Drinking Water Preparation for Water Supply of Villages in the Arctic Region

Y Skolubovich1, E Voitov1, A Tsyba1, D Balchugov1 and D Belonogov1

1Novosibirsk State University of Architecture and Civil Engineering (Sibstrin), 113, Leningradskaia str., Novosibirsk, 630008, Russia

E-mail: skolubovich@sibstrin.ru

Abstract. Our scientific research aim was to develop a technological scheme for drinking water preparation, taking into account the natural waters quality and the water supply conditions of small populated areas in the Far North of Russia. Preliminary experimental studies' results of a new treatment technology, carried out on a pilot installation in the production conditions of the Yakutia settlement with the natural water purification of the river Vilyuy are presented in the article. Studies of drinking water preparation technology, developed by NSUACE (Sibstrin), Novosibirsk, show that it ensures the drinking water quality that meets regulatory requirements, minimizes the cost of building and operating water treatment plants. The cleaning technology is as follows: the source water is supplied to the source water tank from a water supply source. Next, water is supplied to the electrochemical processing unit by the booster pump, consisting of two electrocoagulators. In the electrocoagulators, the aluminum electrodes slowly dissolve; aluminum hydroxide flakes are formed; sorbing impurities of iron; manganese and other contaminants from the treated water.

1. Introduction

The new Arctic development strategy until 2035 consolidates Russia's national interests in the Arctic region: ensuring sovereignty and territorial integrity, preserving the Arctic ecosystem, protecting the territory of indigenous peoples, preserving the Arctic as a world territory, as well as protecting citizens’ high standard of living and well-being in the Russian Arctic zone. Improving the northern settlements well-being, developing industrial production, promising development of the Northern Sea Route and protecting the northern borders of Russia requires a reliable, uninterrupted year-round supply of populated places and industrial facilities with good water quality and in sufficient quantities. The uneven distribution of villages and industrial enterprises over the Arctic vast territory of the Russian Federation and mostly their remoteness from centralized systems of water and energy supply dictates its own requirements and conditions the water supply organization. Due to permafrost conditions, it is difficult to build the foundations of water treatment plants. The natural waters of the northern and permafrost regions are characterized by low temperature, high gas saturation (methane, hydrogen sulfide, carbon dioxide), turbidity, color, high content of iron, manganese, sometimes boron, heavy metals, phenol and oil products. The possibilities of delivering chemicals are limited with no reliable transport communications.

A complex of factors acts on a person in the Arctic and Antarctic conditions, such as low temperatures, fluctuations in geomagnetic and electric fields, atmospheric pressure, cosmic radiation at polar latitudes, disturbed light conditions during periods of polar days and nights, a quality food shortage, drinking water and etc.
Much attention is paid to improving water supply, sanitation and hygiene in the developing world for decades, as it is proclaimed by the UN Goal of Sustainable Development, which focuses on “ensuring universal and equitable access to safe drinking water for all” by 2030. However, the provision of tap drinking water is insufficient in its volumes, which negatively affects the health of the Arctic regions’ population. In addition, climate and environmental changes pose a threat to existing water supply and sanitation systems, reducing the availability of clean water [2].

President of the Russian Federation V.V. Putin announced "New Arctic Development Strategy until 2035." at the V International Arctic Forum in St. Petersburg in 2019. The new strategy clearly establishes Russia's national interests in the Arctic. Key ones are: ensuring sovereignty and territorial integrity, preserving the Arctic ecosystem, protecting the indigenous peoples’ territory, preserving the Arctic as a world territory, as well as achieving a high standard of citizens’ living and well-being in the Russian Arctic zone [3]. The Arctic has an important strategic military significance for Russia. A number of important defense industry’s enterprises are located in the Russian Arctic.

The North economic and climatic conditions are different. Rigorous climate, ubiquitous continuous, discontinuous or island occurrence of permafrost soils (permafrost zone), long winters (8-9 months), snowfall, strong winds (snowstorms), frozen low-flow river runoff are common conditions in the North region. Large-scale projects are implemented for the development of unique natural resources, for habitat and urbanization of vast territories, for industrial and energy facilities construction, railways and highways, pipelines, etc. in permafrost zone [4-6].

Improving northern settlements’ will - being, developing industrial production, promising development of the Northern Sea Route and protecting the northern borders of Russia requires a reliable, uninterrupted year-round supply of populated places and industrial facilities with good quality water and in sufficient quantities.

