

# Transformation of environmental conditions in large former Soviet countries: regional analysis

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**Abstract.** The article studies changes in the structure of environmental conditions of regions in the large former Soviet countries (case study of Russia and Kazakhstan) that have formed considerable contrasts in the placement of industrial complex and population settlement during the previous development stages. The changes related to the transition to market economy have led to essential transformation of environmental conditions. A complex index allowing to assess changes at the regional level in Kazakhstan and Russia and to reveal main similarities and differences between those changes is applied to studying the transformation of regional and industry structure. The article examines both industry-specific and spatial patterns forming environmental conditions at the regional level.

## 1. Introduction

The collapse of the Soviet Union has significantly changed the structure and scales of anthropogenic impact in the former Soviet republics: despite the decrease in absolute measures, relative measures remain too high to state that the environment in the countries is in a satisfactory state [1-5].

Transition to market economy in the former Soviet countries has transformed the scales and geographical structure of anthropogenic impact: a number of industries have been completely reorganized (both in terms of environmental and economic efficiency and in terms of location), some industries have disappeared, while others have appeared only after 1991; millions of people have moved, changing the structure of settlement; new borders have disturbed some economic ties and created new ones; and active state and private investment into new hubs of economic growth has led to new sources of impact.

At the same time the environmental conditions in the industrially developed former Soviet countries rich in natural resources, in particular, Russia and Kazakhstan, still bear the features inherited from the period of the Soviet industrialization [6, 7]. Their role can be revealed through a comparative study of the two countries, the industrial complex of which was formed within a single space.

Integral index of anthropogenic impact has been developed in order to assess changes in environmental conditions in the regions of the Russian Federation and the Republic of Kazakhstan. The scale and method of the research were chosen based on availability of statistical information for various levels and time periods, comparability of environmental indicators in Russia and Kazakhstan and adequacy of the available statistics [8, 9].

Integral indices of environmental conditions started to appear almost simultaneously in the USSR and in the West. But, differences in development conditions of this research method and in its



purposes, impossibility of sharing practices predetermined separate ways already at the initial stage of formation of complex indices. Generalizing the experience of foreign scientists, governmental and international commissions available in this field, it is possible to identify a number of features. First, the use of basic indicators (GDP, gross domestic savings, net domestic product) normalized based on the cost estimate of depletion of natural resources, ecological damage, natural capital [10, 11]. Second, integral indicators of sustainable development (ecological sustainability, real progress, etc.) including both indicators of quality of life and ecological indicators [12 - 15]. The third important feature is the initial orientation towards the search of indicators reflecting a contribution of the countries to global problems, i.e., ecological footprint, living planet index [16]. And finally, proper environmental indices based on either indicators of anthropogenic impact (air emissions, waste water) or "environmental efficiency" (impact of an ecological factor on human health and ecosystems) [17, 18].

Large former Soviet countries, such as Kazakhstan and Russia, require a multiscale environmental research: country assessments lacking a regional component are unacceptable for countries as vast as they are. Subregional assessments are even more promising, however, the ecological statistics at the level of districts and municipalities is too scarce for a comprehensive complex assessment of anthropogenic impact over time. Thus, two levels have been chosen for the research: country and regional, allowing assessment of industry-specific and territorial shifts of areas of anthropogenic impact over time.

Key problems faced by researchers while elaborating a technique for impact assessment at the regional level are a weak statistical base, frequent change of calculation procedures and incomparability of some indicators within intercountry comparisons due to various approaches to measurements and calculations. For example, a key group of indicators highly relevant for the assessment of anthropogenic impact in the Russian regions connected with the impact on forest resources is less relevant for Kazakhstan. Taking into account a common group for conventional forests and haloxylon desert woodlands in the Kazakhstan statistics, the use of indicators of impact on forest resources demands a careful approach and expert adjustment.

The main purpose of this research is to know how anthropogenic impact in Russia and Kazakhstan has changed by using the integral index.

