

MAPPING OF THE ENVIRONMENTAL IMPACTS OF INLAND WATERWAY TRANSPORT IN RUSSIA

ABSTRACT

Nowadays more and more attention is paid to climate change policy and sustainable development, for which transport still presents a major challenge. Road and railway transport plays an important role in the pollution of the natural environment. Waterway transportation is more efficient and environmentally friendly than other modes of transport, but alongside these advantages, it still has a major impact on the quality of the water environment. Therefore, it is highly important to monitor and analyse the environmental impacts of inland waterway transport at the county scale. For this purpose, the thematic ecological database was developed for the territory of Russia and the digital map of the environmental impacts of inland waterway transport was created at a scale of 1 : 20 000 000. The degree of impact of river transport on the water quality is assessed according to three main factors, depending on the capacity of passenger and cargo flows, types of cargo, as well as the self-cleaning capacities of natural water bodies (river discharge and volume of the water bodies). Conducted research aims to support decision makers with comprehensive data on the environmental impact of inland waterway transport and helps to define the priority regions of Russia requiring measures of improvement of transport and ecological conditions.

KEYWORDS: inland waterway transport, environment, pollution, ecological mapping.

INTRODUCTION

The navigable waterways of the Russian Federation extend along some 101,7 thousand km, with over 130 river ports operating along their route [Transport..., 2016].

A single deep water system of the European part of Russia belongs to the inland waterways of international importance. The main water arteries of this system are the Rivers Volga, Kama, Don and Neva as well as the Volga-Don, Volga-Baltic and Moscow Canals. The system extends to some 6,5 thousand km with a guaranteed water depth of 3,6 m.

Overall, inland waterways are connecting 64 regions of Russian Federation, where 80 % of the total population of the country is residing and up to 90 percent of the GDP is produced [Russia..., 2017]. As well, inland waterway transport plays an important role in the life support of hard to access areas of the Far North and equated localities.

In 2017, 118,6 million tons of cargo were transported by rivers. In 1980, the turnover of inland water transport amounted to 481 million tons and was comparable to the road transport. Nowadays, the gap has quadrupled. Passenger transportation by the waterways also have fallen sharply. In 1980, it amounted to 103 million people, in 2017 it reached only 12,7 million people. [Rosstat, <http://www.gks.ru>].

According to Rosmorrechflot, the bulk of traffic that falls on the Volga Basin equals to 35,7 % of the total transport of goods on inland waterways. The share of the Moscow Basin is 16,3 %, Volga-Baltic – 11,6 %, Azovo-Don – 8,4 %, Ob-Irtysh – 5,6 % and Kamsky – 4,2 % [<http://www.morflot.ru>]. At present, over 1500 enterprises and private entrepreneurs have licenses for the transport of goods and passengers on inland waterways. The number of economic entities of inland waterway transport carrying out transshipment of goods exceeds 200 organizations.

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More than 130 river ports operate on the territory of the Russian Federation. Most of the river ports have direct railway access, thus making it possible to tranship goods from water to railways and road transport. The volume of transshipment of goods in ports for 2017 amounted to 138,2 million tons. The largest share of cargo handling in river ports still remains with construction materials – 76,8 %; Liquid cargo accounts for 5,3 % of the total volume of transshipment [<http://www.morflot.ru>].

Although the Russian inland waterways are the longest in the world, they are not used on a full scale. Inland shipping accounts for approximately 1,3 % of domestic freight movements in Russia measured in tonne-km. At the same time, for example, in China, where the length of waterways is comparable to Russia, the turnover of goods is 12 times higher. Even in those countries, where the length of rivers is smaller than in Russia, the inland waterway transport is used to a much greater extent. Thus, river transport in Germany accounts for about 11 % of the freight turnover, in the Netherlands – to 34 % and in France – to 10 % [EU Transport..., 2017].

The main problem is the gradual expansion of the limiting areas (shallow water) on inland waterways, as well as the extreme deterioration of the infrastructure. Most of the port facilities were put into operation about 40 years ago, the average age of the cargo fleet is 32 years, of the passenger fleet – 33 years, of the crane equipment – more than 30 years [Russian River Register, <http://www.rivreg.ru>].

In general, the domestic river transport has great prospects. In the Government's "Strategy for the development of inland water transport in the Russian Federation for the period until 2030", it is planned to increase the traffic capacity in infrastructural bottlenecks, develop the port infrastructure and introduce a number of incentive measures to encourage greater use of river services [<http://www.morflot.ru>].

The development of river transport is an important factor in reducing the overall environmental impact of the transport sector, since the specific figures of carbon dioxide emissions from inland shipping amounts to 5 percent of road transport emissions and 20 percent of rail transport emissions [Galieriková., Sosedova, 2016; Gosudarstvennyj..., 2017].

