RESEARCH PAPER

MONITORING OF ANTHROPOGENIC IMPACT ON THE BAIKAL NATURAL TERRITORY: MUNISIPAL LEVEL

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ABSTRACT. The purpose of the presented study is to develop a methodology for assessing the anthropogenic impact on the environment in the municipalities of the Baikal Natural Territory (BNT) and applying the obtained methodology to the studied territory. The article analyzes the existing methodological approaches to the assessment of anthropogenic impact on the environment. To carry out a comprehensive integrated assessment, the authors proposed an algorithm for calculating the anthropogenic impact index based on 22 indicators integrated into 7 subindexes (impact on the atmosphere, water and forest resources, agricultural impact, solid waste, disturbed lands and objects of accumulated harm, as well as background impact).

The weight of the indicators was determined by interviewing experts representing the scientific community (leading experts in the field of integrated assessments of certain types of impacts or specialists in the field of environmental problems of the BNT), the expert community (leading analytical agencies developing environmental ratings), as well as the environmental management system of the regions included in the BNT. The inertial nature of the anthropogenic impact characteristic of municipalities within the boundaries of the BNT, as well as the general tendency to reduce the impact, has been revealed. At the same time, the absence of positive changes in the environmental state was noted, especially characteristic of the largest impact centers with their inherent unfavorable environment, which suggests the need to take measures to reduce the impact. The advantage of the methodology proposed by the authors can be considered the possibility of extending monitoring in the future, which opens up the possibility of using this algorithm to assess the environmental situation and form environmental policy priorities. The analysis of the results confirmed the quality of the integrated assessment methodology and showed that the districts, cities and towns of the BNT are highly polarized in terms of the level of anthropogenic impact concentrated in certain areas, primarily in the zone of atmospheric influence. The main strengthening of the AI is characteristic of municipalities located along transport corridors, the axis of which is the Trans-Siberian Railway, The Baikal–Amur Mainline and the «Power of Siberia» gas pipeline.

KEYWORDS: municipalities, municipal level, environmental policy, spatial development, integral index, dynamics of a comprehensive assessment of anthropogenic impact

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INTRODUCTION

One of the actual tasks of forming public guidelines for spatial environmental policy that investors and other interested parties can use for responsible investment or following the sustainable development agenda is the introduction of a permanent system for monitoring the environmental situation, which requires both a component-by-component assessment of individual indicators and a comprehensive anthropogenic impact (index AI). Differentiation of spatial characteristics of AI is characteristic of all levels of the administrative-territorial hierarchy, but the municipal level is of fundamental importance, since the scenarios of spatial development and closely related changes in anthropogenic impact (AI) are best displayed if municipalities are used as basic municipal «territorial cells».

Existing approaches to the assessment of regions or cities can theoretically be applied to the assessment of municipalities (at least at the level of municipal districts and urban/municipal districts) (Bityukova 2020; Kasimov 2017). For municipalities indicators of emission from stationary sources, water consumption, wastewater, household and industrial waste are important. However, the municipal level also has a number of limitations: financial weakness of local budgets, statistical support. The methodology for assessing the territorial differentiation of AI for municipal levels should be different: a fundamentally different level of detail is needed, a special method for calculating emission from mobile sources, the area of disturbed land, accounting for emission from furnace fuel in individual residential buildings, etc.

It is important that the municipal level allows to carry out assessments, ignoring the borders of regions, since the same type of municipalities from different regions have much more in common with each other than different types of territories within the same region. The Baikal Natural Territory includes the municipalities of three regions, on the territory of which the lake water protection zone is located. Baikal, the catchment area within the territory of the Russian Federation, as well as specially protected natural territories, which is regulated by a separate federal law (Federal Law No. 94-FZ of 01.05.1999).

BNT is a unique natural and economic system, which, despite the enormous value of a unique natural object, is characterized first by a resource, and then (during the years of Soviet Union) and an industrial type of development. Along the Angara River, the Angara-Yenisei territorial production complex was formed, specializing in non-ferrous metallurgy, forestry and woodworking industry, hydropower. In the coastal zone of the lake there are a number of large cities, such as Irkutsk, Angarsk, Ulan-Ude, in which more than 1.3 million people live in total, there are a number of large industrial centers. Currently, the tourist and recreational resources of the region are becoming relevant. All this creates the need to monitor the anthropogenic impact on this territory in order to take effective measures to reduce it.

CURRENT STUDIES OF THE TOPIC

Studies devoted to the typologization of municipalities, as a rule, reveal contrasts and asymmetry in the development of socio-economic processes at the municipal level (Voroshilov 2019; Romashina 2019). O.V. Kuznetsova notes (Kuznetsova 2021) that the existing typologies of municipalities are actually the result of development of municipalities monitoring and not the basis for such monitoring, since they are based on an assessment of the current socio-economic situation of municipalities. This observation is also true in relation to environmental assessments at the municipal level. They are aimed at finding municipal differences for one region and differ in the goals and breadth of the indicators. Statistically available demographic indicators, volumes of emission, wastewater, agricultural development, as well as phenomena caused not only by anthropogenic, but by natural causes (in particular, the level of forest cover, the development of erosion processes) are most often used. The use of demographic indicators brings some simplification and modeling of specific impacts from the population on the natural environment. In the absence of detailed data for the level of municipalities, this is especially in demand for conducting integral and partial AI assessments (Igenbayeva 2006; Kropyanko 2014; Saprin 2017). Indicators of the natural components state (acidification and salinization of soils, biological and chemical contamination of drinking water sources (Barnaeva 2011; Ovchinnikova 2012), population health (Kuprienko 2006), the degree of anthropogenic transformation of the landscape (Ulengov 2008), the coefficients of population and production concentration or AI correlated with the potential of environmental sustainability (Ugarova 2005; Rybkina 2005) are used less often.

