Comprehensive assessment of water supply and sanitation in single-industry towns

E G Zinovyeva¹, N R Balynskaya¹, S V Koptyakova¹, N N Kostina¹ and N S Shkurko²

¹Nosov Magnitogorsk State Technical University, 38, Lenina ave., Magnitogorsk, 455000, Russia
²North-Eastern Federal University named after M.K. Ammosov, Belinskogo str., 58, Yakutsk, 677000, Russia

E-mail: mgtu@magtu.ru

Abstract. The article presents the results of evaluating the main direction characterizing the state of health and quality of life of the population of single-industry towns: the sphere of water supply and sanitation. To improve the health status and quality of life of the population in single-industry towns, an action plan is proposed to bring the quality of drinking water in accordance with the established requirements for the period from 2017 to 2022. Prediction of improving the quality of drinking water, including lowering the overall hardness, as a result of the installation of a drinking water treatment system as part of the study, was based on the retrospective results of the introduction of similar drinking water treatment systems in municipalities of the constituent entities of the Federation and a probabilistic forecasting system. The results of the calculations showed that the average expected value of improving the quality of drinking water will be 7.039 %.

1. Introduction

Public health protection is a combination of political, economic, legal, sanitary and epidemiological measures aimed at maintaining and strengthening the moral and physical well-being of the population [1]. To effectively manage the well-being of the population, it is necessary to observe sanitary norms and rules, as well as effectively monitor the state of all natural resources, human food and the animal world, next to which a person exists. Human well-being depends directly on themselves. Understanding this ensures the desire of people to take control of all spheres of life and protect themselves from negative influence. To this end, sanitary-hygienic rules and regulations are being developed that are designed to maximize the safety of the population and take control of natural processes.

The relevance of the study is due to the importance of the state of health and quality of life of the population, which are subject to constant influence of such factors as the negative impact of the environment, the work of large enterprises, poor quality of food and natural resources, and labor protection problems.

The aim of the article is a comprehensive study of the sphere of water supply and sanitation in the city of Magnitogorsk.
2. Materials and methods
Theoretical and methodological studies of water quality are considered in the works of Russian scientists: Alferova [2], Butorina [3], Onishchenko [4], Mayorova [5, 6], Steblyanko [7], etc.

The possibilities of using foreign experience in protecting public health in the Russian Federation were studied by such authors as Leaves [8], Jaakkola [9], Fu [10], Gani [11], Alvarez-Herranz [12], Aznar-Sánchez [13], Jiang [14], Pacca [15], etc.

The information base for the study of effective indicators is provided by documents of legislative authorities, regulatory legal acts of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being of the Russian Federation, as well as data from the Office of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being in the Chelyabinsk Region in Magnitogorsk for 2016–2018 [16].

3. Analysis of the effectiveness of the water supply and sanitation sector of the municipality
Assessment of the state of the human environment and its impact on public health involves the study of causal relationships between the health status of the population and the impact of environmental factors on it to take measures to eliminate the harmful effects on the population, as well as identifying priority groups of factors and associated with their negative the impact of basic indicators of public health [17, 18].

The actual direction of management for the city of Magnitogorsk, which should be given special attention to, is the sphere of water supply and sanitation.

Drinking water supply of the municipality is carried out from four infiltration water sources with groundwater intake hydraulically connected to surface water bodies. There is no non-central water supply in the city. Disinfection of water at intakes is carried out with liquid chlorine. All water intakes (Malo-Kizilsky, Verkhne-Kizilsky, Yangelsky and Kuibassovsky) have sanitary and epidemiological conclusions on sanitary protection zone projects. In 2018, compared to 2016 in Magnitogorsk, the proportion of water samples from centralized water sources that do not meet hygienic standards for microbiological indicators increased from 0.6 to 0.8 %. The proportion of water samples from underground sources of centralized water supply that do not comply with hygienic standards in terms of sanitary-chemical indicators has increased 5.3 times in 2018 compared with 2016.

Moreover, the length of the distribution network in Magnitogorsk is 933,396 km, and the percentage of deterioration of water supply networks is 73.0 %. The water quality in the distribution network according to the Office of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being in the Chelyabinsk Region in Magnitogorsk is deteriorating in chemical composition, but the proportion of drinking water samples that do not meet hygienic standards for sanitary and chemical indicators and microbiological indicators in 2018 compared with 2016 is declining.

Non-compliance of the quality of drinking water with hygienic requirements was established for iron, hardness, manganese, color, turbidity. The reasons for this mismatch are the increasing pollution of surface and groundwater; the use of outdated technological solutions for water treatment in conditions of deterioration of water quality; low sanitary condition of some existing water supply networks, their significant deterioration. In order to improve the quality of drinking water supplied to the population, in the city of Magnitogorsk, an Investment Program was developed in the field of water supply and sanitation at the Municipal Enterprise “Vodokanal’ Trust in Magnitogorsk for 2018–2020.

