Prediction of possible injuries at coal enterprises

Boris Kobilyanskiy

PhD.,
Department of health and environmental safety
Teaching and research professional education institute of
Ukrainian engineering and pedagogical academy

Abstract
In this paper, basing on the data of social insurance of employees of the coal mining industrial area of the city, using the methods of high-level classical statistics, there is made a conclusion about the future path of accident development, based on the total costs of elimination of this negative phenomenon consequences.
Keywords: ANALYSIS OF INJURY, COAL ENTERPRISES, STATISTICS.

Level of possible injury is the one of the main criteria for estimation of technology-related risk at enterprises of increased danger, in particular at the coal companies.

The data from the Social Insurance Fund Accident of Makeyevka city, Gornyatskiy district and statistics from mines GC «Makeevugol»: Lenin's mine office, mine «Cold Beam», PIC «Miner-95», mine «Deep» was used to analyze the rate of accidents and occupational diseases.

To begin the analysis it is necessary to determine the dynamics of accidents and diseases at coal enterprises of Makeyevka city, Gornyatskiy district. For this purpose we should eliminate the influence of this generalized district statistics of occupational diseases and injuries (Table 1-2), leaving the dynamics of injuries and diseases, which are not connected with the activity of the coal enterprises (Table 3).

Further we exclude the impact of demographic and epidemiological factors, which affected the increase of injuries in the district, by calculating the coefficients of accidents and diseases increasing, which are not connected with the activity of the coal industry. Also we will adjust the dynamics of the increase of injuries and occupational diseases at the mines of Makeyevka city, Gornyatskiy district, considering these factors (Table 4).

If you take into attention the increase of injuries and diseases, which are not connected with the activity of coal industry, and abstract them to injuries and occupational diseases in the coal industry, we obtain the following array of data presented in the Table 5. This corrected array of injuries may be used for comparison with actual performance and identification of weaknesses concerning prevention of accidents and occupational diseases in the district.

A significant excess of the increase of injuries and occupational diseases in mines observed in 2003, 2007, 2010 and 2011 (Table 6). So it can be concluded that these periods are the most favorable for the establishment of the reasons for increase of injury in the district. In the future these studies may be used for developing of programs for prevention recurrence of injuries and occupational diseases.

Table1. The number of injuries and occupational diseases in Makeyevka city, Gornyatskiy district

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total	172	247	285	277	197	208	206	198	206	203	227	86	107
The number of injuries (H-1)	146	218	253	231	170	162	151	150	171	177	191	71	87
The number of occupational diseases	26	29	32	46	27	46	55	48	35	26	36	15	20

Table 2. The number of injuries and occupational diseases at the coal enterprises of Makeyevka city, Gornyatskiy district

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total	140	182	224	211	136	150	162	149	148	151	188	73	81
The number of injuries (H-1)	118	157	195	172	115	108	109	104	121	129	156	61	63
The number of occupational diseases	22	25	29	39	21	42	53	45	27	22	32	12	18

Table 3. The number of injuries and occupational diseases at Makeyevka city, Gornyatskiy district, which are not connected with the activity of coal industry

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total	32	65	61	66	61	58	44	49	58	52	39	13	26
The number of injuries	28	61	58	59	55	54	42	46	50	48	35	10	24

(H-1)													
The number of occupational diseases	4	4	3	7	6	4	2	3	8	4	4	3	2

Table 4. Calculation of the growth rate of injuries and occupational diseases at Makeyevka city, Gornyatskiy district, which are not connected with the activity of coal industry

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total		2,03	0,94	1,08	0,92	0,95	0,76	1,11	1,18	0,90	0,75	0,33	2,00
The number of injuries (H-1)		2,18	0,95	1,02	0,93	0,98	0,78	1,10	1,09	0,96	0,73	0,29	2,40
The number of occupational diseases		1,00	0,75	2,33	0,86	0,67	0,50	1,50	2,67	0,50	1,00	0,75	0,67

Table 5. Adjustment of injuries and occupational diseases at the coal enterprises

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total		279	168	266	193	127	105	199	233	130	116	69	154
The number of injuries (H-1)		257	149	198	160	113	84	119	113	116	94	45	146
The number of occupational diseases		22	19	68	33	14	21	80	120	14	22	24	8

Table 6. The difference between the actual and adjusted performance of injuries and occupational diseases at the coal enterprises

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	5 month 2011	5 month 2012
Total		-97	56	-55	-57	23	57	-50	-85	21	72	4	-73
The number of injuries (H-1)		-100	46	-26	-45	-5	25	-15	8	13	62	16	-83
The		3	10	-29	-12	28	32	-35	-93	8	10	-12	10

number of occupational diseases													

Let’s carry out the predictive values of possible injury indicators based on three mines at Makeyevka city, Gornyatskiy district from 2001 to 2011. Injury rates at four mines in the period from 2001 to 2011 are given in Table 7.