Researches devoted to integral environmental assessments abroad began to develop earlier than in the USSR on the way from social to ecological, combining the ecological situation with economic development and social progress. The municipal level is represented by estimates of cities (The Urban Sustainability 2012; City Prosperity 2017; Sustainable Cities... 2015; The Green City 2012). In Soviet and Russian practice, environmental indexes appeared earlier, leading positions among them were taken by AI Indexes based on statistical indicators (Kasimov et al. 2014).

Long-term foreign experience reflects the methodological incompatibility of the indexes, the lists of evaluation factors differ, which range from a bias towards documentation of mechanisms to the assessment of quantitative variables such as polluting emissions. Thus, a study in the discrepancy of ESG ratings according to different methods of Kinder, Lydenberg and Domini, Sustainalytics, Moody's ESG, S&P Global, Refinitiv, MSCI, conducted in 2022, revealed the reasons for the discrepancy of ratings assigned to the same object. At the first stage of any assessment, the coverage of the initial elements is determined – it accounts for 38% of the divergence, the discrepancy in the assessment of the initial elements (variables) accounts for 56%, and the differences in the weights of the elements account for the remaining 6% of the divergence (Berg et al. 2002).

In addition, the evaluation criteria for the same element may differ. The most popular approach in building an assessment scale based on the intensity of private impacts on the environment is the method of rationing, mainly using the linear scaling procedure, the second most popular method is ranking, i.e. ranking territorial cells from the minimum value to the maximum. Less numerous are works where a different system of ordering particular indicators is used: a binary system (Kadashova 2011), a point or categorical system (Kalikhman 2010; Barneva 2011; Saprin 2017).

A review of an extensive set of publications in recent years devoted to the widest range of BNT problems allows us to conclude that integrated assessments of various types of anthropogenic impact for this territory have not

yet been carried out, but at the same time numerous problems of the territory have been deeply investigated (Vladimirov et al. 2016; Ecological Atlas 2015).

MATERIALS AND METHODS

The methodology of integral indicators proceeds from the general principles that determine the effectiveness of an integral indicator for monitoring purposes: managerial targeting, multilevel targeting, theoretical validity, reliability and sensitivity, single-criteria and decomposability, informativeness, conciseness (Ayvazyan 2012). The municipal level of assessment most fully meets these principles.

The problem of the harmonized AI assessment is that there is no a posteriori set of indicators, unification of measurement scales and a mechanism for interpreting the parameter assessment itself. Based on these principles and taking into account the significance for the BNT, the following were selected as initial elements (subindexes) and variables for their evaluation.

For the subindex of AI on the atmosphere, quantitative variables were calculated on the basis of official statistics (the density of pollutant emission from stationary sources based on the area of built-up land, from motor transport and small vessels, thousand tons/km of the route network, the toxicity coefficient of emissions), and emissions from autonomous heating systems calculated on the basis of statistical data were also used about the number of households, decryption of satellite images, survey of the population and heads of settlements.

The subindex of anthropogenic impact on water resources integrates indicators of water intake, wastewater discharge, and polluted wastewater discharge per capita of the permanent population. The need to use two indicators of wastewater discharge is due to the fact that wastewater discharge mainly includes warm wastewater from fuel energy facilities, while polluted wastewater comes from industry and housing and communal services, their share varies from 10 to 100% for municipalities of the BNT.

The "Waste" subindex includes the density of solid municipal waste generated and the reduced volume of industrial waste, taking into account hazard class I-V.
Agriculture is a specific area type of load, which is described by the share of farmland in the area of the municipalities, the share of acreage in the total area of farmland, the density of cattle per pasture area.

Taking into account the specifics of the BNT, the subindex "Disturbed lands and objects of accumulated harm" was included in the methodology. The area of the disturbed lands was calculated by the method of visual decoding of high-resolution satellite images Sentinel-2, Landsat-8, WorldView-1, WorldView-2 with further verification of key areas during the expedition research. Information about the localization of deposits of various types of minerals was obtained using an interactive electronic map of subsoil use of the Russian Federation (openmap.mineral.ru), which is accessed through the Internet portal of the Federal Agency for Subsoil Use (rosnedra.gov.ru). By means of GIS, the areas of all contours of disturbed lands were obtained for each time slice, and their dynamics for the period from 2014 were estimated by 2020 in the context of municipalities of the BNT and in the context of settlements of the Central Ecological Zone (CEZ) (Environmental monitoring ... 2009). The objects of accumulated harm include non-recultivated production zones, storage sites of accumulated waste of hazard class I-II, sludge accumulators of waste of hazard class 3, but located near Lake Baikal or rivers flowing into the lake.

The subindex "Background impact" is designed to reflect those types of loads that are not reflected in statistical indicators. The density of the permanent population allows to simulate the intensity of the impact on the environment from everyday (non-productive) life. The density of roads characterizes the degree of transformation of the natural landscape, creates opportunities for the use of resources, pollution of land resources, penetration of the population into the territory, etc. The density of persons (tourists) staying in collective accommodation facilities for the period of rest has a comparable effect with the permanent population on AI. The level of motorization indirectly reflects the intensity of traffic for a territory with an average type of settlement over long distances between settlements.

