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OCCUPATIONAL HEALTH RISKS FOR WORKERS EMPLOYED AT CHEMICAL INDUSTRY ENTERPRISES

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The authors have summarized all the materials collected over many years of research dedicated to working conditions assessment and health of chemical industry workers; mainly, at plants producing ethylbenzene-styrene, olefins oxides, and rocket propellant. We have detected that the most adverse working conditions occur in Unsymmetrical Dimethylhydrazine (UDMH), rubber, and fiber glass production. We have highlighted cause-and-effect relations between working conditions and higher frequency of early (preclinical) stages of occupational diseases as well as basic chronic non-infectious diseases. We have shown that, depending on character, action mechanism and chemical factor intensity, we register apparent staging in pathologic changes evolvement in a body. We have also proved very high degree of occupational causation for early stages of toxic hepatitis (biliary dyskinesia) detected in processing machines operators at rocket propellant (UDMH) production; initial symptoms of hands' vegetative-sensory polyneuropathy detected in gluing workers at rubber production; specific changes in hands' skin detected in operators at fiber glass production. Musculoskeletal system diseases were also defined as occupationally caused ones with high degree of causation for certain workers' groups; arterial hypertension had average degree of causation. As we conducted in-depth medical examination of 2411 workers we detected that the greatest number of practically health people among examined staff worked at large-tonnage ethylbenzene-styrene production (54.7%) and olefins oxides production (35%); the smallest number of practically healthy workers (12%) was detected at rubber production. Other production workers had pathologies in various organs and systems.

As per risk assessment results and assessment of occupational damage to workers health chemical production plants were ranked as per their danger degree; a system of preventive activities and risk management guidelines were worked out. The program implementation enabled to get positive effect equal to more than 2 billion rubles.

***Key words**: chemical industry, occupational risk, workers, occupational diseases, pathologic changes, preventive activities.*

Occupational risk assessment is an efficient technique helping to analyze production factors impact on workers' health [10,11]. The issue is grounded by occupational risk theory which has been developed in Russia since 90ties last century; the theory allows assessing factual loads and contributions into them caused by various factors; it also helps to define priorities for activities aimed at risk minimization and elimination [3,4,5,6,7,8]. Nowadays scientists have accumulated plenty of materials dedicated to assessment of occupational risks causing damage to health of workers employed at various industrial enterprises. A number of works dealt with specific issues of work and workers' health at certain production plants of chemical industry [2,9,12,13,14]. However, so far there has been no research on actual levels of occupational risk in chemical industry on the whole.

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Chemical industry belongs to basic brunches of Russian economy and includes two aggregated types of economic activity: chemical production and rubber and plastic articles production. In turn, chemical production can be divided into basic chemicals production (57.7%), artificial and synthetic fiber production (1.29%), and rubber production (7.74%).

Over the last 5 years there has been a steady growth in number of chemical industry workers employed at plants where working conditions don't conform to sanitary and hygienic standards; the number increased from 15.3% to 21.5% in rubber and plastic articles production and from 23% to 31.3% in chemical production. First of all it was caused by high degree of production assets wear-and-tear; certain production equipment wear-and-tear amounts to 80-100% [1]. According to Rospotrebnadzor data, deteriorating working conditions influenced occupational morbidity levels in chemical industry which over the last 5 years were higher than average Russian levels and in some years reached 3.18-3.21 per 10,000 workers.

Our research goal was to create scientific foundation and to implement a system aimed at occupational risks management at basic chemical productions. Chemical industry occupies one of the leading places as per chemical danger. Working area air at chemical productions can simultaneously contain more than 100,000 substances and multi-component mixtures exerting adverse impact on workers' bodies. So, chemical industry can be used as a most relevant model which enables assessing actual danger of chemicals' impact combined with other adverse production factors influencing workers' health. Significant number of workers employed at chemical plants justifies the necessity to work out scientifically grounded approaches to risk assessment and management under multi-factor and multi-level influence exerted by adverse production factors. Research was carried out at 10 chemical production plants in Republic of Bashkortostan and Republic of Tatarstan. To examine working conditions we chose most typical productions in terms of applied techniques, production facilities and labor organization forms. Ethylbenzene-styrene manufacture (large-tonnage and small-tonnage), olefins oxides manufacture, rocket propellant (UDMH) manufacture was taken as representing basic organic substances production. Working conditions at rubber producing plants were examined on the example of rubberized fabric manufacture and manufacture of aeronautic devices and engineering devices. We used continuous fiber glass manufacture as a model to examine working conditions at artificial and synthetic fiber production.

