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Assessment of Non-Carcinogenic Risk and Body Responses for Oil Refinery Staff

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Abstract

The study is relevant due to the lack of methods for assessing risk to the staff health from exposure to various substances in the production environment, which would take into account the responses of the body. To date, the procedure for special assessment of working conditions allows assessing the risk only at the level of establishing a class of working conditions in order to subsequently establish an additional payment for harmful working conditions, but not quantify the risk to the staff health. In this regard, this paper aims to assess non-carcinogenic risk to the health of the oil refinery staff and to identify dependencies between the magnitude of the risk and incidence of this staff. The leading approach to study this problem is to take into account both separate action of non-carcinogenic substances on individual organs and systems of the human body, and their combined effect to consider the effect of the chemical factor and take into account the effect of potentiation. The paper provides information on substances present in the work area, information about their danger, detailed analysis of their effects on the human body. Three scenarios for calculating non-carcinogenic risk for the workplace of the technician pump operator are considered as an example, an algorithm for the "dose-effect" model was provided, 26 risk groups for the staff of oil refinery were formed, information was provided on incidence of the staff, groups of diseases were identified by unidirectional action of the substances, dependence equations of non-carcinogenic risk and four nosological forms of diseases (respiratory diseases, diseases of kidneys and genitourinary system, eyes and its appendages, cardiovascular system) were obtained, reliability of the obtained dependences was assessed. The materials of the paper are of practical value for the researchers of this issue, employees of the occupational safety departments of enterprises for assessing the risk from exposure to the chemical factor, establishing relation of working conditions with occupational diseases of the staff, identifying risk groups among the staff of the enterprise workshops, and developing measures to improve working conditions.

Keywords: Chemical Factor, Incidence, Non-Carcinogenic Risk, Non-Carcinogenic Substances, Staff Health, Working Conditions

1. Introduction

Human health directly depends on environmental conditions, since changes in the environment entail the growth of environment-related diseases.

To date, the World Health Organization has developed special models to forecast increases in "responses" from the population from increasing exposure to pollutants (Tools and methods).

Direct and medium-strength links were established in studies conducted in many regions of Russia between the average annual concentrations of substances in the atmospheric air and morbidity (deaths) of the population. The values of non-carcinogenic risks are several times exceeded mainly for suspended solids and nitrogen dioxide, (Ecology of Chapaevsk. Environment and public health).

Primary morbidity of Komsomolsk-on-Amur population by all disease classes exceeds the average Russian values by 20 – 30% and tends to increase, (2010). Respiratory diseases have a leading position among clinical entities in the structure of primary morbidity in the city (29%), which can be explained by the influence of both climatic and chemical factors.

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2. Materials and Methods

As of 2011, RN – Komsomolsk Refinery LLCemits over 4715 tons of pollutants in the overall structure of total emissions of this research facility, of which only 0.7% (≈ 32 t) are carcinogenic, 99.3% (≈ 4683 m) are non-carcinogenic. That is, the plant emissions are largely non-carcinogenic (48 items) (2009).

Since the atmospheric air of all three environments reviewed in this study is polluted by a complex of harmful substances, each employee of RN – Komsomolsk Refinery LLC will be subjected to combined action of all chemical factors.

According to the urban observation stations (2011), certification of workplaces by working conditions (2009), and the project of maximum permissible refinery emissions [4], 35 non-carcinogenic substances were selected of all the substances present in the air of the considered sites. Table 1 provides information about the danger of these substances.

Thus, respiratory organs are exposed to 30 substances, CNS – 12, 5 substances effect on liver and kidneys, 4 substances effect on blood, 3 substances effect on eyes, 2 substances effect on cardiovascular, skeletal, nervous system and development, and 1 substance effect on the immune system and body weight.

It can be assumed at the level of qualitative analysis that as a result of the effect of the identified chemicals, body organs and systems will be subjected to the above effects in the order shown in Fig. 1.

Some substances have proven effect on several organs at once. In this case their primary effect is taken into account to identify the most likely affected body systems. The ratio of substances by such primary effect is shown in Fig. 2.

Thus, the respiratory organs (7 substances), central nervous system (6 substances), liver and skeletal system (2 substances), kidneys, blood, eyes and cardiovascular system (1 substance) are primarily exposed.

