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Preparing the Distillate for Drinking: Chemical and Ecological Aspects

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Abstract. The article considers the stages of preparation of distillate, obtained after desalination of sea water, for drinking purposes. The main criteria for assessing the quality of drinking desalinated water are identified. Technological, hygienic, epidemiological, sanitary-epidemiological requirements for the preparation of drinking water are considered, according to the current regulatory documents. Particular attention is paid to the consideration of environmental problems associated with the use of desalination complexes. Today, the growing need for water sources is considered a key element of sustainable development and possible solutions to this integral problem can be found only by rational integration and implementation of new industrial, economic, environmental and social policies. The decision about the large-scale construction of desalination plants in Crimea must be taken after all the required studies and experimental tests have been carried out and also by taking into account the experience of the advanced countries for desalination of sea water all over the world.

1 Introduction

Generation of drinkable water became on the main problems of humanity. Growing lack of the drinkable water can be compensated by desalination of saline water (with salt concentration higher than 10 g/liter) and brine water (with salt concentration equal to 2-10 g/liter) which are stored in oceans, seas and underground springs. The water reserve in these sources is estimated as 98% of all water on Earth.

To draw the attention of the world's population to the problem of lack of fresh water, 2003 was proclaimed the International Year of Fresh water. In the same year, a body 'UN-Water' was established, that deals with issues related to fresh water and sanitation. The UN General Assembly proclaimed 2005-2015 the International Decade for the action "Water for Life". New goals for future international cooperation, the "Sustainable Development Goals" (SDG) for the period up to 2030, were also adopted, where access to clean drinking water and sanitation was allocated to a separate target at number 6. According to the UN, more than 40 percent of the world's population suffers from water shortages and this figure is constantly growing. According to experts, access to clean water deprived 783 million people on the planet and more than 1.7 billion people living in the river basin, need additional sources of fresh water

The Global Water Resources Analysis and Assessment of Sanitation and Drinking Water is carried out by the United Nations World Water Assessment Program (WWAP), led by UNESCO. Since 2003, the World Water Development Reports have been published annually, the main purpose of which is to provide information on how water-related problems are being solved around the world. The reports are the result of close cooperation between member countries and water partners and represent the results of global monitoring of progress in providing access to safe drinking water, as well as sanitation and hygiene [1].

In the past, fresh water was considered to be naturally available and, at most, was processed with the help of some simple physico-chemical process to achieve the characteristics required for final use. Only recently, fresh water was seen as a product that can be manufactured in compliance with quality standards depending on its specific use.

Solution of the drinkable water shortage problem is possible if there are efficient technological schemes which allow to obtain drinkable water which cost and quality will be comparable with the cost of natural water.

One of the most popular method for water desalination is reverse osmosis, which have a lowest specific energy consumption for every desalination plant. Current research shows that modern reverse osmosis plants exergetic efficiency can reach the values of about 20%. Another popular method is electrodialysis, which is suitable for desalination of sea and brackish water with low salinity. Calculation shows that its specific energy consumption is almost directly related with plant capacity. Finally, most suitable method for waste heat utilization in purpose of drinkable water generation is distillation. Current distillation plants usually consists of large number of stages. They can use steam or mechanical compressor as a heat source. Investigation of their energy efficiency shows that plants with compressor (MVC) have a exergetic efficiency about 8-10% which is lower in comparison with reverse osmosis plant but such plants are more convenient for long exploitation. Another modern technologies include shock-wave generation of salts crystalline hydrates.

2 Properties of distillated water

Thermally desalinated water contains organic compounds, which contain toxic components. The concentration of organic substances in the distillate depends on the quality of the sea water and the operating mode of the distillation plant. Purification of the distillate from organic substances is carried out in sorption filters (absorbers) loaded with granular active carbon BAU or AG-3. Filtration of the distillate through the active carbon layer is carried out from the top down at a rate of 8-12 m/h. The height of the adsorbent layer is assumed to be 1,5-2,5 m. The size of the granular adsorbent is standard.

The granular layer retains only the peak concentrations of organic compounds exceeding the maximum allowable concentration. Therefore, the residual concentration of the individual components, including toxic substances in the filter is at or slightly below the maximum allowable. However, the integral sanitary measure of the total simultaneous effect of everything contained in the filtrate of the toxic components is much greater than unity. This fact is one of the reasons of the search for more reliable methods of sorption purification of thermally desalinated sea water. One way to do this is by filtering the distillate through a bed of particulate active carbon having a large area and active adsorption surface.

