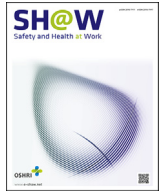




Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Original article

A Retrospective Comparative Study of Serbian Underground Coalmining Injuries



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ARTICLE INFO

Article history:

Received 2 April 2020

Received in revised form

1 March 2021

Accepted 7 July 2021

Available online 13 July 2021

Keywords:

Coal mine

Injury

Preventive measures

ABSTRACT

Background: During 2011, a study was undertaken to assess safety conditions in Serbian underground coalmines by analysis of injury data. The study covered all Serbian coalmines, identified weak spots from the aspect of safety, and recommended possible courses of action. Since then, Serbia has made changes to safety and health legislation; all coalmines introduced new preventive measures, adopted international standards, and made procedures for risk management. After 10 years a new study has been performed to analyze the impact of these changes.

Materials and methods: In this study, the injuries that have occurred in the Serbian underground coal mines over the last 20 years were analyzed. Statistical data analysis was performed by IBM SPSS Statistics v23. The injuries that occurred in the last ten years were compared with the results of the previous study (2000–2009). The average values of injury rates for both periods were compared for each of the categories (severity, age, body part, qualification), and the results were presented as absolute difference or percentile difference.

Results: The results showed reduction in the number of injuries in the category of 20–30 years old workers, where the new training procedures for workers, which were set by mandatory legal regulations, certainly contributed. They also showed an increase in the number of injuries in the category of old workers, which indicates that the law did not have a positive effect on this category.

Conclusion: The total number of injuries is still high; therefore, it is necessary to introduce mechanization and automation in mines and have a better policy for older workers who retire later nowadays.

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1. Introduction

The distinctiveness of mining, especially underground exploitation, is reflected in unfavorable working conditions (confined working space, poor lighting, presence of water and toxic gases, etc.). The occupation of a miner is considered as one of the most dangerous due to a great number of dangerous and harmful conditions [1–3].

Because of a great number of injuries compared to the number of employees in the mines, as well as frequent collective accidents, the researchers have performed numerous studies on the subject of work related injuries in mining. The primary focus of this research is mostly the same, which is to find the main causes of injuries and define the measures that need to be taken to reduce the number of injuries. In complex systems such as mines, it is very difficult to single out individual causes of accidents. A dynamic environment

such as a mine, where a worker and machine share the working space and where geological and natural conditions in the deposit additionally affect and directly change already complex working conditions, represents “a fertile ground” for injuries and collective accidents.

The success and profitability of small mining companies can be seen in the increase in coal production. Because of the non-mechanized method of coal mining, which is a cause of low production performance, the overall pressure of mine survival is transferred to workforce, i.e., the miners, and this pressure inevitably affects the number of work-related injuries. The management of the mining companies in Serbia is focused on keeping the company operational in a period when coal mines around the world are closing and switching to environmentally friendly energy resources, thus making this pressure even more pronounced. Moreover, the free market and import reduce the selling price of

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coal produced in Serbia. In such difficult business conditions, the mine management is forced to put pressure on the employees to achieve the planned production and favorable business performance, which is in direct contrast with the development and affirmation of the safety culture in the mines. Several studies [4,5] showed that the workers' risky behavior was directly related to the attitude of senior management toward the safety culture, as well as the attitude of the managers present during the production process. The important question is what will the management do to improve safety and health conditions at work apart from what the legal regulations prescribe. The complexity of mines and specific working conditions greatly affect the occurrence of injuries, first and foremost, the conditions in the working environment, as well as the worker–equipment relation. Modernization and automation of mines would lead to a reduction of number of mine workers, which would further reduce the number of injuries. Furthermore, instead of a man working in a dangerous place, machines would assume this role. However, the implementation of modern mechanization would further complicate the existing system that could lead to new dangerous situations. Coal mining technology affects the number of injuries. Mines that extract coal mechanically have fewer number of injuries than mines that are partly mechanized or where work is done manually. The authors [6], in the study of two underground coal mines in Turkey where coal was exploited by conventional and mechanized technology, noticed that the total number of injuries was lower in the mine with mechanized technology; however, some of the indicators remained the same: the age category of injured workers and injured part of the body (mostly upper and lower extremities).

Workers' satisfaction, their motivation and commitment to work can significantly contribute to the occurrence of injuries. The fact is that workers in Serbia have lower incomes compared to those in Europe. The situation is similar in mining, especially in the public sector. Furthermore, those who cannot find other jobs choose to work in the mines; therefore the question arises whether such a worker is able to work in such conditions that can endanger his and other people's lives.

Many authors indicated that the cause of injuries in complex systems was very difficult to single out and that the injuries occurred due to several causes. When accidents are observed as complex phenomena, the obvious relationship between the behavior of part of a system and the outcome at the system level cannot be noticed, e.g., system malfunction or human error [7]. Authors [8] also stated that an incident resulting in fatality is multicausal.

To reduce the number of injuries and improve safety, in addition to introduced measures, it is necessary to perform analysis that will identify the main causes of injuries. Shahani et al. [9] found that the most common causes of fatal injuries were mine collapse and blast, accumulation of gas, gas explosion, and falling stones. The same authors recommended the improvement of safety education and training and mechanization of the excavation technology (same as in the analyzed case).

In the study by Md-Nor et al. [10] hazards were sorted in three categories: human error, equipment failure, and working environment. The authors also suggested that human error contributed to almost half the fatalities.

Brocal et al. [11] provided guidelines for improving human and organizational performance to improve risk management in complex systems, especially Organizational and Human Performance, Dynamic Management, Organizational Performance, Human Performance, and Complex Systems.

The authors [5] provided a review of research works regarding organizational and human performance in analysis of accidents where complexities, systemic risks, and organizational and human

performance were seriously involved. Based on the analysis of fatal injuries, Evaz et al. [12] concluded “miners as individuals adapted and accepted the new measures much faster than the management”. This could be explained by the need to adapt the technology and technical solution which was sometimes not possible. However, it also indicated that there was no adequate link on the relation safety–management. Safety measures should be addressed on the managerial level of the mine instead of being imposed as legal obligation from the outside.

