

Artículo de investigación

## Hygienic assessment of health risks of the population living in the areas of intensive oil extraction

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### Abstract

The purpose of the study was to establish hygienic procedures for reducing health risks of the population living and working near oil extraction sites. Based on the results obtained, we evaluated the quality of environmental settings in the oil extraction areas, studied working conditions of oil workers, and assessed public human health and occupational risks of the oil extraction industry. Oil extraction enterprises have been shown to be major sources of environmental and workplace pollution and to create a negative background causing adverse health effects.

**Key words:** Oil extraction area, pollution, environmental setting, working conditions, occupational risks, health status, population, system of measures.

### Introduction

Economic growth and safety in Russia is linked with further development of the oil and gas industry. The Program of the complex development of hydrocarbon resources contains goals related to the creation of new and improvement of the current subsectors of the oil and gas industry.

The Russian oil complex including more than 120 000 operating wells, 50 000 km of pipeline networks as well as a variety of other production facilities is the underlying cause of pollution of environmental settings.

Poor environment along with economic and social factors including working conditions is responsible for adverse health effects of local inhabitants.

At the same time, there is lacking evidence on regional characteristics of human health and the environment protection, a uniform concept model of environmental and occupational risks assessment and management. The national policy priorities in the field of human health promotion by enhancing the quality of the environment in the areas of intensive oil extraction are not systematized.

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A wide range of material covering our long-term research achievements contributed to the development of a modified system of management decisions on shaping adequate working conditions and the environment of the surrounding community, on creating models investigating occupational risks assessment and management in oil extraction areas.

### Literature review

Analysis of literature data shows that impacts to ambient air of the oil extraction areas occur due to pollutants including aliphatic and aromatic hydrocarbons, phenol, formaldehyde, hydrogen sulfide. Natural water and topsoil are contaminated with oil, oil products, chlorides and salts of heavy metals (Chirkova, 2012; Solodovnikov, 2007; Rakhmatullin et al., 2019; Suleimanov et al., 2017; Zeinalov, 2006).

At the same time, according to some authors (Kalmukhanova, 2010; Porvatkin, 2014) concentrations for hazardous substances in environmental settings of oil areas do not exceed the hygienic standard.

According to a survey conducted by researchers there is evidence of direct and significant correlation links between air pollution and primary morbidity among children (Porvatkin, 2016), respiratory diseases, neoplasms, pregnancy and delivery complications (Ivanov, 1997), diseases of blood circulation, nervous and urinary systems (Aitmukhambetov, 2012).

Previous studies (Utesinov, 2008) have associated hydrogen sulfide, sulfur dioxide, nitrogen dioxide with a high rate of morbidity of surrounding populations. In the oil extraction areas, hazardous impacts pose a serious threat of cancers, congenital pathology, infectious and parasitic diseases, and endocrine disorders.

Cohort studies in foreign countries have also confirmed that both children and adults are at great risk of developing environmentally induced diseases (Trasande et al., 2009; Utesinov, 2008; Woodruff et al., 2010).

Along with that it has been shown that hydrocarbons of the aromatic series – benzol, xylol, toluol, ethylbenzol are highly toxic because they provoke the development of cancers and congenital abnormalities (EPA, 2019; Luyten et al., 2018; Kelsh et al., 2008).

Of special concern is contaminated drinking water because water quality degradation poses a

serious threat to the health of populations worldwide (Thompson et al., 2007).

WHO experts have shown that 80% of all diseases worldwide are due to poor quality of drinking water and inadequate sanitation of water supply systems.

According to some estimates (Artemyeva, 2011; Tafeyeva, 2009) in the oil extraction areas, yearly averages of morbidity among children and adults appeared to be significantly lower compared with control.

A number of investigations have concluded that factors associated with intensive oil extraction include maximum family income, good housing conditions, high level and quality of health care services. Considering this, the authors believe that improvement of the socioeconomic indicators of local communities outweighs the factor of environmental hazards in shaping health status of the population (Borshchuk et al., 2010; Parfyenov, 1999).

Few publications focus on issues of occupational impacts on oil workers' health (Valeev et al., 2015; Gimranova et al., 2009; Gromova, 2009; Kalmukhanova, 2010).

According to the researchers, adverse health effects are associated with excessive noise, vibration, microclimate, the severity of the working process and a chemical factor.

In the structure of morbidity of West Siberia oil workers, 68,7% of all cases with temporary disability are related to respiratory disorders, accidents, poisonings and injuries, musculoskeletal and connective tissue diseases, circulatory disorders (Ovcharov, 1996).

