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Research article

# THE IMPACT OF AIR, WATER AND SOIL POLLUTION ON MORTALITY AND MORBIDITY OF CERTAIN CLASSES OF DISEASES AND NOSOLOGIES IN THE REPUBLIC OF TATARSTAN (2019–2023)

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*We have examined influence exerted by eight microbiological and chemical environmental factors on mortality, primary incidence and disease prevalence per 19 disease classes in 45 municipalities in Tatarstan, including children, working age population and elderly people, over 2019–2023. The study aimed to identify priority environmental risk factors causing medical-demographic losses of the population per specific classes of diseases and nosologies in Tatarstan. The study tasks included establishing correlations between environmental and medical-demographic factors as well as their strength; building predictive regression models; assessing regression coefficients of additional mortality and morbidity risks.*

*The results obtained by comparative analysis of influence exerted by ambient air, water and soil quality in Tatarstan confirmed the existing national trends in Russia as regards associations between mortality and morbidity and chemical pollution in ambient air, water supply deviating from the existing sanitary-epidemiological rules and standards, soils not conforming to safe standards per microbiological indicators; in addition, we established some health risks specific for Tatarstan. The greatest number of strong correlations was established for ambient air quality; a smaller number of medium correlations was established for water quality; the smallest number of correlations was established for soil quality. Children remain the most susceptible population group as regards primary incidence and disease prevalence. Multifactorial models established that additional risk of environment-associated incidence ranged between 44 and 67 % for children, equaled 57 % for working age population and 30 % for people older than working age per the existing mean morbidity rates per various classes of diseases.*

*A strong direct correlation was established between incidence of neoplasms in children and the proportion of ambient air samples containing $NO_2$ and $NH_3$ in levels beyond the maximum permissible concentration; the same correlation was established between $NH_3$ levels exceeding the maximum permissible concentration and prevalence/incidence of complications of pregnancy and childbirth among working-age women. Regarding mortality, we revealed correlations of varying strength; a strong non-linear correlation was found between all-cause mortality among people older than 80 years and the proportion of air samples containing $NO_2$ in levels beyond its maximum permissible concentration. Predictive models allow us to calculate a positive effect of modifying environmental factors for reducing additional risk of population morbidity and mortality.*

***Keywords:*** *sanitary and epidemiological well-being, environmental factors, risk modification, mortality, primary incidence, disease prevalence, correlation and regression analysis, predictive model.*



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Approximately 25 % of the global disease burden is associated with environmental threats, which are largely preventable. In 2019, exposure to some chemicals resulted in 2 million deaths (almost half of them were caused by diseases of the circulatory system, chronic obstructive pulmonary disease, and neoplasms) and 53 million of Disability-Adjusted Life Years (DALY)[1] [1]. To minimize adverse effects produced by chemical pollution in water, soil, and ambient air is an urgent task set within the Sustainable Development Goals. A topical issue is to establish possibilities for reducing mortality and morbidity, which could be achieved if health risks were either eliminated or reduced to their minimum possible level[2]. The World Health Organization also emphasizes lack of sufficient data on scopes and intensity of multiple chemical predictors of mortality and morbidity in various environments across the globe. In 2015, the World Health Organization passed a resolution on ambient air quality and health, which defines ambient air pollution as a risk factor causing such non-communicable diseases as ischaemic heart disease, stroke, chronic obstructive pulmonary disease, asthma, and cancer (which is further confirmed in later research [1]), among other things, a factor causing accelerated onset of 49 diseases [2]. Experts from many countries have reported a supralinear relationship between total mortality and nitrogen dioxide pollution in ambient air, that is, a more significant growth in health risks upon low-dose exposures [3–9]. A report issued by the UK Committee on the Medical Effects of Air Pollutants focused on effects produced by nitrogen dioxide pollution on all-cause mortality, predominantly, respiratory mortality [10]. A 2022 report issued by the same Committee concentrated on relationships between ambient air pollution and dementia, which were also mentioned in studies accomplished in other countries [1, 2]. A review accomplished by the German Agency on Environmental Protection in 2018 confirmed a role that belonged to long-term nitrogen dioxide exposure in cardiovascular mortality [11]. Nitrogen dioxide is also a precursor of secondary ambient air pollutants, including organic particles, nitrates, sulfates, particulate matter with the aerodynamic diameter smaller than 10 and 2 μm ($PM_{10}$ and $PM_{2.5}$). They all occur due to a sequence of photochemical reactions initiated by nitrogen dioxide activation in some regions, especially in Eastern Asia; a 20 % increase in nitrogen dioxide emissions is expected by 2050 [12]. Studies accomplished in the Republic of Tatarstan focused on effects produced by ambient air pollution of particulate matter smaller than 10 and 2 μm ($PM_{10}$ and $PM_{2.5}$) [13].