Serbia today has nine underground coalmines with 11 productive units organized under central management of public enterprise for underground coal extraction Resavica (Original name in Serbian: Javno preduzeće za podzemnu eksploataciju uglja Resavica JP PEU). Overall annual underground coal production of JP PEU is about 600 000 t of coal [13]. Low production is a consequence of low-productive mining methods and an extremely low level of mechanization of mining activities. Relatively high incorporation of manual labor results in higher occupational injury rates than other industry branches. Mining and other industrial occupations such as mechanical, construction, metallurgical, and so on are considered as increased risk positions. According to the Serbian Ministry of Labor reports [14], more than 30% of severe occupational injuries and mortalities that occurred in Serbia happened in mining and industry. As a comparison, the second highest number of occupational injuries was related to health and social care (13%) while transportation came third with 8%.

Back in 2011, a retrospective study [15] was undertaken to analyze data on mining injuries in Serbian coalmines. The aim of this study was safety assessment and suggestion of preventive measures. The results of the study were presented to the public, and, as a result, JP PEU Resavica reviewed its internal safety and health acts and ensured their enforcement to be more rigorous. In addition, Serbia has been, as a European Union membership candidate, under obligation to harmonize and coordinate legal acts with the EU norms. Consequently, a number of new legal and sublegal acts covering occupational safety and health have been introduced. To assess the influence of incorporation of new legislation to injury rates a new study was undertaken.

Increased occupational risk in underground mining activities accelerated enforcement of new measures introduced in accordance with European Union and International Labour Organization (ILO) conventions. Serbian Ministry of labor also endorsed the need for legislation coordination with EU norms and presented a number of legal and sublegal acts regarding safety and health at work. Main documents were Strategy on safety and health at work (SSHW) from 2013 [16] and Action plan on Strategy enforcement (APS) [17]. These two documents presented the foundations for existing legislation amendments and new legislation preparation. Outlining all the safety- and health-related documents adopted during previous years would require vast amount of time and space and would excessively burden the text. All of the safety and health acts which are actual in Serbia are listed on Serbian Ministry of Labour website, unfortunately only in Serbian (<https://www.minrzs.gov.rs/?view=lat&action=page&id=%20uprava-za-bezbednost-i-zdravlje-na-radu>).

The majority of the new regulations are related to risk assessment at workplace and working environment. Risk assessment act was first introduced through Serbian Occupational safety and health act in 2005. To further improve it, this act was amended in 2015 [18]. The original guide on risk assessment was introduced in 2006; however, to coordinate it with EU norms it was amended during the same year, then again in 2010 and, to take its final form, in 2015. The actual guide is the Rulebook on the methods and procedures of risk assessment at workplace and working environment [19]. The Rulebook provides clear guidelines on identification

of working positions with increased risk leading to the need to define necessary health conditions a worker must meet to work. The result was the Rulebook on pre-employment and periodical medical examinations of employees at increased risk position. Similar to Risk assessment act, the Medical Examination Act was introduced in 2007 and then, in order to be in accordance with EU norms, first amended in 2008 and again in 2017 to its final form [20]. The law on Mining and Geological Exploration is very important law for miners in Serbia. This law also changed in the mentioned period. The most important changes were seen in the fact that inspection officers, in their inspection checklist, controlled safety and healthy documents directly in mines [21]. However, Serbia Ministry of Mining and Energy has only a few inspectors; thus they cannot control all mines in Serbia.

There were also some changes to procedure of injury reporting. The procedure was outlined in the Rulebook on composition and procedure of issuing occupational injury and professional illness report form published in 2006, amended during the same year and again in 2016 to take its present form [22]. What also needs to be mentioned is the fact that upper limit for retirement was extended from the age of 60 to the age of 65 for male workers, which, as will be shown later, negatively affected safety at work.

During the last ten years, public enterprise for underground coal extraction JP PEU actively followed changes in legislation regarding safety and health at work by adoption of new procedures for risk management and coordination of internal rulebooks (Fig. 1).

During 2008 and 2009, JP PEU incorporated ISO 14001 and OHSAS 18001 standards which were certified by Lloyd's certification body during 2010. During 2009 and 2010 the Company, in accordance with legal recommendations, conducted risk assessment for all working positions and prepared a Risk Assessment Act. The result was reallocation of the work power to adequate positions based on physical abilities and capabilities. In accordance with the Risk Assessment Act and previously mentioned Medical Examination Rulebook a number of workers, mainly from older population, were withdrawn from increased risk underground positions and allocated to surface working positions.

Apart from risk assessment, JP PEU conducted equipment inspection, made improvements in working environment monitoring, acquired necessary air quality and ventilation parameters monitoring systems, organized trainings for workers, and conducted a number of measures to improve safety and health conditions in all nine underground mines.

Insufficient mechanization was seen as the greatest weakness in the observed mines. Apart from the means of transport (belts and chain conveyor) and delivery (monorail and cableway), the other equipment was not available. During this research, more than 30 year later, the mechanized construction of rooms in some of the mines has started. Other equipment (pumps, transformers) was stationary, and injuries could occur during their transport.

Mining stopes were seen as places with the greatest risk of injury, in addition to collapsing, where injuries could occur during

the handling of support material (timber, steel rings), installing the support, or using drilling equipment [6,23,24].

Unfortunately, no significant changes were made to improve mining technology in terms of higher mechanization and automation and lower incorporation of manual labor.

An analysis of injuries that occurred in the last 10 years, with characteristic groups of workers with the greatest number of injuries pointed out, is presented in the first part of the paper. The second part of the paper focuses on a comparative analysis of the injuries that occurred during both periods of time. This analysis was performed to show the result of measures implemented by the management, which were in accordance with the legislation.

The aim of this retrospective comparative study was the assessment of the effects of measures undertaken in Serbian underground coalmines and legislative changes in the field of safety and health at work to injury rates. Since the base for the comparison was the retrospective study from 2011, it was important to follow the same methods so the results could be comparable. Therefore, the data on injuries originated from all nine Serbian coalmines. The original and comparative study cover the same number of years, 10 years period: (2000–2009) and (2010–2019). The primary goal was to compare the two periods and get a clear picture of the safety situation in underground coal mining and how the new legal measures affected injury reduction.

2. Materials and methods

The data on underground coalmining injuries still originate from monthly and annual injury reports of separate mines of JP PEU but are gathered and processed in the central safety service and presented here cumulatively for the Company as a whole.

