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Development of Measures to Amend the Labour Protection Regulations of the Chemical and Petrochemical Industry of Kazakhstan

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Abstract

The chemicals and petrochemicals industry is currently one of the world's leading international economies. But at the same time it also remains an industry where harmful, difficult and hazardous working conditions for workers are present. All occupational safety and health protection measures must be aimed at achieving the main objective of reducing the level of occupational diseases on the basis of, first and foremost, preventive work on risk factors. Professional activity at chemical and petrochemical enterprises reveals the necessity to develop a clear algorithm of occupational risk analysis, which has a common basis with assessment of other technical risks. The chemical and petrochemical industry is an industry with a large number of risks: risk of fire, risk of explosion, risk of leakage of harmful chemicals, risk of evaporation of harmful chemicals. All these risks entail risks of getting sick: respiratory tract cancer, etc. and the resulting disability or disablement.

This article examines some methods of occupational risk assessment in the chemical and petrochemical industry. Analysis of methodologies such as the ranking of occupational hazards, the Kwij Al-Dalemi occupational risk assessment, as well as the French experience of the Laboratory Laboratory Network-Prevention Network-National Surveillance for Occupational Diseases (Research National de Vigilance et de Prevention des Pathologies Professionneles, RNV3P) and the US experience of LHAT-Laboratory for Hazardous Substances Assessment in Iowa State in the USA. The article details the methodology for ranking occupational hazards in chemical plants and shows the ranking of occupational hazards by priority and their short- and long-term exposure.

Keywords: chemical and petrochemical industry, occupational risk assessment, harmful factors, chemicals, laboratories, diseases.

Introduction

Occupational risk assessment methodology is very important for early detection of occupational diseases in chemical and petrochemical plants. This will help to reduce the number of deaths and disabilities due to exposure to hazardous chemicals on human health.

The analysed methodologies on occupational risk assessment, enable accurate assessment of occupational risks at various chemical and petrochemical enterprises in the world and can be recommended for the creation of similar laboratories and systems for studying occupational risk assessment in the healthcare system of Kazakhstan.

The aim of this paper is to analyse risk assessment methodologies for workers in the chemical and petrochemical industry in Kazakhstan.

To date, there are a huge number of methodologies for risk assessment in the chemical and petrochemical industry. In particular, various scholars have considered risks in the chemical and petrochemical industry (Zheng et al., 2020). For example, peculiarities of professional risks are: nature, big variety and unpredictable consequences. In its essence, professional risk has two components, which are equal in importance, but negative in nature: a priori and a posteriori (Al-Dalemi, 2013).

A priori, which may be due to harmful or hazardous working conditions. A posteriori, which allows to estimate the damage to the health of the work of enterprises in the chemical and petrochemical industry. Nowadays risk can be represented as a derivative of a certain risk of a situation, expressed through the frequency and consequences of risk realisation (Kucheneva, 2009). The World Health Organization defines occupational risk as a mathematical concept reflecting severity and frequency of adverse reactions of a human body to the given exposition of a harmful factor of the industrial environment.

The algorithm for analysing occupational risk to protect staff from accidents and occupational diseases can be presented as follows (Dabbagh & Yousefi, 2019):

- Hazard identification (identifying harmful and dangerous factors in the working environment and work process);
- Identifying possible causes leading to undesirable events;
- Risk assessment (probability of the risk occurring, determination of the magnitude of the consequences of an undesirable event, taking into account the potential severity of the incident and the harm to human health, conclusion on the acceptability or unacceptability of the risk);
- choosing and assessing the means of protection against each type of hazard;
- assessment of the residual risk after the implementation of the protection system;
- assessment of the system to protect the life and health of staff as a whole according to the class of working conditions.