We accomplished hygienic research as per standard techniques and carried out studies of air pollution with hazardous substances in working areas, determining in-plant noise levels, microclimate parameters, working process hardness and intensity, with the help of staff from labor hygiene and physiology department[1]. Integrated working conditions assessment was made according to P. 2.2.2006-05 "Guidelines on hygienic assessment of working environment factors and working process. Working conditions criteria and classification".

Health examination was accomplished by in-depth periodical medical check-ups of workers according to the orders of the RF Public Health and Medical Industry Ministry No. 90 dated March 14, 1996, and the RF Public Health and Social Development Ministry No. 83, dated August 16, 2004[2].

Occupational causation degree for detected diseases was estimated with the use of relative risk (RR, unit) and its etiologic fraction (EF, %) calculation, as well as odds relation and confidence interval calculation as per Miettinen (1978). Occupational risk was estimated according to up-to-date methodic approaches (Izmerov N.F., Denisov E.I., 2003, 2009) and normative-procedural documents (P 2.2.1766-03 Guidelines on occupational risk assessment for workers' health. Organizational and methodical grounds, principles and assessment criteria).

Hygienic research results proved that a whole complex of working environment and working process factors (chemical factors, noise, working process hardness and intensity, and adverse microclimate) had its impact on workers employed at contemporary chemical production. The most significant hygienic factor at examined production was chemical factor represented by a complicated set of adverse chemicals belonging to 1-4 danger categories with various impacts on a human body. Main industrial poisons present at chemical productions were divided into the following groups: irritant substances mostly damaging respiratory

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organs, neuro-, hemo-, hepatotropic substances, and industrial carcinogens. We detected correlation between levels of air pollution with toxic substances in working area and production types, physic and chemical properties of substances circulating in workflow, technological processes organization, leakproofness of production equipment, and gas dangerous works. Maximum single concentration at basic organic substances production was equal to 3.5-10 maximum permissible concentrations; it was 3-10 MPC at rubber production, and 1.5 MPC at fiber glass production.

Chemical factor (3.1-3.4 category) combined with in-plant noise (3.1-3.2 category), adverse microclimate (3.1) and working process hardness (3.1-3.3 category) contributed into working conditions having 3.1-3.4 damage category at various productions. Still, working conditions for specific occupations were characterized with a combination of prevailing factors, their intensity being higher than hygienic standards. Working conditions for occupations at the same production were characterized with a prevailing factor with intensity significantly higher than hygienic standards; thus, chemical factor prevailed for processing machines workers; noise for drivers; working process hardness prevailed for fitters and workers employed at rubber production; heating microclimate and chemical factor prevailed for operators at fiber glass production (table 1).

Working conditions for workers employed at examined production plants mostly have 3 category of 3-4 damage degree; they can cause occurrence and evolvement of occupational (occupationally caused) pathology. We determined that working conditions at contemporary chemical production plants were potentially dangerous for workers and directly caused both acute and chronic occupational diseases. The highest levels of accumulated occupational morbidity occurred at continuous fiber glass production and amounted to $92.4^{0}/_{000}$; at rubber production, $24.1^{0}/_{000}$; at basic organic substances production, $7.4^{0}/_{000}$. Occupational diseases index calculated for a specific occupational group, corresponded to an extremely high risk category for fiber glass production operators (0.5-1.0) and processing machines operators at rocket propellant (UDMH) production (0.33-0.5). High risk category included gluing workers at rubber production (0.25): average risk category included processing machines operators at olefins oxides production (0.24) and at ethylbenzene-styrene (small-tonnage) production (0.17) (table 2). We highlighted peculiarities of chronic occupational diseases evolvement in workers, their evolvement periods, and intensity degree.