3 Distillate treatment

Enrichment of the distillate with the carbonate of calcium is carried out by dosing of an aqueous solution of carbon dioxide and filtration through a layer of calcium carbonate loading. The optimum particle size fractions of the load is 0,8-2,2 mm, and an average of 1,5 mm for crushing limestone is often used the fraction with particle size of 0,6-3,4 mm; the average particle size of this download is equal to 2,0 mm. the height of the bed load is taken equal to 3,0 m. the duration of the contact of the distillate with grains of calcium carbonate in dynamic conditions should be around 12 min. filter the enrichment of the metal machines factory-produced (and with the stabilization of distillate). When a one-stage scheme of enrichment of the filtration rate of the distillate can be taken equal to 15 m/h

Experimentally found that increasing the filtration rate in 2 times (30 m/h) effect of enrichment of the distillate increases by 15-20 %. This condition can be accomplished by two-stage filtration of the distillate with the introduction of carbon monoxide in an aggressive form.

The distillate is purified enriched and subjected to corrective processing. The first stage of this is water fluoridation. As a reagent sodium fluoride or sodium fluorosilicate is used. The dosage of aqueous solution of fluoride of the reagent in the treated water can be carried out by a single parameter – consumption, resulting in easier maintenance metering device of a host of water fluoridation. Fluoride is very corrosive in aqueous media. Therefore, the equipment and communications node of water fluoridation should be made with a corrosion resistant design. As structural materials used vinyl, polyethylene, etc. After pumping the solution of fluoride of the reagent the precipitate is removed in the collector sewerages. You should periodically clean the washing of the inner wall surface of the mortar of a tank by spraying water from a pressure water line, which is also used for filling the solution tank and periodic cleaning of the inner surface and the bottom of the expendable tank. In order to prevent contamination of the air in the room unit of water fluoridation loading of the bunker should be performed under a vacuum by pumping air out using a vacuum pump.

The disinfection of drinking desalinated water is produced by treatment with active chlorine, or any other decision taken in this region by way of water disinfection (ultraviolet, ozonization, etc.). In the case of chlorination the residual chlorine concentration in drinking desalinated water must be agreed with the local sanitary-epidemiological station taking into account the characteristics and condition of the water network and the climatic conditions of its operation.

Water desalinated by distillation, is characterized by deep structural transformations of water and changes in its gas, macro and microelement composition, the content of individual organic substances and microorganisms, which determines the need for its conditioning.

The main measures for conditioning the distillate are the correction of its salt and trace element composition, stabilization treatment, post-treatment from unfavorable organic impurities, lowering of temperature and mandatory final disinfection. When using local mineralized waters for the saline correction of drinking desalinated water, an additional treatment unit for mineralized water is provided on the SPA. The consumption of mineralized water depends on its salt content, consumption and salinity of desalinated water, as well as the permissible mineralization of drinking water. When the distillate is diluted with mineralized waters, the following hygiene requirements are necessary: preliminary purification of mineralizing waters from harmful chemical components and microorganisms to levels ensuring, after mixing them with the distillate, the compliance of the quality of desalinated water with the requirements of GOST R 51232-98 Drinking water. General requirements for the organization and methods of quality control [2].

A special place in the correction of salt composition is the enrichment of the distillate with bicarbonate calcium salts, which is an important factor in improving the taste properties of water, its physiological usefulness and stability (reducing corrosive activity, water aggressiveness). For these purposes, filtration methods of enrichment can be recommended for large installations-filtration through the minerals of calcium carbonate (marble, dolomite, corals) with the preliminary introduction of carbon dioxide (carbon dioxide) in the filtered water in an amount equivalent to the expected increase in the calcium content (1,1 mg CO_3/l on 1 mg of Ca/l).

A highly effective method is reagent enrichment with calcium bicarbonate by introducing carbon dioxide (balloon or blowing gases) and calcium oxide, quenched lime or burnt seed pulp into the water.

For the cleaning of distillate from possible contaminants, volatile organic substances and improvement of organoleptic properties (odor) of the water, we recommend the use of activated carbon. As absorbents activated carbon allowed brands of BAU and AG-3. With decreasing sorption ability of the coals in the process of operation below the required levels must be regeneration. Before distribution to a population, the distillate passes a system of structures and for its further purification and conditioning it must have reliable disinfection from not only the prevention of infectious intestinal diseases, but also from the possibility of the intensive development in the water supply of spore-

forming sulphur and iron bacteria, deteriorating the organoleptic and physical and chemical properties of desalinated water.