As regards control of drinking water quality, the WHO has issued four relevant Guides[3] to provide guidelines how to improve water supply policies at the national and regional levels [14]. Some studies accomplished in various countries focus on calculating risks associated with environmental predictors based on biochemical soil samples [15] and drinking water samples for health of specific population group [16]; factors causing morbidity of specific diseases have been assessed in some regions in Russia [17–19]. Overall, a considerable database with methodical approaches has been accumulated in Russia; they all are developed for investigating risk-inducing environmental factors [20]. In 2015, the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing (Rospotrebnadzor) performed a comprehensive study of changes in population mortality and morbidity depending on environmental factors. As a result, three predictor groups were identified in the country: 1) nonconformity with safe standards established for

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[1] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. *WHO*, 2021, 300 p.

[2] The public health impact of chemicals: knowns and unknowns. Data addendum for 2019. *WHO*, 2021, 4 p. Available at: https://iris.who.int/bitstream/handle/10665/342273/WHO-HEP-ECH-EHD-21.01-eng.pdf?sequence=1 (July 25, 2025).

[3] WHO. Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. *WHO*, 2022, 614 p. Available at: https://www.who.int/publications/i/item/9789240045064 (July 28, 2025).

‘Proportion of ambient air samples in urban and rural settlements’ per contents of ‘hydrocarbons, aromatic ones included, nitrogen dioxide, benzo(a)pyrene, toluene, chlorine and its compounds, fluorine and its compounds, ammonia, hydroxybenzene and its derivatives’; 2) non-conformity with safe standards established for ‘Proportion of soils samples’ per microbiological indicators and with safe standards for contents of cadmium and mercury; 3) non-conformity with safe standards established for water sources and centralized drinking water supply systems and for ‘Proportion of water samples from water supply systems’ per microbiological indicators[4]. Results obtained by investigating additional morbidity and mortality rates associated with environmental exposures are given per RF regions in annual state reports issued by Rospotrebnadzor with an emphasis on them being either above or below the national average. To quantify these relationships at the regional level, the Department of Medical Demography, the Research Institute of Healthcare Architecture of the Interregional Clinical Diagnostic Center, analyzed effects produced by microbiological and chemical environmental factors on population morbidity and mortality in the Republic of Tatarstan in 2019–2023. **The aim of this study** was to identify priority environmental predictors determining medical and demographic losses of the population per specific classes of diseases and nosologies in Tatarstan. The study tasks included establishing correlations between environmental and medical and demographic factors as well as their strength; building predictive regression models; assessing regression coefficients of additional mortality and morbidity risks.

**Materials and methods.** To establish priority environmental factors causing medical and demographic losses for the Republic of Tatarstan (RT), the Department of Medical Demography calculated health risks per conventional indicators of sanitary-epidemiological well-being per all 45 municipalities in the Republic over 2019–2023 using the methodology developed by the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing (Rospotrebnadzor)[5]. Six out of 14 above mentioned indicators determining medical and demographic losses in Russia turned out to be zero, accordingly, not significant for the Republic of Tatarstan (‘proportion of ambient air samples not conforming to safe standards per contents of benzo(a)pyrene, toluene, chlorine and its compounds, fluorine and its compounds’; proportion of soil samples in residential areas not conforming to safe standards per cadmium and mercury’). This fact stimulated the Department of Medical Demography to develop an electronic database ‘Modifiable Health Risk Factors of Morbidity and Mortality in Tatarstan (2019–2023)’ [6], which contains 8 indicators established by using the Rospotrebnadzor's Form-18[7]: ‘proportion of ambient air samples in urban and rural settlements not conforming to safe standards per contents of hydrocarbons, aromatic ones included, (in Tatarstan for 5 years from minimal ($x_{min}$) = 0 to maximum ($x_{max}$) = 0.04), nitrogen dioxide ($x_{min}$ = 1.18, $x_{max}$ = 2.17), ammonia ($x_{min}$ = 0.42, $x_{max}$ = 2.26), hydroxybenzene and its de-