Thorough physical examinations of oil extraction workers detected that the most common were diseases of the musculoskeletal and peripheral nerve systems, arterial hypertension, gastrointestinal disorders (Kasymov et al., 2005; Nugaibekov, 1999; Zakirzyanov et al., 2010; Solodovnikov, 2007).

The combination of occupational factors with some congenital, individual, social and household ones contributes to the accelerated development of cardiovascular diseases (Oganov, Maslenniko, 2007; Tomei et al., 2001). The latter along with malignant tumors and injuries are major causes of high mortality rates and loss of potential life among working people (Ostro et al., 2007; Rakhmatullin et al., 2019).

Thus, existing literature regarding the problem under discussion is not sufficient, scares, and controversy to some extent. There is no consensus among researchers on specific features of development and occurrence of work-related diseases. The interpretation of the etiologic role of environmental and workplace factors in the population morbidity is controversial. There is no clear-cut program of the healthcare services provision in the oil extraction areas. Our studies are to fill this gap.

### Materials and methods

To solve these issues a complex of current sanitation and hygienic, epidemiologic and statistical investigation methods, a risk assessment method; hygienic evaluation of health status of children and adults was used for carrying out hematological, immunologic, biochemical and chemical studies.

The studies were conducted in major oil and gas extraction areas of the Republic of Bashkortostan.

The assessment of environmental settings and the work environment was made using survey data provided by the Bashkortostan Centre for hygiene and epidemiology, environmental protection agencies, our own multi-year studies.

Health assessment was made based on statistical analysis of demographic indicators, general morbidity of the population, morbidity associated with certain diseases.

To identify potential impacts of oil production facilities on health and to improve accuracy of results, statistical data on eight-oil extraction and eight control (forestry) areas of the Republic of Bashkortostan were generalized.

Moreover, oil extraction workers underwent regular physical examinations conducted by the Ufa Institute of Occupational Health and Human Ecology staff.

The bulk of oil extraction workers (7487 subjects) were represented by males aged 20-60 years with length of employment varying from 5 to 15 years and over. The workers examined were divided into professional groups: drillers, assistant drillers, well workover operators, well site workers, operators of maintaining the reservoir pressure, operators of desalinating installations, machinists of oil and gas field equipment, locksmiths' repairers.

### Results and discussion

Numerous studies conducted at the Ufa Institute of Occupational Health and Human Ecology have identified the specific nature of the oil extraction industry that is characterized by spatial dispersion of industrial facilities, considerable length of oil pipelines, chemically-induced toxicity and threat to the environment, workers' heavy shift work under the conditions of hazardous work environment. Meanwhile, exploration, production, collection, preparation and transport of oil and gas need large areas where diverse oil field facilities including wells, technological capacities, tanks, cleaning facilities, oil collecting units, oil and gas cleanup units, cluster pumping stations, flares, pump stations, etc. can be located.

During the process of an oil field exploitation, a broad spectrum of pollutants including saturated and unsaturated aromatic hydrocarbons, hydrogen sulfide, oxides of carbon and nitrogen, phenol, formaldehyde, sulfurous anhydride, etc. that are present in the human environment in dangerous concentrations (above the maximum admissible concentration (MAC) is released to ambient air, topsoil and water bodies.

The results of under-flare observations show that the most polluted ambient air level is observed at a distance of no less than 1 kilometre from the oil collecting points, pump stations, installations of complex oil preparation. Maximum one-time concentrations of hydrogen sulfide ranged from 1,6 to 4,0; hydrocarbon - from 2,1 to 2,6 of the current MACs. The route surveys carried out in some residential areas near oil extraction sites failed to reveal the MAC exceedances for hazardous chemicals in the ambient air.

It has been shown that in the oil extraction areas, topsoil is exposed to intensive technogenic burdens due to the presence of oil products, metals, and pesticides. In some locations, an increase in total salinity (from 525 to 2370 mg/kg) is found in the topsoil. Along with this, substances found in high concentrations include sulfide (from 8,7 to 80,4 mg/kg), nitrate (from 7,6 to 61,7 mg/kg), chloride (from 15,0 to 191,0 mg/kg), and oil products (from 170 to 347 mg/kg). At the oil sites, the areas covered with oil spills from wells and pipelines, the topsoil is polluted by great amounts of chlorides, hydrocarbons and heavy metals. In the soil samples collected from the oil wells, the amount of oil is estimated at 1200 mg/kg.