Table 7. Injuries at the coal enterprises

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Aver.
Lenin’s governance of the mine	61	64	83	81	47	36	43	42	43	45	70	56
mine «Cold Beam»	70	87	88	78	58	49	49	47	64	67	60	65
PIC «Miner-95»	7	4	23	13	10	18	10	15	14	17	26	14
mine «Deep»	224	219	162	107	75	46	7	0	0	0	0	79.4

According to this data, we plotted the graph of indicators changes of injuries over the years (Figure 1) and on the appearance of the graph we can select the dependence of the injury time from the first year of the previous decade.

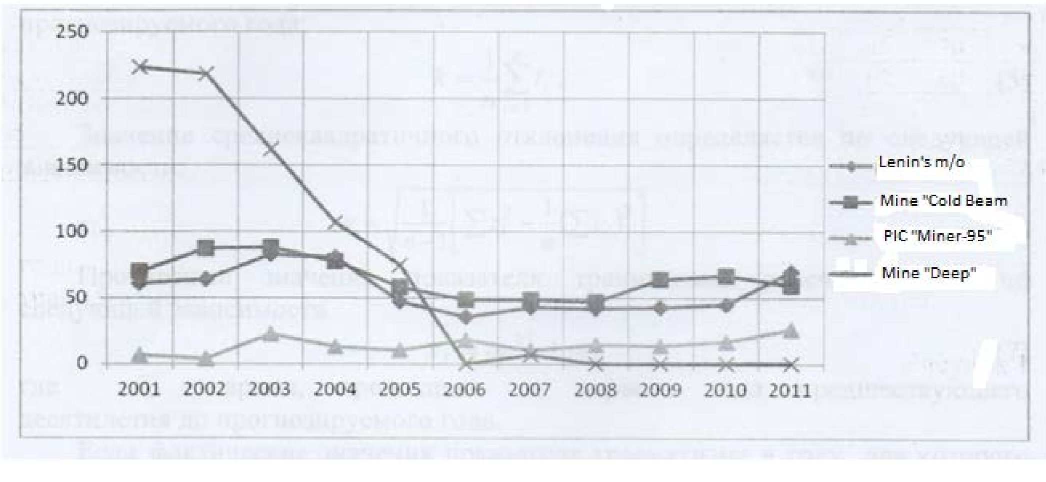

Figure 1. Change of injury rates

Exponential dependence [1-4] in most cases is used as a predictive function

$$x(t) = ae^{bt}, \quad (1)$$

where $x(t)$ – value of the index injury in time (t) from the first year of the previous decade;

a, b – constant coefficients;

t – time, passed from the first year of the previous decade, years;

e – base of natural logarithms. The coefficients a and b are defined by the following relationships:

$$b = \frac{n\sum_{i=1}^{n} t_i \lg x_i - \sum_{i=1}^{n} t_i \sum_{i=1}^{n} \lg x_i}{\lg e\left[n\sum_{i=1}^{n} t_i^2 - \left(\sum_{i=1}^{n} t_i\right)^2\right]} \quad (2)$$

$$\lg a = \frac{\sum_{i=1}^{n} t_i^2 \sum_{i=1}^{n} \lg x_i - \sum_{i=1}^{n} t_i \sum_{i=1}^{n} \lg x_i}{n\sum_{i=1}^{n} t_i^2 - \left(\sum_{i=1}^{n} t_i\right)^2}, \qquad (3)$$

where x_i – the value of the index injury for the *i* year;

t_i – the time passed from the first year of the previous decade to the *i* year;

n – number of observations.

Error of predictive values of injury rates calculated by the following relationship [4-8]

$$m = \pm \frac{\sigma}{\sqrt{n-1}} \sqrt{1 - \frac{n(t_j - k)^2}{\sum (t_i - k)^2}}, \qquad (4)$$

where σ – the standard deviation;

t_i, t_j – the time passed from the first year of the previous decade, respectively to the *i* year of this decade and to the *j* projected year;

$$k = \frac{1}{n}\sum_{i=1}^{n} t_i. \qquad (5)$$

The value of the standard deviation is determined by the following relationship:

$$\sigma = \sqrt{\frac{1}{n-1}\left[\sum z_i^2 - \frac{1}{n}\left(\sum z_i\right)^2\right]} \qquad (6)$$

Predicted values of the injury index are calculated as follows depending:

$$x_T = ae^{bT} \pm m, \qquad (7)$$

where T – the time passed from the first year of the previous decade to projected year.

