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Energy saving in water treatment technologies with polystyrene foam filters

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Abstract

In the article we considered the problem of treating groundwater and surface water for drinking purposes.

The efficiency of whole system work depends on filtration installations in the technological schemes of drinking water preparation. A floating granular filling with expanded polystyrene was first proposed at the Department of Water Supply and Drilling (National University of Water Management and Natural Resources).

In article we showed the structure of polystyrene filters and principle of their work. The authors suggested technological schemes clarifying and discoloration of the surface water in single-stage and two-stage reagent schemes and contact groundwater iron removal with polystyrene foam filters. Described principles of work, parameters and conditions of use the technological schemes. We proposed scheme with hydraulic automatic device with switching modes.

Showed implementation experience developed technological schemes of polystyrene foam filters in the water preparation for drinking purposes and assessed the economic efficiency of proposed solutions.

Key words: *clarification and discoloration of water, drinking water, filtering options, iron removal, polystyrene foam filter, technology scheme*

INTRODUCTION

The centralized water supply in Ukraine provides the population of all cities and 86.4% that of settlements with water. About 70% of the population of Ukraine uses surface water; however, 90% of the country population use underground water resources [ORLOV, MARTYNOV 2015].

Water quality becomes worse due to unsatisfactory water management of the main sources of the centralized water supply. The water quality improvement is now one of the major national economic problems. Article 7 of The Law of Ukraine “About drinking water and drinking water supply” [Zakon Ukraini 2918-14: 2002] requires that the country guarantees

supplying each person with drinking water of standard quality.

Due to the shortage of financial resources, the development of effective resource-saving technologies of water treatment, which are simple at installation and operation is extremely topical. Effective work of the whole systems and the cost of water treatment in technological schemes of drinking water preparation largely depend on the cost of filtering constructions.

It is possible to use “heavy” or “floating” filling for the filters. A floating granular filling with expanded polystyrene was first proposed at the Department of Water Supply and Drilling, Ukrainian Institute of Engineers of Water Management (now – Na-

tional University of Water Management and Natural Resources).

WATER TREATMENT TECHNOLOGIES WITH POLYSTYRENE FOAM FILTERS

Filter filling (polystyrene foam) is obtained from the marketable product of polystyrene by processing it with hot water or steam. Polystyrene sinks in water but after processing by steam or hot water it becomes floatable having a density of $0.02\text{--}0.10\text{ t}\cdot\text{m}^{-3}$. There is the permission of the Ministry of Health [DBN B.2.5-74: 2013; VBN 33-3.4-01: 2001; VBN 46/33-2.5-5-96: 1996] for the use of polystyrene as filter filling in drinking water treatment. Large fractions of polystyrene can be crushed before foaming. So formed granules are called the crushed expanded polystyrene. Polystyrene foam filling can be produced directly at water treatment station by foaming the marketable product of polystyrene in water. After foaming, it is carefully washed out in cold water. Now, there is a large number of devices for foaming with steam, which provide bigger range on densities and big size of polystyrene granules. Thus, we don't need to wash the ready products with water.

Polystyrene foam filling in filters with ascending filtering can be single-layer or two-layer. On the basis of theoretical and pilot studies it was found that the diameter of granules of the bottom layer must be greater than the diameter of granules of the top layer. Also the density of granules of the bottom layer must be greater than that of the top layer.

Polystyrene foam filters form a volume, in which the grille of a special design holds polystyrene foam filling in the impounded state. The polystyrene foam filter works with an ascending filtration stream as presented in Fig. 1.

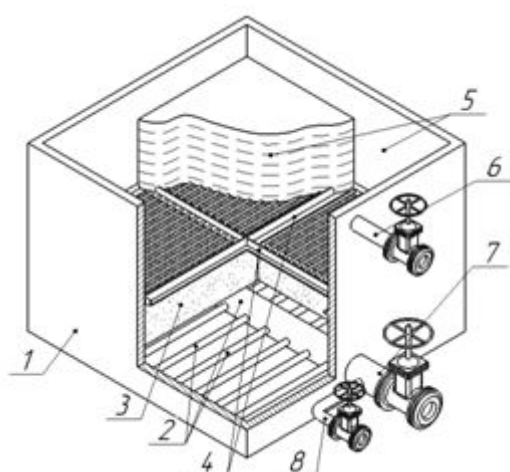


Fig. 1. Scheme of the polystyrene foam filter with an ascending filtration stream; 1 – body; 2 – bottom distributive system; 3 – polystyrene foam loading; 4 – holding grille; 5 – upper part of the filter; 6 – removal of clear water; 7 – removal of washing water; 8 – supply of initial water; source: own elaboration

Raw water is pumped through the pipeline 8 in the bottom distribution system 2, passes a sphere of polystyrene foam filling 3 and cleared gathers in the top part of the filter 5. The filtration cycle ends with the achievement of limit pressure losses or with the deterioration in the quality of the filtrate. The filter uses washing closing valves on the pipeline supplying raw water 8 and opens the gate valve in the pipe with flushing water 7. Pure water from the upper part of the filter space flows down, expands and washes filter filling; then it flows to a distribution system and is discharged into a sewer. Water level in the upper part of the filter space is reduced and flushing stops by closing valves in the pipeline 7 with flushing water. Then, the filter turns once again into the filtration mode by opening the valve for the raw water in pipeline 8. The upper part of the filter space is interconnected to several filters in order to reduce its height.