Based on data obtained from the field hygienic studies, underground waters collected from wells and standpipes in the extraction area have a high level of mineralization (up to 2055 mg/l), extreme hardness (up to 27,5 mg-eq/l). High concentrations of chloride (up to 603 mg/l), sulfate (up to 1229 mg/l), nitrate (up to 214,5 mg/l), iron (up to 0,57 mg/l), strontium (up to 10,9 mg/l), magnesium (up to 149,6 mg/l) are also recorded.

In these areas, a high level of mineralization (up to 20,8 mg-eq/l), high concentrations of chlorides (up to 603,5 mg/l), nitrates (up to 94,9 mg/l), strontium (up to 8,9 mg/l), magnesium (up to 114,6 mg/l) are detectable in well water.

At the same time, the concentration of a number of pollutants is quite low: oil products – 0,02-0,05 mg/l, surfactants – less than 0,015 mg/l, formaldehyde – less than 0,025 mg/l, hydrogen sulfide – less than 0,002 mg/l.

The concentration of metals (zinc, chromium, cadmium, manganese, mercury, lead, copper, nickel) is also significantly lower than the hygienic standard.

The results of hygienic studies on oil extraction enterprises have shown that in the complex of hazardous occupational factors chemicals rank first. They may be divided in three main groups:

- Natural chemicals present in the composition of oil and associated gas (hydrocarbons, hydrogen sulfides, mercaptans);
- Chemicals used to increase recoverable oil, in the preparation, transportation of oil and gas (reagents, acids, surfactants, methanol, welding aerosols);
- Chemicals used in production and research laboratories (coolants, lead, dust, mercury, tin and others).

Oil workers are exposed to the workplace impact of saturated hydrocarbons vapor, associated oil gas and other hazardous substances. However, exposure levels to hazardous conditions in workers engaged in production and exploratory drilling, oil extraction, well workover operations and other worker groups are different.

During drilling activities, the possibility of air contamination with hazardous substances is slim. Emissions generated during this process include emissions from diesel engines and other ancillary facilities, fuel combustion in boilers.

The workplace air of drilling rigs is associated with concentrations of oil, oil products, sulfur dioxide, nitrogen oxides and other hazardous substances.

The concentration of saturated hydrocarbons in the air does not exceed 10-25 mg/m<sup>3</sup>. The concentration of unsaturated hydrocarbons ranges from 0,16 to 179,68 mg/m<sup>3</sup> exceeding the maximum admissible concentration as much as 1,8 times. The concentration of carbon oxide is within a range of 2-4 mg/m<sup>3</sup>. In the boilers from 5 to 10% of carbon oxide tests exceed the MAC as much as 1,1 - 1,5 times. Hydrogen sulfide is more common in the work environment air during the process of drilling in the sites containing hydrogen sulfide and sulfur (in Bashkiria up to 10% of samples are at the MAC level or higher).

In oil enterprises, there are a great number of facilities with equipment generating noise and vibration. They are drilling rigs, diesel engines, electric motors, electric winches, cluster pumping stations in the shops maintaining the reservoir pressure, turbo- and air blower rooms, various (gas and air) compressors, technological pumping stations for water lifting and water blocks. In addition to the stationary equipment diverse facilities including drilling rigs, lift mechanisms for well workover operations, and other similar types of equipment are used.

It has been shown that hazardous occupational noise from drilling rigs is measured as 75 - 97 dBA predominantly at high frequencies. Noise intensity largely depends on the drilling rig type. During drilling activities, vibration is associated with lowering-lifting operations (72-95 dBA) due to longitudinal oscillations of the lowering and lifting system as well as maintenance of vibrating screens (up to 110 dBA). The highest vibration levels are observed at low and median frequencies.

During the dark period, in the majority of drilling rigs, low light illuminates V-doors, shelves, instrument piping. Uneven illumination is observed in the production area and its vicinity. Poor light increases the possibility of injury-causing hazards, tense anxiety among workers and produces adverse health effects.

In the complex of hazardous factors, weather conditions are of great importance for workers of major occupations. Most of operations are open-air ones. Microclimate in major workplaces corresponds to ambient air indicators. During the long cool period (about 240 days), workers are

exposed to general and local cooling, winds, precipitations.

The analysis of current occupational factors in oil workers' workplaces demonstrates that in most cases working conditions of major worker groups are of Class 3 (1- 4) and may cause occupational diseases, increase morbidity rate with temporary disability, work-related pathology.

Thorough physical examinations of workers engaged in major oil occupations in the Republic of Bashkortostan have revealed chronic pathology in 72,6% of cases.

