BULLETIN of Cherkasy State Technological University

Journal homepage: https://bulletin-chstu.com.ua/en

Vol. 28 No. 4. 2023

UDC 628.164-926.41
DOI: 10.62660/2306-4412.4.2023.28-35

Study of possibilities of cleaning of mechanical filters of baromembrane plants

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Abstract. The appearance of contamination on the membrane and filters, which significantly reduces the efficiency of operation (separation efficiency, water permeate flow, salt rejection) and the service life of a reverse osmosis plant, is one of the most urgent problems that arise during water treatment using this plant. Therefore, the purpose of the work is to find optimal methods for cleaning and regeneration of mechanical filters of reverse osmosis plants. The solution to this problem is carried out by means of an empirical analysis of available scientific information and conducting laboratory studies on cartridge cleaning and infiltrate processing. A cycle of experiments on cleaning of used mechanical filters of reverse osmosis in a specially assembled plant with a gradual increase in the concentration of sulphuric acid has been conducted. According to the observations during laboratory research, effective removal of dissolved iron from the solution used to wash contaminated polystyrene filters begins at pH = 4 and up to pH = 10, but at pH = 4 the settling and filtering take 24 hours, and at pH = 10 this process takes no more than an hour. As a result of further research, the most effective hydrogen indicator for settling and almost complete removal of iron from the solution is 4.5. Further increase of the hydrogen indicator to 10 is ineffective. In addition to the chemical method of neutralising the mother solution, the use of electrodialysis is also advisable, while the use of electrolyser with a lead anode would be the best option. Thus, after cleaning of one mechanical filter, almost 80 g of pure gypsum is obtained. This gypsum can serve as a high-quality cement additive or be used for the production of internal cladding plates. Clean water obtained during the process can be used for subsequent cycles of other mechanical filters cleaning

Keywords: reverse osmosis; cartridges; polystyrene filters; regeneration; carbon filters; concentrate

Article's History: Received: 06.09.2023; Revised: 11.11.2023; Accepted: 18.12.2023.

INTRODUCTION

Reverse osmosis (RO) as a method of purification of water of any content to drinking standards is a popular and widespread technology in the world. The possibility of obtaining clean water easily and without unnecessary costs eliminates environmental risks and threats that these plants bring to the environment. Manufacturers of reverse osmosis plants and variable components for them (polystyrene filters, carbon cartridges, membranes, mineralisers and ultraviolet disinfectants) are not interested in investigating the damage that their business is doing to the environment. Scientists from all over the world are focused on the study of optimisation of osmotic and energy processes at plants, modification of membranes, the development of the latest antiscalants and aggressive chemical membrane cleaners that extend their service life. However, the huge complex of damage caused by uncontrolled and growing use of such plants in everyday life, despite their benefits for humans, is not taken into account. In addition to the fact that in the

Suggested Citation:
Karpenko, M. (2023). Study of possibilities of cleaning of mechanical filters of baromembrane plants. *Bulletin of Cherkasy State Technological University*, 28(4), 28-35. doi: 10.62660/2306-4412.4.2023.28-35.

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process of water purification, 1/3 of the inlet water for purification is discharged into the sewer, hundreds of thousands of used polypropylene filters, mineralisers, plastic cartridges with activated carbon, ultraviolet disinfectants and the membranes themselves, contaminated with products of cleaning, are thrown into the environment every year without processing. There is no statistical information on the damage caused, just as there are no environmentally safe methods to regenerate the components of filters and blocks. Therefore, this issue is relevant and still not resolved.

The use of baromembrane technologies for water purification is one of the most effective and widespread technologies in the world, according to an analysis by X. Zhang and Y. Liu (2021). According to D.M. Warsinger *et al.* (2018) and M. Qasim *et al.* (2019), the appearance of membrane and filter contamination, which limits the efficiency of operation (separation efficiency, water permeate flow, salt rejection) and the lifetime of the reverse osmosis plant is one of the most serious problems that arise in RO water treatment. If the membrane can be used for 1-2 years, then mechanical filters must be replaced every three months. Untimely replacement of filters can lead to scale formation on the membrane, and the failure of the entire system, according to T.M. Joseph *et al.* (2023). Contamination and scale formation reduce the hydrophobicity of the membrane and deform the pores, which leads to wetting of the membrane – a critical drawback in the plant, when the nutrient solution flows through the pores in the liquid phase, which threatens the rejection of the membrane and inefficient water purification.