The occupational injury severity was adopted from Serbian regulations as Light (L), Heavy (H), and Fatal (F). According to US MSHA equivalent for Light (L) is No days lost (NDL), for Heavy (H) is Non-fatal with days lost (NFDL) and Fatal (F).

In accordance with the original study, injured miners were classified into four age groups (age 20–30, 31–40, 41–50, and 51–60+ years of age). A remark must be made that, according to changes in Serbian regulations, the retirement limit was raised from the age of 60 to 65 for male workers. This directly influenced the age injury rates since the number of aged miners increased in comparison to other age groups. In addition, the original study stated that the years of work experience were in agreement with the age of workers, which was fairly correct; however, it must be noted here that there were inexperienced workers in all age groups. The reason for this was that the lack of jobs forced people of all age to seek jobs in the mining sector.

The location of the injury according to the injured body part remained the same as in 2011: head; eye, ear, or face; internal organs; poisoning; upper limb; lower limb; chest, back, or neck; and other.

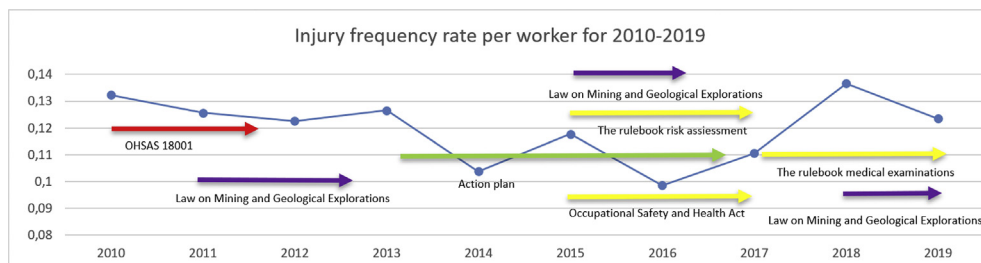


Fig. 1. Injury frequency rate per worker for 2010–2019 and legislation change.

Time of injury was observed according to the shift, covering morning or “I”, the first shift (0–15 h); day or “II”, second shift (15–23 h); and night or “III”, third shift (23–07 h).

Educational background of the injured miners was classified into six groups as it was in the 2011 Study. VSS qualification (higher education) corresponds to university degree or higher [16 or more Years of Education in Total (YET)], while SSS qualification (secondary education) corresponds to 4 years secondary school (12 YET). VKV (highly qualified), KV (qualified), and PK (semi qualified) were only internal qualifications not related to years of educational level but were awarded upon completion of Company trainings. NK designation (non-qualified) stands for no education at all or less than 8 YET. Previous study failed to explain that these designations, in general, consider education in the mining sector and that it is, in theory, possible to have an PhD holder at NK miner position because of no mining related experience.

Based on the available data, the causes of injuries for the period 2010–2019 were analyzed as well, and eight groups were defined based on these indicators: unsafe behavior at work, trips and fall, collapse of material, failure to follow instructions, inadequate use of PPE and collective protection equipment, the inattention of another worker, sudden failure of machines and devices, and other. These data were obtained from the Occupational Injury Report which was filled out by the person responsible for the classification of the injury based on one of the eight causes.

Because the observed periods had the same duration, in addition to the display of percentage share of specific injury category in total number of injuries, an average yearly injury rate was assigned to both observed periods to achieve comparability. The better approach for comparability achievement would probably be the use of rate of injuries per 100 worker-years of exposure but the composition of data did not allow this. It would be impossible, for example, to provide average number of workers per shift because that number fluctuated on a daily basis.

The Statistical Package for the Social Sciences (SPSS) was used for the analysis. The SPSS is a very powerful statistical software tool where almost all conventional statistical methods are implemented.

The average values of injury rates for the periods 2000–2009 and 2010–2019 were compared for each of the categories, and the results were presented as absolute difference or percentile difference. To calculate absolute difference injury rates for the period 2000–2009 were subtracted from the rates for the period 2010–2019. The increase in rates was denoted by the sign “+” while decrease was denoted by the sign “–” in the corresponding table. Percentile difference was calculated as percentage of absolute difference against the values for 2000–2009 period. In the same manner as for absolute difference, plus and minus denoted increase and decrease in observed injury rate, respectively.

The literature review revealed that more recent research [25–28] on occupational injuries issue was mainly oriented towards risk assessment, financial effects of injuries, and/or incorporation of popular research techniques than it was on the core causes of the incidents. The overall impression is that timely preventive actions got lost in overwhelming mathematical apparatus and odds calculus. Some of the research [29,30] was too narrowly oriented while some was too wide to be applicable as a guide for the study while some was already consulted back in 2011 [31–35]. The literature review just confirmed the initial decision to maintain the same methodology as one used back in 2011.

3. Results

During the period 2010–2019, there were 4,844 injuries which was significantly lower than 5,850 injuries covered in the study from 2011. The general trend in the decrease in injury rates was noticeable with several exceptions that will be explained later in the paper.

The overall results are encouraging and supportive of changes in safety and health legislation and policy, especially when slight increase in number of workers is observed.

3.1. Severity of injuries – degree

During the 2000–2019 period, the number of total injuries and fatalities was 10,694. The number of injuries (Fig. 2) reduced year by year, and the peak for the observed period was in 2008 when the largest number of injuries was noticed 669. In the second period 2010–2019, the number of injuries dropped below 534.70 which was the annual rate for the last 20 years, while the lowest number of injuries was 405 in 2016.

The injury frequency rate per worker for period 2010–2019 (Fig. 1) also showed a decrease until 2016; then there was an increase and the highest value in 2018 (0.137 injury per worker).

