based on [18, 20]).

According to the SMA, the highest number of accidents at workplace is observed in hard coal mining and they account for 75-79% of all workplace accidents in the mining industry. Such a large number of accidents in hard coal mining is caused by much more difficult working conditions and the adopted
mining technology in comparison to other mining methods. Additional, in the hard coal mining, there are many more hazards representing a potential risk of an accident, e.g. methane hazards, fire hazards. A similar trend is observed in the number of persons injured in particular areas of mining. Despite the different scale of accidents in the deposit mining industry, a decreasing trend has been observed for many years, both in terms of the number of accidents and the number of persons injured (Table 1). This decreasing trend is caused by decreasing employment as well as increased awareness of the managing staff and education of good habits related to occupational health and safety among employees, which is emphasized in works [8, 16, 21].

**Table 1.** Number of workplace accidents and persons injured in 2010-2017 (own study based on [20]).

| Year | Hard coal mining | Copper ore mining | Surface mining | Borehole mining and geological works | Other mining |
|------|------------------|-------------------|----------------|--------------------------------------|--------------|
| 2010 | Number of workplace accidents | 2615 | 561 | 113 | 20 | 68 |
|      | Number of persons injured | 2631 | 607 | 113 | 20 | 68 |
| 2011 | Number of workplace accidents | 2330 | 480 | 93 | 17 | 55 |
|      | Number of persons injured | 2369 | 488 | 93 | 17 | 57 |
| 2012 | Number of workplace accidents | 2199 | 444 | 88 | 11 | 67 |
|      | Number of persons injured | 2206 | 454 | 88 | 11 | 68 |
| 2013 | Number of workplace accidents | 1916 | 459 | 84 | 14 | 78 |
|      | Number of persons injured | 1949 | 486 | 84 | 14 | 92 |
| 2014 | Number of workplace accidents | 1795 | 337 | 69 | 20 | 53 |
|      | Number of persons injured | 1830 | 351 | 69 | 20 | 53 |
| 2015 | Number of workplace accidents | 1702 | 333 | 58 | 34 | 31 |
|      | Number of persons injured | 1729 | 344 | 59 | 34 | 31 |
| 2016 | Number of workplace accidents | 1575 | 404 | 47 | 24 | 24 |
|      | Number of persons injured | 1590 | 462 | 47 | 24 | 24 |
| 2017 | Number of workplace accidents | 1662 | 317 | 56 | 20 | 23 |
|      | Number of persons injured | 1688 | 334 | 56 | 20 | 23 |

The data prepared by the Statistics Poland presents the accident rate in the Polish mining industry to a greater extent, including the number of persons injured divided into their age, length of work seniority, causes of accidents, events causing injury or type of injury. Thus, in 2009-2017, depending on the age of the persons injured, most of them were among the persons injured aged 20-49 and constituted 21.82% for the age of 20-29, 31.97% for the age of 30-39 and 35.68% for the age of 40-49. For the other age groups, the number of persons injured was much lower (Figure 4). This increased number of persons injured aged 20-49 is caused by high employment level of people in this age group, lack of experience of young employees, as well as routine among people with extensive professional experience. This can also be confirmed by the number of persons injured depending on the length of work seniority (Figure 5). Persons injured with work experience up to 10 years constituted 61.52%, while persons injured with work experience 21 years and over constituted 19.52%.
The workplace accident is related to one event that results in many causes [17]. This means that the number of causes is greater than the number of accidents and it was an average of 2.25 causes per 1 workplace accident in 2009-2017. The highest number of accidents at workplace is related to inappropriate behaviour of a person at work and it constituted on average 63.72% of all causes of accidents at workplace in the analysed period of time (Figure 6). A person's inappropriate behaviour during work should be understood as incorrect employee's action (53.05% of all causes of accidents), inappropriate willful employee's action (9.95%) or inappropriate mental and physical condition of an employee (0.72%). The dominance of human causes resulting in accidents at workplace indicates the need to implement preventive measures that do not require large financial outlays. It is necessary to introduce a number of activities promoting occupational safety in mining enterprises and to increase the regularity and diligence of training, because lack of knowledge and skills to predict hazards leads to a series of errors and increase the exposure of employees to potential accidents.

In 2009-2017, accidents at workplace occurred during the different activities performed by the persons injured (Figure 7) during which they suffered different injuries (Figure 8). The largest number of persons injured in mining industry in the analysed period was during the following activities: movement (31.46%), handling of objects (20.22%), carrying by hand (19.91%) and working with hand-held tools (13.26%). The event causing injury to the persons injured was a struck by object in motion,
collision (37.23%) and other contact-modes injury not specified in the SP list (51.59%), which included, among others, natural hazards. Whereas, the injuries suffered by the persons injured in these accidents were mainly wounds and superficial injuries (34.05%), fractures of bones (30.12%) and dislocations, sprains and strains (20.91%).

