PARTICULARITY OF OBTAINING THE PHYSIOLOGICALLY COMPLETE DRINKING WATER BY USING MEMBRANE METHODS

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According to the World Health Organisation (WHO), more than 80% of diseases are related to the quality of drinking water. High-quality drinking water should not contain substances harmful to humans and should contain useful minerals that are necessary for the normal functioning of our body. People usually consume water with 0.02 to 2 grams of minerals per litre [1]. Iodine, calcium, potassium, magnesium, sodium and many other substances that make up drinking water play a crucial role in the body's biological processes. Their deficiency or excess can create serious health problems, and in some cases even provoke epidemics of serious diseases.

According to the Sanitary and Epidemiological Norms 2.2.4-171.10, the maximum permissible salt content in drinking water is 1000 mg/l, but this indicator is not a characteristic of physiologically adequate water.

Most often, tap water is used for drinking at home, where it should be noted that if the water is treated, it is physiologically adequate if its total mineralisation is at least 100 mg/l, according to the Sanitary and Epidemiological Norms 2.2.4-171-10. Water purified by reverse osmosis mostly meets these requirements.

Water treatment technology involves the following stages:

1.Removal of mechanical impurities

To remove suspended insoluble particles from water, we use a mechanical filter. In this case, water passes through a porous material or mesh, the pores or mesh size of which does not exceed 100 microns (microns).

2. Water softening - reducing water hardness.

A special sorption material can be used - an ion exchange resin (cationite). The resin absorbs calcium and magnesium ions in exchange for sodium ions, which are transferred to the water.

3. Removal of iron, manganese and organic compounds

The technology of using Ecomix complex filter material, where inert material similar to softeners is poured into the devices and the multicomponent mixture stratifies independently when the filter is started, allows to purify water from iron compounds with a concentration of up to 15 mg/l and manganese compounds with a concentration of up to 3 mg/l.

4. Reducing water salinity

It is at this stage that reverse osmosis (RO) technology is used, which is able to qualitatively reduce the salt content in water.

Reverse osmosis technologies require additional equipment: a storage tank into which water is fed after purification and a pumping station.

The modular reverse osmosis units that are produced allow achieving the deepest water purification, but at the same time are the most expensive. In most cases, the water after reverse osmosis is also physiologically complete, so two tasks are solved at once: preparation of water for the whole house and for drinking purposes.

5. Removal of odours

The final stage of water treatment technology for various purposes is the removal of odours from water.

To remove hydrogen sulphide, which gives well water the smell of rotten eggs, special activated carbon Centaur is used. Hydrogen sulfide is toxic in high concentrations, but even at low levels it causes corrosion of metal objects.

After the final stage of water purification and odour removal, the resulting water is almost completely desalinated, so it requires additional mineralisation or the installation of a special alternative mineral cartridge. However, this requires additional costs for flushing the mineraliser and cartridge, which is disadvantageous from an economic and environmental point of view.

In this paper, we consider water purification by reverse osmosis using modified membranes, as a result of which the purified water does not require additional mineralisation, the resulting salt content is 100-110 mg/l, which meets the characteristics of physiologically complete water.

Membrane technology for sustainable water production is an effective solution for purification and filtration. Reverse Osmosis (RO) membrane technology is a pressure-driven process with a wide range of applications and has become the main barrier approach for providing high quality water and reusing drinking water. Spiral-wound thin-film composite membranes with polyamide (PA) as the active layer are the most common RO membranes.

Over the past decades, many efforts have been made to extend the service life of RO membranes, including more efficient pretreatment processes, biofouling prevention methods, and the use of membrane cleaning procedures.

Recycling of membranes through membrane modification and reuse in water treatment and water purification technologies is a promising option not only from an economic point of view, but also from an environmental point of view.

Indirect and direct recycling is used to reduce the economic and environmental impact of the disposal of used membranes.

Indirect recycling of the rubber membranes usually involves unwinding the spiral wound rubber elements and removing the plastic components for individual recycling.

Whereas in direct recycling, the polyamide layer is modified to maintain the spiral configuration.

The surfaces of the membranes can be modified by exposing the membranes to a strong chemical oxidant, such as:

- hydrogen peroxide (H_2O_2) (disadvantage: too long processing time of the membrane element);

- potassium permanganate ($KMnO_4$) (disadvantage: difficult to control the degree of oxidant for membrane element modification, because with greater exposure we get a UV membrane);

- ozone (disadvantage: constant control of the concentration at the same level);

-free chlorine compounds or concentrated solution (NaOCl) (the most controlled method).

Since the barrier polyamide layer of the OC membrane has a low tolerance to free chlorine, and long-term exposure changes the morphology and structure of the membrane, chlorine is a widely used agent for changing the porosity of the polyamide layer.

The dose of chlorine depends on the design of the RO membrane and the desired processed product. In general, the literature on the conversion of end-of-life RO membranes into nanofiltration (NF) and ultrafiltration (UF) membranes uses rather high doses of chlorine exposure in the range of 1000 to 48,000 ppm·h for nanofiltration membranes and 20,000 to 350,000 ppm·h for ultrafiltration membranes [2].

Depending on the type of oxidant, in the case of active chlorine, the modification process can be either passive or active.