3.1.1. Severity degree of the injuries for the 2000–2019 period

If the severity degree of injuries for the entire observed period was analyzed, the highest number of injuries occurred in the category of NDL (9,649) or 90.23%, the maximum number of injuries in this category was 613 (2008), and minimum number was 350 (2016), with standard deviation of 66.36. The total number of NFDL injuries was 1,018 or 9.81%, the lowest number was 38 during a year 2001, and the highest number was 68 (2010) (Table 1). The total number of fatal injuries was 27 or 0.252 % during the last 20 years. Detailed data were available for this category of injuries, and the following can be noticed: the highest number of injuries occurred during the extraction of coal (65.22%) in the category of

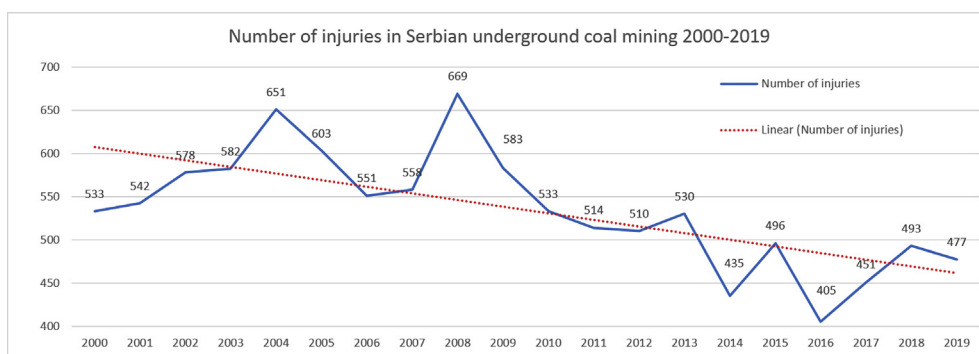


Fig. 2. Number of injuries in Serbian underground coal mine, for 2000–2019.

Table 1
Descriptive statistics of injuries for the 2000–2019 period

Injury severity	Number of years	Minimum	Maximum	Sum	Mean	Standard Deviation
Fatal	20	0	3	27	1.35	0.988
Heavy	20	38.00	68.00	1,018.00	50.9000	7.50368
Light	20	350.00	613.00	9,649.00	482.4500	66.36143

workers aged 40–50 (29.17%) and 30–40 (37.50%) during the third shift (47.83%) [12].

3.1.2. Overview of injuries by severity degree for the 2010–2019 period

The highest number of injuries occurred in the category of Light injuries, where a clear downward trend in the number can be observed (Fig. 7), while category Heavy did not show the downward trend. This indicated that even if the total number of injuries was reduced for this period (2000–2019), no significant improvement related to the category of Heavy injuries was observed (Table 2). Heavy injuries usually leave permanent consequences on workers – they reduce their working ability and imply the use of great number of sick days. Heavy injuries demand further treatment; thus any kind of misconduct by the management (for example not reporting the injury) is not possible. It is unusual that there was no significant improvement related to the reduction of number of injuries in this category in the last ten years, because heavy and fatal injuries should be reported to the department responsible for mining inspection in Serbia. This clearly shows that the department responsible for mining inspection does not implement penal policy or education that could reduce the number of injuries. This further explains the fact that, despite numerous regulation and laws passed by the state, the company’s management does not pay enough attention to the importance of safety culture because there is no penalty system and inspection bodies express indifferent behavior towards the implementation and control of implementation of said regulations and laws. This indifferent behavior is transferred to other levels of management system in the company, and the security is reduced to few people responsible for occupational health and safety and the worker and his awareness of OHS.

3.2. Age of injured workers

The injury frequency rate based on the age of injured workers was the highest for the youngest workers (20–30) until 2013, and after that the trend showed decrease. The trend showed increase for older workers as well. At the beginning of the introduction of measures, workers strictly adhered to the rules, which contributed to the reduction of the injury rate for all age groups. In the second half of the observed period, the measures that caused an increase in the rate of injury occurred (Fig. 3).

Table 2
Descriptive statistics of injuries for 2010–2019 period

Injury severity	Number of years	Minimum	Maximum	Sum	Mean	Standard Deviation
Fatal	10	0	2	11	1.10	0.876
Heavy	10	40.00	68.00	510.00	51.0000	7.34847
Light	10	350.00	479.00	4,323.00	432.3000	40.10833

The relation between the age of the injured person and frequency in which those injuries occur was studied by a great number of researchers [6,36,37]. Based on this research, the authors determined that the highest number of injuries occurred in the category of workers aged 31–40 (3,823), providing the index indicator; thus the analysis of the age of workers showed that the highest number of injuries occurred in the category of workers aged 31–40 (35.45%) (Table 3).

3.3. The location of the injury – injured body part

The results of location of the injury analysis for period 2010–2019 is presented in Fig. 4. It shows that extremities had the highest injury percentage with more than 70% (3,527) of all injuries being linked to upper or lower limbs. As concluded before, this is a consequence of high incorporation of manual labor. Mechanization and automation of the mining process would certainly result in injury decrease. Table 4 shows two cases of poisoning for the 2010–2019 period both cases were in the same year (2018) and without a fatal outcome. This shows that mines have better procedures for this kind of danger, comparing to 2000–2009 period when it has been cases of poisoning showed that the procedures were not established in the mines for those parts that were not properly ventilated.

3.4. Time of injury – working shift

For the 2010–2019 period, based on the working shift, the distribution of injury was the same as in the previous period (Fig. 5). The most of injuries happened during the first shift (44.29%), then the next most injuries happened during second shift (33.22%), and the lowest number occurred during the third shift (22.47%).

3.5. Educational background of injured workers

Observation of the qualification structure of the workers showed that the highest number of injuries still occurred among the lowest qualification structures of the workers (Fig. 6). This is a consequence of probability (largest number of workers belonged to the non-qualified group) and the fact that low qualified workers (NK, PK, and KV) were exposed to the highest risks.

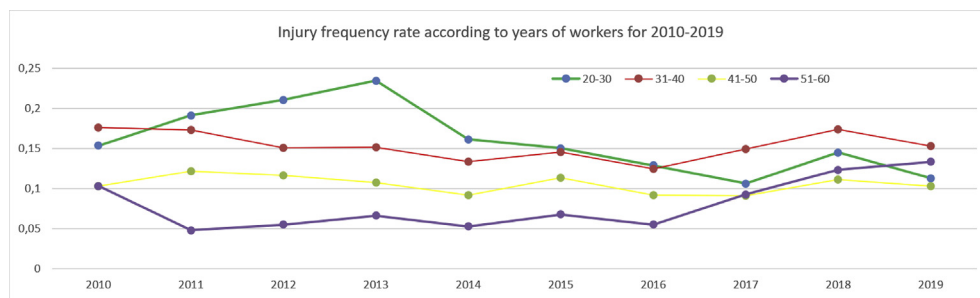


Fig. 3. Injury frequency rate according to the age of workers for 2010–2019 period.

