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Research article

ANALYZING RISKS OF OCCUPATIONAL INJURIES IN BASIC INDUSTRIES

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Our research aim was to analyze occupational injuries in basic industries in Irkutsk region.

Materials and methods. Occupational injuries (OI) in basic industries were analyzed using data from statistical reports issued in 2010–2019. To analyze OI in dynamics, we calculated relative values of OI and applied linear regression and Shewhart charts. Normalized intensity indicators method was used to reveal different probability of injuries in various industries as well as to predict OI risks.

Results. Analysis of OI in dynamics indicates that there is a stable descending trend in a number of injuries. However, in spite of this apparent descending trend, OI values are stably by 1.3–3.0 times higher in some industries than on average in the region. The highest frequency coefficient (FC) for occupational injuries was detected in wood processing where it was equal to 5.35 [2.90–7.71] per 1,000 workers; the indicator varied within 1.00–2.93 per 1,000 workers in other industries. Shewhart chart for FC indicates that systems of occupational health and safety management are not efficient enough in all the analyzed industries since FC exceeds the upper limit in some years. We established that severity of occupational injuries tended to grow in wood processing (C_s = +3.23; 5.33 %), metallurgy (C_s = +0.94; 1.26 %), land transport (C_s = +2.42; 4.39 %), and aircraft production (C_s = +0.59; 1.68 %). The greatest number of fatal OI was detected in mining, construction, and agriculture as a share of fatal OI in the overall structure of occupational injuries amounted to 22.0 %, 19.2 %, and 11.7 % in these brunches accordingly. A probability that an injury becomes fatal is also the highest in them, 11.7 %, 9.0 %, and 6.0 % accordingly. "Wood processing and production of wood articles", "Aircraft production", and "Construction" are among industries where risks of occupational injuries are the most probable.

Key words: *occupational injuries, risk, workers, industries, occupational health and safety.*

Irkutsk region is an area with a lot of operating industries. There are metallurgic enterprises, wood processing plants, aircraft production, mining, coal mining, and some other brunches where more than 500 thousand people are employed [1]. Prevention of occupational injuries is vital since such injuries result in a decrease in working population and higher social expenses [2, 3], and also lead to mortality among working population which has been proven in multiple epidemiological studies [4–8]. It is especially important to analyze levels of occupational injuries since they are determined by existing working conditions and labor safety and changes in them are immediate after any changes in these conditions. Besides, levels of occupational injuries are an important indicator useful for assessing workers' health, working conditions, and labor protection [9]; they can be the most significant criterion in occupational risk assessment and, consequently, are absolutely necessary in labor protection management and for developing efficient preventive activities [10]. We should note that at present the state policy on labor protection is in transition to a risk-oriented model based on prevention since it allows saving or reducing costs related to unfavorable working conditions [11, 12]. There is rather high wear and tear of production equipment in many industries, technological standards are rather poor and modernization is slow as new safe up-to-date technologies and equipment are not being implemented fast enough; capital

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construction and preventive repair of industrial buildings, constrictions, machinery and equipment has also been declining in volumes [1, 13]. There are not enough data available in literature on occupational injuries analyzed as per different industries [3, 4, 14, 15]. Given the structure of production in Irkutsk region with prevailing industries where occupational injuries are likely to occur, it seems necessary to analyze levels and dynamics of occupational injuries in the leading brunches operating in the region.

Our research aim was to analyze occupational injuries in basic industries in Irkutsk region.

Materials and methods. Occupational injuries (OI) were analyzed using data taken from Statistical Report Form No. 7 "Data on occupational injuries and diseases" and Appendix to Form No. 7 "Data on distribution of a number of people who were injured in occupational accidents as per major types of such accidents and their causes" issued by the Federal State Statistic Service in 2010–2019[1]. We considered basic industries that operated in Irkutsk region, notably "Agriculture, hunting, and forestry", "Wood processing and production of wood articles", "Metallurgy", "Production of aircrafts, including spacecrafts", "Production, supply, and distribution of electricity", "Construction", "Land transport", "Public healthcare", "Mining"[2]. We analyzed the following data: average number of workers; a number of injured workers who were unable to work for 1 day or longer; a number of fatal injuries; a number of person-days of temporary disability among injured people who were unable to work for 1 day or long and in case of fatal injuries; a number of injured people with partial disability who were moved from their workplace to another one for 1 working day or longer. Relative OI values were calculated: a coefficient of occupational injuries frequency (C_f); a coefficient of occupational injuries severity (C_s); a coefficient showing losses of working hours (C_l); a coefficient of fatal occupational injuries frequency (C_{fatal}); a coefficient of summarized labor losses (C_{sum}); and also indicator S [16] that was a ratio of a total number of occupational injuries to a number of fatal occupational injuries. The last indicator is the most objective one showing how safe a specific production is. We applied statistic Shewhart charts in our analysis[3]. Normalized intensity indicator method was applied to reveal industries with different risks levels as well as to predict risks of occupational injuries [17]. A level of OI risk in an industry (R) was calculated as per the following formula:

$$R = \mathrm{NII_{in}} \cdot C,$$

where $\mathrm{NII_{in}}$ is a normalized intensity indicator for a given industry, C is a weight coefficient; $\mathrm{NII_{in}}$ = intensity indicator for an industry / regional intensity indicator, C = max $\mathrm{NII_{in}}$ / min $\mathrm{NII_{in}}$.

All data were statistically analyzed using Microsoft Office 2003. Linear regression analysis was applied to analyze OI dynamics. Research results are given as extensive (%) and intensive (per 1,000 workers) values, average values, minimum and maximum values in different years over the examined period.

Results and discussion. Analysis of OI dynamics over the examined period indicates there is a stable descending trend in a number of occupational injuries, both in Irkutsk region

[1] Usloviya truda [Working conditions]. *The Federal State Statistic Service*. Available at: https://rosstat.gov.ru/working_conditions (February 03, 2021) (in Russian).

[2] Obshcherossiiskii klassifikator vidov ekonomicheskoi deyatel'nosti (OKVED 2) OK 029-2014 (KDES Red. 2): prinyat i vveden v deistvie prikazom Federal'nogo agentstva po tekhnicheskomu regulirovaniyu i metrologii ot 31 yanvarya 2014 g. N 14-st (s izmeneniyami i dopolneniyami) [Russian National Classifier of Economic Activities (RNCEA 2) RC 029-2014 (Edition 2): approved on and implemented by the Federal Agency on Technical Regulation and Metrology on January 31, 2014 No. 14-st (with alterations and addenda)]. *GARANT database*. Available at: https://base.garant.ru/70650726/ (April 08, 2021) (in Russian).

[3] GOST R ISO 7870-2-2015. Natsional'nyi standart Rossiiskoi Federatsii. Statisticheskie metody. Kontrol'nye karty. Chast' 2. Kontrol'nye karty Shukharta (data vvedeniya: 12.01.2016) [GOST R ISO 7870-2-2015. The National Standard of the Russian Federation. Statistical procedures. Control charts. Part 2. Shewhart charts (introduced on January 12, 2016)]. *TEKHEKSPERT*. Available at: http://docs.cntd.ru/document/1200124585 (March 25, 2021) (in Russian).

overall and in some industries as well: in wood processing (from 6.14 to 4.27 per 1,000 workers, $y = –0.3382x + 7.2073$, $R^2 = 0.6067$); agriculture (from 3.74 to 2.46 per 1,000 workers, $y = –0.2582x + 4.352$, $R^2 = 0.7737$); metallurgy (from 2.08 to 1.23 per 1,000 workers, $y = –0.1169x + 1.92$, $R^2 = 0.5865$); and mining (from 2.82 to 2.19 per 1,000 workers, $y = –0.1156x + 3.002$, $R^2 = 0.7252$) (Figure 1). But OI dynamics revealed that OI rates were rather unstable in some industries; it is true for production, supply, and distribution of electricity ($y = –0.0045x + 1.0267$, $R^2 = 0.0036$); land transport ($y = –0.1022x + 1.832$, $R^2 = 0.4684$); aircraft production ($y = –0.1591x + 3.418$, $R^2 = 0.2453$); construction ($y = 0.0516x + 1.984$, $R^2 = 0.0378$); and public healthcare ($y = 0.0049x + 1.16$, $R^2 = 0.005$).

However, despite this appearing descending trend, OI rates are still by 1.3–3.0 times higher in some industries than on average in the region and this gives an indirect indication that working conditions are hazardous there and workers are not provided with sufficient protection. Some authors also mention a drastic decrease in rates of occupational injuries and state there are several reasons for that including influence by a risk-oriented approach in organizing state control (surveillance) [11], declining number of workers employed in industries with high risks [2], and hiding data on occupational accidents [18].