**Figure 6.** Number of causes of workplace accidents in the Polish mining industry in 2009-2017 (own study based on [18]).

![Causes of workplace accidents](image)

**Figure 7.** Number of persons injured of workplace accidents in the mining industry in 2009-2017 depending on the specific physical activities performed by the persons injured at the moment of workplace accident (own study based on [18]).

![Specific physical activities performed by the persons injured at the moment of workplace accident](image)
4. Summary

Mining is one of the sectors of the Polish economy in which the frequency of accidents at workplace is the highest. In mining, the incidence rate of accidents at workplace (average 15.61) in 2009-2017 was more than twice as high in relation to all sectors of the economy (average 7.52), and the workplace accident occurred every 137.88-223.43 thousand Mg of extracted mineral in which there were 26378 (according to SP) and 20703 (according to SMA) persons injured. A high incidence rate of accidents at workplace was influenced by the nature and conditions of work and the occurrence of many technical, organisational, human and natural hazards. It should be emphasised that natural hazards most often contribute to mining disasters in which employees suffer serious or fatal accidents.

In the analysed period of time, the highest number of persons injured of accidents at workplace were employees aged 20-49 (89.47%). This is caused by high employment level of people in this age group, lack of experience of young employees, as well as routine among people with extensive professional experience. A similar trend is presented by the number of persons injured depending on the length of work seniority and for employees with the length of work seniority up to 10 years was 61.52%, and for employees with the length of work seniority 21 years and over 19.52%. Workplace accidents occurred during the performance of various activities by the persons injured. The most important are: movement (31.46%), handling of objects (20.22%), carrying by hand (19.91%) and working with hand-held tools (13.26%). The injuries suffered by the persons injured in these accidents were mainly wounds and superficial injuries (34.05%), fractures of bones (30.12%) and dislocations, sprains and strains (20.91%).

The approach of entrepreneurs to occupational health and safety issues has a very large impact not only on the state of safety in the organization, but also on the state of the entire company, including financial. High awareness of the management staff and the introduction of a number of preventive measures, which constitute much lower costs than the costs of an accident at workplace, are very important to ensure the safety of employees at the highest level. Although workplace accidents in the years 2009-2017 occurred much more frequently due to inappropriate human behaviour (63.72%), the introduction of a number of training courses may significantly contribute to the reduction of the incidence rate of accidents at workplace.

Figure 8. Number of persons injured of workplace accidents in the mining industry in 2009-2017 depending on the type of injury (own study based on [18]).
A detailed analysis of accidents at workplace is an important phase of prevention. Understanding workplace accidents, their causes and effects should influence the correct planning and organisation of work. This proper organisation of work, the introduction of preventive measures and skills to predict potential accidents will make it possible to reduce the probability of accidents or eliminate them.

**Acknowledgment**
The work was financed within the statutory project 0401/0048/18 at the Faculty of Geoengineering, Mining and Geology of the Wrocław University of Science and Technology.

**References**

[1] P. Litwa, „Stan bezpieczeństwa pracy w polskim górnictwie (Work safety in Polish mining industry)”, *Górnik i geologia*, vol. 5, issue 3, pp. 75-85, 2010 (in Polish).

[2] M. Stefanicka, „Wybrane aspekty ocen ryzyka w zakładach górniczy (Selected aspects of risk estimation in rock mining production plants)”: *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej. Studia i Materiały*, vol. 131 (38), pp. 149-155, 2010 (in Polish).

[3] R.J. Mitchell, T.R. Driscoll, J.E. Harrison, “Traumatic work-related fatalities involving mining in Australia”, *Safety Science*, vol. 29, issue 2, pp. 107-123, 1998.

[4] L. Sanmiquel, M. Fretjo, J. Edo, J.M. Rossell, “Analysis of work related accidents in the Spanish mining sector from 1982-2006”, *Journal of Safety Research*, vol. 41, issue 1, pp 1-7, 2010.

[5] J.H. Saleh, A.M. Cummings, “Safety in the mining industry and the unfinished legacy of mining accidents: Safety levers and defense-in-depth for addressing mining hazards”, *Safety Science*, vol. 49, issue 6, pp. 764-777, 2011.

[6] L. Sanmiquel, J.M. Rossell, C. Vintró, “Study of Spanish mining accidents using data mining techniques”, *Safety Science*, vol. 75, pp 49-55, 2015.