Table 3
Descriptive statistics of injuries for 2010–2019 period

Age of workers	Number of years	Minimum	Maximum	Sum	Mean	Standard Deviation	%
Years 20–30	10	81.00	128.00	987.00	98.7000	13.03031	20.38
Years 31–40	10	142.00	210.00	1717.00	171.7000	19.55079	35.45
Years 41–50	10	130.00	179.00	1541.00	154.1000	17.12341	31.81
Years 51–60	10	48.00	71.00	599.00	59.9000	9.17061	12.37

The relation between qualification and job position had a great share in the occurrence of injury, primarily because it affected the length of exposure to a dangerous situation, imposed conditions in the work environment, and defined the jobs that a worker performed on certain machines, as well as tools the worker used. Moreover, a low level of education affected the understanding of safety procedures, instructions, training programmes, prohibitions, etc. [38–40].

Table 5 shows that the highest number of injuries occurred in the category of workers with the lowest level of education (KV, PK, and NK), 4,537 of the total number of injuries or 93.66%. The index values showed no significant peaks which indicated that there were no meaningful changes in the awareness of safety culture and training that would be manifested in the reduction of number of injuries among workers with lower levels of education. The workers in this category were those present at the extraction sites and exposed to the highest level of risk. In the category of workers with higher education the number of injuries had a maximum value of 38 (2018). These workers controlled and implemented OSH measures at a lower management level, and, because the changes in the number of injuries were negative, i.e. the number of injuries increased, there were some indication that these workers that represented the link between senior management and workers, were responsible for the stagnation in improving the safety culture in coal mines and that they were not sufficiently aware of the importance of safety at work.

3.6. Distribution of injuries based on the cause

Verma and Chaudhari [4] noticed that a great number of injuries in Indian mines were related to human error, poor organization, or

inadequate management. Zhao and Nie [41], Zheng et al. [42], and Qiao et al. [43] pointed out that human factor and unsafe behavior were the cause of collective injuries and major accidents in Chinese mines.

This can be explained by the fact that the instructions and written procedures were almost never followed exactly, as operators strived to become more efficient and productive and to cope with time and other things that cause pressure [44].

Based on the available data and predefined causes in Fig. 7 and Table 6, unsafe behavior at work was the main cause of injuries. There were 3,050 injuries or 62.96% caused by the unsafe behavior, and 10.07% were caused by trips and falls or, in other words; 488 cases were observed where this type of injury occurred and were mainly related to poor maintenance of access road in the pits. Compared to the total number of injuries, collapse of material was the cause of 565 injuries or 11.66%. Failure to follow instructions and sudden failure of machines and devices caused 4.83 and 4.98% of injuries, respectively. Others did not exceed 2%.

4. Discussion

4.1. Comparative display of injury distribution according to the severity degree

Data on injury rates based on severity degree for the 2010–2019 period (Fig. 8) and their comparison to 2000–2009 period (Table 7) showed significant decrease of fatal and light injuries (31.25 % and 18.83 %, respectively), and mild increase in heavy injuries category (0.39 %). The increase in heavy category (NFDL MSHA equivalent) was a consequence of changes of injury

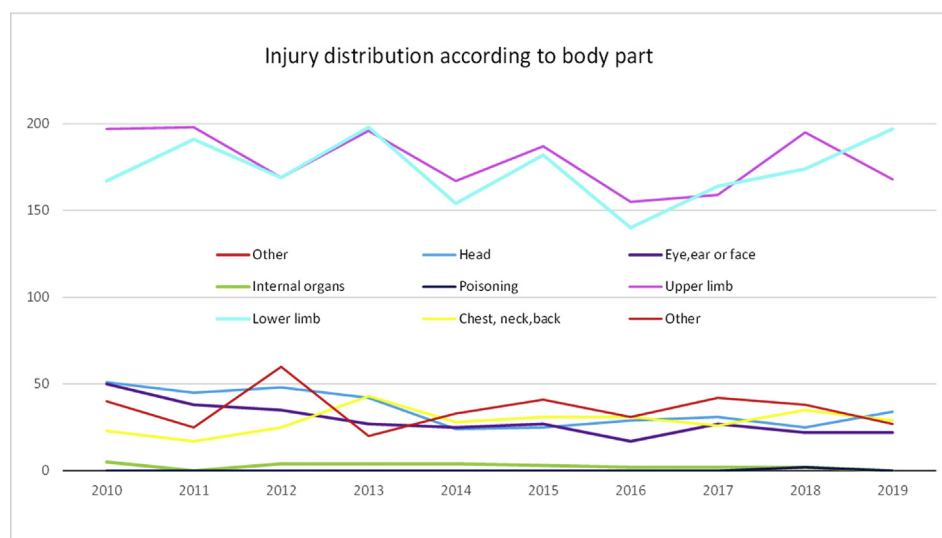


Fig. 4. Injury distribution according to body part, for 2010–2019.

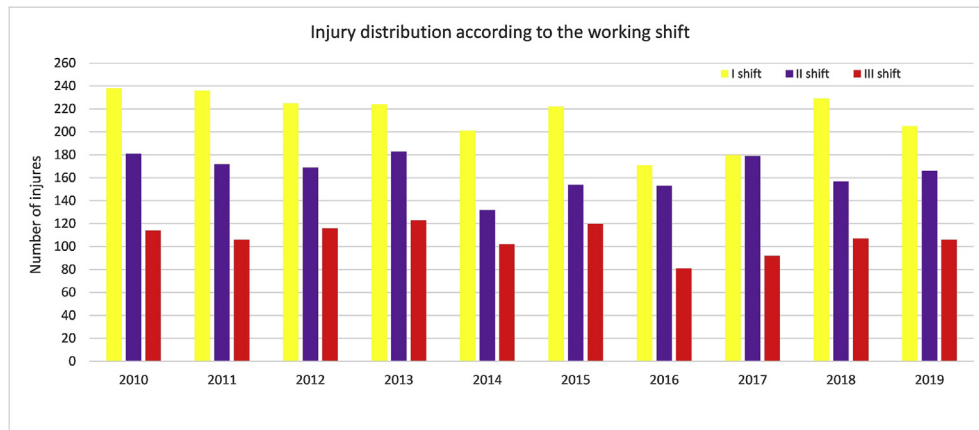


Fig. 5. Injury distribution according to the working shift.