The passive modification process involves immersing the membrane element in a sealed container with an active chlorine solution for a certain period of time until the membrane element reaches the specified rejection. The process of active modification involves the constant passage of an active chlorine solution under a pressure of 1 bar through the membrane element.

When modified with sodium hypochlorite, the oxidation process of the RO membrane is necessarily carried out with different ratios of volume concentrations before or after the conversion of the RO membrane into an NF/UF membrane.

In this work, the process of modifying the RO membrane was carried out as follows:

the first stage - washing (cleaning) of the reverse osmosis membrane fabric to remove contaminants that may be present on the surface of the membrane fabric;

the second stage - soaking the cleaned reverse osmosis membrane in a solution of sodium hypochlorite with a volume ratio of sodium hypochlorite to water from 1:1000;

the third stage - modification of the membrane by the passive method for 24 hours at a solution temperature of 25 °C.

According to the above scheme, the polyamide composite reverse osmosis membrane is oxidised with sodium hypochlorite, which reduces the degree of crosslinking of the polyamide barrier layer of the reverse osmosis membrane and the osmotic resistance of the barrier layer.

To determine the optimal dose of oxidant for modifying the membrane's RO, we used the XLE membrane fabric (DOW Filmtec, USA).

For the modification of the SO elements (3 samples with a surface area of 42 cm^2), a sodium hypochlorite solution with a step of active chlorine concentration of 250-2000 mg/l and a set pH of 10 to 12 was used, which was prepared by diluting commercial NaClO to reach the required concentration. In this case, the duration of the web modification is carried out within 24 hours at a solution temperature of 25 °C.

The concentration of active chlorine in the solutions for modification was constantly monitored according to the method of Sanitary and Epidemiological Norms 2.2.4-171-10 and adjusted to maintain a constant level [1].

The modification process was carried out in passive conditions to obtain a membrane element of a given rejection, which is determined by the composition of the source water and was calculated using the formula given in [3]:

After the direct modification, the membrane fabric was washed from active chlorine with permeate (until there was no reaction with active chlorine).

Next, the characteristics of the modified membrane fabric were determined using tap water under standard conditions to determine the membrane rejection (R). The effect of chlorine dose on membrane rejection is shown in Figure 1.

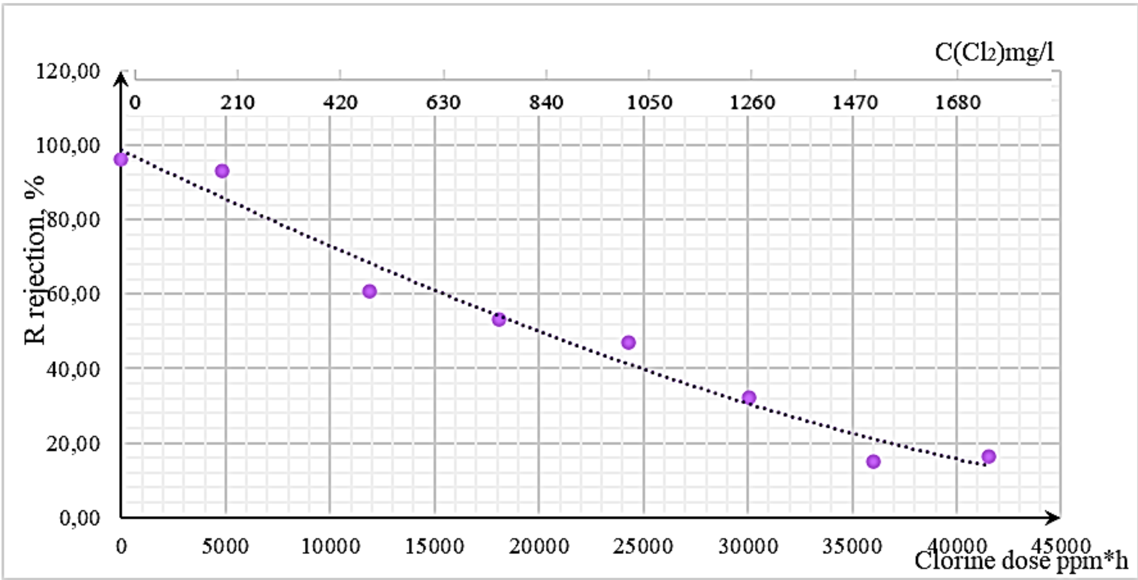

Figure 1 Influence of chlorine dose on the rejection of the RO membrane

Analysing the data obtained (Fig. 1), it is possible to note a decrease in the rejection of the membrane with an increase in the dose of chlorine, which is associated with a change in the structure and permeability of the barrier polyamide layer of the RO membrane under the action of a strong oxidant.

Thus, it was found that the rational oxidant concentration for modifying the XLE reverse osmosis membrane (DOW Filmtec, USA) was 1000 mg/l with a dose of 24000 ppm·h, with the rejection of the modified membrane being 47.5 % (C(Cl_2) = 1000 mg/l) and the salt content of the permeate being 116 mg/l (C(Cl_2) = 1000 mg/l).

The data obtained indicate that it is possible to produce physiologically adequate water without an additional stage of mineralisation of the treated water.

In the future, it is planned to study the pore size of the modified fabric and determine the modification chemistry.

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