The uneven distribution of villages and industrial enterprises over the Arctic vast territory of the Russian Federation and mostly their remoteness from centralized systems of water and energy supply dictates its own requirements and conditions the water supply organization. In addition, the construction in permafrost zones, including water treatment plants with foundations are prohibited or impossible, because there are no transport communications and reagent delivery capabilities. The problem of water supply in small populated areas in the Far North is solved by modular buildings construction and water treatment plants in container design. Modular water treatment plants can be placed directly on the ground or on a temporary foundation, unlike stationary structures. They can be easily transported together with mobile boiler plants, construction teams, columns, expeditions. Modular water treatment is supplied from the river and groundwater sources located near settlements, shift camps, enterprises, recreation centers and other small water supply facilities.

Natural waters of the northern and permafrost regions are characterized by low temperature, high gas saturation (methane, hydrogen sulfide, carbon dioxide), turbidity, color, high content of iron, manganese, sometimes boron, heavy metals, phenol and oil products. It is necessary to take into account the quality of natural waters and the water supply conditions of small populated areas in the Russian Arctic zone, designing water treatment plants for drinking water supply.

The technology for drinking water preparation for villages at water treatment plants in the Far North was proposed in Novosibirsk State University of Architecture and Civil Engineering (NSUACE (Sibstrin)) in Novosibirsk (Figure 1).

The cleaning technology is as follows: the source water is supplied to the source water tank 1 from a water supply source. Next, water is supplied to the electrochemical processing unit by the booster pump 3, consisting of two electrocoagulators 4. In the electrocoagulators, the aluminum electrodes slowly dissolve; aluminum hydroxide flakes are formed; sorbing impurities of iron; manganese and other contaminants from the treated water.
Figure 1. Technological scheme for the drinking water preparation in the Far North. 1 - source water tank; 2 - equimeter; 3 - a booster pump; 4 - electrocoagulators; 5 - pressure reactor clarifiers; 6 - filter of the first stage; 7 - filter of the second stage; 8 - UV sterilizer; 9 - a reservoir of pure water (RPW); 10 - pump for supplying water to consumers; 11 - taps of drinking water supplying to the network; 12 - bottle filling taps; 13 - node of wash water and sediment processing; 14 - flushing pump; 15 - overflow and drainage pipelines of source water reservoir and RPW; 16 - pipelines of wash water discharge; 17 - boiler.

Then, the water is supplied to the filtration unit under residual pressure, which consists of three filtration stages: purification in the clarifier reactors 5, sequential two-stage filtering on filters 6 and 7, respectively. Part of this water is returned to the suction pipe of the pump 3 through the bypass recirculation line and enters again the electrochemical processing unit for accumulation of aluminum compounds in the system.

Pressure clarification reactors (CR) 5 work in parallel. CRs were loaded with fine-grained burnt sand. The size of the reactor loading fractions and its height are determined as a result of technological modeling. The direction of filtering in the expanded CR loading layer is from bottom to top. The loading washing is an ejector with washing water discharge to the washing water and sediment treatment unit 13. Ejectors are located under the CR. Water-sand pulp is fed into the reactor loading space.

From CR, water flows into two series-connected filters. The choice of filter load type (zeolite, activated carbon, etc.) depends on the quality of the source water and other local conditions. The filtering direction is downward.

Switching the filtration / flushing modes for clarifier reactors 5 and filters 6.7 is performed by changing the position of the upper electric actuator valves.

The filters are washed with clean water in the direction from the bottom up using the washing pump 14.

The washing water is also discharged to the washing water and sludge treatment unit 13.

The purified water is subjected to disinfection using a UV sterilizer 8 after the filtering unit and enters the reservoir of pure water (RPW) 9, equipped with an overflow and drainage piping 15. It is possible to supply water to the consumer’s distribution network with the pump 10 through the pipe 11 and its bottling through the water taps 12.

It is possible to preheat the source water to activate the electrocoagulation process using the boiler 17, due to the especially low temperatures in certain periods of the year.
2. Materials and Methods

Preliminary experimental studies of the new cleaning technology are given in a pilot installation in the production environment of Khoro (Yakutia) village on the natural water of the river Vilyuy. The pilot installation and its electrocoagulation unit are shown in Figure 2.

![Pilot installation.](image)

The averaged indicators of the initial River and purified water quality for the characteristic daily cycle of the pilot plant are presented in table 1.

