

Development of the methods of environmental and sanitary-hygienic assessment of urbanized lands (on the example of the Ob-Tom interfluve)

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Abstract. Modern transformations to land legislation draw the government to establishing the boundaries of use-restricted zones throughout the territory of the Russian Federation. First of all, it is connected with the goal of the state to provide safety and provide a favorable background for preserving a person's life and ensure his/her life activity. The Land Code of the Russian Federation has defined a list of use-restricted zones, according to which, the procedure for establishing and approving their boundaries for each type of zone to put data into the Unified State Register of Immovable Property should be defined. Consequently, there is a need to develop an ecological and sanitary-hygienic assessment of the territory, which takes into account all these factors. However, the analysis of the approved regulations for flooding zones shows that the procedure does not stipulate for an integrated analysis of the territory as a single hydraulically connected system, which consists of hydraulic structures, surface, and groundwater. The lack of an integrated geo-information analysis in the current regulations for the corresponding territories induces intensive economic development, the consequence of which could increase human impact. Thus, unreliable information will be put into the Unified State Register of Immovable Property. Consequently, considering all these factors, it is necessary to develop an ecological and sanitary-hygienic assessment of the territory.

1. Introduction

Water is the most important natural resource for all living organisms including humans. However, the development of a large number of enterprises in cities significantly deteriorates the quality of surface waters. In this regard, many localities are switching to groundwater use.

The environmental and sanitary-hygienic condition of the lands of the Ob-Tom interfluve (OTI) is essential since there is the Tomsk underground water intake supplying the population of the city of Tomsk and the Tomsk region since 1973 with potable water.

Despite the fact that water intake is a strategically important object, the necessity to consider the borders in the registry emerged due to of the Federal Law "On cadastral activities" No. 221-FZ in 2007 [1]. Thus, it is a long period from the calculation of the boundaries of the protective sanitary zone (PSZ) [2] to their establishment that leads to the human impact change being a key parameter in the calculation of the PSZ. Such a problem exists in the (OTI) territory. This territory is attractive for the development of residential buildings due to its proximity to the administrative center of the city, and in recent years is intensively being developed, although OTI was planned to be used for recreation when building water intake due to inefficient protection of groundwater.



The last reevaluation of groundwater reserves in this area to consider the water demands of Tomsk [3] and the human impact was carried out in 2003 for a period of 27.4 years and the boundaries of the protective sanitary zone were established. After, the areas of localities within the sanitary protective zones have significantly changed, and the human impact on landscapes in general and on groundwater has increased. In this regard, it is necessary to assess and predict changes in the components of the natural environment due to human impact to obtain reliable information about the state of the land and ways of sustainable land use in the operating conditions of the Tomsk underground water intake.

2. Materials and research methods

From 1992 to the present, the study of economic activities in the selected area was conducted by analyzing land resources use. The system, statistical and correlation-regression analyses were used to estimate and predict the population in the work. To assess the dynamics in the residential area change, the landscape analysis, and system mapping, cartometric analysis using geo-information technologies were used.

In the study, the following source materials were used: topographic maps with 1: 10000 scale (release of 1992 (not updated)), which are the map of the Tomsk Region Administration, the development master plan of the Tomsk administration and rural settlements, the Esri maps, cadastral plans of the Federal Registration Service, cadastral register and cartography of the Tomsk region, information of forest management regulations for Timiryazevsky forestry area in the Tomsk region.

The Federal State Statistics Service data, project declarations and commissioning certificate of the residential district « Severnyj Park» were used to calculate and predict the population size. Statistical analysis and population forecast for the period from 2002 to 2040 were conducted using the Microsoft Excel spreadsheets by constructing diagrams with a trend line.

3. Algorithm ecological and sanitary and hygienic assessment of urbanized lands

The Tomsk underground water intake refers to the water intakes of the linear type and consists of 198 production wells. At the present time, 95 wells are in operation in the normal load mode, 14 of which belong to the control wells to sample the quality of the water supplied. The study subject is the territory of the third zone of the SPZ of the first stage of water intake (wells 19-699) launched on December 13, 1973 [4]. Complete construction of the first stage was over in October 1974 [5].

The area of the SPZ of the Tomsk underground water intake is 26000 hectares. The study area within the third zone of the first stage is 12359 hectares.

The territory choice for the developed technique testing is due to the following main factors: proximity to the city of Tomsk (the administrative centre of the Tomsk region), a large number of settlements and the maximum intensity of economic development human impact on the territory of the Ob-Tom interfluvium.