## 2. Research method

Creation of the integral index included four main stages:

Stage 1. Selection of priority components. In this case, ecological indicators of almost all significant sources of impact were taken into account: production sector, power industry, motor transport, agriculture and forestry, population as a source of impact (through household waste and indirectly through other indicators), indicators of radiative effects and others.

Stage 2. Selection of indicators for each group was based on the principles of systematicity, reliability, availability of statistics, pronounced territorial differentiation, clearly interpreted dynamics. Each type of anthropogenic impact has a set of absolute and relative (specified in brackets) indicators:  $A_1$  – density of air emissions of the production sector and motor transport per the acreage of the cities, production sector, transport;  $A_2$  – coefficient of emission toxicity calculated as the ratio of emission volume normalized to a single toxicity to the gross air emission volume [19];  $B_1$  and  $B_2$  – respectively, share of water consumption and wastewater discharge in surface-water supply;  $C_1$  – solid waste density in view of their hazard class;  $C_2$  – share of disturbed industrial lands;  $D_1$  and  $D_2$  – share of cultivated and reclaimed lands respectively;  $D_3$ ,  $D_4$  and  $D_5$  – mineral, organic fertilizers and pesticides respectively per 1 hectare of arable lands;  $D_6$  – cattle livestock per the area of pastures;  $E_1$  – share of total standing volume of cut timber;  $E_2$  – the area of felling per calculated cut;  $E_3$  – share of unauthorized felling;  $F_1$  – share of inhabitants in radioactive contamination zones;  $F_2$  and  $F_3$  – soil pollution density with  $^{137}\text{Cs}$  radionuclides of the forests and the area respectively;  $F_4$  – share of lands of the cities, production sector, motor transport polluted by radionuclides;  $F_5$  – share of lands of former nuclear test sites and major accidents related to radioactive pollution.

Stage 3. Translation of initial value matrix for assessment indicators into values normalized for addition of different-sized indicators. The following criteria can be used when selecting normalization principles: the nature of asymmetry of separate indicators, their contribution to the final assessment and interpretation of the totals. While searching for an optimum normalization principle, three most widespread methods were applied: ranking, linear scaling and logarithmic scaling. Logarithmic scaling proved to be the most acceptable method for the integral index. For the first time suggested for assessment of territorial differences of anthropogenic impact in the Russian regions, this method not only removes excessive differences of indicators but also adequately reflects the increasing pollution level parallel to the growing integral index (equation (1))[20].

$$X = \frac{\log_{x_{\min}} X_i}{\log_{x_{\min}} X_{\max}} \quad (1)$$

$x_i$  – index value in  $i$  region.

Stage 4. Integral index of anthropogenic impact (IAI) is calculated through the aggregation of group average values for the above-mentioned normalized indicators according to the formula (2):

$$IAI = \left(\frac{A_1 + A_2}{2}\right) + \left(\frac{B_1 + B_2}{2}\right) + \left(\frac{C_1 + C_2}{2}\right) + \left(\frac{D_1 + D_2 + D_3 + D_4 + D_5 + D_6}{6}\right) + \left(\frac{E_1 + E_2 + E_3}{3}\right) + \left(\frac{F_1 + F_2 + F_3 + F_4 + F_5}{5}\right) \quad (2)$$

In order to make the assessment more objective, two calculation options were applied to the integral index: the index of the power of anthropogenic influence (PAI) based on absolute measures and the index of the intensity of anthropogenic influence (IAI) based on relative measures. Use of both absolute and relative measures is especially important taking into account large regions in the studied countries. Application of absolute or relative measures depends on the research objective. If it is focused on the impact on the natural landscape or population health, absolute values are more justified as the whole volume of pollutants caused by a source spreads in the landscape and influences the population.