A share of occupational injuries for women employed in analyzed industries on average amounts to 21.0 [3.2–66.7] %; for men, 79.0 [33.4–96.8] %; it is most likely due to male workers prevailing in industries where injuries are more probable [19].

Relative values calculated for occupational industries were a coefficient of occupational injuries frequency (C_f); a coefficient of occupational injuries severity (C_s); a coefficient of summarized labor losses (C_{sum}); and a coefficient showing losses of working hours (C_l). They are given in Table 1.

The highest coefficient of occupational injuries frequency was detected in wood processing, 5.35 [2.90–7.71] per 1,000 workers. In other industries, this coefficient varied within 1.00–2.93 per 1,000 workers. An average rate of change in C_f turned out to be negative practically in all analyzed industries, except construction; on one hand, it indicates there is a descending trend in frequency of occupational injuries but, on the other hand, it might be due to mild or average injuries not being included into reports. Annually C_f goes down by 5.49 % on average. We built a Shewhart chart that included the upper and lower limits of coefficients showing frequency and severity of

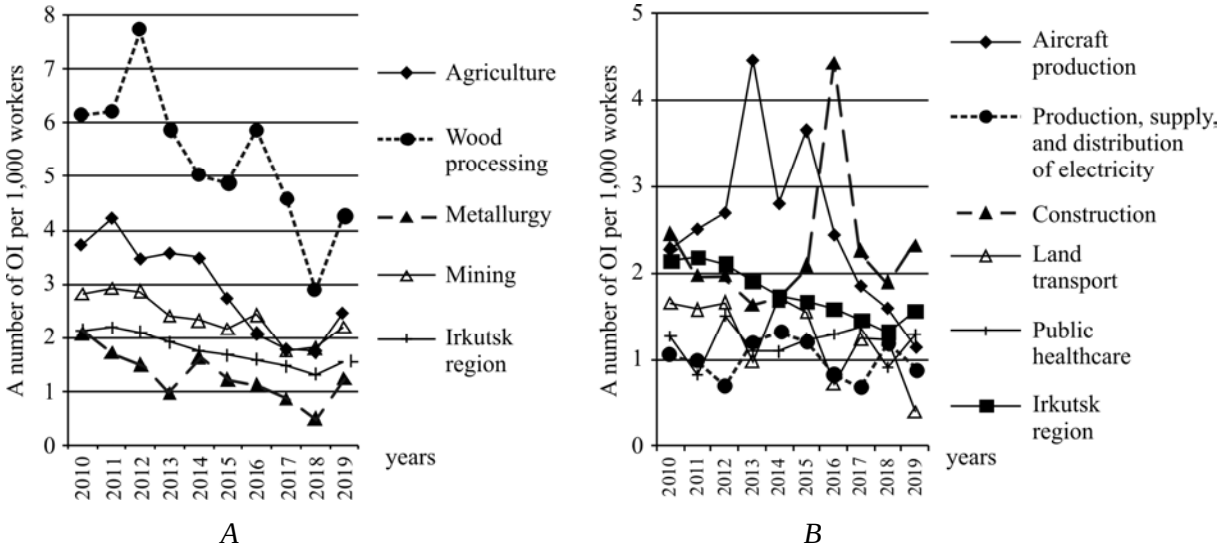

Figure 1. Rates of occupational injuries in basic industries in Irkutsk region in 2010–2019 (per 1,000 workers) taken in dynamic; industries with stable dynamic are shown in part *A*; with unstable, in part *B*

Table 1

Average long-term rates of occupational injuries in basic industries in Irkutsk region in 2010–2019 (per 1,000 workers), *M* [min–max]