In the literature, quite a lot of methods and ways of membrane protection are described, but almost no attention is paid to pre-membrane cartridges (filters), since they are quite cheap, and their regeneration does not have a significant economic effect. However, from an ecological point of view, the accumulation of such waste is quite critical and dangerous. The availability of carbon filters significantly complicates the regeneration of filters for mechanical (pre-membrane) cleaning. In their research, I.I. Radovenchyk *et al.* (2023) studied the problem of filter disposal and environmental contamination due to the use of reverse osmosis systems. They noted that after 3-6 months, such filters are thrown out with the usual garbage. This leads to environmental contamination, which carries with it a number of threats. The authors point out that there are no enterprises in Ukraine dealing with the disposal of such filters. Researchers M.V. Kravchenko *et al.* (2021) proved that contamination and untimely replacement of filters precede membrane contamination and reduce its service life by 30-35%. Preventive and corrective measures are required for continuous operation of the plant. These corrective and preventive measures are necessary according to the properties of the outlet water as well as the properties of purified water, for example, in purified water after desalination, an environment is formed which can cause corrosion in the corresponding equipment. These measures can be implemented in pre-treatment methods, internal therapy modification, and post-treatment requirements. Periodic measurements can be used to analyse productivity.

Scientists X. Zhang and Y. Liu (2021) noted that the quantity and quality of the outlet water can change when the properties of the inlet water and operating parameters change. Scale formation on the membrane is caused by settling on the surface of the membrane (heterogeneous nucleation) or settling in the bulk solution (homogeneous nucleation) followed by settling on the membrane. In their study, C. Skuse *et al.* (2021) noted that calcium and silicon are the two ions that are usually responsible for membrane scale formation.

Scientists M. Jafari *et al.* (2020) described in detail an important indicator for detecting the contamination of membranes and filters – the silt density index (SDI, an indicator of the potential of the outlet water contamination). This is an on-site calculation of colloidal and suspended particles. This is a test to analyse the productivity of equipment used for pre-treatment of water. Silt density index measurements should be performed using pre-cleaning cartridge filters. The value of SDI should be as minimal as possible, which can be achieved by operating the filter material at its calculated pressure drop (ΔP) and proper backwashing of mechanical filters. SDI can also be minimised by using auxiliary filters in the system of polystyrene and carbon cartridges, but in Ukraine this practise has not yet been introduced into mass production.

V. Radovenchyk *et al.* (2023) studied the possibility of mechanical filters cleaning with sulphuric acid solutions and showed positive results of this method. At the same time, oxides and hydroxides of iron (III) pass into the solution and release the pores of the cartridge. However, the use of highly concentrated sulphuric acid is possible only in industrial conditions.

Therefore, the purpose of the study was to find, substantiate and confirm by laboratory experiments ecologically safe and affordable methods for regeneration of polystyrene filters of baromembrane water purification plants in household conditions.

MATERIALS AND METHODS

To perform the task of assessing the possibility of regeneration of used filters of reverse osmosis plants, the method of analysis in laboratory conditions was used, and the method of chemical analysis was used to evaluate the change in the hydrogen index and concentrations of contaminants. The method of functional analysis was used to observe the processes of settling, which made it possible to determine the optimal indicators of settling of the suspension. To determine the content of iron as the main contaminant of mechanical filters, the sulphate salicylic method was used according to DSTU 7262:2012 "Chemical reagents. Methods of determination of iron impurities" (2013).

The experiments were conducted on the basis of the laboratory of the Department of Ecology and Technology of Plant Polymers of the Faculty of Engineering and Chemistry of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". A cycle of experiments on cleaning of used mechanical filters of reverse osmosis (Ecosoft, Ukraine) in a specially assembled plant with a gradual increase in the concentration of sulphuric acid was conducted, the processes of cleaning the pores of the filters from iron compounds were carried out according to formula (1):

$$2Fe(OH)_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2O. \qquad (1)$$

Measurements of concentrations and the hydrogen indicator were made every 8 min after circulation of the solution in a purification plant. Different doses of sulphuric acid were used and the hydrogen indicator was monitored using a pH metre when the acid was gradually introduced into the cleaning solution. The optical density was also measured on a photocolorimeter using the sulphate salicylic method and the content of iron in the solution was determined. The introduction of sulphuric acid was stopped when the concentration of iron ions remained unchanged, that is, when the filters were completely cleaned.