### 3. Results

Integral IAIs were calculated for four time periods: 1990 – the beginning of the transition period, 1998 – the end of crisis, 2003 – the end of the first stage of compensatory growth, 2014 – the most recent statistics available. In general, the results have demonstrated the adequacy of the developed technique for identification of territorial differentiation of environmental conditions in large countries.

The total index has shown a high, though reducing degree of interregional distinctions in terms of the intensity of environmental pressure on the territory of the two countries (from 3.6 to 1.8 times during 1990-2014) (figure 1). Various changing trends in individual factors have also determined the dynamics of the complex regional index after the collapse of the Soviet Union.

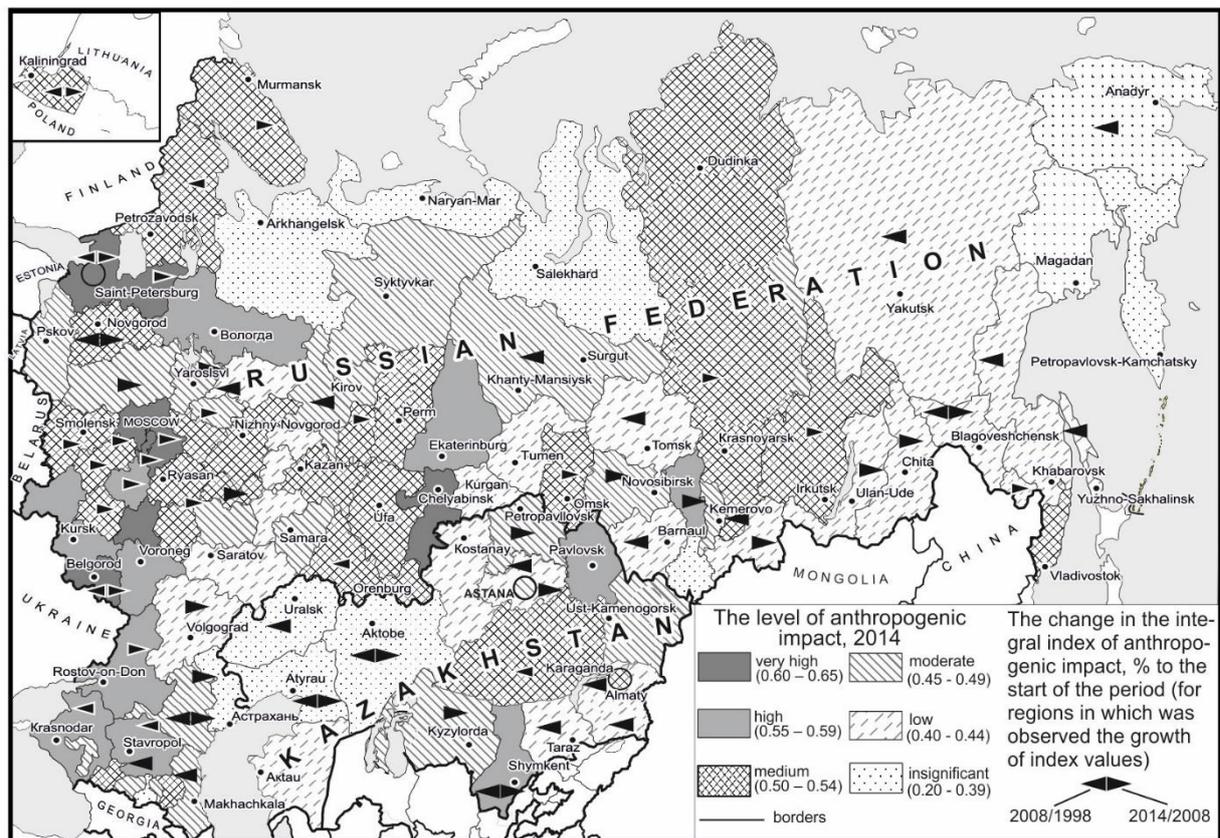
Decreasing AI has become an underlying trend, and internal fluctuations corresponded to the dynamics of economic indicators. At the same time in the early 2000s, during the maximum increase in oil prices, pollution volumes moved to the extracting regions with low population density. As the result, an export-oriented raw zone Taimyr – Yamal – Urals that concentrates over 55% of industrial production in the country and 70% of air emissions is distinguished based on the environmental pollution (especially, air emissions related to the combustion of associated petroleum gas). Unlike the majority of old developed regions where pollution is localized in the cities, the impact is dispersed across the territory in newly developed extracting regions.

