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# Main issues concerning drinking water supply in the Angara River watershed

Water supply for drinking and communal-general purposes plays an important role in every economy all over the world as water is not only widely used for people's everyday purposes, but is also essential for people's vital functions. The principle concerning the priorities of supplying drinking and communal water, stipulated in relevant norms and regulations, presumes that in the first place people should be provided with water according to the existing scientifically grounded health standards. At the same time, drinking water is only a part of natural water resources; thus, it is closely linked to the whole hydro-economic situation of the region, and the connection is one of interrelation and interdependence.

The territory under consideration stretches from the source of the Angara River downwards to the city of Bratsk and constitutes the upper and middle sections of the river. The following features are typical of this territory: high level of urban development, high level of anthropogenic pressure on water resources, wide scope of water quality and quantity conditions; all of the above result in a difference in drinking water provision between the regions and communities.

## Evaluation of surface drinking water sources

**Quantitative aspect:** Centralized communal drinking water supply of the large cities is based on the surface water resources, while the centralized and local water supply of the rural communities is based mostly on underground waters. Traditionally, surface water sources constitute the biggest part of drinking water supply; water from rivers and reservoirs satisfies over 80 % of the need for drinking water.

The reasons for such a wide use of surface water and significantly smaller use of more accessible water resources of the Angara River, its reservoirs and main tributaries is the high level of urban development of the region (urban population living within the basins of the big rivers makes up more than 80% of the population of the region), the lack of exploration of underground water resources, as well as unfavourable hydro-geological conditions which are going to be mentioned further on in this report. In fact, the share of underground water in total water supply is smaller than the estimated number, as the significant amount of water classified as underground is infiltration alluvium water. That is actually the river water and it retains all the features of river water, and only the type of water intake enables us to classify it as underground.

Drinking water supply is characterized by the constant level of water consumption and this consequently raises the issue of permanency of water supply, as irregularities of this supply are deemed inadmissible. Therefore, I consider natural water resources evaluation to be very important, as it is used for project calculations concerning water supply for communities, especially urban ones. In case of organization of a large-scale centralized water supply that utilizes surface water sources, the natural water supply can be estimated by the flow volume constant. This constant is equal to the minimum water flow in the dry winter period, i.e., minimum monthly water flow in the winter period for the rivers with uncontrolled flow, and minimum warranted tailwater flow for the rivers with controlled water flow. Using this technique, the Angara River watershed has been mapped, depending on the quality of surface water resources in the aspect of organizing a large-scale centralized community water supply. These resources were estimated according to the value of constant water flow and the distance between a water source and a given community. Riversides 20 km wide on flat areas and 10 km wide on mountainous areas were considered to be the zone of sufficient water supply, as this is the most economically feasible distance for water transportation. This principle may have practical application in water distribution and supply all over the world.

Territories surrounding the Angara River and its reservoirs are abundant in water supply, as the constant minimum water flow in the river exceeds 1000 cubic meters per second. As far as the water supply is concerned, the cities on this territory can develop without limitation, and it is not accidental that the leading industrial centres of the region are all located near the Angara River and use its water for drinking and communal-general purposes. Nevertheless, a significant part of the region is still characterized by the lack of water supply. These are mostly the areas located between rivers, which due to the lack of water do not have much potential for urban growth (communities there can hardly grow bigger than 50 000 inhabitants). It is possible to improve the situation in the zone of insufficient surface water supply only through exploitation of underground fresh water resources.

**Qualitative aspect:** With regard to water quantity, most parts of the region are well supplied with water from surface water sources. Nevertheless, the quality of the surface water used for drinking purposes leaves a lot to be desired. The analyses of surface water quality with regard to two key factors: anthropogenic and natural, were conducted by the author of this article.