The methods for ecological and sanitary-hygienic assessment of urbanized lands are based on the integrated analysis of the territory with population dynamics analysis, change of the boundaries of urbanized territories, identification of reasons of human impact, evaluation of the landscape and the ecological and economic balance of the territory. The technique consists of the following successive stages:

3.1. 1st stage. Analysis and prediction of population dynamics

The Federal State Statistics Service data on the number of residents registered in urban areas with low-rise buildings (the total population in 2015 was 13756 people) was used to estimate the population dynamics within 2 and 3 zones of the SPZ of the underground water intake. There has been a sharp increase in the population over the period from 2002 to 2008. This is associated with the incorporation of some settlements into the municipal entity “Gorod of Tomsk” in November 2004 (v. Timiryazevskoe, v. Dzerzhinskoe, etc.). In addition, for the period from 2008 to 2015 there is an insignificant stable increase in the population by 11.5%.

To analyze the further possible change in population growth, a forecast was given based on the trend and fluctuations of the statistical series (extrapolations of statistical series) for 2030 and 2040 (fig. 1). The analysis showed that with the current trends in population size within the PSZ intake, by 2030 the

theoretical value of this indicator may increase by 700 people, and by 2040 it may increase by 860 people. Considering the error of the method and the confidence band, according to Student's criterion, in 2030 the actual population value will be from 13579 to 15741, and in 2040 it will be from 12887 to 15487.

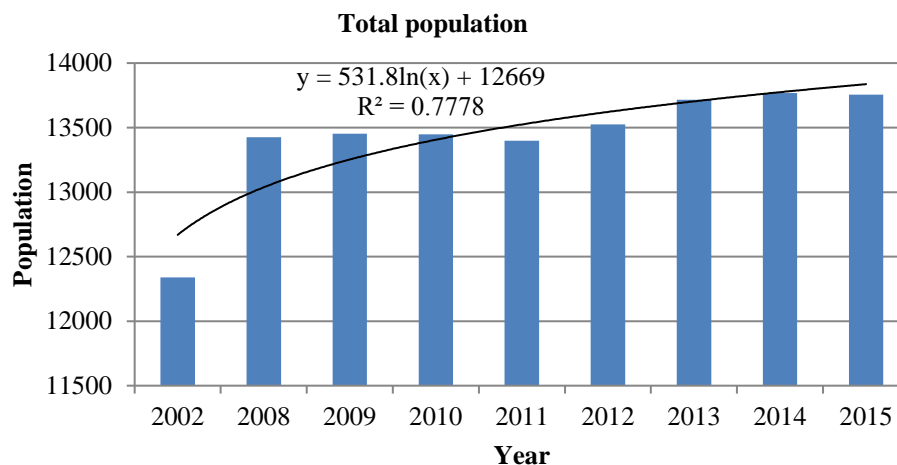


Figure 1. Type of a function for population projection in the populated areas under consideration by extrapolation

However, in recent years, a multi-storeyed residential building has been developing on the left bank of the Tom River. At the moment the area of the residential district Severnyj Park is 35.5 hectares. It is located on the border of 3d zone of the SPZ of the water intake. In this area, according to project statements and commissioning certificates, there are 19 five-storeyed houses (2077 apartments), an eight-storeyed house (76 apartments) and an 11-15 storeyed house (158 apartments), except public amenities. Moreover, in the area of the residential district Severnyj Park there are 12 land plots for low-rise buildings and a large one, not divided land mass (approximately 12 land plots). It can be proposed that the population number of the residential district Severnyj Park after developing the whole territory will be 9340 people (2311 apartments and 24 land plots, providing that the average family composition is 4 people). If we assume that these areas are built similarly to the project documentation of the residential district Severnyj Park, and the number of families is calculated, the population number of the left bank areas will increase by more than 42 thousand people.

3.2. Stage II. Analysis of changes in the boundaries of urban areas

An analysis of the areas occupied by settlements within the territory using archival cartographic materials (tablets) of 1992 and spatial data Esri maps of 2018 led to the conclusion that the territories occupied by settlements increased by 1317.3 hectares, or slightly more than double. Thus, the area reached 2415.7 ha in 2018. For comparison, in 1992 it was 1098.4 ha. It should be noted, that the increase in the area of settlements within the sanitary protective zones falls on individual housing and country house constructions, and not on apartment buildings.