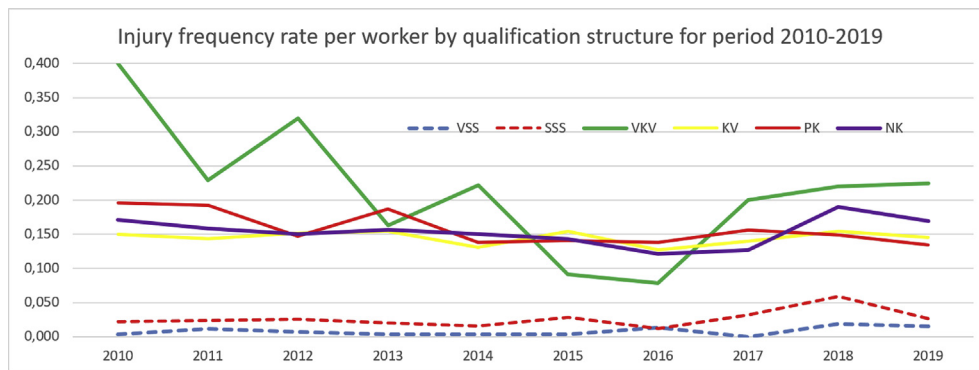


Fig. 6. Injury frequency rate per worker according to qualification structure.

reporting regulations [22] which reallocated certain injuries (some light twisting, some cuts, minor contusions, bruising etc.), which were previously considered as light injury to heavy injury category. High decrease in the fatal category was a consequence of, fortunately, lower general number of fatal injuries (11 over ten years compared to previous period, and 16 fatal injuries over 10 years). Almost nineteen percent decrease in light injuries was a remarkable achievement since light injuries were most frequent and had the highest contribution to overall injury number (around 90 %) for both observed periods. This decrease in light injuries can also be a consequence of legislative changes and reallocation of some injury types; however, it was more likely a result of better safety and health trainings and raised safety awareness of the miners.

4.2. Age of injured workers

In the same manner as in the 2011 study, apart from the raw data on injury rates based on age, the number of workers in each age group was incorporated into analysis by use of injury rates per 100 worker years (Table 8). The first thing that was noticeable was nearly 50% decrease in injury rates for the youngest workers. However, that was partly a consequence of increased number of workers in 20–30 years age group (Table 9). Increase in the number of workers lowered the injury rates per 100 worker-years and opposite, a decrease in number of workers increased rates. Consequently, it was expected that RI/100WY for the youngest workers would be lower, but not to that extent. The result of comparison, presented in Table 9, was a surprise and the only

Table 4
Descriptive Statistics of injuries for 2010–2019 period

Body part	Number of years	Minimum	Maximum	Sum	Mean	Std. Deviation	%
Head	10	24.00	51.00	354	35.4000	105.156	7.31
Eye, ear, face	10	17.00	50.00	290	29.0000	92.000	5.99
Internal organs	10	0.00	5.00	26	2.6000	2.933	0.54
Poisoning	10	0.00	2.00	2	.2000	0.400	0.04
Upper limb	10	155.00	198.00	1791	178.8000	301.067	36.97
Lower limb	10	140.00	198.00	1736	173.6000	354.044	35.84
Chest neck back	10	17.00	43.00	288	28.8000	49.511	5.95
Other	10	20.00	60.00	357	35.7000	127.567	7.37

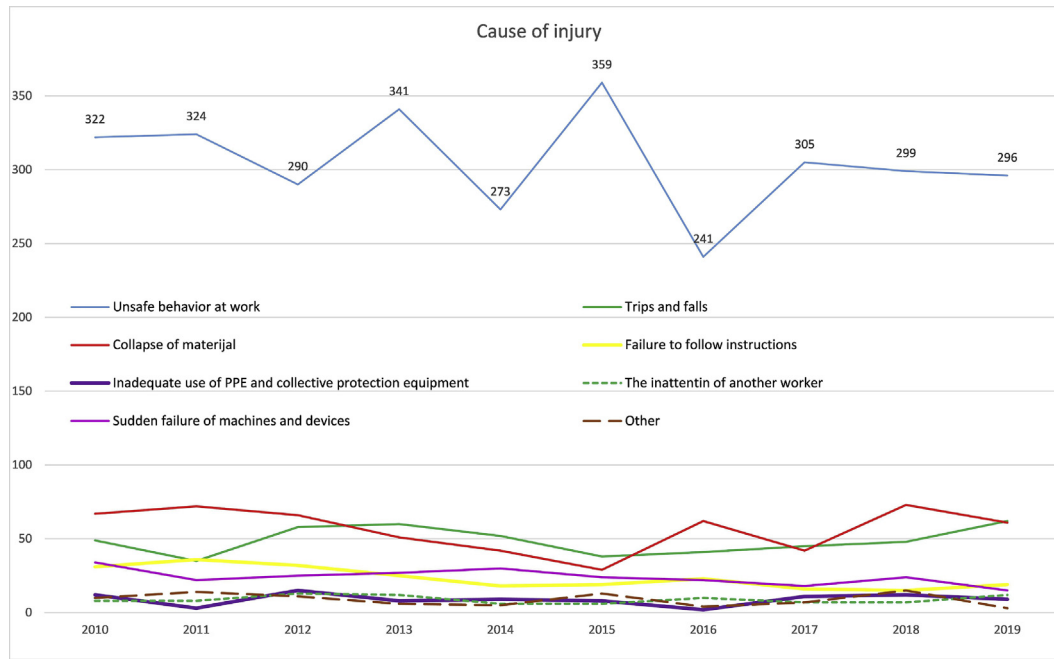


Fig. 7. Injury distribution according to cause of injury.

explanation could be the improvements in training policy of JP PEU. This claim was supported by the fact that despite the decrease of number of workers in the 31–40 years age group injury rates per 100 worker-years decreased.