[4] Raschet fakticheskikh i predotvrashchennykh v rezul'tate kontrol'no-nadzornoi deyatel'nosti ekonomicheskikh poter' ot smertnosti, zabolevaemosti i invalidizatsii naseleniya, assotsiirovannykh s negativnym vozdeistviem faktorov sredy obitaniya [Calculation of actual economic losses and those prevented due to control and surveillance activities in case such losses are caused by mortality, incidence and disability among population associated with exposure to harmful environmental factors]: Methodical guidelines. Moscow, Rospotrebnadzor’s Center for Hygiene and Epidemiology, 2015, 60 p. (in Russian).

[5] Ibid.

[6] Khayrullin R.N., Patyashina M.A., Titova A.A., Ildarkhanova Ch.I., Ershova G.N. Modifitsiruemye faktory riska zabolevaemosti i smertnosti v Respublike Tatarstan (2019–2023 gody) [Modifiable Health Risk Factors of Morbidity and Mortality in Tatarstan (2019–2023)]: State Registration Certificate for Database No. 2025623030 Russian Federation; submitted on June 19, 2025, published on July 15, 2025; submitted by the Interregional Clinical Diagnostic Center, Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, Tatarstan Regional Office (in Russian).

[7] Forma 18. Svedeniya o sanitarnom sostoyanii sub"ekta RF za 2019–2023 gg. [Form-18. Data on the sanitary situation in a RF region in 2019–2023]. *Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, Tatarstan Regional Office* (in Russian).

rivatives'($x_{min}$ = 0, $x_{max}$ = 0.5); 'proportion of water sources and centralized drinking water supply systems not conforming to sanitary-epidemiological rules and standards'($x_{min}$ = 17.2, $x_{max}$ = 20.96); 'proportion of water samples from centralized water supply systems not conforming to safe standards per microbiological indicators'($x_{min}$ = 3.05, $x_{max}$ = 3.96); 'proportion of soil samples not conforming to sanitary-epidemiological requirements per microbiological indicators ($x_{min}$ = 3.2, $x_{max}$ = 5.07)'; data provided by the Tatarstan Ministry of Health: mortality rates including deaths caused by the specific most significant nosologies (acute cerebral circulation disorder, chronic obstructive pulmonary disease, tuberculosis, and pneumonia) for age groups 1–4 years, 0–17 years, older than 80 years; incidence and prevalence of diseases per 19 ICD-10 classes in all 45 municipalities in Tatarstan including their rates among children, working age people and people older than working age[8]. We applied correlation-regression analysis to investigate effects produced by eight microbiological and chemical environmental factors on population health in the Republic of Tatarstan. Factors creating additional incidence, prevalence and mortality in Tatarstan were examined based on predictive models.

The following scale was used to estimate correlation strength and to interpret Spearman's correlation: weak correlation (0.1–0.29), medium correlation (0.3–0.69), and strong correlation (0.7–1). Overall, we built 500 one-factor models per annual indicators, 219 of them with $p < 0.05$; 44 additional annual models were built per the most significant nosologies with $p < 0.05$. Strength of correlations with all identified factors was established by multiple regression analysis of the levels averaged over 5 years. Non-zero significant proportions of ambient air samples with levels of hydrocarbons (aromatic ones included) exceeding maximum permissible concentrations (MPC) were found only in 2021; hydroxybenzene, only in 2019. Their effects can be considered temporary and they were not included in the multiple analysis. We built eight multifactor models with significance taken as $p <$ 0.05; additionally, 28 one-factor models were calculated (in case other predictors were insignificant), significance taken as $p < 0.05$. These foregoing research procedures made it possible to identify the most significant factors.