Industries	Occupational injuries			
	Coefficient of occupational injuries frequency (C_f)	Coefficient of occupational injures severity (C_s)	Coefficient of working hours losses (C_l)	Coefficient of summarized losses (C_{sum})
Agriculture, hunting, and forestry	2.93 [1.74–4.21]	59.23 [34.12–78.51]	167.92 [74.8–294.6]	1,252.9
Wood processing and production of wood articles	5.35 [2.90–7.71]	60.94 [36.72–85.13]	295.79 [251.4–398.7]	2,157.3
Metallurgy	1.28 [0.49–2.08]	75.12 [35.66–92.30]	91.25 [38.2–179.1]	299.6
Production of aircrafts, including spacecrafts	2.55 [1.13–4.47]	35.35 [20.37–56.89]	82.46 [38.7–137.3]	528.5
Production, supply, and distribution of electricity	1.00 [0.68–1.34]	62.64 [34.81–118.23]	59.22 [32.3–121.8]	310.8
Construction	2.27 [1.63–4.42]	61.52 [47.04–80.0]	126.29 [73.4–140.7]	1,200.9
Land transport	1.27 [0.38–1.70]	55.21 [38.09–102.14]	61.44 [39.6–93.9]	404.8
Public healthcare	1.20 [0.82–1.38]	41.14 [27.30–61.68]	47.74 [28.4–78.2]	168.3
Mining	2.37 [1.75–2.91]	77.39 [37.68–214.54]	171.34 [58.8–527.4]	1,850.3

Table 2

Calculated limits of changes in coefficients of occupational injuries frequency and severity in basic industries

Industries	Coefficient of occupational injuries frequency		Coefficient of occupational injuries severity	
	Lower limit	Upper limit	Lower limit	Upper limit
Agriculture, hunting, and forestry	2.29	3.57	49.58	68.86
Wood processing and production of wood articles	4.43	6.15	50.53	70.71
Metallurgy	0.94	1.61	60.89	89.34
Production of aircrafts, including spacecrafts	1.85	3.23	26.55	44.15
Production, supply, and distribution of electricity	0.84	1.17	45.34	79.94
Construction	1.69	2.84	53.38	69.62
Land transport	0.95	1.59	42.32	68.07
Public healthcare	1.05	1.37	33.59	48.68
Mining	2.07	2.66	38.29	116.49

occupational injuries (Table 2). The chart allowed establishing that C_f was higher than the upper limit in some years; hence, occupational safety management systems are not efficient enough in all analyzed industries.

The coefficient of occupational injuries severity, with its indirect indicator being a number of days of disability, was calculated for the examined industries. The highest average long-term coefficient of occupational injuries severity (C_s) was detected in mining and metallurgy; the lowest one, in public healthcare and in aircraft production. Calculation of average rate of change in C_s indicates that occupational injuries tend to become more severe in wood processing (C_s = +3.23; 5.33 %), metallurgy (C_s = +0.94; 1.26 %), land transport (C_s = +2.42; 4.39 %), and aircraft production (C_s = +0.59; 1.68 %). An average rate of change in C_s turned out to be negative in other analyzed industries and it indicates there is a descending trend in severity of occupational injuries.

A decrease in frequency of occupational injuries in some industries highlighted by the relevant coefficient taken in dynamics contradicts to values calculated for the coefficient of occupational injuries severity and growing

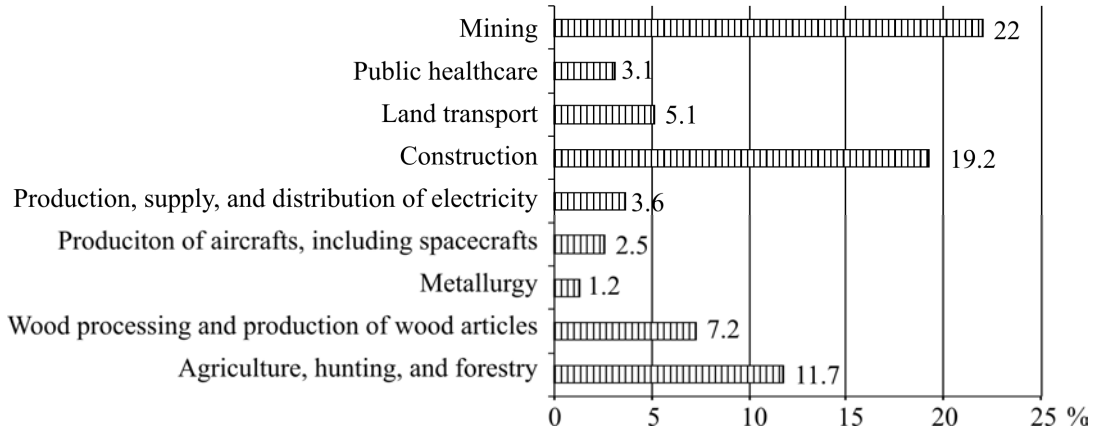

Figure 2. A share of fatal injuries per industries in the overall structure of fatal injuries in Irkutsk region in 2010–2019, %

specific share of fatal injuries; it is probably due to not all injuries being taken into account (only the most severe injuries and fatal injuries are registered).