[7] K. Mianowana, L. Rydzak, V. Mianowska, „Wypadkowość w górnictwie – statystyka i skutki zdarzeń (Accidents in mining – statistics and effects of them)”, *Bezpieczeństwo pracy i ochrona środowiska w górnictwie*, vol. 9 (265), pp. 28-34, 2016 (in Polish).

[8] M. Stefanicka, „Kształtowanie kultury bezpieczeństwa w górnictwie skalnym (Shaping culture of safety in the rock mining industry)”, *Mining Science - Mineral Agregates*, vol. 21(1), pp. 191-201, 2014 (in Polish).

[9] D. Koradecka (ed.) „Bezpieczeństwo i higiena pracy (Occupational safety and health)”, Wyd. Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy, Warszawa, 2008 (in Polish).

[10] J. Jonkisz, I. Łabuda, J. Prykowski, „Ocena ryzyka zawodowego na stanowiskach pracy (Risk assessment in a workplace)”, *Górnictwo Odkrywkowe*, vol. 6, pp. 83-88, 2013 (in Polish).

[11] A. Górny, „Identyfikacja przyczyn zdarzenia wypadkowego. Zastosowanie diagramu Ishikawy do oceny pierwotnych i wtórnych przyczyn zdarzenia wypadkowego (The identification of occupational accident roots. The use of Ishikawa diagram for assessment of both primary and secondary roots of accident)”, *Zeszyty Naukowe WSZOP*, vol. 9, pp. 27-43, 2013 (in Polish).

[12] K. Matuszewski, „Główne przyczyny wypadków śmiertelnych w polskich podziemnych zakładach górniczych w latach 2000-2009 (The principal reasons of fatal accidents in Polish underground mining enterprises in years 2002-2009)”, *Bezpieczeństwo pracy i ochrona środowiska w górnictwie*, vol. 11 (195), pp. 28-34, 2010 (in Polish).

[13] K. Matuszewski, „Określenie przyczyn wypadków przy pracy w górnictwie w aspekcie profilaktyki (Defining accidents at work causes in mining in aspect of prevention)”, *Bezpieczeństwo pracy i ochrona środowiska w górnictwie*, vol. 3, pp. 19-23, 2009 (in Polish).

[14] K. Matuszewski, „Przyczyny wypadków przy pracy w górnictwie w aspekcie profilaktyki (Causes of occupational accidents in mining in the aspect of prevention)”, *Bezpieczeństwo pracy: nauka i praktyka*, vol. 2, pp. 22-25, 2009 (in Polish).

[15] A. Borcz, W. Kozioł, A. Ciepleński, L. Machniak, „Bezpieczeństwo pracy i system ratownictwa górniczego w kopalniach odkrywkowych w Polsce. Część I (Safety at work and mine rescue
system in surface mines in Poland. Part 1), *Przegląd górniczy*, vol 12, pp. 82-89, 2015 (in Polish)

[16] A. Kowal, „Metodyka kształtowania kultury bezpieczeństwa pracy w górnictwie miedzi w aspekcie wypadkowości”, *Doctoral dissertation*, Poznań, 2015 (in Polish).

[17] M. Krause, „Analiza przyczyn wypadków przy pracy w górnictwie na podstawie danych Głównego Urzędu Statystycznego (Analysis of the causes of accidents at work in the mining industry on the basis of data from the Central Statistical Office)”, *Wiadomości górnicze*, vol. 7-8, pp. 395-404, 2015 (in Polish).

[18] Główny Urząd Statystyczny (Statistics Poland), “Wypadki przy pracy (Accidents at work)”, *Raports*, Warszawa, 2010-2018.

[19] M. Szubicki, A. Malon, M. Tymiński (ed.), “Bilans zasobów złóż kopalń w Polsce (The balance of mineral resources deposits in Poland)”, *Raports*, Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Warszawa, 2010-2018 (in Polish).

[20] Wyższy Urząd Górniczy (State Mining Authority), „Ocena stanu bezpieczeństwa pracy, ratownictwa górniczego oraz bezpieczeństwa powszechnego w związku z działalnością górniczo-geologiczną (Assessment of the condition of work safety, mining rescue and general safety in connection with mining and geological activities)”, *Raports*, Katowice, 2010-2017 (in Polish).

[21] E. Ejdys, „Kształtowanie kultury bezpieczeństwa i higieny pracy w organizacji (Schaping occupational and safety culture on organizational level)”, Oficyna Wydawnicza Politechniki Białostockiej, Białystok, 2010 (in Polish).