91.0 % of apartment buildings of the municipality are provided with hot water supply, which implies the operation of a closed hot water supply system. In 2018, as part of the sanitary-hygienic monitoring, 61 samples of hot water were studied by sanitary-chemical indicators, by microbiological indicators, by temperature. Samples that do not comply with hygienic standards for sanitary-chemical indicators and microbiological indicators for the last three years have not been registered. At the same time, the main problems in hot water supply systems are the deterioration of heating mains, which is 54.0 %. In addition, on the territory of the municipality in 800 multi-apartment residential buildings, initially, the project did not provide for a circulation pipeline. During hours of minimum water
consumption, the hot water in the system cools down in the absence of circulation, which leads to a violation of sanitary requirements for the hot water parameter.

To improve the sanitary and epidemiological well-being of the population in single-industry towns, an action plan is proposed to bring the quality of drinking water in accordance with the established requirements for the period from 2017 to 2022 given in Table 1.

**Table 1.** Action plan to bring the quality of drinking water in Magnitogorsk in accordance with the established requirements for the period from 2017 to 2022

| Action                                                                 | Implementation period | Expected results                                                                                                                                 |
|------------------------------------------------------------------------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Reconstruction of the chlorination facility of the Upper Kizilsky water intake, transition to electrolysis treatment | 2017                  | Eliminating liquid chlorine, an environmentally hazardous reagent, from the technological process for the disinfection of drinking water and its replacement with safe sodium hypochlorite. The use of sodium hypochlorite instead of liquid chlorine leads to a decrease in side effects from the use of chlorine, namely: chloramines, trihalomethanes are not formed, organoleptic indicators improve. |
| Iron removal installation for Verkhne-Kizilsky drinking water intake   | 2017–2019             | Reducing the iron content in the wells of the Upper Kizilsky water intake to the standard.                                                                                               |
| Reconstruction and modernization of the main water conduit             | 2017–2021             | Replacing steel pipes with polyethylene pipes and replacing a diameter of 700 by 500 mm in connection with the optimization of the hydraulic characteristics                                               |
| Drinking water treatment system of the Yangelsky drinking water intake | 2019–2022             | Achieving quality indicators for total harness in some wells of the Yangelsky water intake in accordance with regulatory requirements                                              |

The proposed measures will help improve water quality in the territory of the municipality, thereby improving the quality of life and preserve the health of the population.

In order to increase the level of validity of the proposed recommendations for achieving quality indicators of drinking water in some wells of the Yangelsky water intake and bringing them into compliance with regulatory requirements, it is necessary to perform the following actions: to predict an increase in the quality of drinking water as a result of the installation of a water purification system for the Yangelsky drinking water intake. Prediction of improving the quality of drinking water, including lowering the overall hardness, as a result of the installation of a drinking water treatment system, was based on the retrospective results of the introduction of similar drinking water treatment systems in the municipalities of the Chelyabinsk region, presented in Table 2, and a probabilistic forecasting system.

**Table 2.** Results of the introduction of drinking water treatment systems in municipalities of the Chelyabinsk region

| Name of municipality          | Improved quality of drinking water as a result of the introduction of drinking water treatment systems,% |
|------------------------------|------------------------------------------------------------------------------------------------------|
| Verkhneufaleysky city district| 6.4                                                                                                  |
| Karabash city district        | 7.1                                                                                                  |
| Chebarkul city district       | 5.0                                                                                                  |
| Ashinsky municipal district    | 5.0                                                                                                  |
| Etkul municipal district       | 8.2                                                                                                  |
| Katav-Ivanovo municipal district| 10.0                                                                                              |
The system of probabilistic forecasting was used to plan values that smoothly change in different directions and was implemented in the MS Excel environment, which significantly reduced the number of calculations. The system of probabilistic forecasting involves performing the calculations in the following sequence:

1. The average expected value of the event is calculated by (1):
\[
\bar{x} = \sum_{i=1}^{n} p_i \times x_i
\] (1)
where \( p_i \) is the absolute value of the \( i \)-th result; \( x_i \) is the probability of occurrence of the \( i \)-th result; \( n \) is the number of outcome options.

2. The standard deviation of the actual results from the average expected value is calculated by (2):
\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2 \times n}{\sum n}}
\] (2)

The results of the calculation of the average expected value and standard deviation are shown in Table 3.

**Table 3. Results of probabilistic planning to improve the quality of drinking water**

| Reduced hardness of drinking water as a result of installed drinking water treatment system | Probability | Mean expected value of improvement in drinking water quality | Mean quadratic deviation of actual results from average expected value [%] |
|---|---|---|---|
| 6.4 | 0.17 | 1.088 | 0.007 |
| 7.1 | 0.17 | 1.207 | 0.001 |
| 5.0 | 0.33 | 1.65 | 1.37 |
| 8.2 | 0.17 | 1.394 | 0.23 |
| 10.0 | 0.17 | 1.7 | 1.49 |
| Total | 1.0 | 7.039 | +/- 1.76 |

According to the table, the average expected value of improving the quality of drinking water will be 7.039 %. However, there are two possible scenarios:

1) best-case scenario, in which the improvement in the quality of drinking water can amount to 8.799 % (7.039 + 1.76);

2) worst-case scenario, in which the improvement in the quality of drinking water can reach 5.279 % (7.039 – 1.76).