It is important to emphasize that the boundaries of some settlements have increased severalfold (v. Zorkaltsevo; v. Kaidalovka) due to the construction of new the residential districts, which are located in the in neighborhoods of villages and settlements ("Zorkaltsevskie Usadby", "Sloboda Volnaya", "Solnechnyj Plyus", "Snegiri", "Serebryanyj Bor") [6].

3.3. Stage III. Source identification of human impact and boundaries determination of sanitary protective zones

For this study, the classification of factors and impacts of technogenic disturbances of the hydrosphere of the Ob-Tom interfluve [7] was used, on the basis of which a map of sources of human impact was created.

In this area, various farms specializing in livestock production are actively developing. The operation of these farms implies the availability of animal waste, animal burial sites, and manure storage facilities. The growth of settlements leads to an increase in the number of different domestic waste landfills. Within the SPZ [2], there are also industrial enterprises, such as a concrete-asphalt plant, gas stations, as well as warehouses of fuel and lubricants and mineral fertilizers, and other objects that directly exert human impact, and are unacceptable in compliance with sanitary standards (fig. 2).

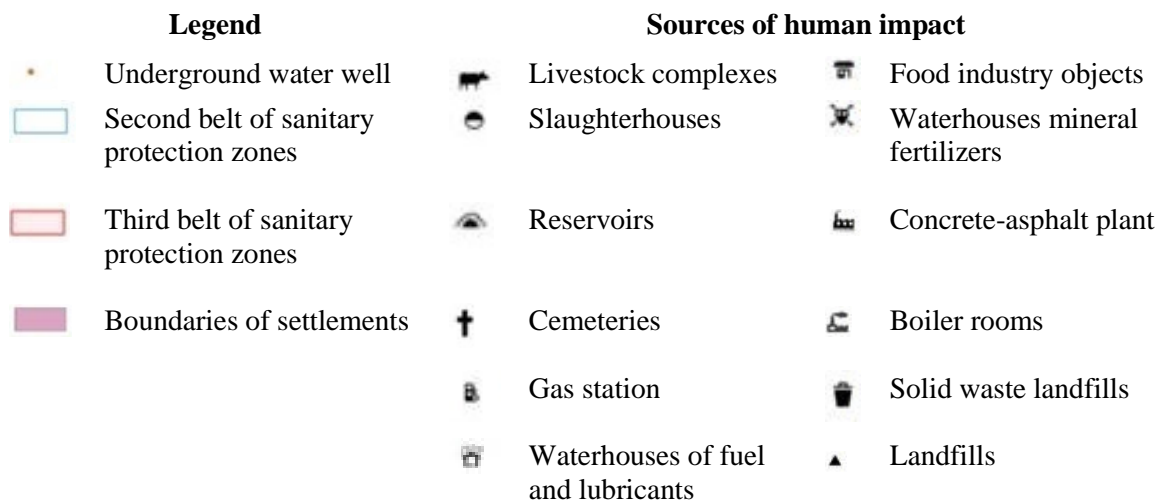


Figure 2. Fragment of the map of sources of anthropogenic impact

According to the sanitary rules and norms, sanitary protective zones of sources of human impact were determined. Based on the cadastral plans of the territories, there is no record of the majority of the boundaries of such objects in the Unified State Register of Immovable Property, so the corresponding sanitary conditions are not ensured and human activity is not limited. Moreover, most of the objects are located within the boundaries of the SPZ water intake, which is unpermitted.

3.4. Stage IV. Landscape analysis to assess the possibility of migration of pollutants with surface runoff

To determine the surface runoff direction, a digital model of the landscape [8] was constructed, analyzing which it was concluded, that the eastern part of the OTI is characterized by low and slightly sloping forms compared to the western part (fig. 3). There are many bayou lakes of the river Tom. Thus, the landscape is a cause of the flow of pollutants from the drain to the water wells.

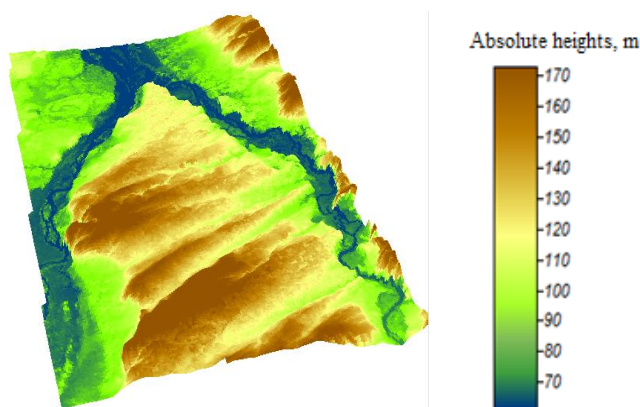


Figure 3. Digital elevation model of the territory of the Ob-Tomsk interfluvium

3.5. Stage V. Assessment of the ecological and economic balance of the territory

The ecological and economic balance (EEB) of lands was carried out on the basis of a site map of the territory. The presented types of landscapes were ranked in accordance with the degrees of human impact by means of an expert method (table 1).