The multiple linear regression equation is given as follows:

$$y = \beta x_1 + \beta x_2 \ldots + \beta x_n + \alpha,$$

where $y$ is incidence / prevalence of disease / mortality; α is the $y$-intersection coefficient, $\beta x_1 \ldots \beta x_n$ are environmental factors.

Additional risk of incidence / prevalence of disease / mortality caused by a given regressor was calculated as the difference between the averaged 5-year incidence / prevalence of disease / mortality and the same indicators in case a factor had a zero value.

**Results and discussion.** As regards incidence per 19 classes of diseases in 2019–2023, a strong direct linear correlation was established between the following indicators: 'Proportion of ambient air samples in urban and rural settlements with nitrogen dioxide ($NO_2$) contents higher than MPC' and 'Proportion of ambient air samples in urban and rural settlements with ammonia ($NH_3$) contents higher than MPC' and neoplasms among children; the determination coefficient is equal to 0.5, which allows considering the model authentic (Table 1).

A medium correlation was established for other predictors of multifactorial models with the determination coefficient below 0.5. As regards incidence of neoplasms among population older than working age, the ambient air pollution regressor $NH_3$ turned out to be insignificant; 'proportion of water sources and centralized drinking water supply systems not conforming to sanitary-epidemiological rules and standards' was additionally introduced

[8] Minnulin M.M., Korosteleva A.V., Khusnullina G.R., Zalyalov R.R. [et al.]. Statistika zdorov'ya naseleniya i zdravookhraneniya (po materialam Respubliki Tatarstan (za 2015–2023 gody) [Statistics of population health and healthcare (per data collected in Tatarstan (over 2015–2023)]: manual. Kazan, 2019–2023 (in Russian); No data on 2019–2021 are available as regards incidence and prevalence of diseases among working age people.

Table 1

Multifactor models to describe correlations between incidence / prevalence of diseases / mortality and environmental exposures in Tatarstan in 2019–2023

| | Additional risk of incidence / prevalence of disease / mortality | $p$-value | $\alpha$ coefficient | $\beta$-coefficients | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | % **ambient air** samples with levels of … higher than MPC | | Non-conformity of centralized drinking **water supply** to safe standards | | Non-conformity of **soils** to safe standards |
| | | | | $NO_2$ | $NH_3$ | % water sources and supply networks | % non-conforming samples per microbiological indicators | % non-conforming samples per microbiological indicators |
| Incidence of neoplasms among children | 2.5 | 0.0156 | 1.2 | 1.6 | 0.02 | - | - | - |
| Incidence of certain conditions originating in the perinatal period | 284.5 | 0.0005 | 283.6 | 150.1 | 64.6 | - | - | - |
| Incidence of respiratory diseases among working age population | 95.8 | 0.0004 | 94.3 | 31.6 | - | 1 | - | 114 |
| Incidence of diseases of skin and subcutaneous tissue among children | 33 | 0.0052 | 33.5 | 18.4 | - | 0.3 | - | - |
| Incidence of diseases of the digestive system among children | 25 | 0.0036 | 31.5 | - | - | 0.3 | 2.9 | - |
| Incidence of diseases of skin and subcutaneous tissue among working age population | 14.6 | 0.0020 | 10.1 | 6.5 | - | 0.2 | - | - |
| Incidence of neoplasms among population older than working age | 5.56 | 0.0007 | 13.1 | 3.9 | - | 0.1 | - | - |
| Prevalence of diseases of skin and subcutaneous tissue among working age population | 46.9 | 0.0251 | 107 | - | - | 0.8 | 7.9 | - |

Note: MPC is maximum permissible concentration.

into the equation as an indicator with the regression coefficient 0.1. $NO_2$ and $NH_3$ were significant with a medium-strong correlation with incidence of certain conditions originated in the perinatal period among children. $NO_2$ pollution is present in all multifactor models, apart from diseases of the digestive system. In addition to this regressor, another determining one for morbidity of diseases of skin and subcutaneous tissue, both among children and working age population, is non-conformity of water sources and centralized water supply systems to sanitary-epidemiological rules and standards. In 2017, a study by the Rospotrebnadzor's Federal Scientific Center for Medical and Preventive Health Risk Management Technologies also found effects produced by drinking water not conforming to safe standards on morbidity of diseases of skin for the total RF population [20].