Average long-term number of fatal injuries varied from 0.02 to 0.31 cases per 1,000 workers in basic industries in Irkutsk region over the examined period. The highest share of fatal injuries in the overall structure of such accidents in Irkutsk region is detected in mining (22.0 %), construction (19.2 %), and agriculture (11.7 %) (Figure 2).

Indicator *S* also shows that a probability of a fatal injury is the highest in these industries, 11.7, 9.0 and 6.0 accordingly; in some authors' opinion [13–15, 21–23], it requires more efforts on providing safe and harmless working conditions. Besides, experts note that only 45–65 % of overall requirements to labor protection are satisfied [14].

Fatal OI rates amount to 0.06–0.41 per 1,000 workers for men and 0.0–0.10 per 1,000 workers among women in all analyzed industries. According to ILO estimates, overall, men account for approximately 80 % of all fatal occupational injuries worldwide [2].

We also analyzed occupational injuries in different industries as per the coefficient showing losses of working hours (C_l); the analysis revealed the highest C_l value in wood processing and the lowest, in public healthcare.

We calculated the coefficient of summarized labor losses (C_{sum}) and revealed that the first rank place belonged to "Wood processing and production of wood articles"; the second one, "Mining"; the third one, "Agriculture, hunting, and forestry"; the fourth one, "Construction"; other industries, given in the descending order, were "Aircraft production", "Land transport", "Production, supply, and distribution of electricity", "Metallurgy", and "Public healthcare".

Risk rates for OI (*R*) in basic industries are given in Table 3.

We should note that a situation seems rather ambiguous in some industries. Thus, OI risk seems to be the lowest in mining although the coefficient of occupational injuries frequency calculated for the industry is comparable to those calculated for aircraft production and construction with OI risks being substantially higher in these industries. In our opinion, it is due, first of all, to average annual fluctuations in parameters that are taken as a basis for OI risk calculation and also, probably, due to deliberate hiding of occupational injuries.

Table 3

Risks of occupational injuries in basic industries in Irkutsk region

Industries	OI risk
Agriculture, hunting, and forestry	2.710
Wood processing and production of wood articles	5.008
Metallurgy	1.846
Production of aircrafts including spacecrafts	4.643
Production, supply, and distribution of electricity	1.611
Construction	4.313
Land transport	2.832
Public healthcare	1.739
Mining	1.693

Table 4

Estimation table for risks of occupational injuries in the analyzed industries

Risk groups	Fluctuation range	Industries
I – the group with favorable forecast (the lowest probability)	1.61–2.74	Agriculture, hunting, and forestry
		Metallurgy
		Production, supply, and distribution of electricity
		Public healthcare
		Mining
II – the group that requires attention (average probability)	2.75–3.87	Land transport
III – the group with unfavorable forecast (the highest probability)	3.88–5.00	Wood processing and production of wood articles
		Production of aircrafts including spacecrafts
		Construction

We assessed OI risks using normalized intensity indicators method and it allowed us to rank the analyzed industries as per several risk groups: favorable forecast, requiring attention, and unfavorable forecast (Table 4).

According to calculated fluctuation ranges, the group with favorable forecast included the following industries: "Agriculture, hunting, and forestry", "Metallurgy", "Production, supply, and distribution of electricity", "Public healthcare", "Mining". "Land transport" was an industry that required attention. Industries where probability of occupational injuries was the highest included "Wood processing and production of wood articles", "Production of aircrafts, including spacecrafts", and "Construction".

Conclusions. Therefore, our analysis revealed multidirectional basic trends in OI in industries operating in Irkutsk region. The situation is especially unfavorable in wood processing and production of wood articles, construction, mining, and agriculture. Although not all actual injuries are included into official statistics [16, 18, 23], our research results indicate that a serious approach is required to preventing occupational injuries. Besides, bearing in mind that rates of occupational injuries tend to change [24] and there can be significant annual fluctuations due to sudden and severe occupational accidents, it is necessary to develop targeted and systemic prevention activities and relevant policies in the sphere of workers' health protection. Prevention of potentially hazardous situations, risk assessment and management of occupational injuries should become top priorities in any such policy.

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Conflict of interests. The authors declare there is no any conflict of interests.

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