To determine the optimal hydrogen indicator, at which complete neutralisation of sulphuric acid in the solution and effective filtering of the obtained suspension would occur, a number of experiments on model solutions were conducted. 26.9 g of $FeCl_3$*$6H_2O$ were dissolved in distilled water, the obtained solution was brought to 1000 ml with the pH = 2.1. Five samples of 100 ml were taken. With the help of NaOH, the pH was gradually increased by 0.5 to 4. With the help of measuring cylinders, the intensity of settling and distribution into suspension and liquid phase were observed. Then the resulting solution was settled for a day and filtered.

RESULTS

The results of measurements of the intensity of settling and filtration of the suspension obtained in the process of mechanical filters cleaning using sulphuric acid solution of different concentrations (the effect of concentration is noted on the hydrogen indicator for $FeCl_3$*$6H_2O$) are shown in Table 1.

Table 1. Results of measurements of settling intensity and suspension filtration

pH $FeCl_3$*$6H_2O$	**2.6**	**3.1**	**3.6**	**4.03**	**10**
V (NaOH), ml	2.5	2.62	2.75	2.78	2.8
The ratio of the liquid phase to the suspension, % during settling for a day	100/0	100/0	98/2	80/20	23/77
The volume of filtrate in the cylinder when filtering the suspension during the day	100	100	72	48	100
Notes*	The filter is coloured but clean, the filtrate is coloured, all iron is in the filtrate	Filtering is very slow, there is little sediment on the filter, the filtrate is coloured, most of iron is in the filtrate	Filtering is slow. The filtrate is transparent, the concentration of iron in the filtrate is 1.6 mg/l	The filtrate is transparent, the concentration of iron in the filtrate is 0.2 mg/l	Filtering is fast, iron is not detected in the filtrate (the reaction to sulphite salicylic acid and ammonia)

Source: developed by the author based on the results obtained

As can be seen from the research results shown in Table 2, the content of iron in the most contaminated filter is 6.5 g/l, with a norm of 0.2 g/l according to State sanitary standards and rules "Hygienic requirements for drinking water intended for human consumption" (2022). At the same time, 60 ml of sulphuric acid with a concentration of 98% has been used to clean one contaminated filter.

Table 2. Results of iron concentration measurements during cleaning of three mechanical polystyrene filters with a gradual increase in the dose of sulphuric acid

Hydrogen indicator, pH	**Concentration of iron ions, g/l**	**Hydrogen indicator, pH**	**Concentration of iron ions, g/l**	**Hydrogen indicator, pH**	**Concentration of iron ions, g/l**
Filter 1		Filter 1, 2		Filter 3	
pH (1) = 4.5	0.001	pH (0) = 5	0	pH (0) = 5	0
pH (2) = 4.0	0.02	pH (1) = 4.5	0.1	pH (1) = 4.5	0.002
pH (3 = 3.4	0.3	pH (2) = 3.8	0.9	pH (2) = 4.0	0.1
pH (4) = 3.2	0.6	pH (3) = 3.3	3.8	pH (3) = 3.5	1.5
pH (5) = 2.5	3.8	pH (4) = 2.7	5.8	pH (4) = 2.5	5.9
pH (6) = 1.1	6	pH (5) = 1.1	5.8	pH (5) = 1.0	6.5

Source: developed by the author based on the results obtained

The next task, after cleaning the filters, is the neutralisation of products of cleaning, because their discharge into the sewage system is unacceptable, since pH = 1. According to observations, effective removal of dissolved iron from the cleaning solution begins at pH = 4 and continues until pH = 10. However, at pH = 4 settling and filtering require 24 hours, while at pH = 10 this process takes no more than an hour. Additional studies confirm that 4.5 is the most effective pH indicator for settling and almost complete removal of iron from the solution. Further increase in the hydrogen indicator to 10 turns out to be impractical. The research data obtained are used to neutralise sulphuric acid, which, together with dissolved iron removed from the used filter, is in the mother solution.

