ATLANTIS PRESS
Advances in Health Sciences Research, volume 28
Proceedings of the International Conference "Health and Wellbeing in Modern Society" (ICHW 2020)

The Quality of Drinking Water of Centralized Water Supply Systems and its Impact on Public Health

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ABSTRACT
This article is devoted to the problems of drinking water quality in centralized drinking water supply systems on the territory of the Russian Federation, as well as its possible impact on public health. Analysis of the current situation on the territory of the Russian Federation showed that the number of operating economic entities carrying out activities in the field of "Collection, purification and transportation of water" amounted to more than 12.8 thousand units. The share of subjects of extremely high, high and significant risk was 66.1 %. It was revealed that for the period 2012–2019, the share of drinking water supply sources and the share of samples not meeting sanitary and epidemiological requirements from these sources decreased by 2.6 % and 2.9 %, respectively. It is shown that a consequence of the decrease in the share of non-standard drinking water samples was an improvement in the situation with the associated morbidity rates in the population: since 2012, the number of cases of diseases associated with the quality of drinking water has decreased by 13.3 %. The priority substances that make the greatest contribution to cases of morbidity associated with the quality of drinking water are: arsenic, nickel, chlorine, chloroform.

Keywords: *sources of drinking water supply, household entities, quality of drinking water, hygienic assessment, risk factors, public health, associated cases of diseases*

1. INTRODUCTION

Drinking water is one of the main resources for sustainable development of society. In households, the areas of application of water are varied and it is used both for preparing food and direct use, and for household purposes (personal hygiene, maintaining a clean room, etc.). Taking into account the wide range of use, as well as the duration of contact with water throughout life, the need to comply with the requirements for the quality of drinking water to maintain and promote health becomes a priority task for any state. At the same time, providing the population with high-quality drinking water is a complex set of measures, including: selecting a source and establishing the flow rate of a water intake for uninterrupted water supply that does not violate the hydrological regime of the water source itself; organization of a sanitary protection zone, within the boundaries of which potential contamination of the source will be minimized; construction of a complex of water treatment facilities and their uninterrupted operation; tracing of water distribution networks, etc.

For a number of regions of the Earth, the issue of simple access to drinking water and the problems associated with it remains relevant, including the lack of centralized drainage systems and, as a result, fecal pollution of water sources with the possibility of implementing the fecal-oral mechanism of transmission of infectious diseases. This is especially true for rural areas of these countries [1, 2].

For developing countries, which are currently at a stage of rapid socio-economic transformations, local reservoirs and watercourses are becoming the main arteries of the driving sectors of the economy. At the same time, the sanitary legislation of these countries does not always meet international standards in the field of drinking water quality protection. These factors create conditions for enhanced chemical contamination of water bodies with priority chemical pollutants. Contamination of water sources can increase under certain circumstances, including in the case of a water source located in geochemical provinces, due to climatic conditions of the area, unsatisfactory condition of the water distribution network, cultural characteristics of the population, etc. [3–5].

For the most developed countries, the problem of water shortages may soon arise, especially in large metropolitan areas, where intensive urbanization processes take place, which increase the population density, thereby creating an increased load on water supply systems. Separate problems in these countries are quality control of drinking water received by the population with the help of private water sources (wells), increased pollution of water sources with nitrates due to the intensification of the agricultural sector, etc. [6, 7].

Separate factors affecting the quality of drinking water are the biological stability of water and the degradation of the infrastructure of water distribution networks. Biological stability implies the preservation of the original quality of

drinking water supplied from treatment facilities to the final consumer. The degradation of the infrastructure of water distribution systems is an irreversible process during their operation and does not depend on the type of material (metal, polymer or cement); however, during their destruction, substances that change the original water quality and are also a substrate for the life processes of microorganisms enter the drinking water. In addition, damage to the pipes often serves as a place for adhesion and fixation of a biofilm [8]. An increase in the concentration of iron and manganese in the course of the gradual destruction of pipes worsens the organoleptic properties of drinking water, and, in the long term, may have an impact on public health. In this regard, timely and adequate monitoring of the quality and safety of drinking water is becoming increasingly important for making management decisions [9].

