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Using crushed stone production waste for drinking water mineralization

The analysis of modern research in the direction of water mineralization during water treatment is carried out. The possibility of mining waste usage for water mineralization after treatment, in particular by reverse osmosis, is considered and substantiated. An experiment in which mining waste was placed in a container with distilled water in the proportion of 100 g of rock per 1 liter of water was carried out. Distilled water was infused during the day. Waste from the crushed stone production process was obtained from PJSC «Tovkachivskyi MPP». The studied rock has the following composition: quartzite – 90–98 %, pyrophyllite – 1–9 %, ore mineral – 0,3–1 %. A study of the chemical composition of water after mineralization was done. It is established that the ratio of mass particles «rock-water» as 1:10 allows us to saturate the water with such useful elements as Calcium, Magnesium, Sodium, Potassium, Silicon, as well as fluorides. However, it should be noted that the content of Iron, Manganese and polyphosphates is also increasing. Determining the optimal ratio of «rock-water», which would allow saturating the water with useful elements and ions, while ensuring compliance with water State sanitary rules and regulations 2.2.4-171-10, is the subject of further research.

Keywords: *mineralization; drinking water; water purification; quartzite; osmosis technology; minerals; mining waste; processing waste.*

Topicality. The peculiarity of the drinking water supply in Ukraine is that it is 70 % based on the use of surface water and only 30 % is groundwater, while in European countries this figure reaches 90 %. The level of provision of the rural population with guaranteed water supply remains very low. Only 24,5 % of rural settlements have centralized water supply systems. The use of mainly surface sources for the supply of drinking water in Ukraine creates great difficulties in ensuring the required quality of drinking water due to the specific chemical composition of water in most water basins of Ukraine. For example, the content of natural organic matter in the water of the Dnipro basin exceeds this value in the rivers of Western and Eastern Europe by about an order of magnitude and reaches 20–30 mg/dm^3. This leads to the formation of toxic organochlorine by-products of water disinfection with chlorine, the emergence and growth of biofilm in distribution networks, which ultimately leads to a significant deterioration in the quality of drinking water [1].

One of the possible ways to improve the quality of drinking water, especially for local water supply and drinking water supply of small and medium-sized cities, is the use of membrane technologies of purification (micro-, ultra-, and nanofiltration) and desalination (electrodialysis, reverse osmosis, nanofiltration, membrane distillation) of natural waters. The total content and ratio of dissolved and dispersed components in natural drinking water vary widely, but they should not exceed the maximum allowable concentrations (MPC) for individual components, which are set by regulations, and should not be lower than physiological (sanitary and hygienic) standards for several vital mineral salts and trace elements. These requirements are particularly important when using natural water desalination technologies such as reverse osmosis, nanofiltration, membrane distillation, electrodialysis and thermal distillation to produce drinking water, as the water obtained by these methods is unfit for drinking without adjusting at least its mineral composition and salt balance [2–4].

Safe drinking water standards are strictly applied in the world to reduce the risk of acute and chronic health threats [5]. A significant amount of research over the past 100 years has focused on reducing the health risks posed by the presence of contaminants in drinking water. However, little attention has been paid to the removal of vital nutrients from water during its purification. Thus, the issue of dominance of water after all stages of its purification is relevant, because reverse osmotic membrane devices with highly efficient membranes (salt retention up to 99 %) do not usually have devices to adjust the mineral composition of water. They effectively purify natural and tap water from most not only harmful but also physiologically important components (hardness salts, trace elements, etc.), and, turn it into a distillate. Such reverse osmosis units can be used under certain conditions only where the salt content in natural water significantly exceeds (3–5 times) the norm, which means during the desalination of saline groundwater and seawater, but in this case a partial adjustment of the mineral composition of drinking water is required [2].

Drinking water due to low mineralization does not meet the requirements for the quality of drinking water, and the use of such water hurts the cardiovascular system, bone mineral saturation, and the state of the human body as a whole. Today, there are various methods to solve this problem, the most common is the salting of water.

However, the use of such water is harmful to human health, because the composition of the salt solution, which salts water, is far from natural mineral waters. Also methods of infusion of water on minerals, such as shungites, are known. Such methods are also ineffective because ion exchange is possible only with direct contact of water with minerals, water molecules can not exchange ions with each other, which means, only the part of the water that is in direct contact with minerals is mineralized. There is a method of conditioning drinking water, according to which the mineralization of water is carried out by calcium. Water passes through layers of calcium sulfate $CaSO_4 \cdot 0,5H_2O$ and calcium chloride $CaCl_2$. Also there is a well-known method of mineralization, which is carried out by passing water through activated carbon, covered with mineralizing components, while an electric current passes. Its disadvantage is the uneven mineralization of water, as well as the need to use electricity [6].