The volume of the mother solution, which has been formed as a result of cleaning of contaminated mechanical filter of the return osmosis plant, is 1 l, its pH = 0.95, the solution contains 65 ml of sulphuric acid, this volume has been used in previous studies for complete cleaning of mechanical filter. A neutralisation reaction (2) is carried out in order to remove sulphuric acid, which is dangerous for discharge, from the used solution. The calculated amount of 37.42 g of CaO is added, bringing the pH to 5.3. At this level of the hydrogen indicator, the most efficient settling of gypsum ($CaSO_4$) and separation of solid and liquid phases occur:

$$CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O. \quad (2)$$

The filtration of the obtained suspension on paper filters "blue tape" is the next stage. The volume of the filtrate is 776 ml. The mass on the filter before drying is 265.61 g. After complete drying in the drying chamber, the obtained substance is brought to a constant mass of 79.50 g (Fig. 1).

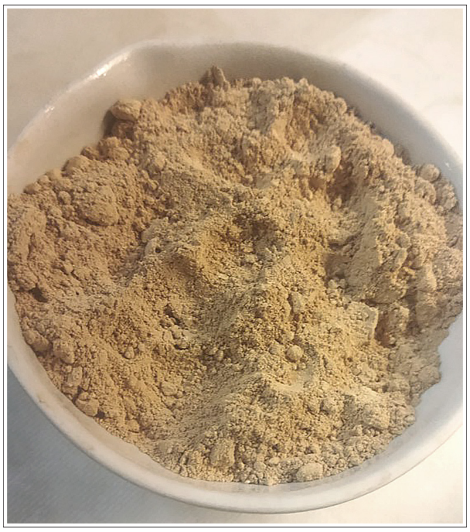

Figure 1. Cement additive obtained as a result of neutralisation of the mother solution from the contaminated filter
Source: developed by the author

This method of regeneration of contaminated filters (using sulphuric acid solution) can be used in the first and third stages of filtration if the first and third filters are made of polystyrene with a corresponding pore diameter of 10 and 5 μm, respectively. By visual examination of the used filters, it has been determined that iron is the most problematic and main contaminant of filters, and even with a small amount of it, it is very difficult to get rid of reddish colour after several stages of cleaning with an acid solution. Therefore, the pH of the cleaning solution should be brought up to 1, while the norm in tap water is 5-6, as shown by the analysis of water samples by the sulphate salicylic method in the laboratory. Figure 2 shows sets of clean (a) and used (b) mechanical filters of the 1st, 2nd and 3rd stages of water purification in reverse osmosis plants.

a

b

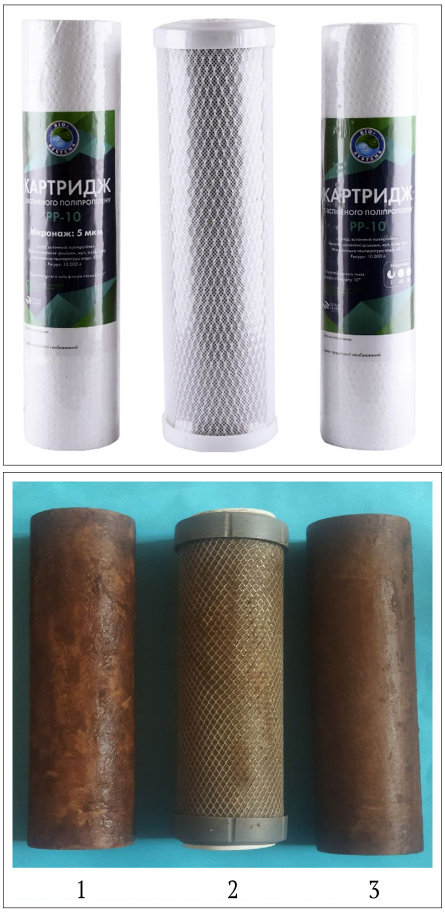

Figure 2. View of Ecosoft filters before and after use in a typical reverse osmosis plant for three months
Source: developed by the author

The set includes two polystyrene filters, which, unlike the carbon one, can be easily cleaned of iron using sulphuric acid. Such a combination of filters for reverse osmosis plant is designated in the international classification as PP, CTO, PP (polypropylene 10 μm, carbon, polypropylene 5 μm). However, sometimes there are other combinations described by F.M. Idrees (2020), such as PP, UDF, CTO (polypropylene 10 μm, from granular activated carbon, pressed carbon cartridge). In general, the approach to cleaning these types of filters does not change, because cartridges are based on coal as the main filler in various modifications.