If the actual values of injuries in the year for which the forecast is made, will be within the range calculated by the formula (3) or less, then this is evidence that injuries remain at the same level or decreased; if the actual values are greater than the calculated, it will point to an increase in injuries.

Lenin's mine office

According to formulas (2) and (3) constant coefficients a and b are calculated. Input data for the calculation are given in Table 8.

Table 8

The year	n	ti	ti2	xi	Lgxi	Tilgxi
2001	1	1	1	61	1.785	1.785
2002	2	2	4	64	1.806	3.612
2003	3	3	9	83	1.919	5.757
2004	4	4	16	81	1.908	7.634
2005	5	5	25	47	1.672	8.360
2006	6	6	36	36	1.556	9.338
2007	7	7	49	43	1.633	11.434
2008	8	8	64	42	1.623	12.986
2009	9	9	81	43	1.633	14.701
2010	10	10	100	45	1.653	16.532
The sum	10	55	385		17.191	92.141

$$b = \frac{10 \cdot 92{,}141 - 55 \cdot 17{,}191}{0{,}4343\left[10 \cdot 385 - 55^2\right]} = -0{,}0672$$

$$\lg a = \frac{385 \cdot 17{,}191 - 55 \cdot 92{,}141}{10 \cdot 385 - (55)^2} = 1{,}8797$$

$$a = 76,$$

then the relation (1) takes the form

$$x(t) = 76e^{-0{,}0672(t-2001)}.$$

Predictive value of the indicator "total number of injured" in 2011 will be equal to

$$x(2011г.) = 76 \cdot e^{-0{,}0672(2011-2001)}$$

$$x(2011г.) = 76 \cdot e^{-0{,}0672*10} = 39$$

predictive values of the injury

$$k = \frac{1}{10} \cdot 55 = 5{,}5$$

$$\sum (t_i - k)^2 = (1-5{,}5)^2 + (2-5{,}5)^2 + (3-5{,}5)^2 + (4-5{,}5)^2 + (5-5{,}5)^2 + \\ + (6-5{,}5)^2 + (7-5{,}5)^2 + (8-5{,}5)^2 + (9-5{,}5)^2 + (10-5{,}5)^2 = 85$$

$$m_n = \pm \frac{17{,}24}{\sqrt{10-1}} \cdot \sqrt{1 + \frac{10 \cdot (10-5{,}5)^2}{85}} = 11{,}0,$$

hence

$$x_T = 39 \pm 10{,}0.$$

The actual value of the total injuries at the mine was 70, which is almost 2 times higher than the calculated, which indicates an increase in injuries at the Lenin's mine office in 2011.

Mine «cold beam»

According to formulas (2) and (3) constant coefficients *a* and *b* are calculated. Baseline data for the calculation are shown in Table 9.

Table 9

The year	N	ti	ti2	Xi	lgxi	Tilgxi
2001	1	1	1	70	1.845	1.845
2002	2	2	4	87	1.940	3.879
2003	3	3	9	88	1.944	5.833
2004	4	4	16	78	1.892	7.568
2005	5	5	25	58	1.763	8.817
2006	6	6	36	49	1.690	10.141
2007	7	7	49	49	1.690	11.831
2008	8	8	64	47	1.672	13.377
2009	9	9	81	64	1.806	16.256
2010	10	10	100	67	1.826	18.261
The sum	10	55	385		18.069	97.809

$$b = \frac{10 \cdot 97{,}809 - 55 \cdot 18{,}069}{0{,}4343\left[10 \cdot 385 - 55^2\right]} = -0{,}0439$$

$$\lg a = \frac{385 \cdot 18{,}069 - 55 \cdot 97{,}809}{10 \cdot 385 - (55)^2} = 1{,}9118$$

$a = 82$,

then the relation (1) takes the form

$x(t) = 82e^{-0{,}0439(t-2001)}$.