According to a study examining a quantitative assessment of the relationship between sanitary and epidemiological indicators and life expectancy (LE), it was shown that with an increase in the proportion of the population provided with quality drinking water, the LE indicator can increase by 61.6 days for the entire population. This indicator contributed 43.9 % to the total increase in life expectancy of the entire population, i.e. it was one of the most significant sanitary and epidemiological indicators [10].

Organoleptic properties of water, knowledge of water treatment processes and information about a water source are of great importance for the population. In a study by I. Delpla et al. it was shown that when choosing tap water as a source of drinking water, the consumer relies on a number of factors: organoleptic properties (taste, color, odor), knowledge of the potential risks associated with the water source and water treatment and transportation processes, and others [11].

In our country, harmonization and updating of sanitary legislation concerning the requirements for the quality of drinking water, the design of zones of sanitary protection of water sources and the effectiveness of control and supervision activities over the quality of drinking water supply and with the calculation of the probable economic damage is also becoming an urgent issue [12–15].

In the Russian Federation, the most common method of water disinfection is chlorination. As a result of using this method, chlorine-containing compounds are formed, which are dangerous in relation to the formation of a risk to public health [16].

Currently, to improve the quality of life of citizens of the Russian Federation, national projects are being implemented in various spheres of society. National project “Ecology”, which includes many priority indicators in the field of environmental protection and improving its quality for the population. One of these indicators is “Increase in the share of the population provided with quality drinking water from centralized water supply systems” [17].

2. METHODS AND MATERIALS

The assessment of the state of water sources and the quality of drinking water was carried out according to the departmental statistical reporting of Rospotrebnadzor (form No. 18 “Information on the sanitary condition of the constituent entity of the Russian Federation”) and data from the Federal Information Fund for Social and Hygienic Monitoring (FIF SHM).

The analysis of the economic entities was carried out according to the data of the register of economic entities subject to sanitary and epidemiological supervision in the territory of the Russian Federation as of 2019.

As sources of information on the state of health of the nation, we used data from state medical statistics: statistical materials of the Ministry of Health of the Russian Federation on morbidity (reference book "Medical and demographic indicators of the Russian Federation") of the population of the Russian Federation for 2012–2019.

The calculation of the number of cases of health disorders associated with the quality of drinking water was carried out for the constituent entities of the Russian Federation and the whole of Russia in accordance with MR 5.1.0095-14 “Procedure for calculating cases of health disorders associated with the negative impact of environmental factors, and cases, prevented by the actions of Rospotrebnadzor” (Appendix 2) [18].

3. RESULTS

In the Russian Federation, as of 01/01/2020, the number of economic entities operating in the field of “Collection, purification and transportation of water” and subject to sanitary and epidemiological supervision amounted to 12,807 units.

In a share ratio, 66.1 % of all subjects of supervision belonged to significant, high and extremely high risks (33.5, 25.2 and 7.4 %, respectively) in accordance with the criteria set out in MR 5.1.0116-17 [19]. The objects of low potential risk of harm to health were attributed to 1.0 % (Fig. 1).

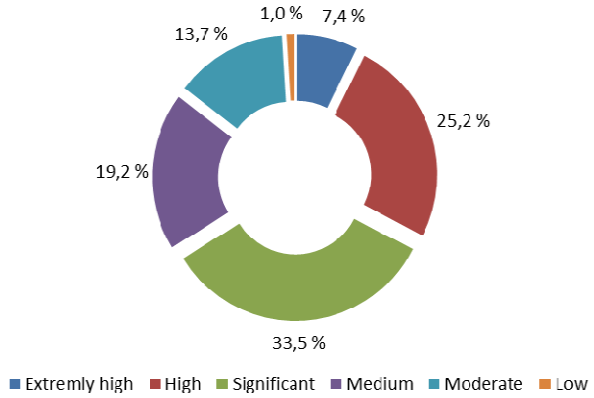

Figure 1 The structure of economic entities implementing the activity “Collection, purification and transportation of water”, by categories of risk of harm to health in the Russian Federation, %

The final consumer of the services of these economic entities is the population using the centralized drinking

water supply systems. In the course of using the service, the oral and cutaneous routes of human contact with the aquatic environment, containing contaminants of various nature, are implemented. According to MR 5.1.0116-17 [19], potential harm to health during the activities of economic entities in the field of "Collection, purification and transportation of water" is formed in relation to such classes of diseases as "Diseases of the genitourinary system", "Diseases of the endocrine system, eating disorders and metabolic disorders", "Diseases of the nervous system", "Diseases of the blood, blood-forming organs and certain disorders involving the immune mechanism", "Diseases of the digestive system", "Neoplasms".