The comparison results for 41–50 and 51–60 age groups were, however, concerning. The 7% increase in injury rates for 41–50 age group was a consequence of 10% less miners in this group. This leads to conclusion that legislation and policy changes did not affect this group. The reason for that was probably the mental and cognitive condition of the workers [23]. Younger workers were more capable of adopting new knowledge and more prone to change their behavior according to new requests than elderly workers. In addition, the youngest group had no previous experience and modus operandi to unlearn before complying with new rules while the older ones were more likely to behave according to the “old way” policy. These results could be observed from the point of job position as well. Younger workers mainly work in the transport and delivery. Fall and injuries involving cargo, as well as rotating parts of a conveyor, represent the main dangers for them. As they gather experience, they are sent to complete the training for positions related to extraction. This was the reason for higher number of injuries among older workers. In reality, they were in greater danger and did not possess agility present in younger workers.

The alarming results were observed in the increase in injury rates (12%) amongst the eldest workers, despite the increase in

their number of nearly 30%. The increase in the number of workers was a consequence of several factors. One of them was the legal limit for retirement which was extended to 65 years of age. According to Serbian regulations, a worker can retire once he meets either age limit or once he reaches 40 years of work experience. Some underground mining workers have a 6-month benefit, meaning that for each 12 months of work they are awarded 18 months of work experience. In theory, it would be possible for an underground miner to retire at the age of 45 if he started working at the age of 18. However, majority of workers decides not to retire early because their salary is much higher than their monthly retirement compensation would be. In some cases, the elderly miners decide to continue working because they are financially supporting their children who are either unemployed or with salaries not sufficient to provide financial security.

In addition, JP PEU is to go through the process of restructuring meaning that a number of workers will be offered to voluntarily leave the Company. The majority of elderly workers who already met the experience retirement requirement are waiting for this restructuring in hope of high severance pay offers.

The increase of injury rates amongst the oldest population of workers is merely a consequence of their age. Their reflexes are slower; their awareness of the environment is muffled due to reduced sharpness of the senses. In underground coalmining, good eyesight is of extreme importance. The low illumination conditions,

Table 5 Descriptive Statistics of injuries for 2010–2019 period

Qualification structure	Number of years	Minimum	Maximum	Sum	Mean	Standard Deviation	%
VSS	10	.00	5.00	22.00	2.20	2.844	0.45
SSS	10	8.00	38.00	177.00	17.70	66.233	3.65
VKV	10	4.00	20.00	108.00	10.80	22.400	2.23
KV	10	177.00	231.00	2,035.00	203.50	470.500	42.01
PK	10	69.00	95.00	794.00	79.40	96.489	16.39
NK	10	143.00	195.00	1,708.00	170.80	303.511	35.26

KV, qualified; PK, semi qualified; SSS, secondary education; VKV, highly qualified; VSS, higher education.

Table 6
Descriptive statistics of injuries for the 2010–2019 period

Cause of injury	Number of years	Minimum	Maximum	Sum	Mean	Standard Deviation	%
Unsafe behavior at work	10	241	359	3050	305.00	33.869	62.96
Trips and falls	10	35	62	488	48.80	9.295	10.07
Collapse of material	10	29	73	565	56.50	14.797	11.66
Failure to follow instructions	10	15	36	234	23.40	7.351	4.83
Inadequate use of PPE and collective protection equipment	10	2	15	89	8.90	4.012	1.84
The inattention of another worker	10	6	13	89	8.90	2.644	1.84
Sudden failure of machines and devices	10	15	34	241	24.10	5.486	4.98
Other	10	3	15	88	8.80	4.367	1.82

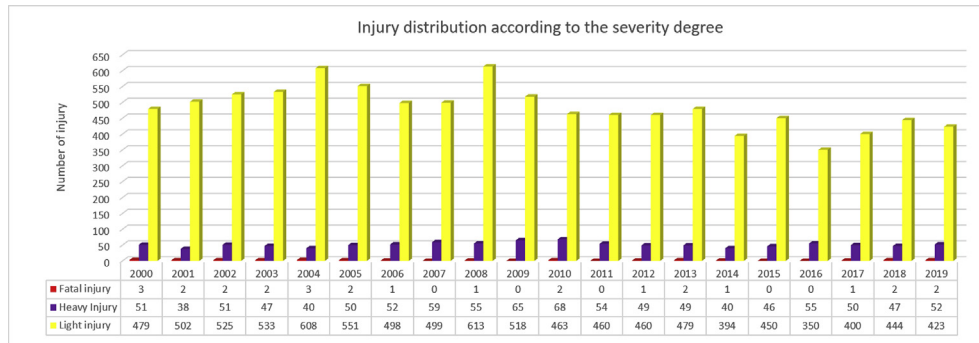


Fig. 8. Injury distribution according to the severity degree.

shadowy environment, constant noise, and cramped spaces make it extremely difficult to notice threats if eyesight is reduced. All this leads to elderly workers being more subjected to injuries explaining the higher injury rates.

Present conditions and the results presented here show that the decision of the Government to raise the retirement limit had highly negative effect on safety conditions especially in underground mines. This should stimulate the Government to reconsider the decision because it is evident that even when JP PEU, in accordance with the Risk Assessment Act, reallocated elderly

Table 7
Comparative display of injury distribution according to the severity degree

Degree	2000–2009	2010–2019	Difference	
	Average	Average	Absolute	%
F	1.60	1.1	-0.50	-31.25
H	50.80	51.00	+0.20	+0.39
L	532.60	432.30	-100.30	-18.83
Σ	585.00	484.4	-100.60	-17.20

Table 8
Injury rates per 100 worker years based on age and comparison to 2000–2009 period

Age	2010–2019	2010–2019	2010–2019	2000–2009	Difference	
	ANW	Injuries	RI/100WY	RI/100WY	Absolute	%
21–30	703	987	14.04	29.60	-15.56	-52.57
31–40	1114	1717	15.41	17.10	-1.69	-9.89
41–50	1388	1541	11.10	10.39	+0.71	+6.87
51–60	901	599	6.65	5.83	+0.81	+13.97
Σ	4106	4844	11.80	14.32	-2.52	-17.62

ANW, average number of workers; RI/100WY, rate of injuries per 100 worker-years.

workers to positions more suitable to their age they are still subjected to injuring.

4.3. The location of the injury-injured body part

Comparison with the results from 2011 (Table 10) show the decrease in injury rates for all body parts indicating that preventive measures were effective to a certain extent. Poisoning had the highest decreasing differences 75%, which showed that mines now had better procedures for training people about gases in mines, because according to the 2000–2010 period reason for all poisoning was entry in forbidden zones. Two of ten reported cases of poisoning had fatal outcome as a result of workers entering unventilated rooms.