Literature Review

At each stage of the analysis there are specific mechanisms, the application of which is determined by the peculiarities of the working environment, economic opportunities of the enterprise, professional competence of the personnel, allowing to make the transition from reactive management of labour protection (compensation for harm to health) to the preactive one (prevention of harm), i.e. to preventive measures (Yousefi, Jahangoshai Rezaee, M., & Moradi, 2020). In the Research Institute of Occupational Medicine of RAMS, an assumption was made about the possibility of risk value on the index of diseases, which summarizes their frequency and severity in one-number value (Viel et al., 2000).

Russian researcher Kucheneva (2009) has proposed two ways of assessing a posteriori risk: the first is to estimate morbidity; the second is to add up all risks of work-related morbidity and to add up all risks of occupational injuries, occupational diseases and morbidity with temporary disability from accidents.

The Russian scientist Izmerov (Kucheneva, 2009) also investigated several options for assessing occupational risk in the petrochemical industry. These are the method of complex point assessments; the Fi-Kinney method and assessment through an occupational risk index (RPI).

Specific standards - occupational exposure limits (OELs) - are developed as the main reference points for the control of hazards and are used in the development of protective measures by industrial hygienists to decide on safe levels of exposure to various chemicals that are present in the workplace(Safety and health in the use of chemicals at work, 2014, pp.6-7). The definition and use of these standards (RELs) for certain chemicals is the main working principle. An ELL is a limit of exposure expressed in numerical form. Generally, these limits define a weighted average level of exposure, where no health problems should arise for plant workers (Safety and health in the use of chemicals at work, 2014, p.6).

In particular, the occupational exposure limit (OEL) for benzene should be calculated taking into account the possibility of causing leukaemia in workers. However, such a standard may not take into account another factor, that in addition to the possibility of getting leukaemia, this substance is also very flammable and here the risks of fire must be provided for (Safety and health in the use of chemicals at work, 2014, p.7). It is also possible to adopt an established standard for one metal that provides for a certain occupational exposure limit (OEL), but for another metal this occupational exposure limit may not be provided for. Thus, it is necessary to provide for the exposure of all possible metals to human health who have contact with chemicals throughout the entire work cycle (Safety and health in the use of chemicals at work, 2014, p.7).

To address these problems in assessing human health exposures to hazardous metals, a method that has been applied by the LHAT- Hazardous Substances Assessment Laboratory in the US state of Iowa could be used (Gibson et al., 2014).

This laboratory uses the types of hazards used by each laboratory group (Gibson & Wayne, 2013):

1) biohazards;
2) chemical hazards;
3) radiation hazard;
4) laser danger;
5) monomolecular hazards.

In particular, the LHAT laboratory uses 4 main categories (Jones, 2005), (Cooper & Philips, 2004):

- Level A: High level (pyrophoric chemicals);
- Level B: Severe hazard level (severe fire);
- Level C: Medium hazard level (low hazard);
- Level D: Low level (low ignition level).

That is, each petrochemical facility can be assessed according to the levels of risk of impact on human health and safety.

The experience of France in identifying risks to workers in chemical plants could also be used (Faisander, 2011).

In France, for example, a prevention network, the National Surveillance for Occupational Diseases (Research National de Vigilance et de Prevention des Pathologies Professionneles, RNV3P) has been established (Walsh et al., 2005). This network monitors all patients who fall ill at chemical and petrochemical plants.

In order to determine the relationship between diseases and occupational exposures suffered by workers in petrochemical plants and to determine how these exposures influence the occurrence of disease, the Database Individual Occupational Copying Concept - ONR (Bonnetere et al., 2008) could be used.

In the context of occupational health, the French National Network for Surveillance and Prevention of Occupational Diseases (RNV3P) has created a growing database that records all occupational health problems (OHP) diagnosed by a network of specialist doctors each year (Bonneterre et al., 2009).

This network monitors all patients who fall ill at chemical and petrochemical plants. To determine the relationship between diseases and the composite occupational exposures that have been received at petrochemical plants and to determine how these exposures affect the occurrence of these diseases. The Concept of individual occupational diseases of employees from the radiation of substances of chemical and petrochemical enterprises could be used (Faisandier et al., 2007).