The most important condition for receiving good quality desalinated water is the necessary preventive sanitary supervision for the design and construction of desalination facilities, as well as the current sanitary and technological control of their work. The organization of sanitary, hydrogeological, topographical and other studies is the responsibility of design and business organizations.

The procedure of control over the quality of water desalinated in the distillation units, is determined by the requirements of GOST R 51232-98 drinking Water. General requirements to organization and methods of quality control [2] (if provided by centralized potable water) and the Methodological guidelines [3].

Sanitary control is carried out at a sanitary-epidemiological station. In the operational station, for the preparation of drinking water, once a day a bacteriological analysis of mineralized desalinated and drinking water is produced, according to the figures given in table 1.

Table 1. Indicators of bacteriological analysis of mineralized, desalinated and drinking water

Indicators	MAC
The total number of bacteria, units / ml	≤ 100
Indicators for the coliform group:	
coli-index, unit / liter	≤ 3
colitis, ml / unit.	≤ 300

The storage facilities of the station must store the consumption quantities of loading materials: active BAU or AG-3 coal, marble chips or crushed limestone and river quartz sand, and also reagents: liquefied carbon dioxide, active chlorine, lint, or calcined soda, aluminum sulfate and polyacrylamide [4]. In production conditions, especially at large water treatment plants, wet storage of reagents is used in metal or reinforced concrete containers in the form of concentrated solutions and suspensions, which are periodically pumped from pumps to supply tanks with appropriate dilution to the working concentration. Principal scheme of the fresh water treatment station is presented on figure 1.
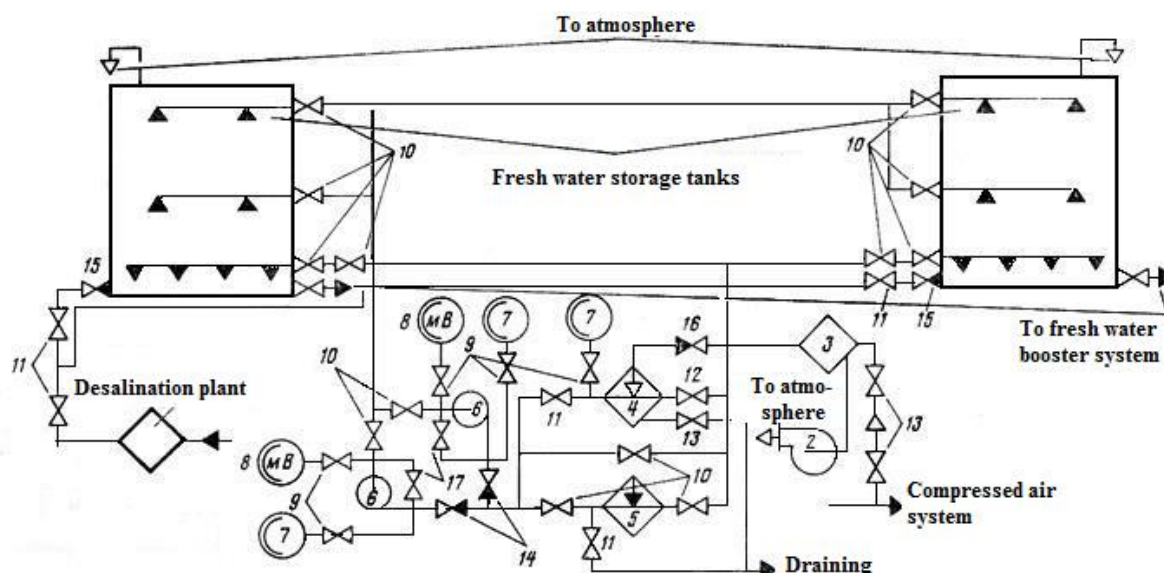
1 – Freshwater plant; 2 – Centrifugal electric fan; 3 – ozonizer; 4 – mixer; 5 – mineralizer; 6 – feeding pump; 7 – manometer; 8 - vacuum manometer; 9 – manometer valve; 10-17 – valves

Figure 1. Principal scheme of the fresh water treatment station

The preliminary treatment of desalinated water which helps to reduce the formation of scale is of great importance in ensuring the sustainable operation of desalination plants. Scale formation is the

main obstacle to the improvement of desalination plants (reducing their size and cost, increasing efficiency and ease of maintenance). Despite the fact that in recent years a lot of effective methods for the reduction of scale formation have been found, the problem cannot be considered solved, since each of these methods has its drawbacks and is only suitable for certain conditions. The analysis of all factors affecting the rate of scale formation has established that the rate of deposits at low temperatures the saturation of the secondary steam is about ten times lower than at high (100 ℃ or more). The work life of a multi-stage vacuum distiller between cleanings can reach 8000...10000 h. More precisely the rate of limescale build-up can be installed for trial testing of the desalination plant.