Purification with a sulphuric acid solution can be used in the first and third stages of filtration if the first and third filters are made of polystyrene. In addition to the chemical method of neutralising the mother solution, the electrodialysis method can be used, while an electrolyser with a lead anode would be the best option. In the process of cleaning the filters, a suspension, from which iron is settled with CaO, filtered and dried, has been obtained. After cleaning of one mechanical filter, almost 80 g of pure gypsum has been obtained. This gypsum can serve as a binding cement additive or be used for the production of internal cladding plates, and clean water can be used for subsequent cycles of mechanical filters cleaning with the subsequent addition of sulphuric acid to it. According to laboratory studies on model solutions with different iron content (from 5.38 to 16.4 grams per 1 litre of solution), the effect of sulphuric acid on iron solubility is shown in Table 2.

As a result of the experiment on cleaning of used mechanical filters, it is found that the content of iron in the most contaminated filter is 6.5 g/l. At the same time, 60 ml of sulphuric acid with a concentration of 98% is used to clean one contaminated filter. From the results of the measurements, it can be seen that with gradual addition of sulfuric acid to the cleaning solution, iron compounds begin to actively dissolve at pH = 3.3, and the maximum efficiency of filters cleaning from iron compounds is achieved at pH = 1.6. The introduction of sulphuric acid has been stopped at an unchanged indicator of iron ions concentration, in other words, at complete cleaning of filters, which occurs at pH = 1.6. These results have been also confirmed during repeated naturalistic experiments with real contaminated filters, removed from users of household reverse osmosis systems in Kyiv. Since the naturalistic experiment involved filters of various degrees of contamination, which depends on the intensity of use, the number of people in the family, the season and the period of use (from 3 to 7 months), the necessary volume of sulphuric acid, needed for filter cleaning, was in the range from 20 to 78 ml per 1 litre of the cleaning solution.

DISCUSSION

According to the results of the experiment, used polypropylene filters can be regenerated and reused in baromembrane water purification plants. Bacteriological safety of using such filters was confirmed by scientists T.Yu. Nyzhnyk *et al.* (2019). However, the reuse of mechanical polystyrene filters was confirmed only by bacteriological indicators. The conducted research also proved the possibility of regeneration for the main chemical contaminant – iron compounds. Therefore, the conducted studies complement and do not contradict the obtained results. In their work, S.V. Huliienko *et al.* (2020) noted that salt rejection and permeate flow were key factors for analysing the productivity of reverse osmosis plants. Membrane productivity can also be analysed by the salt rejection rate of the membrane system.

In the course of research, it has been determined that an aqueous acidic environment (having a pH from 1 to 4) is the best cleaner for replaceable blocks (filters and membranes) of reverse osmosis plants. Increase in acidity, i.e. bringing the pH closer to 1, ensures the dissolution of water-insoluble calcium and silica salts, iron compounds and organic contaminants. Positive effect of the hydrogen indicator on the rejection of salts from reverse osmosis filters and membranes was theoretically described in the works of S.V. Huliienko and I.V. Syman (2018) and A.P. Safonyk *et al.* (2020). In the conducted research, it is possible to prove this theory in practise and to determine specific pH limits, in which the acidity of the environment will be effective. It has been proven that a further decrease in pH < 1 is impractical, because undissolved iron on the filters can no longer exist at this state of the environment. According to the results of the experiments, increase in the hydrogen indicator to 10 is impractical. The obtained research data are used to neutralise sulphuric acid, which, together with dissolved iron extracted from the used filter, is in the mother solution. Researchers M.V. Kravchenko *et al.* (2021) concluded that the settling on the surface of membranes and cartridges of some calcium salts, such as gypsum, is also influenced by high temperatures, as they reversely dissolve with increasing temperature. Gypsum crystals can block and deform the pores, which leads to a rapid decrease in water flow and wetting of the membrane. Calcium ions can also precipitate as calcite or in a complex with organic compounds and cause severe flow reduction, a phenomenon described in detail by S. Virych (2023).