At the enterprises where water is purified by reverse osmosis technology, various dosing equipment is used: a concentrated mineralization solution is introduced into the stream of purified water by a pump-dispenser. By varying the combination and concentration of salts, as well as adjusting the equipment (frequency and volume of solution injection), the desired composition of purified water can be achieved [7]. There are various methods of artificial mineralization of water, in particular: enrichment of artesian, demineralized, mineral, tap water with artificial salts and minerals of natural origin (Morshyn, Slavic, seawater, sea salt). This approach has many disadvantages associated with the macro- and microelement composition of substances used for artificial mineralization of drinking water, the need to use several substances to achieve a balanced mineral composition [8].

There is a method of artificial mineralization of drinking water, which involves the use as a source of mineral components of natural fossil minerals – carnallite, mirabilite, bischofite, which are diluted in water to total mineralization of 0,5–3 g/dm^3. The method is carried out by extracting concentrated solutions of bischofite, carnallite, mirabilite minerals, which are salt deposits of seas of the Jurassic and Permian periods from a depth of 1,5–2,5 km. To do this, artesian or any suitable water for these purposes is injected, which dissolves minerals under pressure. The extracted salt brines have total mineralization of 340–420 g/dm^3. The disadvantage of this method is its complexity and high cost. The authors [9] developed a method of mineralization of water with magnesium and calcium ions, which involves its contact with unburned dolomite. Magnesium and calcium oxides, which are part of calcined dolomite at a temperature of 750–800 °C, are used as mineralizing substances. The contact time of water with an initial hardness of 0,15–5,5 mg-eq/dm^3 and pH 3,0–8,0 with dolomite with a size of 1,75–12,5 mm is 1–9 minutes. There is also a method of mineralization of drinking water, which provides a contact of water with pH correctors. Using at least one liquid pump, the entire volume of water is continuously cyclically pumped through the pH correctors, while the water is in direct contact with the pH correctors, and the process of cyclic water pumping is continued during a predetermined time, required to reach the appropriate pH. pH-correctors are pH-correctors of alkaline metals and rocks. The use of pH-correctors of alkaline metals and rocks provides enrichment of the entire volume of water with cations Ca^{2+}, Mg^{2+} and anions CO_3^{2-}, HCO_3^-, SO_3^{2-} [6].

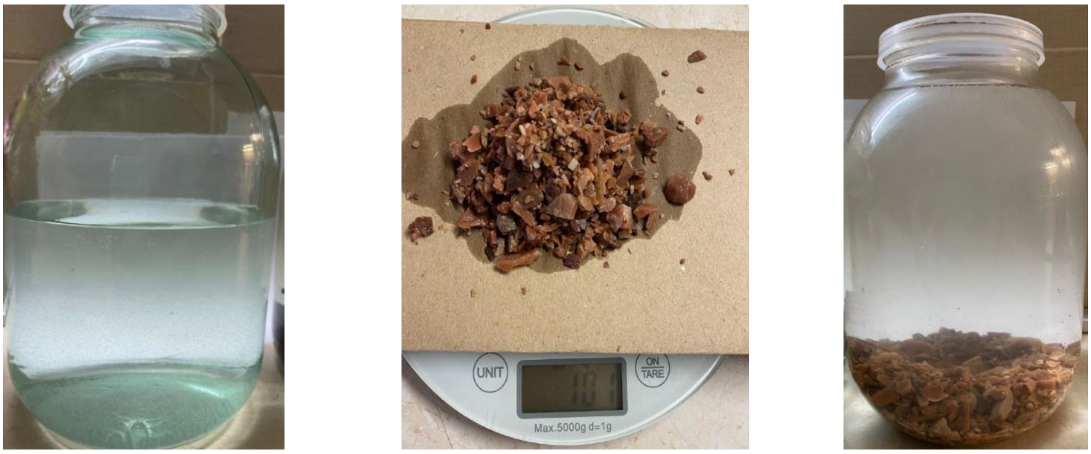
The authors [10] developed a method of artificial mineralization of drinking table, medicinal table, medicinal water, during which as a source of chloride-magnesium-potassium, iodine-bromine ions solutions of natural fossil minerals (carnallite, mirabilite, bischofite) are used.

The aim of the study is to substantiate the possibility of using mining waste, in particular waste from the crushed stone production process, for mineralization of water, which was previously purified by reverse osmosis.

Results of the research. For the mineralization of pre-treated water, the possibility of using mining waste, in particular waste from the process of gravel production at PJSC «Tovkachivskyi MPP» from quartzites, is considered in the paper. Given that the level of mining waste usage in Ukraine is extremely low – no more than 12 %, while in advanced countries it reaches 80 % and does not fall below 65 % [11], the possibility of their use in water treatment technologies is a relevant scientific and practical task. Reducing the volume of dumps will reduce their sawing and the load on the environment as a whole. Besides, the use of such waste as a part of mineralizers will increase the level of resource conservation, as there will be no need to specifically extract natural resources to use them in the process of water mineralization. To achieve this goal, the authors carried out an experiment during which mining waste were placed in a container with distilled water in the proportion of 100 g of rock per 1 dm^3 of water (Fig. 1). Distilled water was infused during the day.