The most important element for BNT is the impact on forest resources. This is the most unstable type of load, which is determined by both natural and socio-economic factors. It is described by indicators of the proportion of forests that died under the influence of adverse factors, passed by fires and the ratio of the actual volume of wood harvesting to the maximum allowed.

The method of constructing the integral index of AI provides for the possibility of not only its territorial, but also temporal comparison. The key point for the possibility of dynamic use of the integral index is the choice of normalization using stable reference points. The normalization of the indicators included in the index is carried out according to the linear method according to the data for 2014-2020, therefore, the determination of the value of each indicator takes into account the values for the entire period under consideration. At the same time, limitations in the availability of data on some indicators in the context of municipalities in different years lead to the fact that the number of indicators taken into account varies in different years. For this reason, it is necessary to take into account that the dynamics of the index may be due not only to objective reasons for changes in anthropogenic impact, but also to subjective reasons for differences in the completeness of statistical data.

In order to neutralize the influence of statistical outliers, the so-called interquartile interval method was used to determine the rationing boundaries. Its essence consists in allocating a rationing interval cleared of emissions and assigning a minimum or maximum value to emissions (0 or 1 if the rationing interval is taken as [0;1]). The value of the interquartile interval is calculated as the difference between 75 and 25 percentile elements. After determining the interquartile distance, the normalization boundaries [a;b] are determined by formula 1.

$$\left[x_{25}-1.5\times\left(x_{75}-x_{25}\right);x_{75}+1.5\times\left(x_{75}-x_{25}\right)\right] \quad (1)$$

where x_{25} and x_{75} 25 and 75 percentiles of the indicator distribution,

$$a=x_{25}-1.5\times\left(x_{75}-x_{25}\right), b=x_{75}+1.5\times\left(x_{75}-x_{25}\right)$$

The final normalization of all observations is made according to the formula 2:

for $x_i \varepsilon$
$$x_i \varepsilon [a;b] - x_i^n = \frac{x_i - a}{b-a} \quad (2)$$

where x_i^n – normalized observation value, a and b are defined in formula 1;

for
$$x_i > b = 1; for\ x_i < a = 0$$

To assess the significance of various indicators, 47 experts from different fields of science, different scientific schools, academic institutes and universities, experts in the field of environmental ratings and representatives of the environmental management system in the territory of the BNT were interviewed. The weight of each indicator was determined as the average value of the scores set by experts in the range 1-9.

The integral index of anthropogenic impact (IAI) is calculated as the sum of the average values of the sub-indices and theoretically can vary in the range [0:1]. In order to exclude the influence of a subjective factor in assessing the integral index of anthropogenic impact, when considering its dynamics for 2014-2020, the «Waste» block was excluded from its composition due to the lack of basic statistical data for the period 2014-2018. The choice of the period for assessing the dynamics is due to minimal changes both in the methodology of environmental indicators and in the economy of the regions. It is especially important for the BNT that the largest source of pollution, the pulp and paper mill in Baikalsk, was closed before this period, further development of the territory will take place while preserving the remaining sources.

DISCUSSION AND RESULTS

The dynamics of the AI index for the period 2014-2020 for all 41 municipalities included in the BNT shows a wave dynamic: from 2014 to 2016, there is an increase in the average and median value of the index – from 0.283 to 0.308 (+7.2%), since 2017 - its gradual decrease – to the level of 0.269 (-12.8% of the local maximum). Such dynamics may indicate a reduction in the level of anthropogenic impact in municipalities in recent years.

The municipalities included to the BNT demonstrate a relatively stable level of the IAI, the leaders and outsiders retain their positions, which indicates that the results obtained are not accidental (Fig. 1).

The cores of environmental tension localized in the Irkutsk-Angara agglomeration with an equal contribution of all subindexes, as well as the districts ... (Selenginsky, Petrovsk-Zabaikalsky, Mukhorshibirsky municipal districts) are among the leaders.

The group of areas with an increased level of anthropogenic impact has expanded during the period under review. There are urban municipalities that have an increased level of background impact due to the population, the average value of the AI subindex on the atmosphere and water resources (urban districts of Ulan-Ude, Severobaikalsk, Petrovsk-Zabaikalsky, Svirsk and Shelekhovskoye municipality). The impact increased in suburban and coastal areas (Tarbagataysky, Irkutsk, Slyudyansky), in areas with developed mining (Bichursky, Cheremkhovsky, Krasnochikoysky), as well as in the peripheral Kazachinsko-Lena district, where the main impact on water and forest resources is formed as a result of the implementation of the «Power of Siberia» gas pipeline project.

The medium level of AI remained in a small number of rural areas and small towns with an average level of impact of agriculture and forestry (Usolsky and semi-peripheral Kyakhtinsky districts, as well as districts of Ust-Ordynsky district) due to the fact that this group left areas in which the impact increased.