The Irkutsk region is characterized by a high level of industrial development; therefore, one of the factors that have the most negative impact on the water quality, is the discharge of untreated industrial wastewater. The situation concerning industrial wastewater in the upper and middle part of the Angara River watershed is rather unfavourable. Wastewater discharge into the water bodies of the region amounts to about 0.9 km3/year, and 90% of the wastewater was not properly treated. The district under consideration (the upper and the middle section of the Angara River watershed) produces more than 80% of all wastewater in the Irkutsk region.

The situation is also aggravated by the inefficiency of water treatment facilities. Of all wastewater treated by these plants (more than 0.5 km3/year), less than 1% complies with water quality standards, and more than 99% that is discharged into the water bodies is insufficiently treated. The cause of this problem is: the large amount of wastewater and high level of pollution, outdated facilities, deteriorating devices, and economic and administrative issues occurring due to the treatment plants being managed by the municipal government. The irregular operation of large industrial enterprises, such as pulp-and-paper mill, chemical and petrochemical industries, causes serious difficulties for the work of water treatment facilities. In spite of the fact that the capacity of the sewage facilities exceeds the demand by 1/4 (due to the reduction of water consumption in the region in general), still some cities (Irkutsk, Usolie-Sibirskoye) suffer from the shortage of sewage capacity, which constitutes up to 40–45% of the capacity required to process the actual amount of wastewater. This results in the discharges of untreated water into the water bodies of the region and consequently, the large amount of water pollutants is carried by the wastewater, e.g.: hundreds of thousands of tons of chloride; dozens of thousands of tons of sulphates, organic matter and suspension; thousands of tons of nitrates, ammoniacal nitrogen; hundreds of tons of phosphorus, fat, nitrite, iron, mineral oil; dozens of tons of methanol, synthetic surfactants, fluorine, formaldehyde, aluminium, magnesium, tons of phenol, copper, zinc, lead, hundreds of kilograms of mercury, chromium, and hydrogen sulphide. In spite of the reduction of the total amount of wastewater within 4 years (from 2006 to 2010) by 20%, the quantity of pollutants did not decrease (Bezrukov 2001).

Within the abovementioned period there were no positive changes in the amount of suspension, surfactants, formaldehyde, sulphates, nitrite, and lead. What is more, the quantity of some substances even increased: the quantity of iron and aluminium increased by 5–25%, the quantity of phenol, chloride and fluorine increased 1.5–1.7 times and the amount of methanol and tannin increased 2–2.2 times. Consequently, the deterioration of sewage facilities progressed faster than the reduction of wastewater amount.

The main sources of pollution in the region are as follows: industrial wastewater constitutes 3/4; the quantity of municipal runoffs amounts to almost 1/4 and other branches of economy (agriculture, transport, construction etc.) constitute only 0.2%. Significant share of wastewater comes from chemical and petrochemical industries (31%); timber, woodworking and pulp-and-paper industries (19%), and power production (18%). The high level of industrial pollution is caused by the high concentration of industrial enterprises in the Irkutsk region; most of them are outdated (more than 3/4 of all the industrial technologies used in the region) and deteriorated. The degree of exploitation of production assets amounts to: 49.5% in power production, 50.3% in machine building, 52.8% in pulp-and-paper industry, 54.0% in chemical industry, 56.1% in non-ferrous metallurgy, 59.0% in ferrous metallurgy and 71.3% in petrochemical industry (Nature Resources and Environment Protection. Statistical Report 2007).

The high coefficient of water recycling is indicative of environment friendly technologies, as it points to the economy of fresh water use as a result of recycling and reuse of technologies. The average coefficient of water recycling in the region is 69%, which is 9% less than the average of water recycling in Russia, but for separate branches of industry, the gap between the water recycling coefficient in the region and the average percentage in Russia is even more pronounced: it is 10% for the chemical and petrochemical industry, 17% for power production, 24% for machinery construction, 46% for ferrous metallurgy and 53% for microbiology, etc. Only in three branches of industry, the average value for the region is higher than the corresponding value for the whole Russia. The average in question is higher by 15% in the food industry, and by 10% in non-ferrous metallurgy and coal-mining industries.