In the structure of pathology revealed, diseases of the muscular-skeletal and peripheral nerve systems (33,5%), blood circulation (30,0%), ENT (17,7%), and gastrointestinal tract (11,3%) predominate.

Muscular-skeletal and peripheral nerve diseases in oil workers are presented mainly by vertebrogenic lumbar-sacral pathology (21,3%). Cervicalgia, scapulohumeralperiartrosis, deforming osteoarthritis have been detected in 7,2%; 2,8%; and 2,2% of cases, respectively.

In major worker groups, the incidence of arterial hypertension was 29,2%, ischemic heart disease – 0,9%. ENT disorders were diagnosed in 17,7% of the subjects examined including chronic upper respiratory diseases in 6,1% of cases, otitis – 5,9%, sensorineural hearing loss – 5,7%. In the structure of gastrointestinal pathology, ulcers occurred in 4,7% of cases, chronic gastritis – in 4,5%, biliary dyskinesia – in 2,2%.

Statistical data analysis has revealed that in the oil extraction areas the demographic and population morbidity indicators are worse compared with control (forestry) ones. In these areas, there are high levels of general morbidity and mortality, cancer morbidity and congenital abnormalities.

Thus, in the oil extraction areas, during some observation periods there was a 7%-increase in general mortality indicators compared with control. In children the incidence of referrals to health care specialists was significantly higher ( $p < 0,05$ ) with the exceeding factor of 20,1%. Along with this, general morbidity among children of the first year of life living in the oil extraction areas exceeded the control as much as 21,3%, respiratory diseases frequency – up to 32%. Besides, we have revealed adverse trends in disease classes that are regarded by WHO as

environmental indicators – neoplasms and congenital abnormalities.

Over the last 4 years, the level of primary cancer morbidity among the population in proximity to the oil extraction sites has been 275,7 per 100.000 exceeding the similar control indicator by 24%. In addition, at the oil sites there is an exceeding number of patients with malignant tumors (up to 29%), indicators of cancer mortality (up to 13%). The incidence of congenital abnormalities in children living near such sites exceeds the median level of the control sites by 23%.

The results of studies on environmental settings have shown that the most priority risk factor for local people is contamination of the utility and drinking water supply system. This is confirmed by the findings of sociologic studies on people living near the oil sites and the workforce of the given industry. About 59% of respondents consider the quality of drinking water to be poor.

Analyses of a database on environmental health protection emphasize that in some areas, underground waters cannot be used for domestic purposes due to increases in salinity and the population has to use bottled water. The calculations have shown that in many oil extraction areas there is a high organoleptic risk (more than 0,1) of total hardness, the content of chlorides and sulfates. Currently, worldwide, the basis for making management and government decisions at any possible level is the concept of potential health risk for the population.

In some oil extraction areas a total individual cancer risk is in a range of  $1,6 \times 10^{-4}$  to  $3,5 \times 10^{-5}$ , characterizing them as areas from maximum admissible to an inadmissible health risk for the population in general. The obtained values of a carcinogenic health risk for local people are due to the presence of carcinogens – chromium, cadmium, pesticides in underground waters.

The results of noncarcinogenic assessment of public human health risks confirm that there is a threat to the blood system pathology development (a 5,7-fold exceeding of the admissible value), the cardiovascular system (a 5,8-fold). Besides, quite high (warning) indicators for the development of bone system pathology due to the presence of strontium as well as the renal system associated with an increased concentration of calcium and lindane in underground waters have been revealed.

Our calculation results are consistent with the observations (Artemyeva, 2011) which have revealed that among local people exposed to oil extraction hazards, a carcinogenic risk is over four times (4,4) higher than the limit of an acceptable risk. Hazard indices of noncarcinogenic risks also exceed acceptable levels pertaining to diseases of the blood system, liver and respiratory organs.

According to the occupational risk assessment the category of a priori occupational risk has also been found to be high for certain population groups directly engaged in oil extraction (drill-operators, assistant drillers, operators of well workovers, machinists of oil and gas field equipments) and to be modest for operators maintaining the reservoir pressure and demineralization installations.

A posteriori assessment of oil workers' ill health has revealed a frequent detection of these diseases and disorders in the genesis of which unfavourable working conditions (lumbalgia, lumbar-sacral radiculopathy, and arterial hypertension) may play a role.

With an increase in length of oil workers' employment (more than 5 years), there is an increase in frequency of detecting high risks for cardiovascular diseases (according to the SCORE risk charts). The study materials have shown that in 34,9% of oil workers there is a high and extremely high level of risks for fatal cardiovascular diseases, in 24,1% - median, in 10,8% - moderate.