The reduced level of AI is formed mainly in semi-peripheral municipalities. Due to the absence of large sources, the level of impact is quite stable, but the ratio of

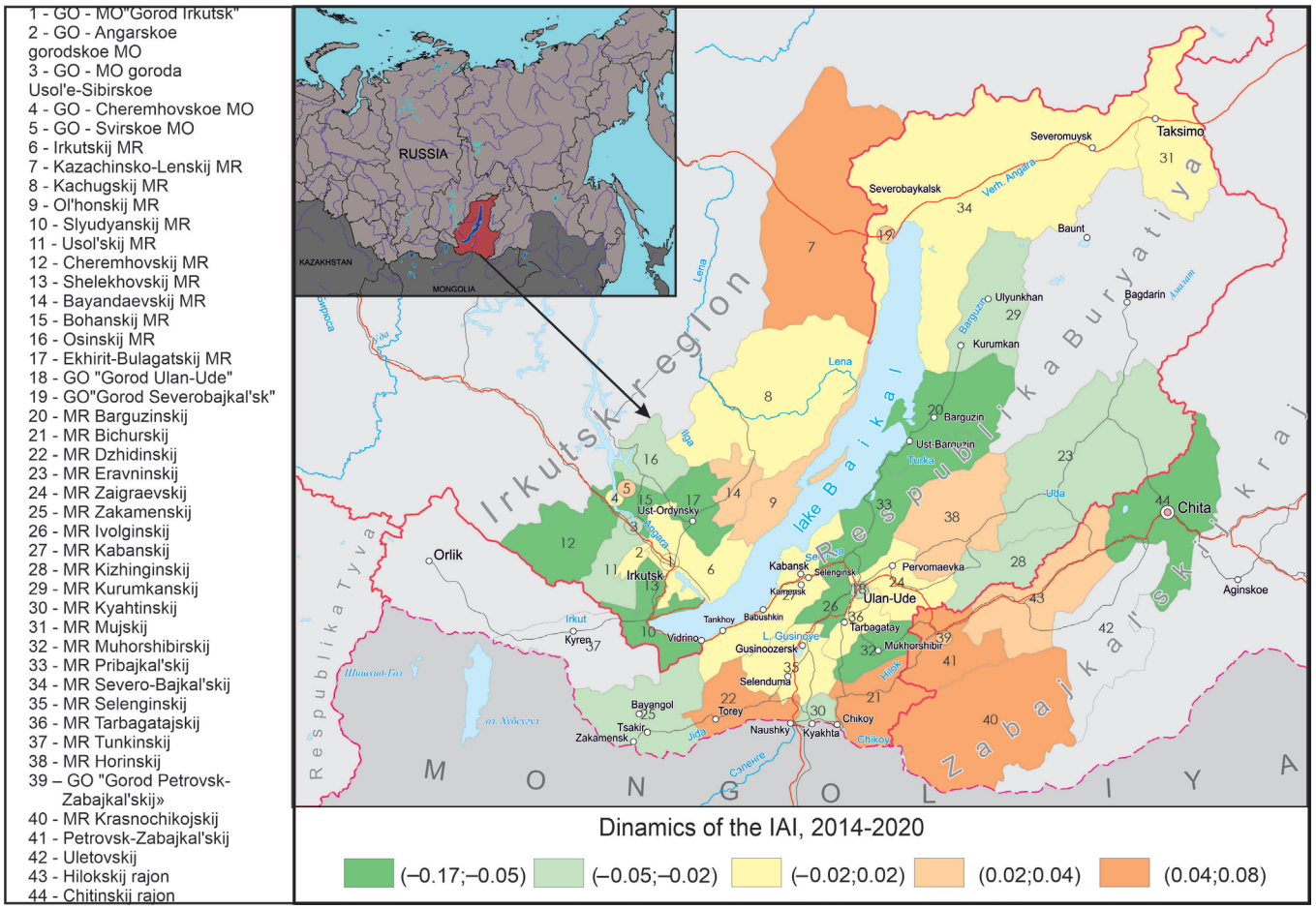

Fig. 1. Dynamics of the AI index in 2014-2020 in the municipalities of the BNT

Source: authors' calculations

subindixes is constantly changing, since the main role is played by unstable impacts on forest resources. In some suburban areas with developed agriculture and relatively high development density (Baikal, Ivolginsky and Chita in the part included in the BNT districts), the level of motorization and development is changing. In Khiloksky, Dzhidinsky and Zaigraevsky districts, the damage caused to forest resources is reduced in the index structure. In Kabansky district, atmospheric pollution has decreased as a result of the introduction of new cleaning systems at the pulp and cardboard mill, but the background impact has increased as a result of the life of the population and recreation.

Districts with low AI levels are the most stable group. The index of anthropogenic impact is characterized by moderate but increasing values of the background and agricultural sub-indices. Stability is also promoted by a relatively high proportion of atmospheric pollution from heating oil.

Among the municipalities included in the BNT, for the period 2014-2020, 14 demonstrated significant dynamics (deviation by 20% or more from the values of 2014): in 5 of them, the IAI significantly increased. Among the municipalities included in the BNT, for the period 2014-2020, 14 demonstrated significant dynamics (deviation by 20% or more from the values of 2014): in 5 of them, the AI index significantly increased (Krasnochikoysky district +37.5%, Bichursky district +26.6%, Olkhonsky district +24.8%, Djidinsky district +24.3%, Petrovsk-Zabaikalsky district + 20.6%), decreased significantly in 9 (Chitinsky D district -47.1%, Bokhansky district -32.7%, Mukhoshibirsky district -29.5%, Ivolginsky district -26.9%, Shelekhovsky district -25.7%, Pribaikalsky district -24.8%, Barguzinsky district -24.3%, Slyudyansky district -23.4%, Cheremkhovsky district -22.5%).