In order to process this RNV3P data is given in the form of a relationship network, where each RNV3P is represented in the RNV3P database as a node (vertex) V=$(p, e)^T$, which has a unique combination of diseases (pathology) "p" and it is associated with 3 dimensional exposure composite constructs e=$(h, o, s)^T$, which are characterised by hazard set "h" and occupations "o" and 5 (Wild, 2005).

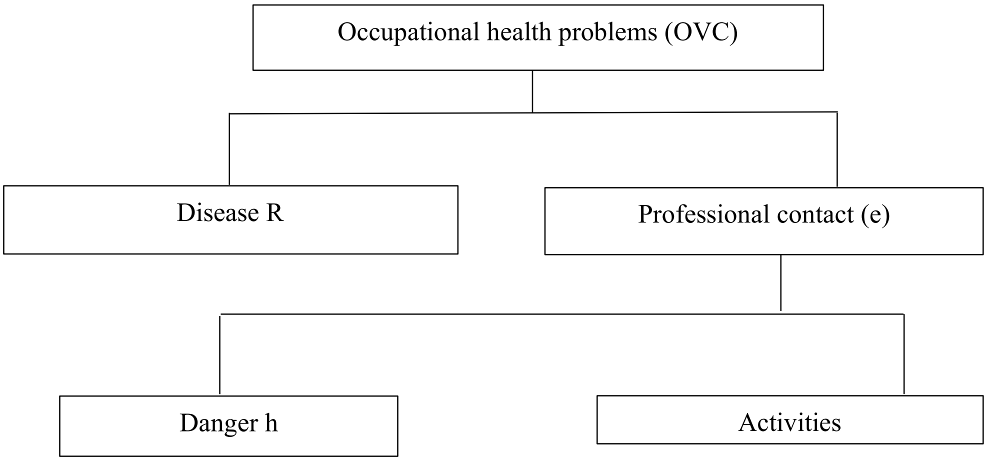
Conventionally, the hazard vector h=(h1, h2, h3 ,h4, h5) can include from 1 to 5 explicit hazards that are present in occupational activities and are characterised as "o" and "s" and are suspected to be derived from illness. Each node (i=OHP) is weighted by a common number "w" an identical ONR copy in the database) of which each network can be held.

Methodology

From this point onwards, the influence graph can be generated in the following order.

Say C_{ij-n}(Co≤$C_{ij} \leq 5$) is defined by the number of hazards that are separated by 2 vertices $U_{i,}$,U,U_j (i,j=1,2......v) appearing each as $^{\eta}$ copies in this database (Barabasi, 2007).

The network aims to provide and develop expertise on possible diseases: the relationship between exposures, using the RNV3P database, to develop OHP surveillance and to identify emerging associations between diseases and occupational exposures (Goh, 2007)



Danger 1

Danger 2 Occupational activities

Danger 3 Sector S

Danger 4

Danger 5

Figure 1. Health problems resulting from professional activities

Note-compiled by the author from the source (Faisandier et al.)

For example P = Hodgkin's lymphoma (Goh et al., 2007, p. 83) and (Muller et al., 2005)

$$h=\begin{cases} h1 - solvents\ (35110) \\ h2 - benzene\ \ (21311) \\ h3 - ionizing\ radiation\ (47100) \end{cases}$$

A theoretical framework for occupational exposure, defined as a network of OHP associated with occupational exposures, was developed as a new approach that allowed the characterization and analysis of the disease-exposure relationship represented in the RNV3P database in the form of a relational network. Further, occupational exposures are structured in terms of occupational exposure groups, which constitute informative subsets of hazards considered as a spectrum of the occupational exposure backbone tree, potentially associated with disease (Alexander et al., 2007).

To illustrate the vast possibilities of this method, the RNV3P uses an exposure approach.