Comparing the data of two diagrams (Figures 1 and 2), we can point 3 groups of substances with unchanged positions – the substance that affect the respiratory system, central nervous system and liver.

Non-carcinogenicrisks were calculated in three scenarios. Scenario No. 1 involved consideration of only the industrial and technological environment; it was based on data on concentrations of substances in the working area (2009). Scenario No. 2 also considered industrial environment, but now it is conventionally divided into two time periods: time spent in the production and technological environment and time spent under other conditions (offices, outdoors, etc.) - in the production environment, where measurements were not carried out in the course of certification of workplaces, so the information on the concentrations of substances in these areas were chosen based on the results of the project dispersion of maximum allowable emissions of the company (2009).

Scenario No. 3 is, in turn, clarifying previously considered scenario No. 2, as well as takes into account the concentrations of pollutants in an urban environment. It has been assumed that the urban environment is about the same for every employee. This is primarily due to the lack of data and impossibility of zoning the city territory by the level of contamination.

Elements of the chosen route of exposure:

1 – The source of substances to the environment: the city industry and transport (including the object of study);
2 – Perceiving, transporting and exposing environment: atmospheric air;
3 – Receptor point (point of exposure): workplace, urban environment;
4 – Route of exposure in contact of a person with a chemical: inhalation (inhalation of contaminated air).

Consider in detail the calculation of non-carcinogenic risk for the workplace of a machinist of process pumps of the 4th grade in isomerization unit of workshop No.1 (workplace No. 30-1) for each of three scenarios. To do this, the following summary tables 2 – 4 compiled (AC – concentration of substances in the air, mg/m^3; RfC – referential (safe) concentration, mg/m^3; HQ – hazard coefficients for individual components of the mixture of exposing substances; HI – hazard indices for individual routes of exposure.

Further, the diagram (Fig. 3) shows the ratio of hazard indices depending on the exposure scenario.

As can be seen from Fig. 3.11, the main contribution to formation of the risk amount is from the industrial environment – 98.6%, urban environment – 1.4%. Scenario No. 3, in spite of complexity of calculations, gives the most complete picture of the concentrations of substances throughout the day in different environments.

Because some substances can effect on multiple organs and systems simultaneously, THI coefficients were calculated for these groups of substances. Results are given in

Table 1. Information about the Danger of Non-Carcinogenic Substances

Substance		CAS No.	RfC, mg/m^3	Critical Organs/Systems											
				Respiratoryorgans	Blood	Eyes	Body weight	CNS	Nervous system	Liver	Kidneys	Development	Immune system	Cardiovascular system	Skeletalsystem
1	Nitrogen dioxide	10102-44-0	0,04	++	+										
2	Nitrogen oxide	10102-43-9	0,06	++	+										
3	Acrolein	107-02-8	0,00002	++		+									
4	Aluminum oxide (III)	1344-28-1	0,005	++			+								
5	Ammonia	7664-41-7	0,1	+											
6	Acetone	67-64-1	31,2		+			+		++	+				
7	Butyl acetate	123-86-4	0,7	+											
8	Suspendedsolids	-	0,075	+											
9	Hydrogensulfide	7783-06-4	0,002	+											
10	Hydrogenchloride	7647-01-0	0,02	+											
11	Hexane	110-54-3	0,2	+				++	+						
12	Kerosene	8008-20-6	0,01							+					
13	Nitric acid	7697-37-2	0,04	+											
14	Sulphuric acid	7664-93-9	0,001	+											
15	Xylol	1330-20-7	0,1	+				++		+	+				
16	Manganese and its compounds	7439-96-5	0,00005	+				++	+						
17	Sodium hydroxide	1310-73-2	0,002	++		+									
18	Crude oil	2228840	0,071								+				
19	Ozone	10028-15-6	0,03	+											
20	Wood dust	-	0,05	+											
21	Inorganic dust (up to 20% SiO_2)	14464-46-1	0,05	+											
22	Inorganic dust (70-20% SiO_2)	14464-46-1	0,003	+											
23	Cement dust	-	0,1	++									+		
24	Sulphur dioxide	7446-09-5	0,05	+											
25	Toluene	108-88-3	0,4	+				++				+			
26	White spirit	8030-30-6	1					+							
27	Hydrocarbons	-	0,071	+		++		+		+	+				
28	Carbon xide	630-08-0	3		++			+				+		+	
29	Phenol	108-95-2	0,006	+				+		+	+			++	
30	Gaseousfluorides	7664-39-3	0,03	+											++
31	Poorly soluble fluorides	-	0,013	+											++
32	Chlorine	7782-50-5	0,0002	+											
33	Ethanol	64-17-5	100	+				++							