The impact of waterway transport on the environment is primarily related to spills or accidental releases of oil products during loading and unloading operations, discharges of polluted waters, dust pollution coming from dry bulk cargos and disturbances of water bodies during dredging.

Atmospheric pollution caused by river vessels in the Russian Federation is mainly related to the age of the vessels in operation, equipped with diesel engines that are characterized by an extremely high toxic effect [Ivanchenko et al., 2015]. The inland shipping sector offers many opportunities for technological innovations in vessels [Rutkowski, 2016].

Regular ship traffic have effects of physical and mechanical as well as of chemical and material nature. In addition there is a potential risk due to accidents where possibly large amounts of harmful polluting substances may come into the water and subsequently into the food chain and drinking water [Van Lier, Macharis, 2014; Andersson et al., 2016].

Physical and Mechanical Effects:

- Re-suspension of Sediments / Turbidity;
- Damage by Ship Waves and Ship Propellers;
- Transport of Water Organisms.

Chemical and Material Effects:

- Mineral Oil;
- Surfactants;
- Ship Paints;
- Waste from Navigating Ships;
- Energy Consumption / Emissions with Relevance for the Climate.

In addition to the environmental impacts from regular ship traffic, there is the important risk of burdens caused by accidents. Compared to rail transport, waterway transport has a higher accident risk which can be particularly critical with the downstream transport of spilled hazardous substances (oil, chemicals) [Novikov et al., 2016].

The likelihood of accidents in inland shipping depends mainly on the following factors: traffic density nautical conditions: water depth, width of the navigable channel, visibility, signalling, flow speed, etc. travelling speed training and reliability of the crew the technical state of the ship the availability and use of effective and reliable navigation systems. The ecological effects of accidents in shipping vary from case to case. An accident where loaded goods and fuel are lost must be rated much more severe than a collision without any loss of goods. In case of such a loss of load, the ecological impacts again largely depend on the type of transported goods [Gosudarstvennyj..., 2017].

Taking into account all the adverse environmental effects imposed by inland waterway transport, it can be noted that it is still more environmentally friendly than road and railway transport [Kader, 2014], (Fig. 1).

Pollution type	Emission levels per tonne-km		
	Road	Rail	Inland waterways
Carbon monoxide	6.10	0.18	0.11
Hydrocarbons	1.15	0.06	0.07
Nitric oxide	3.05	0.89	0.69
Sulphur dioxide	0.15	1.09	0.10

Fig. 1. Emission levels from different modes of transport

In order to study a number of problems which exist in the transport industry, spatial analysis and an integrated cartographic assessment of the current traffic situation is required. A series of thematic maps created using GIS technologies can be used to demonstrate the state of the transportation system, its interrelationship with the socio-economic development of the country, as well as its environmental impacts. A similar approach has been already implemented in a series of thematic maps devoted to the environmental impacts of different types of transport, such as road transport [Nokelaynen, 2015, 2017], railway and inland water transport [Nokelaynen, 2016; Maslennikova, Nokelaynen, 2017], developed as a part of the Environmental Atlas of Russia. The aim of this study is to summarize the previous expertise on mapping of the environmental impacts of transport and produce an up-to-date geodatabase and map of the influence of inland waterways on the environment in Russia.

MATERIALS AND METHODS

Atlas information system on the sustainable development of Russia, created at the Faculty of Geography of the Lomonosov Moscow State University, contains a variety of resources for simulation, visualization and integrated analysis of information on natural, economic and socio-demographic sustainability across the regions of Russia. All the components of the system are analyzed considering their dynamic behavior and Russia is seen as an integral part of a global system [Tikunov et al., 2007]. The transport section of the system includes an extensive spatiotemporal database developed according to the existing standards of geodatabase design [Butler, 2008].

The thematic structure of the Water Management block of the "Sustainable Development of Russia" geodatabase includes:

1. Basic Inventory Maps (annual mean discharge, water availability, annual ground and surface waters abstraction, household water consumption per capita, wastewater treatment facilities, density of hydrological networks, navigable sections of rivers, etc.);

2. Assessment Maps (water resources availability and use, contaminated wastewater flow, trends in annual pollutant loads, fresh water conservation, water pollution incidents, self-cleaning capacities of natural water bodies, surface water quality, etc.);

3. Integrated Maps assessing how different regions are correlating with the model of sustainable development (integrated assessment of water management factors of sustainable development of the subjects of the Russian Federation) [Skornyakov et al., 2003].

The developed geodatabase was already used for thematic mapping of inland waterway transport implemented with the contribution of the author in a number of federal projects, such as:

- Environmental Atlas of Russia;
- Atlas of natural and technological hazards of the Russian Federation;
- National Atlas of Russia;
- Atlas of socio-economic development of Russia.