As a result, it was found that professional work in NHL (National Chemical Laboratory) Exposure-Function - can be described in terms of 86 embedded exposure groups, defined as a set of common data of at least one component of the professional multi-exposure (Fabro-Preay et al., 2001) (Rana et al., 2021). For example, "organic solvents and diluents" are the most representative threat associated with NHL. Exposure can also be related to "benzene", "ionizing radiations" or "agricultural products" (Viel et al., 2000). Based on the knowledge stored in a database of experts by physicians, occupational exposures are a crucial step towards the development of monitoring of multiple exposures associated with this disease.

Let us consider the following method of assessing occupational risks developed by Imasheva, Nurgalieva, Alpysbaeva at the Republican Scientific Research Institute for Labor Protection of the Ministry of Labor and Population of Kazakhstan (Imasheva et al., 2011). In particular, it was proposed to use the method of a priori ranking of factors in processing data obtained from a survey of respondents.

This experiment provides an opportunity to identify the object of study, to confirm or refute some preliminary hypotheses, thereby giving a comparative assessment of the impact of various factors on the optimisation parameters.

A priori ranking of production factors has the following steps (Imasheva et al., 2011, p.85):

- calculating the raw data;
- calculating the sum of the ranks ($\sum_{i=1}^{m} aj$);
- calculating the difference of the sums of each factor and the average sum of the ranks (Δ_i) and the sum of the squares of variance (S):

$$\Delta\mathrm{i} = \sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{aj} - \frac{\sum_{\mathrm{j}=1}^{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{aj}}{\mathrm{n}} \quad (1)$$

$$\mathrm{S} = \sum_{\mathrm{i}=1}^{\mathrm{m}} (\Delta\mathrm{i}) \quad (2)$$

Where "aj" is the rank of each i-th factor in j-th respondent;

m-number of respondents;

n-number of factors;

assessing the consistency of all respondents' opinions is (determining the coefficient of concordance ω):

$$\omega = \frac{12\mathrm{S}}{\mathrm{m}^2(\mathrm{n}^3 - \mathrm{n}) - \mathrm{m}\sum_{1}^{\mathrm{m}} \mathrm{Tj}} \quad (3)$$

$$\mathrm{Tj} = \sum(t^3 - tj) \quad (4)$$

Where it is the number of corresponding ranks in the j-th ranking.

If the value of the concordance coefficient is much different from zero, it can be said that there is an enormous relationship between the opinions of respondents (Imasheva et al., 2011, p.86). This coefficient of concordance can only be applied after assessing its significance, which can only be determined by x^2-criterion. It is calculated as follows:

$$\mathrm{x}^2 = \frac{12S}{m(n+1) + \frac{1}{n-1\sum_{1}^{m} Tj}} \quad (5)$$

Verification of this hypothesis of respondents' unity of opinion can be confirmed if, for a given number of degrees of independence, the table value x^2- is lower than the calculated for 5% of the tabular level of verification (Imasheva et al., 2011, p.86).

Table 1. Values x^2-relevant tolerance values $\alpha = P\{x^{2(k)>}|x^2 a\}$

k	α					
	0,990,99	0,95	0,90	0,10	0,05	0,01
1	2	3	4	5	6	7
1	0,0002	0,004	0,02	2,71	3,84	6,64
2	0,02	0,10	0,21	4,61	5,99	9,21
3	0,12	0,35	0,58	6,25	7,82	11,34
4	0,30	0,71	1,06	7,78	9,49	13,28
5	0,55	1,15	1,61	9,24	11,07	15,09
6	0,87	1,64	2,20	10,65	12,59	16,81
7	1,24	2,17	2,83	12,02	14,06	18,48
8	1,65	2,73	3,49	13,36	15,51	20,09
9	2,09	3,33	4,17	14,68	16,92	21,67
10	2,56	3,94	4,87	15,99	18,31	23,21
11	3,05	4,58	5,58	17,28	19,68	24,72
12	3,57	5,23	6,30	18,55	21,03	26,22
13	4,11	5,89	7,04	19,81	22,36	27,68
14	4,66	6,57	7,79	21,06	23,69	29,14
15	5,23	7,26	8,55	22,31	25,00	30,58
16	5,81	7,96	9,31	23,54	26,30	32,00
17	6,41	8,67	10,09	24,77	27,59	33,41