The high relative increase in the index of anthropogenic impact in 2014-2020 in 5 municipalities is associated with various reasons. In the Olkhonsky district, a small absolute increase due to the effect of a low base led to a relatively high increase in the integral indicator. At the same time, the main contribution to the increase in the index was made by the block "Background impact" due to intensive motorization of the population. In the Krasnochikoysky district, the impact on the block of indicators "Water resources" increased significantly, to a lesser extent, the increase was associated with an increase in the area of disturbed land. All this is connected with the development of the gold mining industry in the municipality. Mining (coal mining) is also associated with growth in the Petrovsk-Zabaikalsky district due to an increase in production at the Tigninsky field (Fig. 2).

In the group of municipalities with the maximum relative decrease, the key reason for the decrease in the integral IAI is the reduction of the component of the impact on forest resources (Fig. 3) in all municipalities, and in the Barguzinsky and Ivolginsky districts – also the impact on water resources.

A component-by-component analysis of the integral index of anthropogenic impact (based on median values for all municipalities) allows us to identify the causes of dynamics for 2014-2020. (Fig. 4). A steady upward trend is characteristic of the block of indicators "Background impact", which is associated with the trend of increasing motorization of the population and an increase in the density of highways on the territory of the BNT. The territorial mobility of the population is steadily increasing, which causes, on the one hand, an increase in the consumption of motor fuel, and on the other hand leads to an increase in the degree of "penetration" of the population into the territory – the frequency and mass of visits to the landscapes surrounding settlements.

The impact on the block of indicators "Agriculture" is relatively stable (a decrease of 7.3% for 2014-2020). This is due to the relatively conservative situation in the area of agricultural land, as well as the downward dynamics in the intensity of land plowing and cattle breeding on the territory of the BNT. The latter trend is largely due to the processes of depopulation of the rural population and the refusal to keep pets in private subsidiary farms of the population.

The subindex characterizing the impact on the atmosphere demonstrates low volatility: the median value for all municipalities decreased by 6.6% in 2014-2020. The highest relative level of reduction (more than 20%) was recorded in Zaigraevsky (-39.3%), North Baikal (-31.2%) districts, as well as a group of municipalities of the Irkutsk region located in the zone of atmospheric influence of the BNT: Bayandaevsky (-55.2%), Ehirit-Bulagatsky (-57.3%), Bokhansky (-32.4%), Osinsky (-36.1%) municipal districts. The growth of AI in the block of indicators "Atmosphere" by 20% or more is noted in three municipalities – Djidinsky district (+20%) of the Republic of Buryatia, Irkutsk (+60.6%), Olkhonsky districts (+59.1% but from a low base level) Irkutsk region and in the town of Petrovsk-Zabaikalsky (+40.9%) of the Zabaikalsky krai.

The upward dynamics in these municipalities is associated with an increase in the emission of pollutants into the atmosphere from stationary sources and vehicles, the number of which is constantly increasing.

A small dynamism is characteristic of the block of indicators characterizing disturbed lands and the presence of objects of accumulated harm. The development of new mineral deposits leads to an increase in the area of disturbed lands, while the reclamation process does not compensate for their new areas. Noticeable dynamics is typical for a small number of municipalities in the Irkutsk region, Shelekhovsky (+42%) and Usolsky districts (+120%), as well as Krasnochikoysky district (+30%) and Bichursky district (+73%) stand out against the general background.

The greatest changes in the subindex and, as a result, the maximum contribution to the dynamics of the entire index of anthropogenic impact is made by a block of indicators of impact on forest resources. This is due to a set of indicators in the block, the volatility of which is very high from year to year and is associated with the death of forests, the scale of which, due to natural and anthropogenic reasons, can vary many times from year to year (fires, forest diseases). During the period 2014-2020, the median value of the subindex was reduced by almost two times, and from the peaks reached in 2015-2016 – by more than 4 times. The main reason for the reduction is the reduction of the area of forests that died from adverse factors and the area of forests covered by fires. According to statistics, in 2015, 1.18 million hectares were affected by fires on the territory of the BNT, and in 2020 it was 9 times less – only 0.14 million hectares; the difference in the area of dead forests from unfavorable factors in 2015 (taken into account according to 2016 statistics) and in 2020 also reduced by 8 times.

The key impact on forests within the BNT, where industrial exploitation of forest resources is limited (and actually prohibited within the Central Ecological zone (CEZ), are fires and diseases, the spread of which is facilitated by human activity or, conversely, inaction associated with improper care of forest resources.