Table 1. The grading of Tomsk central part of the underground water intake by degrees of anthropogenic load.

Degree of anthropogenic load	Score	Types of land	Area, (ha)
Higher	6	Residential areas	6 112.4
Very high	5	Agricultural land for comprehensive use	7 502.5
		Land used for growing crops: irrigated, arable	10 398.5
High	4	Agricultural land used for livestock	5 417.0
Average	3	Forests, perennial plantations	5 206.9
Low	2	Forest Park Zones	9 517.9
Very low	1	Green areas	5 018.6
		Conservation lands	479.0
		Unused land (reserve land)	45.7
Total area			49 698.4

The assessment of the condition of the land use structure of the study area was carried out based on the expert assessment method [9] and the classification [10] of land use. To assess the EEB, the absolute tension ratio of the territory was used, which characterizes the ratio of severely disturbed areas (the development of urbanized areas leads to not only the activities of industrial enterprises but also traffic congestion) and lands of poorly disturbed or uncultivated.

As a result of the ecological and economic balance assessment of the territory, it was discovered an imbalance between human impact and reproduction potential of natural ecosystems on the territory of the Ob-Tom interfluvium within the SPZ of Tomsk underground water intake with the most intensive human impact caused by the active urbanization processes.

4. Conclusion

The proposed technique for the environmental and sanitary-hygienic assessment of the urbanized lands is a comprehensive approach to the study of the interaction of natural and human factors.

The Ob-Tom interfluvium is considered to be a favorable territory for the formation and preservation of groundwater due to hydrogeological, physiographic, and ecological conditions. However, when developing this territory, it is necessary to take into account the possibility of infiltration of groundwater in some areas. The application of the developed technique for the environmental and sanitary assessment of urbanized lands allowed us to conclude that during a period of the Tomsk underground water intake development, the boundaries of the populated areas within the PSZ boundaries significantly extended, and human impact in the landscape increased. It may lead to groundwater pollution.

Moreover, the ecological situation in the study area is becoming worse due to noncompliance with technological regulations at the located industrial facilities and agricultural enterprises, deforestation, the development of garden co-operatives and cottage development within the boundaries of the SPZ.

Special attention should be paid to the districts that are being built in close proximity to the SPZ boundaries, in which, a large number of people and vehicles will be concentrated in a small area unlike in low-rise areas. In the event of an increase in the boundaries of the SPZ with the next revaluation of groundwater reserves, this territory may fall into the border of 3 zones. Thus, the residential district Severnyj Park is an example of the Ob-Tom interfluvium. During the construction and operation of such facilities, special attention should be paid to the creation of measures that minimize the impact on the environment.

The economic development of territories can be considered successful [11], and rational only taking into account all the natural factors that determine the condition of the landscape as a whole. It is impossible to choose a rational direction of land use, predict the further development of the territory, as well as achieve environmental compatibility neglecting natural factors and the ecological situation of the territory.

Thus, currently, land management (in the use and protection of the land reserves of the Russian Federation) should take into consideration increase in anthropogenic activities: intensive agriculture, urbanization [12], technogenesis effect [13], climate change.

To organize the sustainable development of land use in such areas, the following measures are proposed (for example, OTI) within the framework of land-use planning:

1. To introduce the boundaries of the PSZ water intake on the scheme of land-use planning of the Tomsk region.
2. To establish the industrial object of the SPZ and put such boundaries into the Unified State Register of Immovable Property.
3. To revise the Rules for Land Use and Development and town planning regulations in terms of the territory use restrictions, taking into account the SPZ.
4. To review and change the territories of perspective development within the boundaries of the SPZ.

Regarding the sources of human impact: liquidation and conservation of objects, restriction of activities, land restoration, environmental protection measures: landscaping, creation of natural parks, organizational and technical measures for waste disposal, discharge treatment.

5. Acknowledgments

The authors express their appreciation and deep gratitude to Victor Konstantinovich Popov, professor of the Division for Geology of the NI TPU, for advice and valuable comments when working on these studies.

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