Table 1

Integrated assessment of working conditions for workers employed at chemical plants

Production	Occupation	Working condition category as per factors intensity					Integrated assessment
		chemical	noise (Leq.)	microclimate	Working process hardness	Working process intensity	
Ethylbenzene-styrene; small-and large-tonnage	Processing machines operator	3.1–3.2	2	2	2	3.2	3.2–3.3
	Maintenance fitter	3.2	3.1	2–3.1	3.2	2	3.3
	SI&AD* fitter	2	2	2	2	2	2
	Processing machines operator	2	2	2	2	3.1	2
	Maintenance fitter	2	2	2	2	2	2
	SI&AD fitter	2	2	2	2	2	2
UDMH	Processing machines operator	3.3–3.4	2	2	2	3.1	3.3–3.4
	Maintenance fitter	3.3–3.4	2	3.1	3.1	2	3.3–3.4
Ethylene and propylene oxides	Processing machines operator	3.2	2	2	2	3.2	3.3
	Maintenance fitter	3.2	3.1	2–3.1	3.2	2	3.3
	SI&AD fitter	2	2	2	2	2	2
Rubber	Solutioning machine operator	3.2	3.1	3.1	3.3	2	3.3
	Gluing worker	3.1–3.2	2	2	3.2	2	3.1–3.3
Fiber glass	operator	3.1–2	3.2	3.2	3.1	2	3.3

They were determined by specific working conditions, intensity and period of influence exerted by adverse production factors; they also depended on chemical substances impact. Diseases of chemical etiology had the greatest share (72.5%) in occupational diseases structure; mild chronic intoxications with a complex of toxic substances and toxic hepatitis prevailed at basic organic substances production; hyperkeratosis and skin cancer prevailed at fiber glass production; chronic intoxications with solvents and vegetative-sensory polyneuropathy of hands prevailed at rubber production. Sensorineural hearing loss was diagnosed mostly in compressor plant operators and maintenance fitters.

Clinical signs of occupational diseases in workers employed at contemporary chemical plants were characterized with polymorphism, vagueness, few symptoms, absence of tendency to progress. We detected that, depending on selective impact on certain organs, action mechanism, and chemical factor intensity, there was apparent staging in pathologic changes in a body; workers with short working period at chemical plants had changes in their bodies on sub-cellular and cellular levels; if contact with harmful chemicals was long changes evolved in organs. Functional changes were detected at working conditions with 3.1 danger category; certain intoxication signs and syndromes, as well as occupational diseases in mild and severe form were diagnosed under working conditions having 3.2-3.4 danger category. Main target organs under exposure of production chemical factors were hepato-biliary system in workers at rocket propellant (UDMH) production; bronchopulmonary system, at olefins oxides production; nervous system, at rubber production; skin, at fiber glass production.

Table 2

Occupational risk categories for workers with basic occupations in chemical industry depending on occupational morbidity index (Iom)

Production, occupational group	Nosologic form	Cr*	Cs*	Index om*	Risk category
ethylbenzene-styrene (small-tonnage): processing machines operators, maintenance fitters	Chronic intoxication with ethylbenzene and styrene, mild form	2	3	0,16	average
Rocket propellant (UDMH): processing machines operators	Chronic intoxication with complex of toxic substances (toxic cerebropathy, astheno-organic (vegetative) syndrome, toxic hepatitis) toxic hepatitis	1 1	2 3	0,5	extremely high
Occupational morbidity total index				0,33 **0,88**	
Olefins oxides: processing machines workers, maintenance fitters	Chronic intoxication with ethylene oxide and propylene oxide	2	3	0,16	average
Rubber: solutioning machines operators;	All diseases:	1	3	0,33	High
	Humeroscapular periarthrosis	2	3	0,16	average
	radiculopathy	2	3	0,16	average
Occupational morbidity total index	epicondylitis	2	3	0,16 **0,81**	average
Gluing workers at rubber production	Chronic intoxication with organic solvents (petrol, dichlormethane), mild form	1	2	0,5	extremely high
	vegetative-sensory polyneuropathy	1	3	0,33	high
Occupational morbidity total index				**0,83**	
Fiber glass: operators	Local hyperkeratosis	1	2	0,5	extremely high
	Skin blastoma	1	1	1,0	extremely high
Occupational morbidity total index	Skin cancer	2	1	0,5 **2,0**	extremely high
Chemical productions: maintenance fitters, compressor plants operators	Sensorineural hearing loss, I-II degree	1	5	0,2	average