Substance		CAS No.	RfC, mg/m³	Critical Organs/Systems											
				Respiratoryorgans	Blood	Eyes	Body weight	CNS	Nervous system	Liver	Kidneys	Development	Immune system	Cardiovascular system	Skeletalsystem
34	Ethyl acetate	141-78-6	3,2	++				+							
35	2-ethoxyethanol (ethylene glycol ethyl ether)	111-90-0	0,003	+											

Legend:

++ - priority impact; + - has impact

Table 2. Example of HI Calculation According to Scenario No. 1

Substance	AC, mg/m³	RfC, mg/m³	HQ	Organ/system
Hydrochloride	0,5000	0,0200	25,00	Respiratory organs
Xylene	3,6720	0,1000	36,72	CNS, respiratory organs, kidneys, liver
Hydrogene sulfide	0,4140	0,0020	207,00	Respiratory organs
Sulphur dioxide	0,8160	0,0500	16,32	Respiratory organs
Total risk		**HI** $_{resp.organs}$	**285,04**	
		HI $_{CNS,\ resp.organs,}$ **liver, kidneys**		**36,72**
		HI $_{total}$		**285,04**

Table 5 with the contributions of substances to the resulting THI.

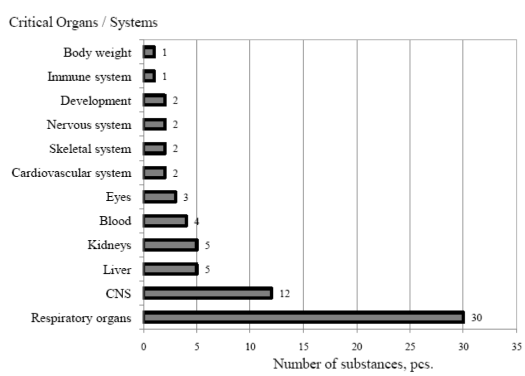

Fig. 1 The Ratio of Substances Having Effect on Critical Organs/Systems

If identify the critical body systems, respiratory organs, liver, central nervous system, kidneys and eyes are primarily such target organs.

The list of priority non-carcinogenic substances for people working as machinists of process pumps of isomerization unit includes by the level of importance: hydrogen sulfide, xylene, saturated hydrocarbons, sulfur dioxide. Hydrocarbons and sulfur dioxide provide general pollution of the plant, are priority non-carcinogenic substances according to ranking results effect on the health of all staff. Hydrogen sulfide and xylene should be attributed to specific pollutants with concentrations higher in certain technological areas of the company. So, commodity shop No. 3 is the main source of xylene emissions, and shop No. 2 is the source of hydrogen sulfide emissions. The presence of these substances at the workplace can be explained by neighboring location of shop facilities.