Use of pollution density indices (as compared to absolute values of volumes) moves three types of regions down in rankings, both in Russia and in Kazakhstan. First, large regions with an intense but rather localized AI (Krasnoyarsk Krai, Tyumen, Karaganda, Arkhangelsk, Rostov, Vologda, Irkutsk). Second, regions with large rivers under serious anthropogenic pressure but with low density of impact (Novosibirsk, Omsk, Perm). Third, strong agro-industrial regions (Stavropol Krai, Altai Krai,

Kostanay) have seen an advancing production decline in the leading agricultural regions with the most intensive agriculture since the 1990s. On the contrary, industrial regions with localized impact (Tula, Lipetsk, Belgorod) and especially federal cities of the Russian Federation and cities of republican significance rise in ranking. Agricultural pressure exacerbates ecological stress in the Black Earth and southern regions of the Russian Federation, as well as in traditionally agrarian regions of Kazakhstan – North Kazakhstan and Akmola.

However, centers of ecological stress, unevenly spread across the territory of both Russia and Kazakhstan, are the same for any assessment method. These are the Chelyabinsk, Sverdlovsk, Kemerovo, Moscow and Bryansk regions. All Russian macro-regions have regions with serious anthropogenic impact that distinguishes them from others. Old developed regions are characterized with a more evenly distributed impact density which is more localized beyond the Urals. In general, regional differences are rather balanced.

In Kazakhstan, the center of ecological stress, Pavlodar-Karagandy-East Kazakhstan area, has actually begun to smear during the considered period due to decreasing impact in the East Kazakhstan region and new centers of ecological stress: oil-extracting West and densely populated South of Kazakhstan.



**Figure 1.** Changes in the integral index of anthropogenic impact in 1998 – 2014.

Despite considerable economic shifts and transition to a new type of economy, the inherited factors still play a crucial role in the ranking of regions. Almost all regions with a very high level of anthropogenic impact have large industries since the USSR, that determine specialization of the region. The Chelyabinsk and Sverdlovsk regions and metallurgical and industrial centers of the European part of Russia, i.e., the Lipetsk, Vologda, Tula regions, are the center of regions with the greatest intensity of anthropogenic impact. Capital regions are an important part of this center: the

Moscow region suffers additional pressure due to an inflow of population and sources of impact, while the Leningrad region has high rates of IAI mostly owing to the industrial development. Radioactive pollution, though having reduced considerably, is still noticeable in the zones of accidents of the previous period (Bryansk and other regions affected by the Chernobyl accident and the Chelyabinsk region that still bears the footprint of the accident on the Mayak Production Association).

Environmental rankings of regions based on the complex index are an efficient way of determining the priorities of environmental policy. The integral index provides new insights into the complexity and versatility of the environmental conditions. Nevertheless, a clear understanding of calculation specifics of the complex indicator is necessary to make the ranking a convenient decision-making tool in terms of environmental control and environmental management. The selected AI measurement technique considerably affects the outcome. It is important to use AI density for large countries with isolated intense sources of impact and extensive unaffected territories. Moreover, Kazakhstan that has experienced essential changes of agricultural areas (arable lands, pastures have reduced in the regions by 30-50%) and urban lands during the land reform, has the territorial structure of the intensity integral index considerably changed towards increase since 2003, while the indices for 1990 and 1998 prove to be underestimated.