As far as territorial aspect is concerned, close to 99% of the whole water pollution in the region comes from large cities. There are 4 main industrial centres – Angarsk, Bratsk, Irkutsk and Usolye-Sibirskoye – that discharge 91% of the overall amount of wastewater. About 8% of wastewater is discharged by other large cities, and less than 1% comes from administrative districts (Industry of the Irkutsk Region in 2007. Statistical Report 2008).

The overwhelming amount of wastewater – 92.5% – is discharged directly into the Angara river and its reservoirs. The highest anthropogenic pressure is observed in the section of the river located between the cities of Irkutsk and Usolye-Sibirskoye. Main tributaries of the Angara river – the rivers of Oka, Iya, Irkut – receive 6.6% of the wastewater, and 0.9% is discharged into other water bodies.

Thus, the conclusion can be reached that the discharge of industrial wastewater is the main source of water pollution in the region.

The deterioration of the quality of surface water in the region is also caused by hydropower production. The change of the natural water regime of the river due to the construction of a whole series of hydroelectric power stations caused a significant decrease of self-purification capacity of the river, water stagnation in the reservoirs (water rotation in the Bratsk reservoir currently lasts 2 years), lengthening of the freezing period, and decomposition of sunken wood. Due to the decrease of self-purification capacity, the impact of wastewater pollution increased significantly.

The construction of hydropower stations also influenced water quality, i.e., decomposition of wood in the area of flooded forests produces phenol, lignin, resins and other deleterious substances. When the Bratsk reservoir was filling up, 1.35 thousand km2 of forested area was flooded and 16 mil. m3 of trees got under water. Moreover, about 250–450 000 m3 of wood enters the reservoir due to shoreline erosion, along with pollutants and garbage from the residential territories and agricultural areas washed out by water. The level of water fluctuation in the reservoirs, which in, for example, the Bratsk reservoir amounts to 10m, also has a very negative impact.

In the upshot, hydropower production has serious negative influence on water quality, as it causes the decrease in self-purification capacity, forest area flooding, shoreline erosion, and water level fluctuations.

Water quality in the Angara and the Bratsk water reservoirs does not comply with health standards and is assessed as unsatisfactory, which prohibits the use of the water for drinking purposes without treatment in the intake facilities. However, the water treatment techniques applied do not ensure required water quality due to their inefficiency or mishandling. According to the medical research, water pollution results in an 10–40% increase in sickness rate. It means that people's health in 20–30% depends on water quality.

The most widely used technique of water treatment is liquid or gaseous chlorine disinfection, or the so called chlorination, which is a simple and efficient method. On the other hand, chlorination may lead to transformation of organic substances that are present in the water subjected to treatment into polychlorides, which are characterized by high toxicity, carcinogenicity and mutagenicity.

The situation is aggravated during certain periods of the year when surface water pollution in the intake is above average and the amount of chlorine needed for disinfection increases significantly. Due to the high level of negative anthropogenic impact on the majority of surface waters, the existing water treatment techniques are insufficient. Therefore, the need to either improve the water treatment techniques or start using less influenced underground water becomes evident. Another issue concerning the use of surface water for drinking purposes is the natural shortage of mineral substances.

Firstly, the average annual solid residual concentration is rather low (200/400 mg/l) in all the surface water sources. What is more, in the Angara River and its reservoirs this value is smaller than 100 mg/l. Health researches consider low concentration of minerals to be a negative factor influencing health.

Secondly, there is a scarcity of such chemical elements as calcium, magnesium, sodium, potassium, and of such trace elements as fluorine and iodine. The average annual concentration of the abovementioned chemical elements is: about 11–15 mg/l of calcium (minimum concentration allowed is 20 mg/l), 2.8–5.1 mg/l of magnesium, 3.4–5.8 mg /l of sodium and potassium, and 0.1–0.37 mg/l of fluorine (minimum concentration allowed is 0.5–0.8 mg/l). The shortage of these minerals, especially of fluorine and iodine, leads to cardiovascular and endocrine pathologies, caries, as well as other diseases and health dysfunctions. In order to make up for the lack of mineral substances in surface water of the Angara River, it is reasonable to construct combined sewers where both surface water and underground water (more abundant in minerals) would be processed.