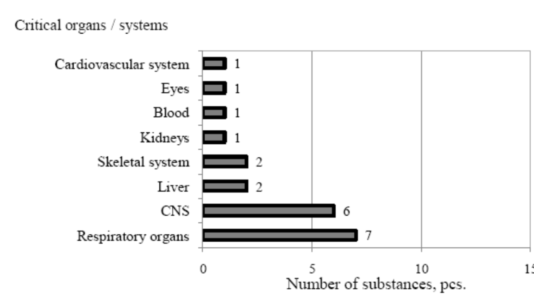

Fig. 2 The Ratio of Substances by Priority Effect on the Critical Organs/Systems

Table 3. Example of HI Calculation According to Scenario No. 2

Substance	**AC, mg/m³**	**RfC, mg/m³**	HQ	**Organ/system**
Nitrogen dioxide	0,0028	0,0400	0,07	Respiratory organs, blood
Nitrogen oxide	0,0013	0,0600	0,02	Respiratory organs, blood
Ammonia	0,0007	0,1000	0,01	Respiratory organs
Hydrochloride	0,5000	0,0200	25,00	Respiratory organs
Kerosene	0,2800	0,0100	28,00	Liver
Xylene	3,6820	0,1000	36,82	CNS, respiratory organs, kidneys, liver
Hydrogen sulfide	0,4141	0,0020	207,05	Respiratory organs
Sulphur dioxide	0,8162	0,0500	16,32	Respiratory organs
Toluene	0,1200	0,4000	0,30	CNS, respiratory organs
Saturated hydrocarbons (C_1 - C_5)	0,8333	0,071	11,74	Eyes, respiratory organs, liver, kidneys, CNS
Saturated hydrocarbons (C_6 – C_{10})	2,0000	0,071	28,17	Eyes, respiratory organs, liver, kidneys, CNS
Saturated hydrocarbons (C_{12} – C_{19})	0,3333	0,071	4,69	Eyes, respiratory organs, liver, kidneys, CNS
Carbon monoxide	0,0167	3,0000	0,01	Blood, cardiovascular system, CNS
Total risk		**$HI_{resp.organs}$**	**330,19**	
		HI_{liver}		**109,42**
		HI_{CNS}		**81,73**
		$HI_{kidneys}$		**81,42**
		HI_{eyes}		**44,60**
		HI_{blood}		**0,10**
		$HI_{cardiovascular\ system}$		**0,01**
		HI_{total}		**358,20**

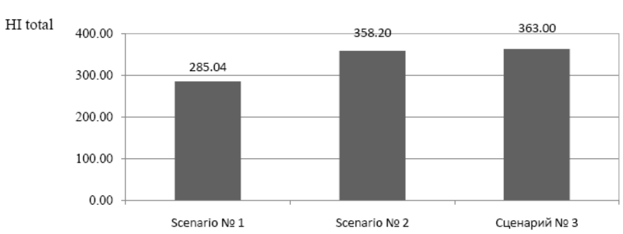

Fig. 3 Results of Calculations for three Scenarios

The calculation results of inhalation non-carcinogenic risk for all 517 workplaces of RN – Komsomolsk Refinery LLC. According to calculations, the values of HQ, HI and THI coefficients hundreds and thousands of times exceed safety criterion. It is believed that if the hazard ratio is greater than one, the likelihood of harmful effects in human increases in proportion to the increase in coefficient, but there are no exact indications of the value of such probability yet.

3. Results

Upon results of calculations, 26 professional groups were formed depending on the belonging to a particular shop, unit or plant of the shop, as was done previously in the study of carcinogenic risk (I.V. Afanasyeva, 2012). The list of groups and the values of average non-carcinogenic hazard ratios are given in Table 6.

The code of each group contains a number that determine the belonging to a particular shop. Alphabetic abbreviations designate intrashop units or processing plants.

Thus, total non-carcinogenic risks (total hazard indices) were obtained in the course of the study, formed in 3

Table 5. THI Hazard Indices at the Combined Effect

Critical organ (system)	**Substances**	**HQ**	**Contribution to THI, %**	THI
Respiratory organs	Hydrogen sulfide	207,05	61,91	334,44
	Xylene	36,82	11,01	
	Saturated hydrocarbons (C_6 – C_{10})	28,17	8,42	
	Hydrochloride	25,00	7,48	
	Sulphur dioxide	16,63	4,97	
	Saturated hydrocarbons (C_1 - C_5)	11,74	3,51	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	1,40	
	Suspendedsubstances	2,56	0,77	
	Nitrogen dioxide	0,82	0,25	
	Phenol	0,45	0,13	
	Toluene	0,30	0,09	
	Nitrogen oxide	0,20	0,06	
	Ammonia	0,01	< 0,01	
Liver	Xylene	36,82	33,51	109,87
	Saturated hydrocarbons (C_6 – C_{10})	28,17	25,64	
	Kerosene	28,00	25,48	
	Saturated hydrocarbons (C_1 - C_5)	11,74	10,69	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	4,27	
	Phenol	0,45	0,41	
CNS	Xylene	36,82	44,51	82,73
	Saturated hydrocarbons (C_6 – C_{10})	28,17	34,05	
	Saturated hydrocarbons (C_1 - C_5)	11,74	14,19	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	5,67	
	Carbon oxide	0,56	0,68	
	Phenol	0,45	0,54	
	Toluene	0,30	0,36	
Respiratory organs + CNS	Xylene	36,82	44,81	82,16
	Saturated hydrocarbons (C_6 – C_{10})	28,17	34,29	
	Saturated hydrocarbons (C_1 - C_5)	11,74	14,29	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	5,71	
	Phenol	0,45	0,55	
	Toluene	0,30	0,37	
Respiratory organs + liver + kidneys + CNS	Xylene	36,82	44,97	81,87
	Saturated hydrocarbons (C_6 – C_{10})	28,17	34,41	
	Saturated hydrocarbons (C_1 - C_5)	11,74	14,34	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	5,73	
	Phenol	0,45	0,55	
Eyes + respiratory organs + liver + kidneys + CNS	Saturated hydrocarbons (C_6 – C_{10})	28,17	63,16	44,60
	Saturated hydrocarbons (C_1 - C_5)	11,74	26,32	
	Saturated hydrocarbons (C_{12} – C_{19})	4,69	10,52	