4. Conclusion
The proposed measures to improve the health status and quality of life of the population in single-industry towns in the field of water supply and sanitation include:
- to provide for the construction of treatment facilities in storm sewers;
- to carry out the reconstruction of urban treatment facilities;
- bring the quality of drinking water to compliance with the requirements of sanitary legislation.

Thus, the proposed action related to the use of new drinking water purification systems is effective because it will significantly reduce the total hardness of drinking water, which will lead to an increase in the quality of drinking water and bring it in line with the established standards of sanitary rules.

The research results are of practical importance, as they can be used to improve existing programs at the federal and regional levels in order to improve the environmental situation.
References

[1] Zinovyeva E, Balynskaya N and Koptyakova S 2019 Features of sanitary and epidemiological population welfare in monoprofile cities within the conditions of technogenic environment *Economic and Social: Mater. XIV Int. conf. Russian Regions in the Focus of Changes* (Ekateringburg, 14–16 November 2019) pp 54–62

[2] Alferov I N and Yakovenko N V 2016 The problem of providing high-quality drinking water to the population of the water-deficient region of the Orenburg region *Human Ecol.* 4 3–8

[3] Butorina N N, Bychkov A A, Samutin N M, Orlova I G and Pozdnyakov S A 2017 Modern approaches to the regulation of waste management of non-canalized facilities at the regional level *Ecol. and industry of Russ.* 10 68–71

[4] Onishchenko G G 2012 Results and prospects for ensuring the sanitary and epidemiological well-being of the population of the Russian Federation *Hygiene and sanitat.* 4

[5] Kolokoltsev V M, Vdovin K N, Maiorova T V and Ponomareva O S 2017 Ecological indicators in the system of non-financial re-porting at industrial enterprises *CIS Iron and Steel Rev.* 13 4–10

[6] Mayorova T V and Ponomareva O S 2015 Methodology for assessing the economic efficiency of environmental management of enterprises in the metallurgical industry *Vestnik of Nosov Magnitogorsk State Technical University* 4(52) 112–6

[7] Steblyanko V L, Zinovyeva E G and Koptyakova S V 2019 Efficiency of monitoring the sanitary-epidemiological state of Magnitogorsk *Steel* 4 80–3

[8] Leaves G D and Herbert R D 2002 Economic and environmental impacts of pollution control in a system of environment and economic interdependence *Chaos, Solitons & Fractals* 13(4) 693–700

[9] Jaakkola J J K et al 2000 Use of health information systems in the Russian Federation in the assessment of environmental health effects *Environmental Health Perspectives* 108(7) 589–94

[10] Fu Y, Cui X, Liu L, Zhao J and Zhang S 2019 Equilibrium cost of water environmental protection based on watershed sustainability *J. of Hydrol.* 579 124216

[11] Gani A and Scrimgeour F 2014 Modeling governance and water pollution using the institutional ecological economic framework *Econ. Modell.* 42 363–72

[12] Alvarez-Herranz A, Balsalobre-Lorente D, Shahbaz M and Cantos J M 2017 Energy innovation and renewable energy consumption in the correction of air pollution *Energy Policy* 105 386–97

[13] Aznar-Sánchez J A, Belmonte-Ureña L J, Velasco-Muñoz J F and Manzano-Agugliaro F 2018 Economic analysis of sustainable water use: A review of worldwide research *J. of Cleaner Product.* 198 112032

[14] Jiang K, You D, Li Z and Shi S 2019 A differential game approach to dynamic optimal control strategies for watershed pollution across regional boundaries under eco-compensation criterion *Ecol. Indicators* 105 229–41

[15] Pacca L, Antonarakis A, Schröder P and Antoniade A 2020 The effect of financial crises on air pollutant emissions: An assessment of the short vs. medium-term effects *Sci. of The Total Environment* 698 133614

[16] The impact of environmental factors on public health. Medico-demographic situation in the Chelyabinsk region. Retrieved from: http://www.mineco174.ru/files/media/doklad/2014/6-1.htm

[17] Zinovyeva E G and Koptyakova S V 2019 Integrated assessment of sanitary and epidemiological safety management efficiency of the population in Industry – based cities in the Russian Federation *Advances in economics, business and management research* 47 512–6

[18] Zinovyeva E G, Koptyakova S V, Balynskaya N R and Stepashkov P Y 2019 Assessment of monitoring efficiency for the state of sanitary and epidemiological well-being of the population of metallurgical monocities *IOP Conf. Ser. Earth and Environmental Sci.* 350 012050