The analysis of statistical data showed that in 2019 in the Russian Federation there is a tendency to decrease the total number of sources of centralized drinking water supply compared to 2012 (by 7.4 % or 7,517 units in absolute terms). The predominant amount of decommissioned water sources fell on underground sources (98.0 %). This trend is observed in relation to surface sources (-8.43 %, 168 units in absolute terms).

Along with a decrease in the number of water sources, there is a tendency towards a decrease in the number of sources that do not meet sanitary and epidemiological requirements. Compared to 2012, the share of such water sources decreased by 5.27 %, despite a slight increase in the indicator relative to 2018 (+0.35 %) (Fig. 2).

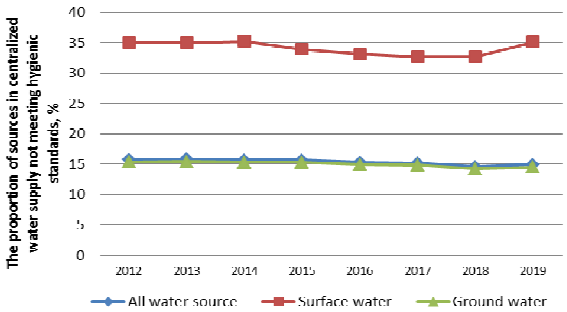

Figure 2 Dynamics of the share of centralized drinking water supply sources that do not meet sanitary and epidemiological indicators for the period 2012–2019, %

As of 2019, the share of sources and water pipelines that do not meet the requirements of sanitary legislation in the Russian Federation amounted to 14.93 %. The most common reason for non-compliance was the absence of sanitary protection zones (72.26 %).

For the period 2012–2019 a tendency towards a decrease in the proportion of samples from centralized drinking water supply sources that do not meet hygienic standards has been established. The rate of decline for this indicator was 10.2 % (hereinafter in relation to 2012), 24.7 % for microbiological indicators and 10.3 % for parasitological indicators (Fig. 3).

The share of non-standard samples that do not correspond to sanitary and chemical indicators was recorded higher in underground water sources (25.8 %). At the same time, in surface water sources the share of non-standard samples for microbiological indicators was higher (15.4 %).

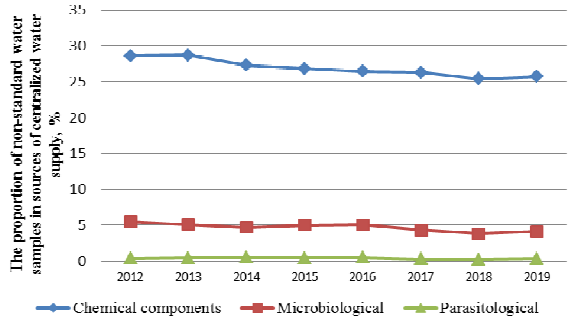

Figure 3 Dynamics of the share of drinking water samples from centralized drinking water supply sources that do not meet sanitary indicators for the period 2012-2019, %

The assessment of the data on the water distribution network showed that for the period 2012-2019, the share of water pipelines that do not meet the hygienic requirements of drinking water quality decreased by 2.61 %. At the same time, the number of water pipelines not provided with the entire complex of treatment facilities and disinfection facilities increased by 1.3 and 0.2 %, respectively.

The assessment of the quality of drinking water samples from water pipelines showed that the share of drinking water samples in terms of sanitary and chemical indicators in dynamics (2012–2019) improved by 11.3 % and amounted to 15.8 % in 2019.

Assessment of the quality of drinking water from the distribution networks of centralized water supply showed that for the period for 2012–2019, the share of non-standard samples decreased in terms of microbiological sanitary and chemical indicators (the rate of decline was 25.8 % and 39.8 %, respectively). Samples that did not correspond to parasitological parameters did not show significant changes (Fig. 4).