Table 1. Qualitative indicators of the source, purified water and quality requirements for purified water.

| Pos-s. | Indicators     | Units of measuring | Water source | Purified water | Purified Water Requirements (sanitary rules and regulations 2.1-4.1074-01) |
|-------|----------------|-------------------|--------------|----------------|---------------------------------------------------------------------------------|
| 1     | Hydrogen       | pH units          | 7.82         | 7.7            | 6-9                                                                             |
| 2     | pH value       | mg / l           | Up to 100    | 1.5            | 1.5                                                                             |
| 3     | Turbidity      | mg O₂ / l        | 7            | 3.4            | ≤ 5                                                                             |
| 4     | Oxidizability  | mEq / l          | 5.75         | 5.5            | 5.5                                                                             |
| 5     | pemanganate    | mg / l           | 2.35         | 1.6            | 1.6                                                                             |
| 6     | Total hardness | mg / l           | 0.25         | 0.1            | 0.1                                                                             |
| 7     | Ammonia        | mEq / l          | 5.6          | 5.2            | 5.2                                                                             |
| 8     | Manganese      | mg / l           | 14.6         | 4              | 4                                                                                |
| 9     | Alkalinity     | points           | 2            | 1              | 1                                                                                |
| 10    | Silicon        | mg / l           | 40-60        | 50-60          | 50-60                                                                           |
| 11    | Smell          | mg / l           | 30-40        | 80-85          | 80-85                                                                           |
| 12    | Sulfate ion    | mg / l           | 4.59         | 0.3            | 0.3                                                                             |
| 13    | Chlorides      | ppm               | Up to 200    | 20             | 20                                                                             |
| 14    | Iron is common | CFU / ml         | 27           | 19             | ≤ 50                                                                           |
| 15    | Color          | CFU / 100 ml     | 23           | absent         | absent                                                                          |
| 16    | OMC            | CFU / 100 ml     | not found.   | absent         | absent                                                                          |

Laboratory tests of water quality were carried out by an accredited testing laboratory center in Vilyuisk (Yakutia).
The purified water quality in terms of its physical, chemical and bacteriological properties met the regulatory requirements for sanitary rules and regulations 2.1.4.1074-01 for drinking water, as it was shown by the evaluating results of the natural water purification effectiveness.

3. Results

The world community pays great attention to the Arctic ecosystem conservation, protection of the indigenous peoples' territory, conservation of the Arctic as a world territory, as well as ensuring a high living standard of and Arctic zone' population well-being. However, the provision of tap drinking water is not enough, which negatively affects the health of the Arctic regions’ population. In addition, climate and environmental changes pose a threat to existing water supply and sanitation systems, reducing the availability of clean water.

It is necessary to take into account the quality of water from natural sources and the features of water supply in small populated areas in the Arctic zone of Russia, designing water treatment plants for drinking water supply. Preliminary studies of the drinking water preparation technology, developed by NSUACE (Sibstrin), Novosibirsk, shows its ensuring the quality of drinking water that meets regulatory requirements and minimizes the cost of building and operating water treatment plants. Special studies are required for the selection and justification of the optimal design and technological parameters of equipment in the Far North and methods for the disposal of washing water and sludge development.

References

[1] Kamenetsky M I 2015 Spatial development of land territories of the Arctic zone of the Russian Federation as a sphere of specialized activity of the construction complex, Energy and Environmental Management, 1/16, pp 402-417
[2] Thomas W Hennessey 2017 Arctic Council Initiative to Improve Health in the Arctic Region by Providing Access to Domestic Water and Sanitation Systems, Institution Science "Northwest Scientific Center for Hygiene and Public Health", pp 251-252
[3] Vdovin Yu I, Vishnevskaya N S 1976 Water intake and treatment facilities in water supply systems in the permafrost zone of Russia, Moscow, Publishing, RUDN, pp 236
[4] Lyutov A V 1976 Construction and operation of pipelines of land and channel laying in the North, L, Stroyizdat. Leningrad branch, p 112
[5] Fedorov N F 1979 Handbook on the design of water supply and sanitation in areas permafrost, L, Stroyizdat. Leningrad branch, p 160
[6] Lyutov A V 1981 Engineering communications on permafrost, L, Stroyizdat. Leningrad branch, p 124
[7] Terekhov L D 2008 Water supply and sanitation in the northern climatic conditions, Khabarovsky, DVGUPS Publishing House, p. 124
[8] Alpatov V 2016 MATEC Web of Conferences 86 02005 doi:10.1051/matecconf/20168602005
[9] Alpatov V Y, Lukin A A 2015 Procedia Engineering 111 20–29 doi:10.1016/j.proeng.2015.07.030
[10] Ilyukhin A V, et al 2019 IOP Conference Series: Materials Science and Engineering 643 012102 doi:10.1088/1757-899x/643/1/012102
[11] Onishchenko A, Lapchenko A, Fedorenko O, and Bieliatynskyi A 2020 Advances in Intelligent Systems and Computing 104–116 doi:10.1007/978-3-030-57450-5_10
[12] Pushkareva L, Pushkarev M 2019 E3S Web of Conferences 135 04070 doi:10.1051/e3sconf/201913504070
[13] Duong V A T, Pushkareva L 2020 E3S Web of Conferences 164 11011 doi:10.1051/e3sconf/202016411011