In addition to the materials obtained from the Atlas information system on the sustainable development of Russia, other sources of data were analyzed, such as the official statistics from the Russian Federal State Statistics Service [www.gks.ru], the materials from the official site of the Federal Agency for Maritime and River Transport of the Ministry of Transport of the Russian Federation [www.morflot.ru] and Russian River Register [www.rivreg.ru].

Information about the use of water resources and discharge of waste water into water bodies by types of economic activity under the responsibility of the Federal Water Resources Agency (Rosvodresursy) is published in the annual reports ("State and Protection of the Environment of the Russian Federation", "On State of Water Resources") that are published on the website of the Ministry of Natural Resources and Environment of the Russian Federation [www.mnr.gov.ru], and in official publications of Roshydromet ("Review of the State of the Environment and Environmental Pollution in the Russian Federation") that are publicly available from the official website [www.meteorf.ru].

The use of GIS technologies allowed mapping of the environmental impacts of inland waterway transport in Russia, which was conducted in ArcGIS environment according to the following steps:

1. Updating the geodatabase on the modern inland waterway network of Russia (navigation season, guaranteed depth of passage, availability of digital nautical charts).
2. Creating a series of thematic layers on inland waterway operations (freight and passenger traffic, sailing frequency, etc.).
3. Creating a series of thematic layers on inland waterway ecology (transportation of chemicals and hazardous materials, oil loading and offloading points, pollution incidents, self-cleaning capacities of natural water bodies, etc.).
4. Creating a series of thematic layers on river ports (freight and passenger turnover, types of cargoes, etc.).
5. Developing a methodology for assessment of river transport pollution.
6. Developing a methodology for estimation of transport pollution in river ports.
7. Composing a thematic map of environmental impacts of inland waterway transport in Russia.

RESULTS AND DISCUSSION

The main outcome of the research is the creation of the map "Environmental Impacts of Inland Waterway Transport in Russia" at the scale of 1 : 20 000 000, where the negative environmental effects caused by inland water transport are characterized by the degree of vessel-sourced pollution to inland waters (Fig. 2).



Fig. 2. Environmental Impacts of Inland Waterway Transport in Russia

The degree of river transport impact on the water quality is assessed according to three main factors, depending on the capacity of passenger and cargo flows, types of cargo, as well as the self-cleaning capacities of natural water bodies (river discharge and volume of the water bodies).

A high degree of water pollution caused by river transport has not been reported yet.

Navigable rivers, canals and water bodies with a cargo traffic of more than 1 million tonnes and with a significant share of transported oil products are referred to a moderate degree of pollution. Those are primarily the main inland waterways of Russia: the White Sea-Baltic Canal, the Volga with a system of reservoirs (downstream from Tver), Kama (downstream from Berezniki), Belaya (downstream from Ufa), Ob (from Novosibirsk to Khanty-Mansiysk), Irtysh (downstream from Omsk), the Moscow Canal, etc.

A low degree of pollution is assigned to water bodies with a cargo traffic of more than 1 million tonnes and with a small share of transported oil products: the Northern Dvina, the Yenisei (from Krasnoyarsk to Igarka), the Lena (from Kirensk to the mouth of the Vilyuy), the Amur (from Blagoveshchensk to the mouth of the Ussuri), Lake Onega, Rybinsk Reservoir, etc.

Navigable rivers and reservoirs with a cargo traffic of less than 1 million tonnes per navigation season are characterised by a very low degree of pollution: Don (up to the Tsimlyansk reservoir), most of the navigable rivers of the Northeast Russia, Baikal, Obkaya Bay, Ladoga Lake, etc.

The degree of transport pollution in river ports is also indicated on the map. It is differentiated as high, moderate or low, depending on the freight turnover and types of cargo that are being handled (e. g. bulk liquid materials, bulk solid materials, general cargo or containers).

CONCLUSION

The construction, operation and maintenance of waterway infrastructure are causing substantial negative impacts on the natural environment. The conducted research enabled to define the key regions of Russia which are subject to a significant anthropogenic load associated with the inland water transport and which require adoption of new environmentally-oriented policies and industry standards. The map "Environmental Impacts of Inland Waterway Transport

in Russia" which was produced as a part of this study helped to assess the degree of pollution along all the major waterways and in river ports of Russia. The approach that was used shows that the creation of thematic maps using GIS technology and multi-layer analysis can be used for an assessment of inland waterway transport pollution, and can serve as an essential part of a decision support system in order to facilitate:

- Local and regional inland waterway environmental impact and safety assessment.
- Environmentally – oriented inland waterway infrastructure development projects.
- Nature protection initiatives in the inland waterway transport sector.

All the information involved in this study was gathered and stored in a format of an ArcGIS geodatabase, which makes the database dynamic and easy to edit and allows updating the attribute information, conducting additional multi-layer analysis and creating new maps.

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