Waste from the crushed stone production process was obtained from PJSC Tovkachivskyi MPP, which is developing the Tovkachiv section of the Ovruch deposit. Metamorphic quartzites of the Ovruch series of the Upper Proterozoic and Upper Quaternary, modern undivided and modern Quaternary sediments take part in the geological structure of the explored Tovkachiv section of the Ovruch deposit. Macroscopic quartzite is a rock of light pink, pink and pink-red color that differs in the durability of mineralogical texture and structure. They lie almost horizontally with a slight slope to the north. The relief of the day surface almost repeats the surface of quartzites. The absolute marks of the quartzite surface within the reconnaissance contour vary from 163,68 m to 173,77 m, making a difference of 10,09 m. Quartzites are broken by numerous steeply falling (vertical) and gently falling (horizontal) diagonal cracks, which are from 10–25 to 40–60 cm, less often they increase to 50–80 cm. Horizontal cracks cut quartzites at distance from each other from 30–40 cm up to 1,2–1,5 m, with depth the fracture almost does not decrease. The studied rock has the following composition: quartzite – 90–98 %, pyrophyllite – 1–9 %, ore mineral – 0.3–1 %.

On the uneven surface of quartzites, there are undissected Upper Quaternary and modern sediments, represented by grayish-brown, gray, yellowish-gray dense sands and fine-grained quartz fragments, with blocks and fragments of quartzites up to 5–35 %. There are sands on the sandstones, the thickness of which varies from 1,5 m to 7,7 m within the open pit of the quarry. They are found in almost all workings. The sands are covered everywhere with a soil-vegetation layer, represented by the same humus sand, with a thickness of 0,1 m to 0,4 m.



a *b* *c*

Fig. 1. Container with distilled water (a), scales with rock at the stage of weighing (b) and container with distilled water and mining waste (quartzite) (c)

The analysis of the obtained water was carried out by the Laboratory of Ion Exchange and Adsorption of the Faculty of Chemical Technology of the National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute». The results of the analysis of the obtained water sample are given in the Table. 1.

Table 1

The results of water analysis after mineralization by quartzites

Characteristic	Indicator value	
	in fact	State sanitary rules and regulations 2.2.4-171-10
Calcium, mg-eq/dm^3	0,1	no regulation
Magnesium, mg-eq/dm^3	<0,005	0,83–6,67
Sodium, mg/dm^3	3,9	<200
Potassium, mg/dm^3	0,7	no regulation
Total iron, mg/dm^3	0,087	<0,2
Manganese, mg/dm^3	0,018	<0,05
Polyphosphates (in terms of PO_4^{3-}), mg/dm^3	0,036	<3,5
Fluorides, mg/dm^3	<0,2	0,7–1,5
Silicon, mg/dm^3	0,59	<10

As a result of the research, it is established that wastes of crushed stone production, in particular wastes of PJSC «Tovkachivskyi MPP», can be used as raw materials in water purification technology with subsequent mineralization. Due to the presence of natural minerals and trace elements in the rock, the mineralization process is carried out by dissolving them in water. The chemical composition of water after mineralization was studied. It is established that the ratio of mass particles «rock-water» as 1:10 allows us to saturate the water with such useful elements as Calcium, Magnesium, Sodium, Potassium, Silicon, as well as fluorides. However, it should be noted that the content of Iron, Manganese and polyphosphates is also increasing. Determining the optimal ratio of «rock-water», which would allow saturating the water with useful elements and ions, while ensuring compliance with water State sanitary rules and regulations 2.2.4-171-10, is the subject of further research.

Conclusions and prospects for further research.

1. The possibility of using mining waste for mineralization of water after purification, in particular by reverse osmosis, is considered and substantiated.

2. An experiment was carried out, in which mining waste was placed in a container with distilled water in the proportion of 100 g of rock per 1 dm^3 of water. Distilled water was infused during the day. Waste from the crushed stone production process was obtained from PJSC «Tovkachivskyi MPP». The studied rock has the following composition: quartzite – 90–98 %, pyrophyllite – 1–9 %, ore mineral – 0.3–1 %.

3. The chemical composition of water after mineralization was studied. It is established that the ratio of mass particles «rock-water» as 1:10 allows us to saturate the water with such useful elements as Calcium, Magnesium, Sodium, Potassium, Silicon, as well as fluorides. However, it should be noted that the content of Iron, Manganese and polyphosphates is also increasing. The determining of the optimal ratio of water and rock, as well as other factors influencing the efficiency of the mineralization process, is the subject of further research by the authors.

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