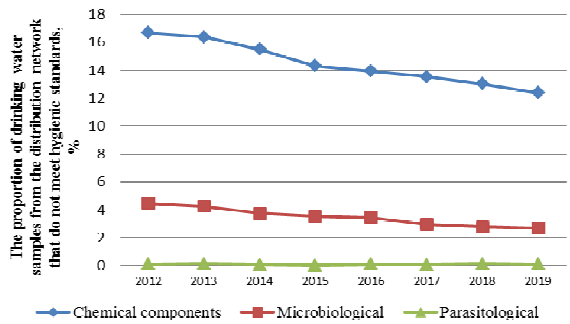

Figure 4 Dynamics of the share of drinking water samples from the distribution network of centralized water supply that do not meet sanitary indicators for the period 2012–2019, %

As a result of the optimization of the monitoring programs for the analyzed period (2012-2019), the number of monitored substances decreased from 110 to 87 (30 substances were excluded from monitoring, 7 new priority components were added).

Most often in 2019, MPCs were exceeded for silicon (18.9 %), chlorine (14.7 %), iron (13.5 %), sodium (12.8 %), lithium (11.7 %), manganese (9.4 %), chloroform (9.34 %). Compared to 2012, the share of non-standard samples of priority substances has changed (Fig. 5). The share of water samples exceeding the maximum permissible concentrations for: chlorine (from 39.1 to 14.7 %), lithium (from 35.89 to 11.69 %), iron (from 21.3 to 13.5 %), chloroform (from 18.72 to 9.34 %). At the same time, the share of samples increased for: silicon (from 4.1 to 18.9 %), boron (from 4.5 to 8.5 %), strontium (from 1.3 to 7.2 %).

These substances are priority for most regions of the Russian Federation.

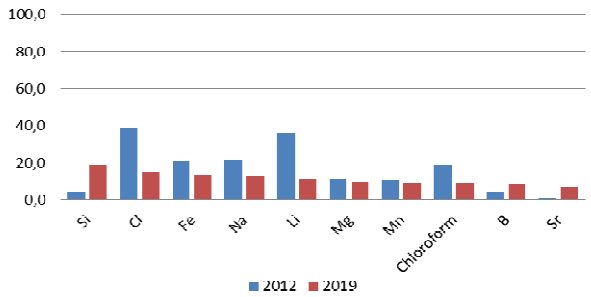

Figure 5 The share of non-standard samples for priority chemicals in 2012 and 2019, %.
Note: PHMG is Polyhexamethylene guanidine.

The analysis of data on the quality of drinking water and data from official medical statistics showed that in absolute terms, more than 1,680 thousand associated cases of diseases were associated with poor-quality drinking water in 2019. In comparison with 2012 (1,942.4 thousand abs. cases), there is a decrease in the number of cases by 13.3 % (Fig. 6).

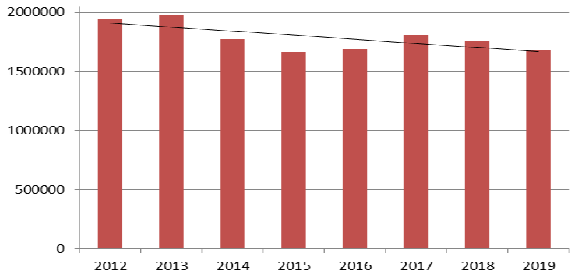

Figure 6 Dynamics of absolute cases of diseases associated with drinking water quality for the period 2012-2019 among the entire population.

Over the same period, among the child population, the number of cases of diseases likely associated with the quality of drinking water decreased by 7.4 % and amounted to more than 557 thousand cases in 2019.

An analysis of the incidence rates of the entire population, probabilistically associated with the quality of drinking water, showed that the highest values in 2019 were formed in the Republic of Karelia, the Republic of Sakha, and the Republic of Mordovia (more than 5.7 thousand cases per 100,000 of the total population) (Fig. 7).

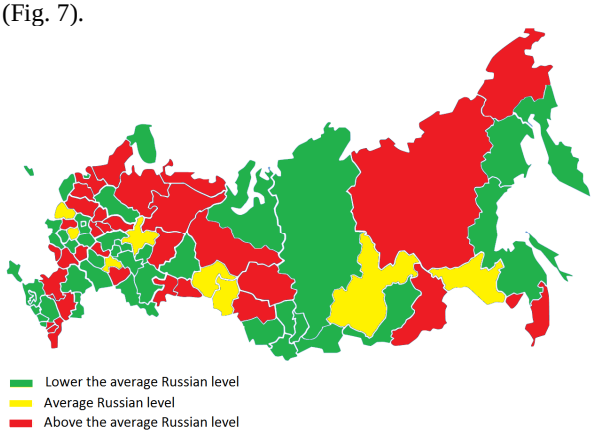

Figure 7 Morbidity level map for the constituent entities of the Russian Federation.