As a result of examination of the content and analysis of the used carbon filler, it is found that it is impossible to chemically regenerate carbon filters. According to the conducted studies, even with a high level of purity of water supplied to activated carbon filters and regular thermal sanitisation (washing with water at 95°C for 2.5 hours), it is impossible to completely remove biological contamination from the cartridge filler. During the process of hot water sanitisation, surviving single planktonic cells begin an active process of microcolonies formation and biofilm creation as a survival mechanism in extreme conditions. Already three days after heat treatment, the formation of a biofilm is observed on the surface of activated carbon granules, which leads to a phenomenon known as biological activation of coal. In her work, M.V. Kravchenko (2022) consistently investigated the behaviour of coal cartridges and proved that due to the peculiarity of coal bulk material, it cannot be restored by detaching contaminant ions. Researchers Ch.Ch. Wu *et al.* (2019), describing the reproduction of bacteria in contaminated carbon filters, came to the same conclusion about the impossibility of regeneration of these filters precisely because of sorption-biological interaction of the sorbent and the contaminant. The results of the observations refute the possibility of creating cartridges with a separate zone for the accumulation of waste contaminants, since in practise the carbon filter behaves differently than in the theoretical work of N.O. Matlakh *et al.* (2022), where methods of modifying polypropylene and carbon filters are shown, with structural construction of filter sections so that sediment accumulates at the bottom of the sections, the bottom of the section must be unscrewed so that the sediment can be removed, and new filters must be easily inserted into the section. The work includes measures to control contamination of pre-membrane filters (titanium plates and ammeter). This solution can extend the service life of mechanical filters, but will not solve the issue of their regeneration and disposal.

Silica scale formation is slower than that of calcium salts such as gypsum because silicic acid polymerises more slowly than gypsum crystallises. Processes of silica scale formation described by I.A. Tereshchenko (2021) proved a high level of threat of silica influence on cleaning efficiency at neutral pH ranges. Even NaCl solutions can cause flow reduction if available in supersaturating concentrations. A. Kayvani Fard *et al.* (2018) investigated that scale mitigation by methods that include volume filtration and antiscalant addition was a rather fictitious way to extend the service life of the membrane and the plant as a whole.

However, the use of a standard set of cartridge filters helps to minimise flow reduction by removing precipitated salts before they reach the membrane. Therefore, timely replacement of filters makes it impossible to damage the membrane with subsequent loss of its efficiency. However, the problem of environmental contamination with such filters has still not been solved globally, because most of them are thrown away either in the trash or in special containers. The achievement of more sustainable and environmentally safe alternatives becomes a critical task for preserving natural resources and maintenance of sustainable development.

CONCLUSIONS

The use of carbon filters complicates the process of restoring filters for mechanical (pre-membrane) cleaning. Iron is the most significant and main contaminant for mechanical polystyrene filters. Even with small iron content, after several stages of cleaning with an acid solution, it is very difficult to remove the reddish colour. Therefore, in order to achieve the effectiveness of the solution cleaning, it is necessary to reduce its pH to the level of 1. This deviation from the usual value of tap water, which is 5-6, has been confirmed by the analysis of water samples using the sulphate salicylic method in the laboratory. After that, filters must undergo forced washing in the circulation network to normalise the hydrogen indicator in the thickness of material and be safe for further reuse in the reverse osmosis plant after regeneration.

It can be seen from the results of measurements that during gradual introduction of sulfuric acid into the cleaning solution, iron compounds begin to actively dissolve at pH = 3.3, and the highest effectiveness of filters cleaning from iron compounds is achieved at pH = 1.6. The addition of sulphuric acid is stopped when the concentration of iron ions remains stable. In general, complete cleaning of filters takes place at pH = 1.6. The obtained results are confirmed during repeated natural experiments with real contaminated filters, which have been taken from users of household reverse osmosis systems in the city of Kyiv.

If polystyrene filters can be completely regenerated with sulphuric acid and after further washing can be used again in the system, then carbon filters are almost impossible to regenerate. The reason is that contaminated coal filler is in a non-separable structure and the very structure of the filler does not allow the contaminant to be removed from the thickness of the coal layer. The case is not disassembled and after removing the carbon filler from it, it must also be disposed of. In Ukraine and in the world, such cartridges are simply thrown away. Regardless of whether they have fillers or have already had them removed, the amount of waste remains the same. This method of regeneration of contaminated filters can be used in the first and third stages of filtration if the first and third filters are made of polystyrene. And reverse osmosis carbon filters, unlike mechanical ones, cannot be cleaned.