Critical organ (system)	Substances	HQ	Contribution to THI, %	THI
Blood	Nitrogen dioxide	0,82	51,90	1,58
	Carbon oxide	0,56	35,44	
	Nitrogen oxide	0,20	12,66	
Respiratory organs + blood	Nitrogen dioxide	0,82	80,39	1,02
	Nitrogen oxide	0,20	19,61	
Cardiovascular system + CNS	Carbon oxide	0,56	55,45	1,01
	Phenol	0,45	44,55	
Blood + cardiovascular system + CNS	Carbon oxide	0,56	100	0,56
Cardiovascular system + kidneys + CNS + liver + respiratory organs	Phenol	0,45	100	0,45

Table 6. Results of THI_{avg} Calculation by Professional Groups

Pos. No.	Group code	Group description	THI_{avg}	Excess of $THI_{perm.}$ = 1, times
1	G(CA-5)	Staffof chemical analysis(CA) of shop No. 5	2454,79	2454,79
2	G(6)	Staffof shop No. 6	1617,40	1617,40
3	G(A-5)	Administration(A) of shop No. 5	1070,98	1070,98
4	G(9)	Staffof shop No. 9	846,07	846,07
5	G(46)	Staffof shop No. 46	587,58	587,58
6	G(3)	Staffof shop No. 3	541,72	541,72
7	G(ESL-5)	Staffof ecosafety laboratory(ESL) of shop No. 5	485,27	485,27
8	G(EDP-3-1)	Staffof electrical desalting plant No. 3 (EDP-3) of shop No. 1	467,39	467,39
9	G(TC-14)	Staffof training centre(TC) of shop No. 14	453,35	453,35
10	G(RG-1)	Staffof repair group (RG) of shop No. 1	446,46	446,46
11	G(11)	Staffof shop No. 11	434,61	434,61
12	G(8)	Staffof shop No. 8	433,18	433,18
13	G(15)	Staffof shop No. 15	387,90	387,90
14	G(2)	Staffof shop No. 2	387,37	387,37
15	G(IP-1)	Staffof isomerization plant (IP) of shop No. 1	355,64	355,64
16	G(4)	Staffof shop No. 4	332,41	332,41
17	G(GRP-14)	Staffof gas rescue party(GRP) of shop No. 14	310,78	310,78
18	G(7)	Staffof shop No. 7	309,43	309,43
19	G(CRU-1)	Staffof catalytic reforming unit(CRU) of shop No. 1	283,93	283,93
20	G(EDP-2-1)	Staffof electrical desalting plant No. 2 (EDP-2) of shop No. 1	260,80	260,80
21	G(33)	Staffof shop No. 33	212,82	212,82
22	G(12)	Staffof shop No. 12	169,54	169,54
23	G(A-1)	Administration(A) of shop No. 1	165,01	165,01
24	G(MCS-14)	Staffof medical care station (MCS) of shop No. 14	71,13	71,13
25	G(22)	Staffof shop No. 22	62,24	62,24
26	G(NAS)	Staffof nitrogen-air station (NAS)	43,67	43,67

environments, allowing to rank work places and professional groups of the refinery by the hazard level.

Inflated values of the hazard indices at a rate of HI = 1 can be explained by the use of a new international criterion – reference concentration RfC. Nevertheless, the entire personnel of the company is exposed to a sufficiently high level of non-carcinogenic risk, and the greatest contribution to the hazard index value is from the industrial environment (98.6%).