Predictive value of the indicator "total number of injured" in 2011 will be equal to

$$x(2011г.) = 82 \cdot e^{-0{,}0439(2011-2001)}$$

$$x(2011г.) = 82 \cdot e^{-0{,}0439*10} = 53$$

predictive values of the injury

$$k = \frac{1}{10} \cdot 55 = 5{,}5$$

$$\sum (t_i - k)^2 = (1-5{,}5)^2 + (2-5{,}5)^2 + (3-5{,}5)^2 + (4-5{,}5)^2 + (5-5{,}5)^2 + (6-5{,}5)^2 + (7-5{,}5)^2 + (8-5{,}5)^2 + (9-5{,}5)^2 + (10-5{,}5)^2 = 85$$

$$m_n = \pm \frac{20{,}78}{\sqrt{10-1}} \cdot \sqrt{1 + \frac{10 \cdot (10-5{,}5)^2}{85}} = 13{,}0,$$

hence

$x_T = 53 \pm 13{,}0$.

The actual value of total injuries at the mine was 60. As the predictive value of the index of general injury varies from 40 to 66, one may consider that injuries at the mine «Cold Beam» in 2011 remained at the same level.

Pic «miner-95»

According to formulas (2) and (3) constant coefficients *a* and *b* are calculated. Input data for the calculation is given in Table 10.

Table 10

The year	n	Ti	ti2	xi	Lgxi	Tilgxi
2001	1	1	1	7	0,845	0.845
2002	2	2	4	4	0. 602	1.204
2003	3	3	9	23	1.362	4.085
2004	4	4	16	13	1.114	4.456
2005	5	5	25	10	1.000	5.000
2006	6	6	36	18	1.255	7.532
2007	7	7	49	10	1.000	7.000
2008	8	8	64	15	1.176	9.409
2009	9	9	81	14	1.146	10.315
2010	10	10	100	17	1.230	12.304
The sum	10	55	385		10.731	62.150

$$b = \frac{10 \cdot 62{,}150 - 55 \cdot 10{,}731}{0{,}4343\left[10 \cdot 385 - 55^2\right]} = 0{,}0874$$

$$\lg a = \frac{385 \cdot 10{,}731 - 55 \cdot 62{,}150}{10 \cdot 385 - (55)^2} = 0{,}8643$$

$$a = 7,$$

then the relation (1) takes the form

$$x(t) = 7e^{0{,}0874(t-2001)}.$$

Predictive value of the indicator "total number of injured" in 2011 will be equal to

$$x(2011г.) = 7 \cdot e^{0{,}0874(2011-2001)}$$

$$x(2011г.) = 7 \cdot e^{0{,}0874*10} = 17$$

predictive values of the injury

$$k = \frac{1}{10} \cdot 55 = 5{,}5$$

$$\sum (t_i - k)^2 = (1-5{,}5)^2 + (2-5{,}5)^2 + (3-5{,}5)^2 + (4-5{,}5)^2 + (5-5{,}5)^2 +$$
$$+ (6-5{,}5)^2 + (7-5{,}5)^2 + (8-5{,}5)^2 + (9-5{,}5)^2 + (10-5{,}5)^2 = 85$$

$$m_n = \pm \frac{4{,}14}{\sqrt{10-1}} \cdot \sqrt{1 + \frac{10 \cdot (10-5{,}5)^2}{85}} = 3{,}0,$$

hence

$$x_T = 17 \pm 3{,}0.$$

The actual value of total injuries at the mine was 26. As the predicted value of the index of general injury varies from 14 to 20, one may consider that injuries on PIC«Miner-95» in 2011 are increased.

Summarizing the above, we can conclude that with increase of work intensity the level of injury also increases. Further increase of production capacity requires both staff training in the field of their safe working and introduction of new technology with increased level of safety.

References

1. Yeremeev V.S., Sosnowski D.O., Titov A.V. Probability and Mathematical Statistics. Melitopol Ltd, Publishing house MMD, 2009. 188 p.
2. Kendall M., Stewart A. Theory of distributions. Moscow, Nauka, 1966. 588 p.
3. Kremer N.S. Probability theory and mathematical statistics: a textbook for university students of economics. Moscow, UNITY-DANA, 2007. 551 p.
4. Mosteller F., Tukey J. Data Analysis and Regression: in 2 vol. Issue 1 / Trans. from English. N. Annunciation; Ed. JP Adler . Moscow, Finance and Statistics, 1982. 317p.
5. Orlov I.V. Economic-mathematical methods and models. Performing calculations in Excel. Moscow, JSC "Finstatinform", 2000. 135 p.
6. Tumasyan, A.A., Vasilevska L.I. Industrial statistics: a tutorial. Minsk, The new knowledge. Moscow, Infra-M, 2012. 429 p.
7. Himmelblau D. Analysis of statistical methods. Moscow, Mir, 1973. 959 p.
8. Hollender M., Wolfe D. Non-parametric statistical methods. Moscow, Mir, 1983. 518 p.