A multifactor model, which determined correlations with incidence and prevalence of diseases of the digestive system among children, included only the following significant factors: non-conformity of centralized water supply systems to safe standards, namely, the proportion of non-conforming water sources and water supply systems and the proportion of water samples deviating from safe standards per microbiological indicators. Soil samples deviating from safe standards per microbiological indicators are an additional predictor of diseases of the respiratory system among working age population together with $NO_2$ pollution in ambient air and non-conformity of water sources and centralized drinking water supply systems with sanitary-epidemiological rules and standards.

In case only one regressor was significant for incidence and prevalence of certain classes of diseases or specific nosologies, its effects were estimated using one-factor models (Table 2).

Table 2

One-factor models to describe correlations between incidence / prevalence of diseases / mortality and environmental exposures in Tatarstan in 2019–2023

| Class of diseases or nosology | Additional risk of incidence / prevalence of disease / mortality | $R$ | $\alpha$ coefficient | $\beta$-coefficients | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | % **ambient air** samples with levels of … higher than MPC | | Non-conformity of centralized drinking **water supply** to safe standards | | Non-conformity of **soils** to safe standards |
| | | | | $NO_2$ | $NH_3$ | % water sources and supply networks | % % non-conforming samples per microbiological indicators | % non-conforming samples per microbiological indicators |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Incidence of pregnancy and birth complications among working age women | 13.3 | 0.0000 | 45.5 | - | 1441 | - | - | - |
| All-cause mortality among people older than 80 years | 3979.7 | 0.0000 | 10843.9 | 4865.9 | - | - | - | - |
| Prevalence of neoplasms among people older than working age | 30.6 | 0.0000 | 104.2 | 20.7 | - | - | - | - |
| Prevalence of pregnancy and birth complications among working age women | 11.8 | 0.0000 | 47 | - | 856.2 | - | - | - |
| Incidence of certain infectious and parasitic diseases among children | 25.6 | 0.0011 | 33.1 | 15.1 | - | - | - | - |
| Prevalence of diseases of the genitourinary system among children | 27.7 | 0.0005 | 39.6 | 19.9 | - | - | - | - |
| Incidence of diseases of the genitourinary system among children | 11.6 | 0.0003 | 15.8 | 8.1 | - | - | - | - |
| Total incidence among children | 536 | 0.0028 | 1224.1 | 313.4 | - | - | - | - |
| Incidence of diseases of the musculoskeletal system among children | 13.3 | 0.0196 | 18 | 9.2 | - | - | - | - |
| Mortality caused by diseases of the respiratory system among working age population | 2.9 | 0.0058 | 21 | - | - | 0.1 | - | - |
| Incidence of mental disorders among people older than working age | 1.9 | 0.0119 | 1.4 | - | - | - | 0.2 | - |

End of the Table 2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Incidence of diseases of the digestive system among working age population | 1.9 | 0.0083 | 18.7 | - | - | 0.3 | - | - |
| Mortality caused by pneumonia among working age population | 1.8 | 0.0168 | 10 | - | - | 0.1 | - | - |
| Incidence of mental disorders among working age population | 0.9 | 0.0093 | 1.8 | 0.5 | - | - | - | - |
| All-cause mortality | 1020 | 0.0199 | 1388.5 | - | - | - | 26.6 | - |
| Incidence of diseases of the respiratory system among children | 327.7 | 0.0230 | 839.7 | 184.6 | - | - | - | - |
| Prevalence of diseases of the respiratory system among working age population | 58.8 | 0.0324 | 164.9 | 22.4 | - | - | - | - |
| Prevalence of diseases of the respiratory system among people older than working age | 45.4 | 0.0249 | 202.8 | 29.3 | - | - | - | - |
| Incidence of diseases of the respiratory system among people older than working age | 40.4 | 0.0321 | 133.6 | 27.4 | - | - | - | - |
| Mortality caused by old age | 39.5 | 0.0224 | 100.6 | - | - | - | 9,9 | - |
| Prevalence of diseases of the skin and subcutaneous tissue among people older than working age | 17.9 | 0.0189 | 25.9 | 8.9 | - | - | - | - |
| Prevalence of congenital malformations, deformations and chromosomal abnormalities among children | 12.8 | 0.0503 | 28.9 | - | - | - | 1.6 | - |
| Prevalence of diseases of the skin and subcutaneous tissue among working age population | 12.1 | 0.0291 | 21.6 | 5.2 | - | - | - | - |
| Prevalence of certain infectious and parasitic diseases among working age population | 11.2 | 0.0226 | 17.3 | - | - | - | - | 72 |
| Incidence of certain infectious and parasitic diseases among people older than working age | 6.1 | 0.0204 | 6.6 | 3.7 | - | - | - | - |
| Incidence of certain infectious and parasitic diseases among working age population | 4.5 | 0.0307 | 6.1 | 2.3 | - | - | - | - |
| Incidence of diseases of the circulatory system among children | 4.2 | 0.0309 | 6.7 | 3.7 | - | - | - | - |
| Incidence of diseases of the digestive system among people older than working age | 2.3 | 0.0366 | 18 | - | - | - | 1.6 | - |