NB: C_r and C_s – risk category and occupational diseases severity category; Index (om) – occupational morbidity index

According to examination results some workers had symptoms confirming impact of harmful; production factors; symptoms' evidence varied. If a worker had relevant complaints, specific symptoms proving damage to critical organs and systems, or changes in homeostasis, we used it as a criterion for placing such workers into a higher "risk" category in the context of occupational diseases evolvement. "Risk" groups at various productions accounted for 2-24% of the total number of workers.

We detected cause-and-effect relations between working conditions and damage to health for workers of leading occupations in the chemical industry; these relations appeared as higher frequency of early (preclinical) stages of occupational diseases, as well as main chronic noninfectious diseases. We determined a significantly high occupational causation for early stages of toxic hepatitis (biliary dyskinesia) for processing machines operators at rocket propellant (UDMH) production (3.4 category); for initial symptoms of vegetative-sensory polyneuropathy of hands for gluing workers at rubber production (3.3 category): specific changes in hands' skin for operators at fiber glass production (3.3 category). Such diseases as musculoskeletal diseases were also put into occupational diseases category with high causation degree for certain workers' groups; arterial hypertension had average causation degree (table 3).

Table 3

Occupational causation degree for health disorders detected in chemical production workers

Production	Occupation	Diseases	Leading factors, working conditions category	*RR*	*EF*, %	OR/confidence interval	Causation degree
Ethylbenzene-styrene (small-tonange)	Processing machines operators	Biliary dyskinesia Arterial hypertension	chemical -3.2	2,1 1,9	53	2,4/1,1–5,2	high average
	Maintenance fitters	Musculoskeletal system diseases Skin and subcutaneous tissue diseases	chemical -3.2	2,5 2,6	61 62	3,5/1,8–6,9 2,7/0,7–10,5	high high
Rocket propellant (UDMH)	PMO Maintenance fitters	Biliary dyskinesia Biliary dyskinesia	working process hardness-3.2	5,0 2,4	80 60	8,9 /4,3–18,6 3,1/1,4–6,9	Almost complete high
Olefins oxides	Processing machines operators	UAP chronic diseases Chronic bronchitis Biliary dyskinesia VNSD	adverse microclimate3.1	2,7 2,7 1,8 2,3	64 63 47 57	4,0/1,9–8,5 4,0/1,9–8,5 2,7/1,0–4,7 2,7/1,2–6,3	high high average high
	Maintenance fitters	Chronic bronchitis Musculoskeletal system disorders (lumbodynia) Skin and subcutaneous tissue diseases	chemical -3.4	1,8 2,5 3,2	45 60 67	2,1/0,9–4,7 2,7/0,9–8,3 3,2/0,7–14,4	average high high
Rubber	Solutioning machines operators	Musculoskeletal system disorders (lumbodynia, arthrosis) Skin and subcutaneous tissue diseases	chemical -3.4	2,2 2,6	55 61	3,8/2,3–6,4 2,7/0,9–7,7	high high
	Gluing workers	VNSD of segmental type Biliary dyskinesia	chemical -3.2	10,3 1,8	90 44	18,7/7,9–44,5	Almost complete average
Fiber glass	Operators	Skin diseases Musculoskeletal system disorders (dorsum diseases) Arterial hypertension	chemical-3.2	10,2 17,7 1,9	90 94 47	13,3 / 3,9–44,8 2,3/13,4–44,1	Almost complete Almost complete average
Basic organic substances	Drivers	Symptoms of damage to hearing done by noise	chemical-3.2	20,6	95,1	2,57/3,5–187,8	Almost complete

NB: VNSD – vegetative nervous system disorder, UAP – upper air passages, RR – relative risk, EF – etiologic fraction, OR – odds relation.