Polystyrene foam filters can be used (Fig. 2) in a two-stage reagent protocol of clarifying and discoloration of water for final water cleaning after settling tanks or clarifiers with suspended sediment (scheme a) or in a single-stage protocols as contact polystyrene foam filters (scheme b) for iron removal in the pre-treatment of surface water or in wastewater treatment [ORLOV 2008; ORLOV, MARTYNOV 2015; ORLOV *et al.* 1999].

In reagent protocol of water clarification and discolorations, raw water is treated with an oxidizer (for example, chlorine) to oxidize organic matter and then the coagulant is added to water. For muddy raw water it is possible to use polystyrene foam filters with a layer of accumulating sediment. When the

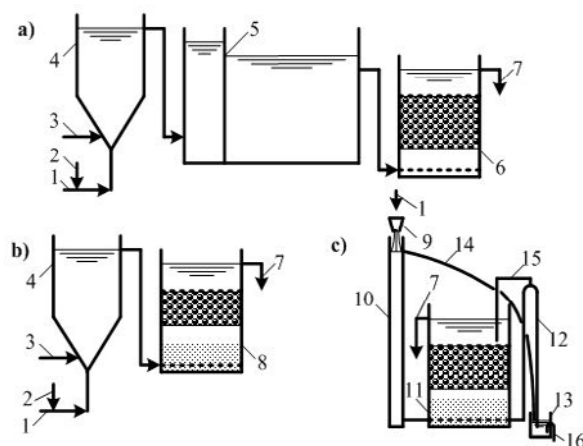


Fig. 2. Technological schemes of drinking water preparing with polystyrene foam filters; 1 – supply of initial water; 2 – introduction of chlorine; 3 – introduction of a coagulant; 4 – mixer; 5 – settling with flocculation chamber or clarifier with suspended sediment; 6 – fast polystyrene foam filter; 7 – treated water removing; 8 – polystyrene foam filter growing a layer of suspended sediment; 9 – aerator; 10 – sand filter; 11 – filtration speed regulator – air separator; 12 – polystyrene foam filter with a contact mass in the lower part; 13 – flushing siphon; 14 – water seal; 15 – filling tubes; 16 – siphon discharge; source: own elaboration

source water is cloudy, one can use filters with a layer of polystyrene to increase sediment settling. Before any filtration after washing the bottom of the filter layer it is necessary to leave sediment, which gradually increases upon filtration and removes the main part of contaminants (scheme b).

The upper part of polystyrene foam filter should be filled with the layer of sorption filling. The best to remove odors and flavors is activated carbon AG-3 in a form of polystyrene foam-carbon filter. The sorption capacity of carbon AG-3 allows using it for up to one year without recovery. The use of sorption fillings of worse sorption properties is impractical because of they need to be frequently replaced. In addition, the high uniformity of coal AG-3 provides favorable hydraulic filter modes, especially during washing.

For iron removal from water it is recommended to use (scheme c) aeration followed by filtering. At low concentrations of ions in raw water, the ordinary polystyrene foam filter is sufficient, but at a considerable concentration of ions the growing sediment layer and polystyrene foam filling is necessary. It is possible to build the air separator and the filter in a metal tower column. Thus, the simplified aeration with free water flow in an air separator of a height not less than 0.5 m can be used or more vigorous aeration by the vacuum aerator. During iron removal from water, filter run is terminated by the loss of pressure. Therefore, the switch of the filter from filtration mode to washing mode and vice versa is carried out by means of the hydraulic device without fittings (scheme c). Bent tubes which can provide smaller expenses of water for own needs of installation can be installed instead of a hydrolock and a siphon of depletion.

Filtration speed is set up at $7\text{--}10\text{ m}\cdot\text{h}^{-1}$ in filters without suspended sediment layer and at $4\text{ m}\cdot\text{h}^{-1}$ in filters with the suspended sediment layer. Flushing of polystyrene foam filling provides downstream flow of treated water with an intensity of $10\text{--}12\text{ l}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ for 3–4 min. Terms of schemes are given in [ORLOV, MARTYNOV 2015; ORLOV *et al.* 1999].