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18	7,02	9,39	10,86	25,99	28,87	34,81
19	7,63	10,12	11,65	27,20	30,14	36,19
20	8,26	10,85	12,44	28,41	31,41	37,57
21	8,90	11,59	13,24	29,62	32,67	38,93
22	9,54	12,34	14,04	30,81	33,92	40,29
23	10,20	13,09	14,85	32,01	35,17	41,64
24	10,86	13,85	15,66	33,19	36,42	43,98
25	11,52	14,61	16,47	34,38	37,65	44,31
26	12,20	15,37	17,29	35,56	38,89	45,64
27	12,88	16,15	18,11	36,74	40,11	46,96
28	13,56	16,93	18,94	37,92	41,34	48,28
29	14,26	17,71	19,77	39,09	42,56	49,59

Continuation of table 1

30	14,95	18,49	20,60	40,26	43,77	50,89
40	22,16	26,51	29,05	51,81	55,76	63,69
50	29,71	34,76	37,69	63,17	67,51	76,15
100	70,07	77,93	82,36	118,50	124,34	135,81
Note: compiled according to Imasheva et al. (2011, p.87).						

*Ranking chart *construction.*

As a result of the calculations, the tabulated value of the x^2criterion is lower than the calculated one, which means 95% confidence that respondents' opinion about the degree of influence of factors is in conformity with, first of all, the coefficient of concordance ω (Imasheva et al., p.88, 2011). Having given a value of concordance to all respondents, it is necessary to construct an average ranking diagram, plotting on the x-axis the factors and on the y-axis the corresponding sums of ranks. The lower the sum of ranks of a given factor, the higher its place in the chart. This diagram will be used to assess the significance of factors (Imasheva et al., p.88, 2011).

If the event is not uniformly exponentially decreasing, then a certain proportion of the factors can be excluded from further study. If the event is uniform, then all factors can be included in the experimental study. This ranking diagram can be used to identify the most influential factors and to remove factors that have a negligible minimum impact.

In cases with a very large number of factors, in addition to the overall unity of the respondents' opinions, determine by x^2 –distribution and unity for each factor individually (Imasheva et al., 2011, p.88).

Table 2. Ranking of production factors by significance of impact on employees in workshop No. 5 of AZKhS JSC

	Ranking by factor								
Respondent (m)	Harmful chemicals and substances	Tension Labour	Vibration	The complexity of the work to be done	Micro Team climate	Illuminated by availability	Noise	Average sum of ranks and sum of squares of deviations	Tj
1	1	2	3	4	5	6	7		
2	3	5	4	1	2	6,5	6,5		6
3	2	6	7	4	1	3	5		
4	2	5	7	4,5	4,5	3	1		6
5	2	7	4	6	5,5	5,5	3		6
6	1	2	7	5	4	3	6		
Sum of ranks	11	29	36	26,5	19	24	26,5	24,571428	18
Δi	-13,571	4,429	11,429	1,929	-5,571	-0,571	1,929		
Δi^2	184,184	19,612	130,612	3,719	31,041	0,327	3,719	373,214	
Specific value x^2-criterion			13,44916345						
Note-compiled by the author from (Imasheva et al. (2011, p.88).									

Considering the above method of a priori ranking of factors, it is possible to identify factors that do not have a significant impact on the parameter under study, these factors can be excluded from the study (Imasheva et al., 2011, p.88).

Using the methodology used above, a ranking of production factors was determined at JSC "Aktobe Chromium Compounds Plant" in the shops where chromium anhydride and chromium oxide are produced in the Table 2 (Imasheva et al., 2011, p.88).