*Key factors maintaining territorial structure of AI areas in Russia and Kazakhstan are as follows:*

1. Inherited development. The largest AI centers in the territorial structure of Kazakhstan and Russia are still the regions where the industrial base was developed and formed in the Soviet period: the Urals and industrial regions of the European part, Pavlodar and Karaganda regions. Despite low efficiency and insignificant economic feasibility related to production and extraction of some minerals, a number of large enterprises seriously harming the environment continue to exist. It is all the fault of the existing structure of population settlement (miner's towns) and impossibility to move people from depressive monotowns. This factor is more typical of Russia than of Kazakhstan.

2. Institutional factor. Despite the stated models of the free market and general privatization, only few foreign companies could establish full control over large industrial enterprises in Russia that has contributed to the stability of the territorial structure of AI areas.

*Factors influencing transformation of AI territorial structure:*

1. Becoming part of the global resource market. Soaring hydrocarbon prices have caused active development of oil and gas fields in the East of Siberia and the Western regions of Kazakhstan. It created new AI centers in the Western Kazakhstan: increase in oil production of the Atyrau region from 2.5 million tons in 1990 up to 31.9 million tons in 2014, development of the Karachaganak oil and gas field in the West Kazakhstan region caused increase in oil production from 4 million tons in 1990 to 13 million tons in 2014.

2. Institutional factor. Emergence of the western companies in mining and manufacturing industry of Kazakhstan has reduced the level of environmental impact in terms of specific indicators, for example, Kazakhstan has almost half as much emissions than Russia per unit of oil produced. It influences the territorial structure of pollution areas: new industrial centers in Kazakhstan are less significant on a national scale than in Russia (based on relative measures).

3. State environmental policy. A weak state policy in relation to the oil companies has made Khanty-Mansi Autonomous Okrug a "leader" in air pollution for the first time in 2004-2007. Having doubled air emissions, the district "has outrun" Krasnoyarsk Krai. After signing the resolution "On measures to encourage the reduction of air pollution products flaring gas in flares" in 2009 which sets the target indicator of combustion of associated gas on flares of no more than 5% of the extracted associated gas and provides for an increased payment for its combustion above the limit, large-scale investment has been made. As the result of the utilization coefficient of associated petroleum gas growing from 75.5% in 2011 up to 91.7% in 2013 and 93.2% in 2014 there was a reduction of its combustion in flares and a decrease of pollutant emissions by 21.4%.

4. Reaching the limit of ecological capacity in some regions. Most of regions in Kazakhstan are located within semi-arid and arid zones where ecological limits of water sources, pastures and arable lands are almost reached. When using relative measures, the Mangystau and South Kazakhstan regions

demonstrate very high specific rates of anthropogenic impact on limited water sources and land resources. Therefore, any minimum increase of anthropogenic impact in regions with ecological capacity close to its limits leads to a serious degradation of the environment.

5. Demographic changes as a factor transforming the territorial structure of anthropogenic impact are typical first of all of Kazakhstan that has AI increasing in the South due to population growth and falling in the North due to depopulation.

#### 4. Conclusion

Integral assessment of environmental conditions in the regions of Russia and Kazakhstan has revealed both similarities caused by the consequences of an accelerated industrialization during the Soviet period and differences in the formation of environmental situation caused by different natural and social and economic conditions. The impossibility of blaming decisions made 50 years ago for all problems becomes clear, the reasons for environmental problems are much deeper. The regions of advancing development that possess competitive advantages have high AI level. Rich resource extracting regions see AI strengthening throughout the whole natural complex, faster than the economy develops. The largest city agglomerations experience the effect of the economy of scale that attracts investment and labor, creating greater transport pressure on infrastructure, waste disposal problems, deforestation, environment degradation, depletion of water resources. The state is responsible for the development of the whole territory, measures of regional environmental policy gradually improve the situation.

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