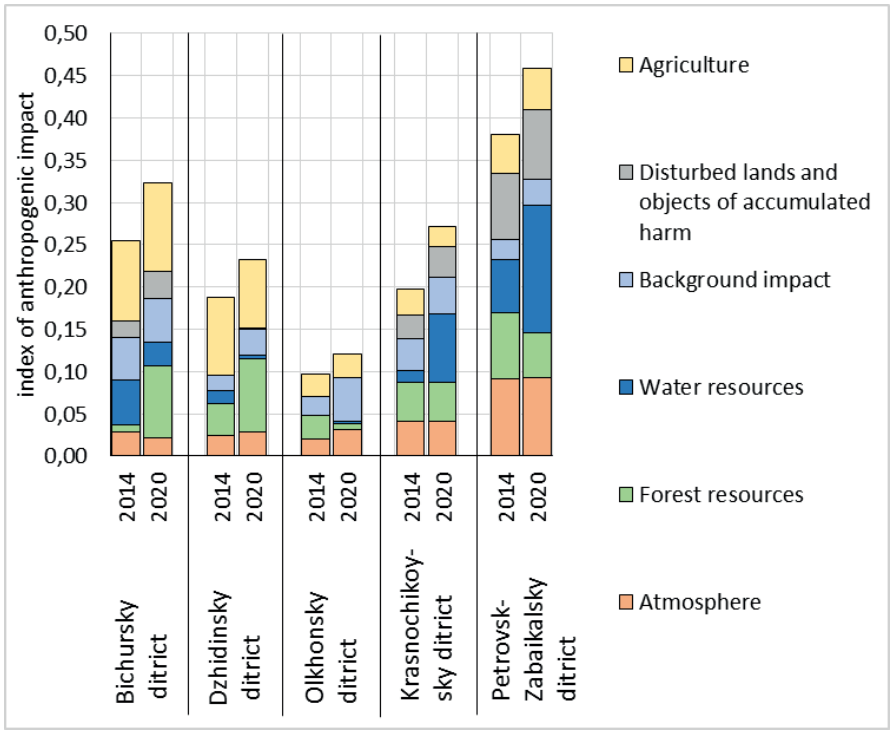

Fig. 2. The structure of the AI index for the municipalities of the BNT, which showed the maximum relative increase in 2014-2020

Source: calculated by the authors

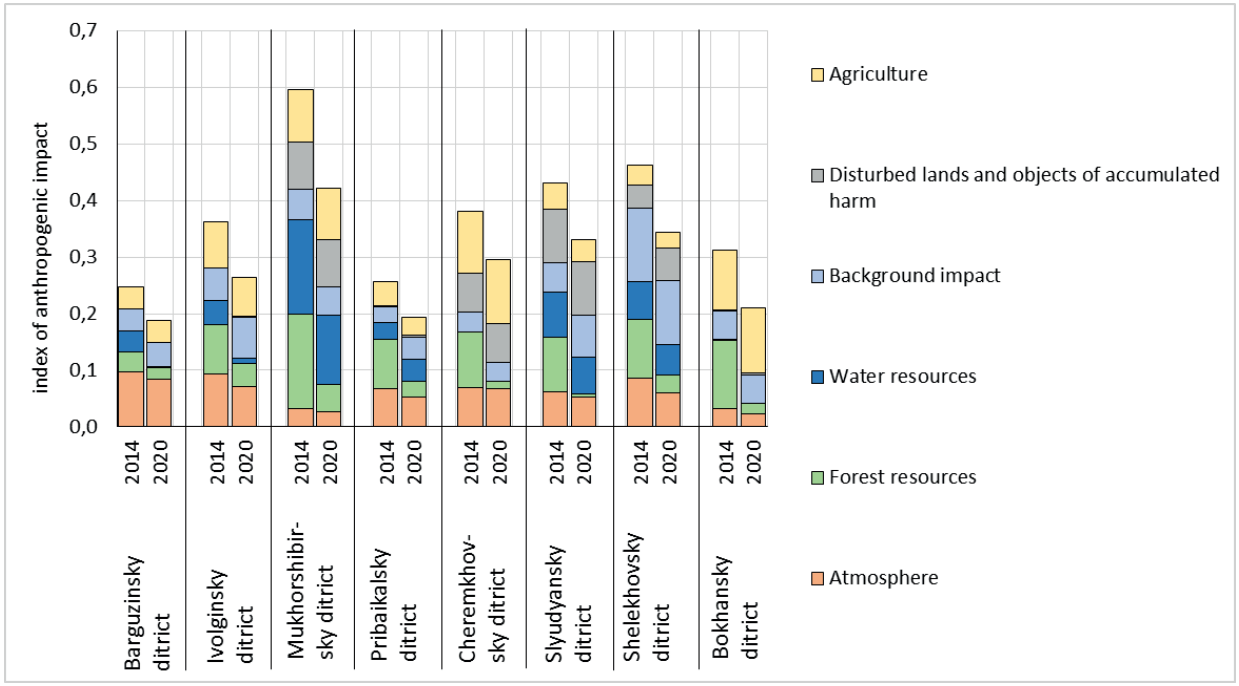

Fig. 3. The structure of the AI index for the municipalities of the BNT, which showed the maximum relative reduction in 2014-2020

Source: calculated by the authors

Most of the fires in the Baikal forests are associated with anthropogenic factors (Evdokimenko 2013), and shortcomings in the organization of work and financing of forestry enterprises, lack of technical capability and inaccessibility of forests within the BNT, create favorable conditions for the development of wildfires and the death of forests from diseases (for example, from bacterial dropsy that affected the forests of the southern Baikal region). There are legal conflicts: for example, the actual impossibility to organize the arrangement of mineral strips around settlements in the CEZ or to organize continuous sanitary logging of affected areas of protective forests. This does not allow solving the pressing problems of forest management. In this regard, the reduction of the subindex of the impact on forest resources should not be misleading. It was achieved rather not by reducing the impact or more rational use of forest resources, but due to the high base of previous years – large-scale forest loss (2015-2016) at the beginning of the study period, against which the current values due to more favorable weather conditions are lower.

The relative increment of the IAI index is important for tracking the dynamics of anthropogenic impact, however, without taking into account the base position of the municipality in 2014, it is difficult to draw conclusions about the absolute scale of the impact transformation. To

do this, it is necessary to consider the increment of the IAI by its absolute value (Fig. 5).