4.4. Time of injury – working shift

The comparative study confirmed the results from the 2011 study showing that the highest number of injuries occurred during the first, morning shift (Table 11) simply because morning shift had the largest number of workers and all the servicing and maintenance were undertaken during the morning. The highest frequency

Table 9
Comparison of average number of workers based on age

Age	ANW		Difference	
	2010–2019	2000–2009	Absolute	%
21–30	703	573	+130	+22.69
31–40	1114	1233	-119	-9.65
41–50	1388	1571	-183	-11.65
51–60	901	708	+193	+27.26
Σ	4106	4085	+21	+0.51

ANW, average number of workers.

Table 10
Comparative display of injury distribution according to injured body part

Body part	2000–2009	2010–2019	Difference	
	Average	Average	Absolute	%
Head	51.40	35.40	–16.00	–31.13
Eye, ear, or face	33.10	29.00	–4.10	–12.39
Internal organs	3.00	2.60	–0.40	–13.33
Poisoning	0.80	0.20	–0.60	–75.00
Upper limb	207.40	179.10	–28.30	–13.65
Lower limb	199.70	173.60	–26.10	–13.07
Chest, neck, back	34.00	28.80	–5.20	–15.29
Other	55.60	35.70	–19.90	–35.79
Σ	585.00	484.40	–100.60	–17.20

Table 11
Comparative display of injury rates based on the working shift

Working shift	2000–2009	2010–2019	Difference	
	Average	Average	Absolute	%
I	260.60	213.10	–47.50	–20.05
II	190.70	164.60	–26.10	–14.69
III	133.70	106.70	–27.00	–22.46
Σ	585.00	484.40	–100.60	–17.20

of mining operations and the most work force resulted in higher probability of injury. The other reason was economic, i.e. the need to perform repairs as soon as possible to start production. Such conditions and work under pressure with the aim to meet the production plan led to the increased number of injuries during the morning shift.

Table 12
Injury rates per 100 worker years based on qualification and comparison to the 2000–2009 period

Qualification	2010–2019		2000–2009		Difference	
	ANW	Injuries	RI/100WY	RI/100WY	Absolute	%
VSS	295	22	0.75	0.95	–0.21	–21.87
SSS	625	177	2.83	1.63	+1.20	+73.40
VKV	50	108	21.60	17.54	+4.06	+23.14
KV	1420	2035	14.33	15.96	–1.63	–10.21
PK	510	794	15.57	33.31	–17.75	–53.27
NK	1206	1708	14.16	16.86	–2.70	–16.02
Σ	4106	4844	11.80	14.32	–2.52	–17.62

ANW, average number of workers; KV, qualified; PK, semi qualified; SSS, secondary education; VKV, highly qualified; VSS, higher education.

Table 13
Comparison of an average number of workers based on qualification

Qualification	ANW		Difference	
	2010–2019	2000–2009	Absolute	%
VSS	295	220	+75.00	+34.09
SSS	625	747	–122.00	–16.33
VKV	50	61	–11.00	–18.03
KV	1420	1359	+61.00	+4.49
PK	510	344	+166.00	+48.26
NK	1206	1354	–148.00	–10.93
Σ	4106	4085	+21.00	+0.51

ANW, average number of workers; KV, qualified; PK, semi qualified; SSS, secondary education; VKV, highly qualified; VSS, higher education.

4.5. Educational background of injured workers

Table 12 shows a very large increase in injury rates for SSS and VKV qualifications, but this was not just the result of a low number of workers within these qualification groups, compared to 2011 results (Table 13). The reason for this increase can be that educated workers by the new law had more responsibility for their non-qualification workers, and they were now directly in the dangerous area doing jobs with workers. It is considered that they previously acquired sufficient knowledge during their education to avoid injury. It turned out to be wrong. In complex business conditions, the management placed the supervisory technical staff under constant pressure to achieve the planned production. This approach had an impact on the increase of the number of injuries among this category of workers as well.

The same counts for a significant decrease in injury rates for the highest educated workers which was merely a consequence of increased number of personnel.

5. Conclusion

The retrospective comparative study of underground coal-mining injuries in Serbia showed that the effects of legislation changes and preventive measures undertaken by the JP PEU were positive and that decreasing trend in injury rates was noticeable. Low injury rates among the youngest population of miners compared to the results from 2011 indicated that longer and rigorous training periods incorporated by the company upon the recommendations from previous study indeed increased safety awareness. Introduction of International Organization for Standardization (ISO) and Occupational Health and Safety Assessment Series (OHSAS) standards improved the reporting and analysis system. However, feedback from the medical service after the treatment of heavy injuries was not present and the workers ability to work was not assessed until the next annual medical examination. This issue is not a local problem and it affects all industrial branches so it should be addressed by the Government because the solution requires cooperation of all the Government, Ministry of Labour, and Ministry of health.

The remaining high percentile of limb injuries, regardless of the decrease in comparison to 2011, supported the necessity of mechanization and automation of mining process. Therefore, the recommendation would be to increase efforts to mechanize, if not all, then some of the mining process phases (supply, development, and loading as the most critical).

High injury rates among the oldest population of workers indicated that the Governmental decision on extending the retirement limit to the age of 65 was not adequate and, from safety aspect, quite contraproductive. However, it would be extremely difficult to influence this decision; therefore, the solution should be searched within the company. One of the solutions would be increased frequency of medical assessments and reallocation of elderly workers to positions more suitable for their age and capabilities. This problem will surely be partially and temporarily resolved in the near future because the majority of elderly workers will accept the offer to leave the company voluntarily with severance payments. For the future, the company should consider ways to encourage workers to retire once they meet the work experience requirement probably by beneficial and tempting severance packages.

What is encouraging is the fact that Serbia is moving towards the safer working environment and that coalmines are ready to undertake necessary measures to further increase the safety of workers. Financial situation is unfavorable and prevents major investments in safety and health; however, the positive attitude and

adoption of changes will gradually lead to safety first, last, and always.

Conflicts of interest

Authors hereby state that the research and the study were not funded by any agency, company or institution and that it was governed by scientific curiosity therefore the authors disclose no conflict of interest of any kind.

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