The strongest correlation was found between ambient air samples containing $NH_3$ in levels higher than MPC and incidence of the disease class 15 ‘Pregnancy, childbirth and the puerperium’ among working-age women; no other factors had any significant effect as regards this class of diseases. The highest determination coefficient ($R^2 > 0.5$) among all one-factor models indicates the model has a high approximation level. Mean 5-year frequency of pregnancy and birth complications equaled 58.75 cases per 100 thousand working age women in Tatarstan. Additional risk of incidence caused by this regressor is equal to 13.25 cases per 100 thousand working age women according to the linear model. $NH_3$ pollution in ambient air is not significant for any other class of diseases or nosology.

A strong correlation was found between the proportion of ambient air samples with $NO_2$ levels higher than MPC and mortality among people older than 80 years. The mortality rate is higher in this age cohort relative to all others, 14,823.6 deaths per 100 thousand people. According to the created linear model, additional mortality risk is 3979.7 per 100 thousand people (Table 2). This persistent association between $NO_2$ pollution in ambient air and mortality in the Republic of Tatarstan confirms the results obtained by an international meta-analysis of relative risk of total mortality *RR*, which was estimated to equal 1.02 with the 95 % confidence interval when a nitrogen dioxide level grew to 1.01 ≈ 1.04 per 10 $\mu g/m^3$ [21]. This study has not confirmed an association between non-conformity of water sources and centralized drinking water supply systems with safe standards and incidence of diseases of the genitourinary system, which was previously reported in the Republic of Tatarstan [18].

The study results made it possible to create models describing relationships between environmental exposures and population mortality / morbidity per classes of diseases that determine medical and demographic losses. Comparative analysis of effects produced by environmental exposures in the Russian Federation as a whole[9] and in the Republic of Tatarstan has revealed similar trends: 1) $NO_2$ pollution in ambient air is associated with mortality due to diseases of the respiratory system in Russia and with incidence of such diseases among children and elderly people in Tatarstan (this cause of death holds the 5$^{th}$ rank place per its significance in the Republic in Tatarstan and the 6$^{th}$ one in the Russian Federation as a whole); 2) non-conformity of water sources and centralized drinking water supply networks with sanitary-epidemiological rules and standards is associated with morbidity of the diseases of the digestive system among children in the Russian Federation (this cause of child mortality holds the 7$^{th}$ rank place per its significance in the Republic of Tatarstan and the 8$^{th}$ rank place in Russia) and with incidence of these diseases among people older than working age in Tatarstan (the 5$^{th}$ rank place as a cause of death in Tatarstan and the 4$^{th}$ in Russia), with incidence of diseases of skin and subcutaneous tissue, with incidence of neoplasms among working age population in Russia and among people older than working age in the Republic of Tatarstan (this death cause holds the 2$^{nd}$ place per its contribution in the nation-level and regional burden of disease among elderly people and the 3$^{rd}$ place among children); 3) soil samples not conforming to safe standards per microbiological indicators are associated with morbidity of diseases of the respiratory system (among children in Russia and working age population in the Republic of Tatarstan)[10].