Findings and Discussion

By calculating the values Δi for each of the factors of workshop No.5, the degree of unity of the respondents' opinions is determined (Imasheva et al., p.89, 2011). To do this, the coefficient of concordance of opinions of respondents surveyed is applied ωwhich in this case has been calculated and is equal to 0.37, i.e. different from zero. Therefore, we can say that there is a correlation between the opinions of respondents. Therefore, the researchers do not identify the factors in the same way (the value of the concordance coefficient found ω is different from zero). The significance of ω can be calculated using the x^2-criterion. The calculated tabular value of x^2-with a=0.05 and number of degrees of freedom f=7-1=6 is 12.59 [20, p.89]. Therefore at a given number of degrees of freedom the calculated value is lower than the calculated value for 5% level of significance (12,59<13,45). Thus, we can say with 95-% confidence that the respondents' opinion on the degree of influence of factors goes in accordance with the coefficient of concordance $\omega = 0,37$.

All this will make it possible to construct an average a priori ranking diagram for the factors under study.

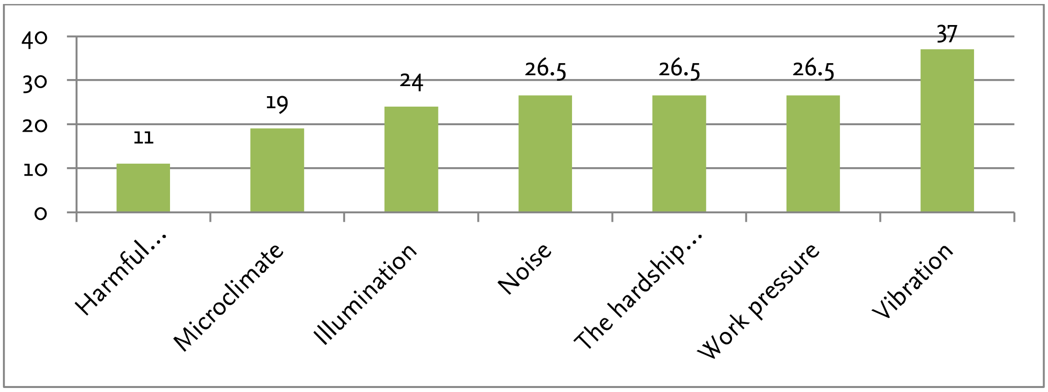

Figure 2 - Distribution of production factors in workshop no. 5

for the production of chromium anhydride pigment chromium oxide JSC AZKhS

Note-compiled by the author from Imasheva et al. (2011, p.89).

As can be seen from this diagram, the first place is occupied by harmful substances (sum of ranks 11), which have the greatest impact; the second is microclimate (19), then light (24), then noise and heaviness of work, all having the same degree of impact (26.5 each); next are work stress (29) and vibration (36) (Imasheva et al., 2011, p.89).

Indeed, as a result of measurements of harmful factors of production at the workplaces of the main professions of workers of the petrochemical plants, it was determined that the average concentration of harmful substances Cr+6 exceeds the maximum permissible values by 2 times, the microclimate indicators - the temperature of the working environment during the warm periods exceeds the standard values by 5-7^{0}C, relative humidity and air velocity less than the normative values, lighting indicators below the required value (Imasheva et al., 2011, p.89).

Conclusion

Thus, of the methodologies we have considered for assessing occupational risks, the methodology for ranking harmful factors of production and work process is the most acceptable. It can be used in determining the harmful factors of exposure in the production process and for any industry, not only in the petrochemical industry.

In addition, it is effective in developing a set of preventive measures and measures to reduce risks at work.

In addition, we recommend the use of these techniques in the outsourcing of occupational health and safety systems.

The methodologies considered for assessing occupational risks can be recommended for the establishment of laboratories and systems for studying occupational risk assessment in the healthcare system of Kazakhstan.

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