In conclusion, it can be noted that reverse osmosis carbon filters, unlike mechanical ones, cannot be processed. The author came to this in the result of a dissection of the cartridges containing these filters. The case is not disassembled and after removing the carbon filler from it, it must also be disposed of. According to the examination of the content and analysis of the used carbon filler, it becomes clear that it is impossible to chemically regenerate carbon filters. According to research, it is impossible to completely clean the cartridge filler, activated carbon, from biological contaminants. Even with high indicators of purity of water entering carbon filters, and periodic thermal sanitisation (washing with water at 95°C for 2.5 hours), it turns out to be impossible to stop microflora development for a long time. During the sanitisation treatment of the filter with hot water, surviving individual plankton cells begin the process of active microcolonies formation and biofilm creation as a survival mechanism in extreme conditions. Already three days after heat treatment, biofilm formation is observed on the surface of activated carbon granules, which leads to the so-called biological activation of coal.

Therefore, the most effective method to recycle carbon filters is to develop a collapsible design of the cartridge, which can be filled with fresh activated carbon, and the used carbon can be burned at high temperatures or sent to the production of coal briquettes. Such briquettes are completely safe for the environment and can be used as solid fuel. The identified and researched methods of regeneration and recycling of mechanical and carbon pre-membrane filters can be applied on an industrial scale with the condition of their larger-scale testing. This technology is inexpensive and allows polystyrene filters to be fully regenerated and reused and it is possible to obtain fuel briquettes from carbon filters during further research on improving the recycling scheme. Among the directions for further research, the following ones can be highlighted: design development and improvement; study and use of new technologies for filters cleaning; energy efficiency, etc. In addition to the mentioned directions, the following aspects are important for study: persistence of contaminations and efficiency of removal of various types of them, materials and membranes, etc.

ACKNOWLEDGEMENTS

The author expresses her gratitude to the staff of the Department of Ecology and Technology of Plant Polymers of the Faculty of Engineering and Chemistry of the National Technical University of Ukraine “Igor Sikorskyi Kyiv Polytechnic Institute” for consultations and assistance in conducting laboratory research. Thanks are also expressed to the residents of Kyiv who agreed to participate in the experiment and provided statistical information, used cartridges and membrane blocks of reverse osmosis plants (Olena Kyrylenko, Oleksii Antonov, Olga Petryshyna, Alina Sobol, etc.).

CONFLICT OF INTEREST

None.

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Дослідження можливостей очищення механічних фільтрів баромембранних установок

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Анотація. Однією з найбільш актуальних проблем, які виникають при обробці води за допомогою установки зворотного осмосу, є поява забруднення на мембрані та фільтрах, що суттєво зменшує ефективність роботи (продуктивність розділення, потік пермеату води, відторгнення солі) і термін служби установки. Тому метою роботи став пошук оптимальних методів очищення та регенерації механічних фільтрів установок зворотного осмосу. Розв'язання цієї проблеми проводилося шляхом емпіричного аналізу наявної наукової інформації та проведення лабораторних досліджень з очищення картриджів та обробки інфільтрату. Було проведено цикл дослідів з очищення використаних механічних фільтрів зворотного осмосу в спеціально змонтованій установці з поетапним збільшенням концентрації сірчаної кислоти. Згідно зі спостереженнями під час проведення лабораторних досліджень, ефективне виведення розчиненого заліза з розчину, яким проводилось промивання забруднених полістирольних фільтрів, починається при pH = 4 та до pH = 10, проте при pH = 4 відстоювання і фільтрування потребує 24 години часу, а при pH = 10 цей процес займає не більш ніж годину. В результаті подальших досліджень найефективніший водневий показник для осадження і практично повного виведення заліза з розчину становить 4,5. Подальше підвищення водневого показника до 10 є недоцільним. Крім хімічного методу нейтралізації маточного розчину, ефективним варіантом є застосування електродіалізу, при цьому оптимальним вибором є використання електролізера з анодом зі свинцю. Отже, після очищення одного механічного фільтра було отримано майже 80 г чистого гіпсу. Цей гіпс може слугувати як високоякісна добавка для цементу або використовуватися при виготовленні плит для внутрішнього облицювання. Чисту воду, яку отримано під час процесу, можна використовувати для наступних етапів очищення інших механічних фільтрів

Ключові слова: зворотний осмос; картриджі; полістирольні фільтри; регенерація; вугільні фільтри; концентрат