The maximum increase in absolute terms among the municipalities of the BNT occurred in three municipalities in the south-east of Lake Baikal: Petrovsk-Zabaikalsky and Krasnochikoysky districts of the Zabaikalsky krai and Bichursky district of the Republic of Buryatia. We can say that a fairly large area of increased anthropogenic impact on the environment has been formed. The main reasons for the increased impact are the development of the mining industry in these municipalities, primarily the development of coal and placer gold deposits. Despite the sufficient distance from the lake, the reasons for the increase in the impact and the nature of the spread of possible consequences (through runoff through the hydrographic network) suggest an increase in the potential danger of anthropogenic activity for Lake Baikal.

In the Kazachinsko-Lensky district of the Irkutsk region, the increase in anthropogenic load is also associated with the extractive industry (development of gas fields and construction of gas transportation infrastructure), and in the Dzhidinsky district of the Republic of Buryatia – with an increase in the impact on forest resources.

The second group of municipalities that showed a weak growth in the IAI (about 0.02 units) is represented by seven territories scattered across various parts of the BNT. It is impossible to single out a single reason for increasing the IAI for them, it is individual for each municipality. 12 municipalities demonstrate insignificant dynamics of IAI, 8 municipalities show a slight decrease (in the range of 0.02-0.05 units), 10 municipalities show a significant decrease (more than 0.05) (Figure 5). The decrease in IAI in 18 municipalities is primarily due to the contribution of a block of indicators of impact on forest resources.

The observed dynamics of the IAI in 2014-2020 and its subindexes allows us to make some assumptions about the nature of its changes in the near future. First of all, it is worth considering that the background impact on the environment from daily human activities will, most likely, increase. This is due to the increase in spatial mobility of the population – the growth of motorization, construction and modernization of highways in the BNT zone. Despite the fact that the rural population density in the absolute majority of municipalities will continue to decline for natural reasons, in large cities it will decrease much more slowly in the near future. The temporary population, especially in the context of the development of domestic tourism, which has been experiencing an upswing in recent years against the background of a decrease in outbound tourist traffic, on the contrary, will increase. At the same time, the existing infrastructure (communal, household, recreational) is clearly insufficient to meet all current needs. Of particular importance in this case is the high degree of concentration of exposure from the temporary population, which is localized in a small number of tourist destinations directly on the lake shore.

There are also few prerequisites for reducing IAI by decreasing the impact on the atmosphere, water resources, and reducing the areas of disturbed land. The industrial profile of the municipalities' economy will remain in view of the high inertia of the economy of the Baikal regions focused on the exploitation of natural resources. Some prospects for reducing the impact are possible if a large-scale program of gasification of the territory is implemented, which will allow the energy and utility sector to switch from coal to natural gas. However, given the current pace of construction of gas transportation infrastructure, this is possible only in the medium and long term.

The impact from agriculture, due to the inertia of the branch, has few prospects for a significant reduction. The crop industry plays a vital role for the local population, and abandoning it does not meet the interests of food security in the region. Reducing the impact of the livestock industry is possible in the case of the development of intensive industrial enterprises that operate taking into account all modern requirements for environmental protection, but this will require large-scale investments. The impact from private households in the foreseeable future will decrease due to the natural causes of a decrease in the density of the rural population.

The greatest concerns about the reversal of the dynamics of the IAI are caused by the impact on forest resources. The accumulated problems in the industry after the adoption of the Forest Code are increasing every year, creating prerequisites for the death of forests from anthropogenic and natural causes. The question of when