Having conducted in-depth medical examination of 2411 workers, we found out that a biggest number of practically healthy people among all examined staff worked at large-tonnage ethylbenzene-styrene production (54.7%) and olefins oxides production (35%); the smallest number (12% practically healthy workers) was detected at rubber production. Other workers had pathologies in various organs and systems.

Prevalence of chronic noninfectious diseases among workers from leading occupational groups at examined productions had its own peculiarities and depended on specific working conditions (table 4). Digestive organs diseases, primarily biliary dyskinesia, took the first rank place in workers at rocket propellant (UDMH) production, where leading adverse production factor was represented by hepatotoxic substances. Such diseases were diagnosed in practically every second processing machines operator while only 9.9% of workers from control group suffered from them ($p<0.001$).

To carry out an integrated assessment of occupational risk at examined chemical productions we used four basic criteria (working conditions, occupational morbidity, a share of workers with occupational diseases symptoms, occupational causation degree of a disease).

As we ranked productions as per a priori risk degree we found out that the most adverse working conditions occurred at rocket propellant (UDMH) production, rubber production and fiber glass production. Ethylbenzene-styrene (small-tonnage) production and olefins oxides production had average risks for workers' health. The highest a posteriori risk was also determined at rocket propellant (UDMH) production, rubber production and fiber glass production (table 5).

Gluing workers at rubber production, processing machines workers at rocket propellant (UDMH) production and operators at fiber glass production run the highest risk among all occupational groups; risks for processing machines

Table 4

Prevalence of chronic noninfectious diseases among workers of leading occupations at chemical production, %

Diseases	Production				
	Ethylbenzene-styrene (small-tonnage)	Rocket propellant (UDMH)	Olefines oxides	Rubber	Continuous fiber glass
1 rank place	Circulation organs (35%)	Digestive organs (49.6%) (biliary dyskinesia)	Respiratory organs (upper air passages) (42.2%)	Nervous system (30.4%)	Musculoskeletal system (28.4%)
2 rank place	Musculoskeletal system (24.1%)	Circulation organs (28.3%)	Circulation organs (29.7%)	Circulation organs (40.0%)	Skin and subcutaneous tissue (25.6%)
3 rank place	Digestive organs (21.5%)	Musculoskeletal system (24.8%)	Digestive organs (29.3%)	Digestive organs (33.3%)	Circulation organs (25.5%)
4 rank place	Nervous system (17.7%)	Nervous system (23.5%)	Nervous system (25.5%)	Musculoskeletal system (32.2%)	Ear and mastoid (18.9%)

Table 5

Occupational health risk for workers employed at chemical production

Production basic organ-ic chemicals:	A priori risk (as per hygienic criteria)	A posteriori risk (as per medical and biological criteria)	Integral risk assessment
Ethylbenzene-styrene (small-tonnage)	average	average	average
Rocket propellant (UDMH)	high	extremely high	extremely high
Olefins oxides	average	average	average
Rubber	high	extremely high	extremely high
Continuous fiber glass	high	extremely high	extremely high