Thus, the use of surface water for communal-general purposes is very favourable in terms of quantity, however, it causes serious qualitative issues, like high anthropogenic pollution and deficiency of minerals essential for people's health. The problem lies in the fact that upgrading the existing water treatment facilities is rather a costly and difficult task.

## Ways of communal and drinking water supply improvement

Water supply for the population of the region is considered a priority. Water supply conditions influence health and people's living standards. There are two aspects of this burning issue that surprisingly occurred in the region abundant in water resources. The first aspect is the shortage of drinking water in a number of rural communities and districts. The second one is low water quality in many districts and settlements. The issue concerning the possible ways of water supply improvement in the region will be discussed further on in this report.

Improvement of water treatment facilities at water intakes.

This solution is one of the most important means of improving water quality in the region in question, as it involves the replacement of the outdated method of water chlorination with more advanced techniques of disinfection.

However, the increasing pollution of surface water demands even more effective and upgraded water treatment facilities, which is difficult to realize due to the significant expenses required for their installation. The situation is worsened on the one hand, by the natural shortage of minerals in surface water that is difficult to make up for, and on the other hand, by the presence of toxic chemical elements, like mercury, difficult to remove.

Moreover, the personnel of the treatment facilities is not always sufficiently educated. Due to the various reasons, the implementation of measures of the first group cannot fully solve the issue of reliable water supply. Therefore, the implementation of the proposed measures requires thorough analysis of all positive and negative aspects.

## Improvement of water quality in the water sources

The second method suggests improvement of water quality directly in the rivers and other water sources, so that the water treated by the application of usual techniques would meet the quality standards.

This solution, though, is extremely costly and time-consuming. Taking into consideration the existing production facilities in the region, as well as the level of water pollution and the state of the regional economy, the significant improvement of water quality in the water sources is hardly achievable.

## Drinking water bottling

Nowadays, drinking water bottling and packaging is considered to be one of the most efficient ways of solving problems concerning drinking water. In fact, the consumption of bottled drinking water in developed countries is currently much higher than in Russia. In the discussed region, the whole complex of water bottling enterprises that is being constructed utilizes the water from Lake Baikal in order to boost this market.

However, deep water from Lake Baikal is too expensive for the majority of the population and it is characterized by low concentration of minerals. Therefore, it is not recommended by health service for everyday use. Bottling of the underground water will be less costly, although most people in the region are not yet accustomed to the use of bottled water instead of that from the centralized water supply

## Water saving

Saving water can be helpful in solving the issue of its shortage in some districts. There is a great scope for water saving in the industrial sphere: reduction of industrial water consumption down the established norms, implementation of water rotation schemes either within one or several enterprises, discontinuation of use of high quality underground water for industrial purposes, shift from water cooling to air cooling technology and introduction of closed cycle water saving technologies. There is also a great scope for water saving in the public sector, where water consumption can be reduced 2–3 times by means of eliminating water loss both in the pipelines and in the houses.

### Use of underground water for drinking purposes.

Clearly, the ways that have been proposed can solve the issue of drinking water supply in the region. I believe that shifting to the use of underground water for drinking purposes is the most efficient way of handling this problem.

Thus, I consider it necessary to do everything possible for the water quality improvement, to utilize all the above mentioned ways and measures to the highest degree possible in the existing economic and environment conditions. Nevertheless, the implementation of water supply based on underground water is considered to be the most efficient way to solving the drinking water issue. So it is necessary to introduce the most efficient projects of underground water usage and apply them in practice having considered all their pros and cons.

## Literature

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## Abstract

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