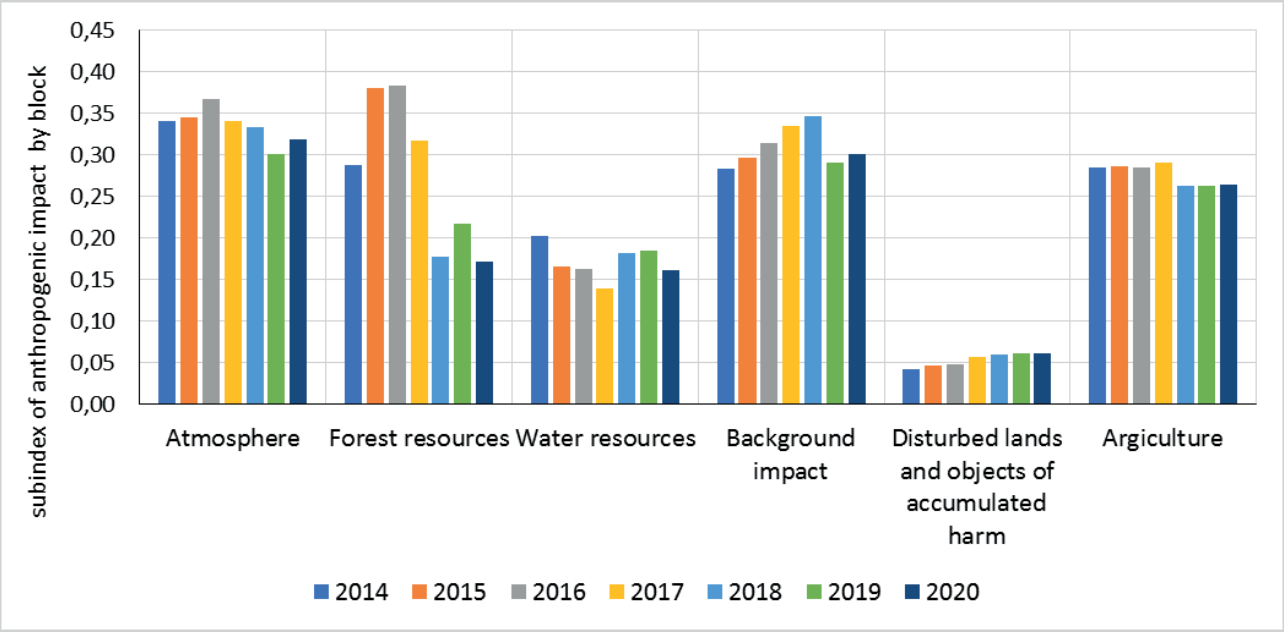

Fig. 4. Median values of private indexes of anthropogenic impact by indicator blocks, 2014-2020

Source: authors' calculations

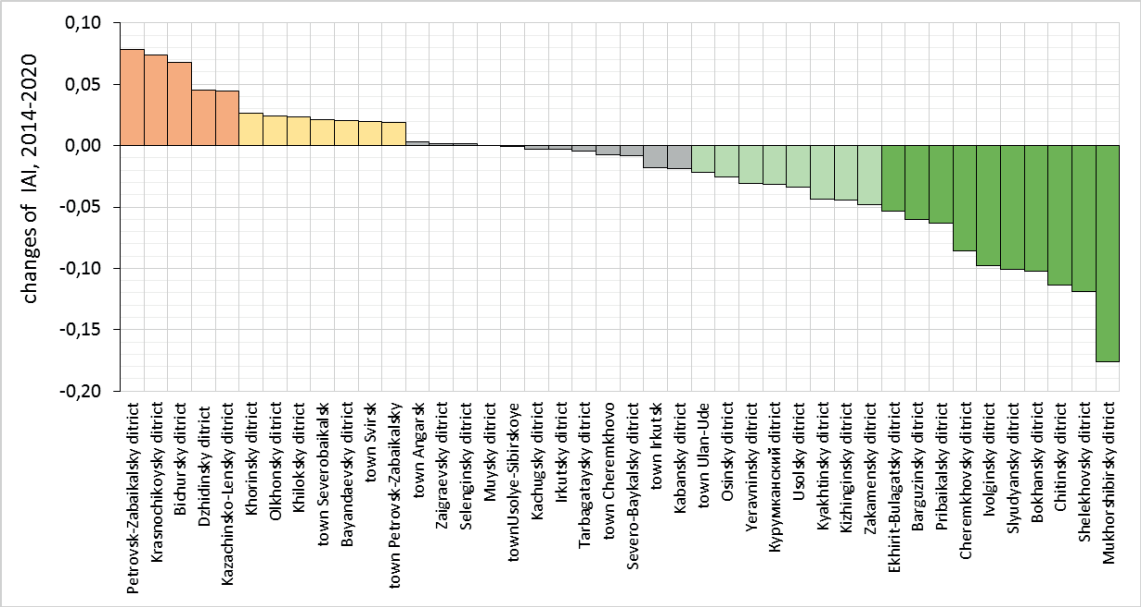

Fig. 5. Dynamics of changes in the absolute value of AI in the municipalities of BNT for 2014-2020

Source: calculated by the authors

they are realized in the form of the loss of these resources is only a matter of time and weather fluctuations. Unlike all other areas of influence, in this direction it can be realized in the shortest possible time.

CONCLUSIONS

The elaborated method of integral assessment of anthropogenic impact made it possible to trace the change in the load in retrospect. The analysis of the results confirmed the quality of the integrated assessment methodology and showed that the districts, cities and towns of the BNT are highly polarized in terms of the level of anthropogenic impact concentrated in certain areas, primarily in the zone of atmospheric influence. The main strengthening of the AI is characteristic of municipalities located along transport corridors, the axis of which is the Trans-Siberian Railway, The Baikal–Amur Mainline and the «Power of Siberia» gas pipeline.

1. The average (median) values of the integral index of anthropogenic impact on municipalities for the period 2014-2020 has a general downward trend, in 2015-2016 its local increase was observed;

2. Municipalities included in the Baikal Natural Territory demonstrate a high level of stability IAI, which indicates the inertial nature of the anthropogenic impact associated with the accumulated impact actors on their territory. Low volatility indicates the adequacy of the methods used to assess AI;

3. The contribution of the assessment indicator blocks to the overall dynamics is different: the upward trend is realized through an increase in background exposure from the population and an increase in the area of disturbed land; the decrease in the IAI is associated with a reduction in the impact of agricultural activities, partly due to a reduction in the impact on the atmosphere, but especially large due to a reduction in the impact on forest resources. The latter trend, however, is also related to natural causes and should not be misleading when assessing the real causes of changes in IAI.

4. The differences between the buffer zone and the atmospheric pollution zone are gradually decreasing, since the impact of the largest sources is decreasing on the west bank, accumulated damage objects are being eliminated, in the buffer zone the impact on forests, disturbed lands and even emissions are slightly increasing.

The absence of positive changes in the ecological state indicates the need to take measures to reduce the level of impact, primarily in the largest centers, the environmental situation in which remains unfavorable. An important advantage of the presented algorithm is the possibility of its extension in the future to track trends and form priorities of intraregional environmental policy.

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