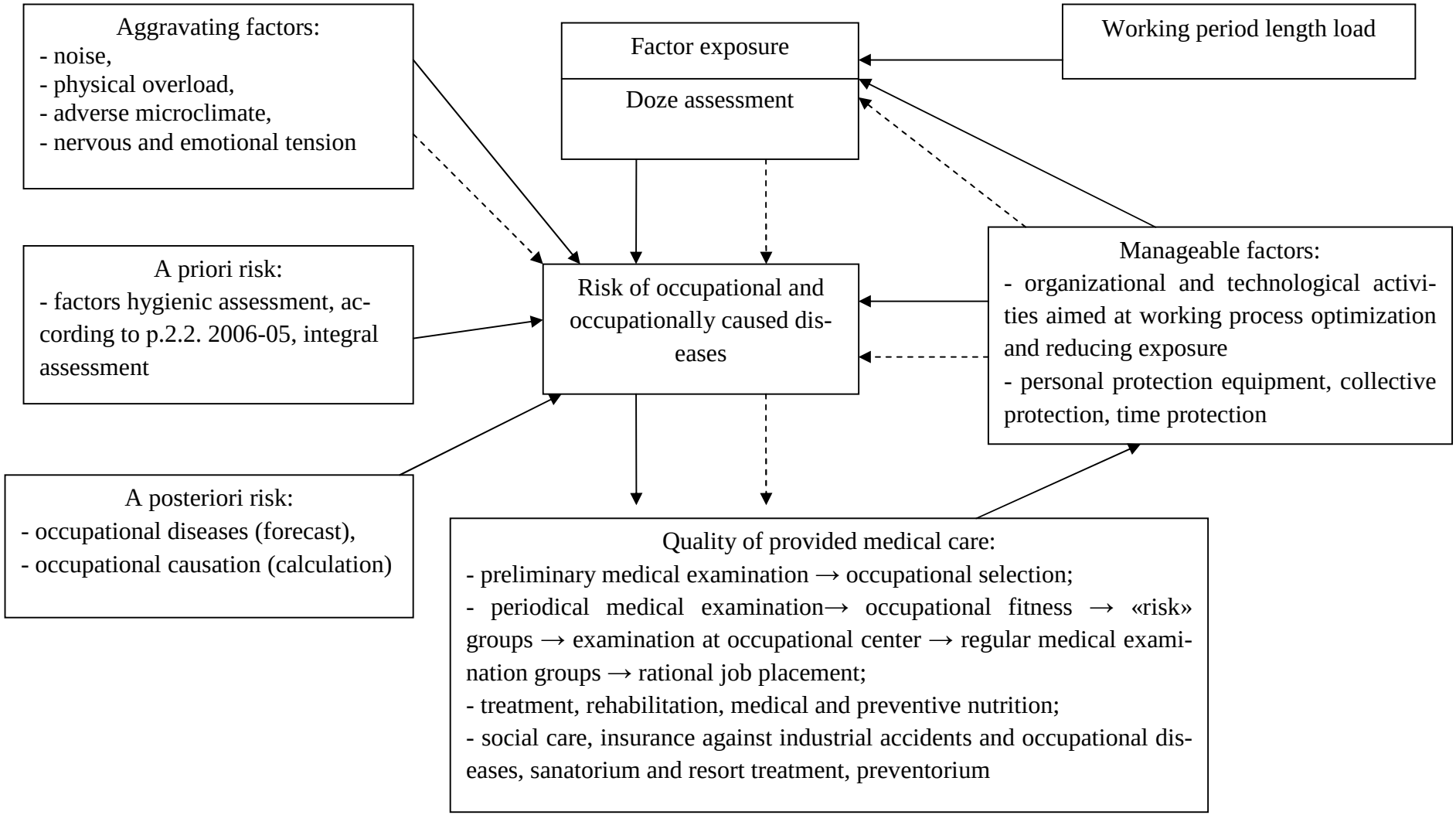

Figure 1. Occupational risk assessment and management program for workers employed at chemical production plants

operators at other productions (basic organic substances, such as ethylbenzene-styrene and olefins oxides) and for compressor plants drivers at basic organic substances production are not so high.

On the whole, the obtained results of integral health assessment for chemical production workers according to examined medical and biological parameters are consistent with integral assessment of their working conditions.

A complete program aimed at occupational risk assessment and management in chemical industry, including organizational-and technological sanitary and hygienic, medical and preventive activities, is shown in the figure 1. At present it is successfully implemented at chemical plants examined by us in two republics. Its economic effect amounted to more than 2 billion rubles. We recommend implementation of this program at similar chemical plants all around the country taking their technological and regional peculiarities into account.

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