Due to the possible effect of various specific factors on the staff health (lifestyle, level of medical care development, etc.), calculation data should be compared with the real incidence of diseases, which was done further.

The biological effect of exposure to a chemical compound or a complex of compounds on the staff depends on both the properties of substances, and intensity and duration of exposure to a complex of related factors (physical activity, noise, low and high temperature, etc.). Other factors are also important: medical (health disorders, treatment measures, medicamental prevention, etc.), social (transfer to another job, setting working conditions, food, rest, etc.), and personal (individual sensitivity, lifestyle, bad habits, etc.).

In case of chronic exposure, due to developing processes of adaptation to the effect of chemical substances, body reactivity can be cyclically changed by repeated substitution of compensation by decompensation, whereby morbidity among workers exposed to harmful factors in higher concentrations at some stage may be lower than among those exposed to harmful factors in lower concentrations.

Features of body responses to exposure to chemical factors various in intensity and duration, as well as the effects of other factors on them make it difficult to obtain a clear dependence of the change in health of workers on the effecting factor.

There are numerous but scattered publications about detection of various harmful effects under exposure to various chemical compounds at levels above their maximum permissible concentration. However, very little has been published on the establishment of dependence "concentration-effect" to predict probability of health disorders under the effect of certain chemicals. Collection of these data and development of these forecast models is one of priority tasks of occupational medicine.

The following tasks were set to find dependencies between the influence of factors and response health reactions of workers of RN – Komsomolsk Refinery LLC:

1. Analyze the overall incidence of diseases of staff by nosological entities;
2. Select groups of diseases by similar effects of substances on target organs;
3. Calculate indices of total non-carcinogenic hazard (THI) by critical organs and systems according to the selected types of diseases;
4. Compare the data of average staff incidence values with the values of the corresponding THI indices for professional groups;
5. Analyze the correlation of THI index and staff morbidity by professional groups.

The development algorithm of partial models according to "dose-effect" type is shown in Fig. 4.

The total number of employees of RN – Komsomolsk Refinery LLCis 1,348 people: of these 293 women, or 21.7% of staff, 1,055 or 78.3% of men. Predominance of men is due to the production specifics. No workers under 18 (2009).

989 people are employed at heavy works, works with harmful and (or) dangerous working conditions, which is 77.5% of the total staff: 156 women (53.2% of all employed women and 11.6% of all staff) and 833 men (79% of men and 61.8% of all staff). In the absence of persons under 18 at the plant, there is no such group of workers in hazardous working conditions (2009).

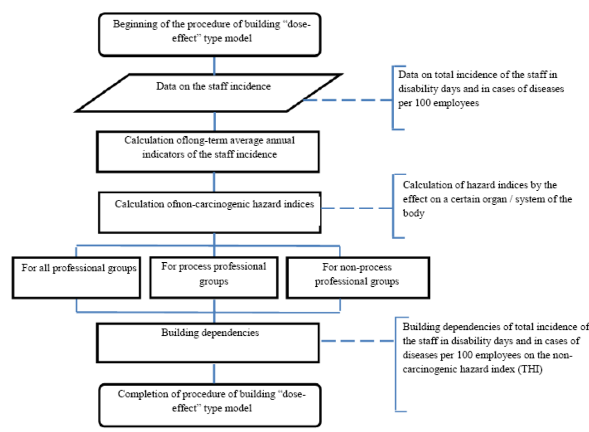

Fig. 4 Development Algorithm of a Partial Model According to "Dose-Effect" Type

The permissible working conditions are provided for 359 workers (22.5% of the staff).

Graphical representation of the staff structure of RN – Komsomolsk Refinery LLC is shown in Fig. 3.13, where the percentage of workers employed in harmful and (or) dangerous working conditions is also clarified.

The data on dynamics of the overall incidence of the staff for the period from 2004 to 2010 in relative units (the number of cases and the number of disability days per 100 employees) are given in Table 7 and in the diagrams (Figures 6 and 7) (Analysis of incidence of KNPZ for 12 months of 2005-2012).