Results of complex hygienic studies made it possible to create the system of measures and decisions aimed at prophylaxis and reduction of morbidity risks for the population exposed to adverse factors of the oil extraction industry.

The model of management decisions on the human environment improvement and prevention of the population morbidity includes the following blocks:

- 1) Implementation of environmental health policy of industrial enterprises and improvement of working conditions.
- 2) Development of infrastructure and improvement of housing and communal services in the residential areas.
- 3) Prevention of cancer diseases and congenital abnormalities.

- 4) Improvement of health and demographic indicators and reduction of population morbidity.
- 5) Improvement of managerial machinery and monitoring of the environment and population health.
- 6) Development of medical and ecological principles of rehabilitation of local people living in oil regions.

The present model has been tested by the territorial Directorate of oil extraction and appeared to be highly effective.

### Conclusions

Today, certain experience of health risk assessment in the oil extraction areas has been gained in the Russian Federation and other near/far-abroad countries. However, despite existing literature on a relationship between the population health and working conditions and environmental quality, many methodological issues on establishing hygienic safety and health protection of the population under the conditions of oil extraction need further improvement.

Numerous studies conducted at the Institute have shown the specific nature of the oil extraction industry that is characterized by spatial dispersion of industrial facilities, great length of oil pipelines, toxicity and danger of chemicals for the environment, heavy shift work under the conditions of hazardous work environment. During the process of oil field exploitation, a broad spectrum of pollutants including saturated and unsaturated aromatic hydrocarbons, hydrogen sulfide, oxides of carbon and nitrogen, phenol, formaldehyde, sulfurous anhydride, etc. that are present in the human environment in dangerous concentrations (above the maximum admissible concentration (MAC) is released to ambient air, topsoil and water bodies.

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Oil workers are exposed to the workplace impact of saturated hydrocarbons vapor, associated oil gas and other hazardous substances. However, the degree of exposure to hazardous conditions in

workers engaged in production and exploratory drilling, oil extraction, well workover operations and other worker groups is different.

Unlike drilling processes, the adverse effects of hazardous chemicals during well workover and oil extraction operations are more pronounced. Along with this, of great importance are physical and chemical properties of the extracted oil and accompanying gas of various fields that differ significantly when the concentration of various hydrocarbon, sulphur, and mercaptan fractions is concerned. For Bashkortostan oil fields, a high concentration of sulfur, paraffin, liquid methane hydrocarbons and pitches in the extracted oil is typical.

The analysis of current occupational factors in oil workers' workplaces shows that in most cases working conditions of major occupational groups are of Class 3 (1- 4) and may cause occupational diseases, increase morbidity rate with temporary disability, work-related pathology.

Thorough physical examinations of workers engaged in major oil occupations in the Republic of Bashkortostan have revealed chronic pathology in 72,6% of cases.

The survey of statistical data has revealed that in the oil extraction areas the demographic and population morbidity indicators are worse compared with control (forestry) ones. In these areas, there are high levels of general morbidity and mortality, cancer morbidity and congenital abnormalities.

In some oil extraction areas a total individual cancer risk is in a range of  $1,6 \times 10^{-4}$  to  $3,5 \times 10^{-5}$ , characterizing them as areas from maximum admissible to an inadmissible health risk for the population in general. The obtained values of a carcinogenic health risk for local people are due to the presence of carcinogens – chromium, cadmium, pesticides in underground waters.

The results of noncarcinogenic assessment of health risk for the population confirm that there is a threat to the blood system pathology development (a 5,7-fold increase of the admissible value), and the cardiovascular system (a 5,8-fold increase).

According to the occupational risk assessment the category of a priori occupational risk has also been found to be high for certain population groups directly engaged in oil extraction (drill-operators, assistant drillers, well workover operators, machinists of oil and gas field

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A posteriori assessment of oil workers' ill health has revealed a frequent detection of these diseases and disorders in the genesis of which unfavourable working conditions (lumbalgia, lumbar-sacral radiculopathy, and arterial hypertension) may play a role.

With an increase in length of oil workers' employment (more than 5 years), there is an increase in frequency of detecting high risks for cardiovascular diseases (according to the SCORE risk charts). The study materials have shown that in 34,9% of oil workers there is a high and extremely high level of risks for fatal cardiovascular diseases, in 24,1% - median, in 10,8% - moderate.

Our long-term studies enabled the development of a system for improving management decisions on setting favorable working conditions and the environment of the population, creating a concept model of risk assessment and management in the oil extraction areas.

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