Such technological schemes are implemented in wastewater treatment plants Zhytomyr, Kyiv, Khmelnytsky, Cherkasy, Donetsk region, the Republic of Crimea, including Dzerzhinsk filtration plant (Fig. 2)



Phot. 1. Contact polystyrene foam filters of Teteryv River water treatment: a) top view; b) flushing valve with pneumatic actuator (photo: S. Martynov)

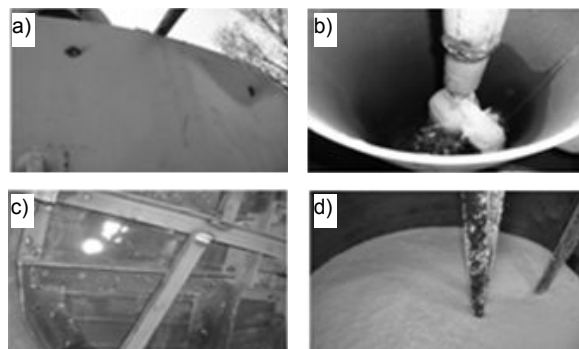
and in Sokol block filtering stations (Phot. 1) with reconstructed facilities that process drinking water color and low dreggy waters of the Dnieper River and Seversky Donets.

Water treatment station with the contact polystyrene foam filters was built (Phot. 1) to clean the low turbidity and low colored waters of the Teteryv River in Korostyshiv.

In the Kiev region, polystyrene foam filters with the ascending filtering flow were located in the open air for a number of settlements. Raw water with the iron concentration of $4\text{ mg}\cdot\text{dm}^{-3}$ from the well gets to the aerator and then into air separator and two filters. Interconnectivity of the upper part of the filter of two metallic filters of a diameter of 3 m is provided by the pipeline 0.25 m in diameter.

At present, one of the most promising designs are iron removal stations of a tower type, where the polystyrene foam filter for water treatment are installed directly inside the metal water tower. Their daily output is 200 m^3 . The work of such water treatment tower plants, as well as the usual water towers, is directly connected with the pump installed in the water supply wells (the filter works in a slight mode).

Photography 2 shows the typical components of iron removal station tower.



Phot. 2. Structural elements of iron removal station tower: a) air vents; b) air separator; c) holding grille; d) polystyrene foam download with pipes of underground water and aerated water (photo: S. Martynov)

CONCLUSIONS

Compared with the existing technological schemes, in which the final stage of cleaning is done with filters filled with heavy sand, proposed schemes provide savings in capital investment by 40–50%, in the operating costs by 30–40%, in the cost of electricity by 7–9%. They also reduce water consumption for own needs by 10–25%, the amount of buildings and structures by 8–36%, the demand for reinforced concrete products by 15–43%, that for metal pipes by 26–

51% and for gate valves by 40–52%. Other advantages include non-flushing pumps and tanks, more successful arrangement of facilities for installation reservoirs of clean water at high altitudes, reduced number of staff, and significant simplification of the operation [ORLOV, MARTYNOV 2015; ORLOV *et al.* 1999].

Thus, these results suggest the feasibility of the use of energy saving technologies with polystyrene foam filters in the drinking water treatment.

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Oszczędność energii w technologiach uzdatniania wody za pomocą filtrów ze spienionego polistyrenu

STRESZCZENIE

W pracy przeanalizowano problem uzdatniania wód gruntowych i powierzchniowych do celów konsumpcyjnych. Wydajność pracy całego systemu zależy od instalacji filtrów w technologicznym układzie przygotowania wody pitnej. Pływające ziarniste wypełnienie ze spienionego polistyrenu zaproponowano po raz pierwszy w Zakładzie Zaopatrzenia w Wodę i Wierceń (Państwowy Uniwersytet Gospodarki Wodnej i Zasobów Naturalnych).

W publikacji przedstawiono strukturę polistyrenowych filtrów i zasady ich działania. Autorzy sugerują technologiczny schemat klarowania i odbarwiania wód powierzchniowych w układzie jedno- i dwuetapowym z usuwaniem żelaza w kontakcie z filrami ze spienionego polistyrenu. Opisano zasady działania, parametry i warunki stosowania technologicznych rozwiązań. Zaproponowano układ z automatycznym urządzeniem hydraulicznym do przełączania sposobów pracy.

Przedstawiono także doświadczenia we wdrażaniu zaawansowanych technologii uzdatniania wody pitnej z użyciem filtrów polistyrenowych i oceniono ekonomiczną efektywność proponowanych rozwiązań.

Słowa kluczowe: *filtry ze spienionego polistyrenu, klarowanie i odbarwianie wody, schemat technologiczny, usuwanie żelaza, warianty filtrowania, woda pitna*