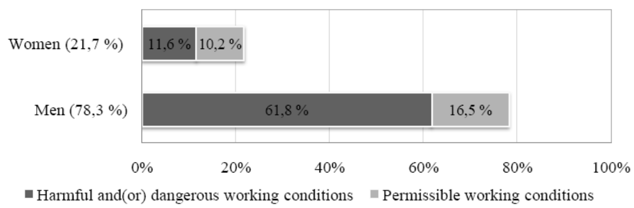

Fig. 5 Staff Distribution by the Hazard Degree of Working Conditions

According to disease dynamics, it can be concluded that since 2004 there has been an increase in the overall incidence of the staff, both in the number of cases and the number of disability days. At the same time, the number of disability days decreases in 2007, indicating a decrease in severity of disease that year.

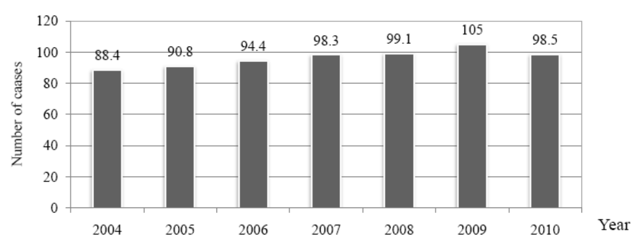

Fig. 6 The Number of Cases of all Diseases (per 100 Employees)

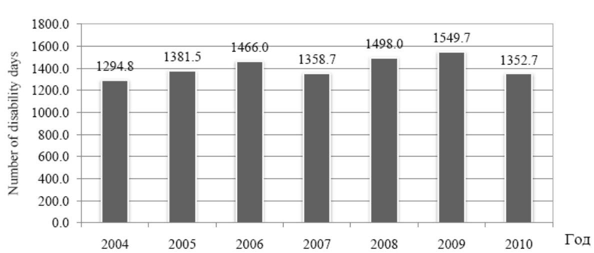

Fig. 7 The Number of Disability Days by all Types of Diseases (per 100 Employees)

Four forms deserve special attention of all the diseases: respiratory diseases, diseases of kidneys and urinary tract, diseases of the eye and its appendages, cardiovascular system diseases. It was suggested that these diseases are caused by the presence of substances in the air of direct effect on the following organs and systems:

- Respiratory organs (30 substances);
- Kidneys (5 substances);
- Eyes (2 substances);
- Cardiovascular system (2 substances).

We considered medical center data on morbidity by selected nosological entities, and conducted a comparative analysis with indexes of non-carcinogenic hazard by professional groups. To clarify the relation of the incidence with exposure to non-carcinogenic substances, professional groups of the process shops (No. 1, 2 and 3) and non-process shops (see the algorithm, Fig. 4) were analyzed separately.

The following are the equations of incidence depending on the value of the index of non-carcinogenic hazard to the staff of the process and non-process shops, obtained by the method of least squares:

1. For the respiratory diseases:

– To determine the number of cases of respiratory diseases per 100 employees: y = 0,0121x + 24,202 (for the process plants); y = 0,0044x + 22,454 (for non-process shops).

– To determine the number of disability days due to respiratory diseases per 100 employees: y = 0,1047x + 253,68 (for the process plants); y = 0,0589x + 190,24 (for non-technological plants).

An increase in hazard risk per 300 points will result in 1 additional case of the respiratory disease, and about 13 additional disability days per 100 employees. Under the same conditions, an increase in THI index per 300 points for the process groups will result in 3,6 additional cases of incidence and 31,2 additional disability days per 100 employees. For non-process groups, the same increase in THI index will result in 1,2 additional cases of incidence and 17,4 additional disability days per 100 employees.

2. Diseases of the kidneys and urinary system:

– To determine the incidence of diseases of the kidneys and urinary tract per 100 employees: y = 0,005x + 2,542 (for groups of the process plants);

– To determine the number of disability days due to incidence of diseases of the kidneys and urinary tract per 100 employees: y = 0,122x + 34,46 (for groups of non-process shops).

Table 7. The Overall Incidence of Staff per 100 Employees

Incidence indicator	Year						
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Number of cases	88,4	90,8	94,4	98,3	99,1	105,0	98,5
Numberofdisabilitydays	1294,8	1381,5	1466,0	1358,7	1498,0	1549,7	1352,7

When considering all professional groups, 1 additional case of disease and 11,5 disability days per 100 employees will occur with increasing THI index per 500 points. For the process groups, the same increase in the index will lead to 2,5 additional disease cases and 61 additional disability day per 100 employees. For non-process groups, the dependence has not been confirmed.