In the structure of morbidity, probabilistically associated with the quality of drinking water, the largest share was occupied by diseases of the digestive system, 36.9 % (more than 620 thousand cases), and of the genitourinary system, 26.8 % (more than 450 thousand absolute cases). A significant contribution was also made by diseases of the skin and subcutaneous tissue, 13.1 % (more than 221 thousand abs. cases); diseases of the endocrine system, nutritional disorders and metabolic disorders, 6.7 % (more than 113 thousand abs. cases); neoplasms, 5.5 % (more than 91 thousand abs. cases) and diseases of the musculoskeletal system and connective tissue, 5.1 % (more than 85 thousand abs. cases).

The analysis of morbidity indicators from diseases of the digestive system, probabilistically associated with the quality of drinking water, showed that the Republic of Karelia (6.0 thousand cases per 100,000 of the total population), the Republic of Sakha (5.2 thousand cases per 100,000 of the total population) and the Republic of Mordovia (2.2 thousand cases per 100,000 of the total population) hold the leading positions. These territories were leading in terms of morbidity in the class “Diseases of the genitourinary system”, probabilistically associated with the quality of drinking water: the Republic of Karelia (5.3 thousand cases per 100,000 total population), the Republic of Sakha (4.8 thousand cases per 100,000 total population) and the Republic of Mordovia (1.7 thousand cases per 100,000 total population). The highest morbidity in the class “Diseases of the skin and subcutaneous tissue”, probabilistically associated with the quality of drinking water, is also typical for these territories: the Republic of Karelia (2.4 thousand cases per 100,000 population) and the Republic of Sakha (2.1 thousand cases per 100 000 population).

The greatest contribution (up to 50–85 %) to the formation of additional cases of morbidity associated with unsatisfactory water quality in centralized drinking water supply systems was made by exceeding the hygienic standards for the content of arsenic, nickel, copper, manganese, iron, ammonia, chlorine, chloroform, boron in water, strontium, fluorine, etc., as well as microbiological pollution of water.

4. CONCLUSION

The results of the study performed showed that for the period 2012–2019, in the field of centralized drinking water supply, the following changes are observed:

1. On the territory of the Russian Federation, activities in the field of "Water intake, purification and transportation" are carried out by 66.1 % of subjects belonging to the categories of extremely high, high and significant risks;
2. There is a decrease in the share of sources that do not meet sanitary and epidemiological indicators, the rate of decline was 5.3 % (from 15.8 to 14.9 %), as well as the share of water pipelines that do not meet sanitary and epidemiological indicators, the rate of decline was 14 .2 % (from 18.4 to 15.8 %);
3. The situation with the quality of drinking water is improving: during the study period, a decrease in the share of non-standard samples of drinking water from: sources of centralized drinking water supply (the rate of decline was 10.2, from 28.6 to 25.7 %); from water pipelines (the rate of decline was 11.3 %, from 17.8 to 15.8 %); from the distribution network (the rate of decline was 25.8 %, from 16.7 to 12.4 %);
4. Optimization of the drinking water quality monitoring system with a focus on priority risk factors allowed for the period 2012–2019 to reduce the amount of analyzed substances from 110 to 87, taking into account the inclusion of 7 new priority substances;
5. The priority chemicals according to the criterion of the proportion of non-standard samples for the analyzed period were: silicon, chlorine, iron, sodium, lithium, manganese, chloroform and others. The share of non-standard samples for priority substances varied from 7.2 to 18.9 %;
6. In a natural way, there was a decrease in the number of cases of diseases, probabilistically associated with the quality of drinking water: since 2012 by 13.3 % (from 1,942.4 thousand to 1,683.4 thousand abs. cases);
7. In the structure of morbidity, the largest share was occupied by: diseases of the digestive system (36.9 %), diseases of the genitourinary system (26.8 %), diseases of the skin and subcutaneous fat (13.1 %), etc.;
8. The priority factors forming additional cases of morbidity were: arsenic, nickel, copper, manganese, iron, ammonia, chlorine, chloroform, boron, strontium, fluorine, etc.

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