Specific features of the situation in Tatarstan include the following: effects produced by $NO_2$ pollution in ambient air on incidence of diseases of the circulatory system among chil-

[9] Raschet fakticheskikh i predotvrashchennykh v rezul'tate kontrol'no-nadzornoi deyatel'nosti ekonomicheskikh poter' ot smertnosti, zabolevaemosti i invalidizatsii naseleniya, assotsiirovannykh s negativnym vozdeistviem faktorov sredy obitaniya [Calculation of actual economic losses and those prevented due to control and surveillance activities in case such losses are caused by mortality, incidence and disability among population associated with exposure to harmful environmental factors]: Methodical guidelines. Moscow, Rospotrebnadzor’s Center for Hygiene and Epidemiology, 2015, 60 p. (in Russian).

[10] Ibid.

dren (this cause of child mortality holds the 6th place per its significance in Russia and the 4th in the Republic of Tatarstan), diseases of the musculoskeletal system and genitourinary system; effects on diseases of skin and subcutaneous tissue among working age population; also, together with ammonia, this pollutant influences incidence of certain infectious and parasitic diseases and certain conditions originating in the perinatal period among children. Non-conformity of water samples with safe standards per microbiological indicators is associated with total mortality, mortality from old age and incidence of mental disorders among people older than working age; non-conformity of water sources and centralized drinking water supply systems with sanitary-epidemiological rules and standards has an effect on mortality caused by diseases of the respiratory system, pneumonia included, among working age people. Non-conformity of soil samples to safe standards per microbiological indicators is associated with prevalence of certain infectious and parasitic diseases. Our analysis has revealed that these identified trends cannot yet be considered a demographic catastrophe but given the existing descending trends in the population number and birth rates as well as growing mortality any positive modifications of environmental exposures will promote a decline in burden of specific diseases and eventually reduction in medical and demographic losses.

Future prospects of this research also should involve further detailed investigations with their focus on the identified factors using the Exposure – Response method[11] at the regional level; comparing identified risks with permissible levels and establishing priorities and scenarios related to preventing and reducing medical and demographic risks in the Republic of Tatarstan. A specific study can be conducted to analyze additional variables, for example, performance indicators of the healthcare system.

**Conclusions.** The greatest number of strong correlations was established for ambient air quality; a smaller number of medium correlations was established for water quality; the smallest number of correlations was established for soil quality. Children remain the most susceptible population group as regards primary incidence and disease prevalence; we established the greatest number of correlations between ambient air, soils and water pollution and children morbidity. A smaller number of correlations with various strength was found between morbidity among working age population and elderly people. Multifactorial models established that additional risk of environment-associated morbidity ranged between 44 and 67 % for children, equaled 59 % for working age population and 30 % for people older than working age per the existing mean morbidity rates per various classes of diseases. One-factor models allowed establishing that non-conformity of drinking water supply to safe standards created additional 12–15 % risk of mortality due to various causes among working age population and 28 % risk among people older than working age. Additional risk of congenital malformations equaled 30 % of the existing level among children; additional risk of diseases of the digestive system among working age population, 9 %; additional risk of diseases of various classes among people older than working age, between 11 and 57 %, the correlation having medium strength. Strong correlations were established for models that describe additional risks caused by ammonia pollution in ambient air: 20 % of incidence and 22 % of prevalence of birth and pregnancy complications among working age women as well as 27 % additional risk of mortality caused by nitrogen dioxide pollution among people older than 80 years; medium correlations were established for one-factor models describing effects produced by nitrogen dioxide pollution an ambient air on

[11] Guide R 2.1.10.3968-23. Rukovodstvo po otsenke riska zdorov'yu naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh sredu obitaniya [Health Risk Assessment upon Exposure to Chemical Pollutants in the Environment], approved by A.Yu. Popova, the Head of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, the RF Chief Sanitary Inspector on March 06, 2023.

additional risk, namely 23–47 % of incidence and prevalence of diseases from various classes.

Our conclusions as regards authentic models built for the Republic of Tatarstan can be taken into account when assessing health risk factors in neighboring regions. Models that describe additional risks of morbidity and mortality per the most significant classes of diseases for medical and demographic losses, including diseases of the circulatory system, neoplasms, diseases of the respiratory and digestive system, bring greater relevance to modification of environmental exposures, analysis and search for additional predictors, among other things, within achieving goals fixed in the National projects of the Russian Federation.

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