Therefore one of the objectives of the design and operation of desalination plants in the considered aspect is the creation and maintenance of such operation of the desalination plant at which scale deposition would be minimal, and its consequences — the least unfavorable.

4 Environmental problems of desalination

As soon as the use of desalination of marine waters increases in many countries, it is important to address the environmental problems associated with the use of desalination facilities. These include: greenhouse gas emissions and air pollution; education of brines and concentrates and their subsequent discharge into the sea; the use of large amounts of seawater for cooling purposes and as feed water resulting in the death of marine organisms; problems related to the construction of desalination facilities in coastal zones.

Desalination is a process that is energy intensive. Analysis of the costs of desalination processes indicates that most of the cost of the water is related to the cost of energy. The consumption of energy (fuel) of various desalination processes is directly related to the amount of emissions. The burning of fossil fuels in power plants produces a large amount of greenhouse gases and toxic emissions. It is assumed that in fossil fuel plants, in the production of water at 10 million m^3/day, the amount of CO_2 emissions will increase by 200 million tons/year, SO_2 by 200,000 tons/year, NOx by 60,000 tons/year and VOCs (volatile organic compounds) - by 16,000 tons/year [5]. Therefore, it is proposed to use low-power plants (with a capacity of 5 to 10 m^3/h) and to locate in places where there are problems with a centralized water supply. Considering also a sharp increase in the cost of energy in recent years and a likely upward trend, it seems necessary to find suitable alternative solutions for the supply of desalination complexes. The energy resistance of desalination processes can be improved by combining desalination technologies with renewable energy sources. To date, there is a wide range of well proven technologies for the use of renewable energy sources at desalination plants [5].

When the water of the open seas is desalinated, the problem of removing brines is most often solved by dumping it back into the sea. However, the ways to realize the brine, its impact on the ecological situation and the damage to other natural resources and the environment at the present stage, must be considered as one of the main conditions for the design of the plant.

Depending on the process, environmental problems may occur due to high concentrations of inorganic salts or high temperature waste stream, which may increase the salinity and the temperature of the environment at the place of unloading and can adversely affect local ecosystems. Increase of the seawater salinity negatively affects heat exchangers efficiency. Change of the seawater specific heat capacity leads to decrease of the seawater temperature on the exit of water-brine heat exchanger and increase of the distillate temperature on the exit of water-distillate heat exchanger (which witnesses not total use of distillate latent heat Evaporators are affected by decrease of the effective temperature head due to temperature depression and this causes decrease of the effective heat capacity of the evaporator. In addition, pre-treatment of feed water contains chemical additives, some of which is discharged as waste water. Because sea water is a highly corrosive environment, the waste stream may also contain small amounts of metals that fall into the solution during corrosion of the metal parts inside the unit.

Increasing salinity can be controlled by pre-dilution with other waste streams, such as cooling water, diffusion through a multiport diffuser systems or discharge to the mixing zone, which can effectively dissipate the salt load due to strong wave action.

However, the issue of waste management should be addressed from the standpoint of economic feasibility. In addition, the natural areas of the Crimea are not able to restore the original balance, which can cause serious deviations in the development of flora and fauna in those areas where brine discharges are possible. The discharge of brines into the sea can lead to a change in salinity, alkalinity and average temperatures of seawater and, as a consequence, to a change in the marine habitat. This problem should be solved by creating complexes using wasteless technology for desalination. The receipt of commercial products with a decrease in economic costs for environmental measures contributes to the solution of the problem of utilization of highly concentrated salt solutions.

The environmental impact of desalination plants is currently causing concern in those areas where the potential of desalination is large and constantly increasing. Sustainable desalination is not a utopia, and requires a commitment to provide water at a reasonable price that not only includes a conventional construction and operating costs but also the costs necessary to reduce impacts on the environment, including the cost of environmental studies, advanced technology and compensatory measures.

5 Conclusion

Today, the growing need for water sources is considered a key element of sustainable development and possible solutions to this integral problem can be found only by rational integration and implementation of new industrial, economic, environmental and social policies. The decision about the large-scale construction of desalination plants in Crimea must be taken after all the required studies and experimental tests have been carried out and also by taking into account the experience of the advanced countries for desalination of sea water all over the world.

Acknowledgments

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