3. Diseases of the eye and its appendages:

– To determine the incidence of diseases of the eye and its appendages per 100 employees: y = 0,0013x + 1,6155 (for groups of non-process shops);

– To determine the number of disability days due to incidence of diseases of the eye and its appendages per 100 employees: y = 0,0096x + 28,194 (for groups of non-process shops).

The dependence was not found for the process shops, indicating a complex nature of the influencing factors and undiagnosed root causes of this nosology of the disease in the main production staff.

For non-process groups, 1 additional case of the disease is possible by increasing THI index per 1000 points, which will also lead to the same 9 additional disability days per 100 employees.

4. Cardiovascular system diseases:

– To determine the incidence of cardiovascular system diseases per 100 employees: y = ,2446x + 1,705 (for the process shops); 13,05x + 8,151 (for non-process shops).

– To determine the number of disability days due to incidence of cardiovascular system diseases per 100 employees: y = diseases (for the process shops); y = 447,4x + 367,2 2 (for non- process shops).

For all professional groups, 1 additional case of disease and 32 additional disability days per 100 employees will be observed with an increase in the hazard index per 0,1 point. Under the same specified conditions, for the process groups it will give 0,2 additional cases and 6 additional disability days. For non-process groups – 1,3 additional cases and 45 disability days per 100 employees.

Correlation and determination coefficients were calculated in assessing the significance of the above pair regression equations.

Correlation coefficients for most equations have shown a relationship, but the relationship is weak (0,3 < |r| <0,5). In one case, the value amounted to |r| = 0,664 and fell into the range of 0,5 < |r| <0,7, which proves the moderate relationship already (to determine the number of disability days due to cardiovascular system diseases per 100 employees).

Determination coefficients showed that the linear regression equations explain 1 to 44% of the resultingfactor, i.e. the number of cases and the number of disability days; the remaining 56 to 99% of the results fall on the share of unaccounted factors (it may be the sex of employees, age and so on).

Heteroscedasticity of the models was estimated using Spearman rank correlation test and Goldfeld-Quandt, allowing to reject the hypothesis of the presence of heteroscedasticity.

The significance of regression equations was assessed using F-test as well. During the test of the hypothesis of statistical insignificance of regression equations, the actual and critical (table) values of Fisher's F-test were compared. At a significance level α = 0,05 and α = 0,01, the hypothesis of statistical insignificance and unreliability of regression equations was confirmed, indicating the insufficient number of the explanatory variables included in the equation to describe the dependencies of this type.

Given the fact that upon the results of the World Health Organization research, the contribution of chemical factors to the incidence is an average of 15 – 20%; it can be argued that the results reflect the real situation.

4. Discussion

Reliability of the results is confirmed by using official data on content of substances in the environment in the calculations, namely:

– Data on results of measurements of environmental safety laboratory of RN – Komsomolsk Refinery LLC, performed to certify workplaces by working conditions;

– Data on dispersion of substances on the premises of the company from the approved Project of maximum permissible emissions of RN – Komsomolsk Refinery LLC;

– Data on concentrations of substances in Komsomolsk-on-Amur, published as part of the State Report on Condition and Environmental Protection of the Khabarovsk Territory in 2010.

5. Conclusions

This paper details a procedure for non-carcinogenic risk assessment. A conceptual model of the territory was developed for the calculations; a route of substances into the body of employees was selected and justified. Three environments were distinguished where every employee of the company stays throughout the day: industrial-technological, production and urban.

The results of non-carcinogenic risk assessment:

1. Substances were ranked by general and priority influence.
2. The individual non-carcinogenic risks were calculated for 517 workplaces of the plant.
3. 26 professional groups were formed, which have been ranked by the value of non-carcinogenic hazard ratio.
4. It was found that the entire staff of the plant is exposed to a sufficiently large value of non-carcinogenic risk. It is believed that if the hazard ratio is greater than one, the probability of harmful effects in man increases in proportion to an increase in the ratio, but still there are no indications of the exact value of this probability.
5. Predictive models by "dose-effect" type are developed for four nosological entities of the staff. Correlation and determination coefficients were calculated in assessing the significance of the above pair regression equations, as well as, assessment of heteroscedasticity models, checking the significance of regression equations using F-test. A conclusion was made on in insufficient explanatory variables included in the equation to describe the dependencies of this type.

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