ECOLOGICAL ASSESSMENT OF DIFFERENT ARSENIC REMOVAL METHODS IN WATER TREATMENT

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА РАЗЛИЧНЫХ МЕТОДОВ УДАЛЕНИЯ МЫШЬЯКА В ВОДООЧИСТКЕ

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ЕКОЛОГІЧНА ОЦІНКА РІЗНИХ МЕТОДІВ ВИДАЛЕННЯ АРСЕНУ В ВОДООЧИЩЕННІ

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High arsenic level in drinking water is very big problem for many countries in the world. In some regions of Ukraine, especially in the Carpathians, groundwater also has high concentration of arsenic. There are a lot of different methods of arsenic removal from water, but main part of these approaches is not environmental friendly due to producing of toxic waster during treatment process. Thus, ecological assessment is very important in the selection of the treatment method for arsenic removal. Integral assessment is based on the points of view of three experts and includes evaluation of different criteria.

Keywords: *integral evaluation, water treatment, treatment methods, arsenic compounds*

Высокий уровень мышьяка в питьевой воде является большой проблемой для многих стран мира. В некоторых регионах Украины подземные воды также имеют высокую концентрацию мышьяка. Существует много различных методов удаления мышьяка из воды, но основная часть этих подходов не является экологически безопасной из-за образования токсичных отходов в процессе очистки. Тоесть, экологическая оценка очень важна при выборе метода деарсенизации. Интегральная оценка основана на точках зрения трех экспертов и включает оценивание различных критериев.

Ключевые слова: *интегральная оценка, водоподготовка, методы очистки, соединения мышьяка*

Високий рівень арсену в питній воді є значною проблемою для багатьох країн світу. У деяких регіонах України, особливо в Карпатах, підземні води також мають високу концентрацію сполук арсену. Існує багато різних методів видалення арсену з води, але основна частина цих підходів не є екологічно безпечними через утворення токсичних відходів під час очищення. Таким чином, екологічна оцінка є дуже важливою при виборі методу деарсенізації. Інтегральна оцінка базується на точках зору трьох експертів і включає оцінювання різних критеріїв.

Ключові слова: *інтегральна оцінка, водопідготовка, методи очищення, сполуки арсену*

INTRODUCTION

High arsenic level in drinking water is very big problem for many countries in the world. According to the WHO recommendations, 10 μg/L is maximum allowable concentration of arsenic in drinking water. But in some countries, especially Chile, Mexico, China, India, Iran and many others, arsenic content in groundwater can reach thousands of μg/L [1].

In some regions of Ukraine, especially in the Carpathians, groundwater also has high concentration of arsenic [2]. Arsenic due to its high toxicity provokes a lot of different health problems (cancer, skin lesions, neurological disorders, etc.) [3]. So, arsenic removal is necessary treatment stage in these regions.

There are a lot of different methods of arsenic removal from water (Figure 1), but main part of these approaches is not environmental friendly due to producing of toxic wastes during treatment process.

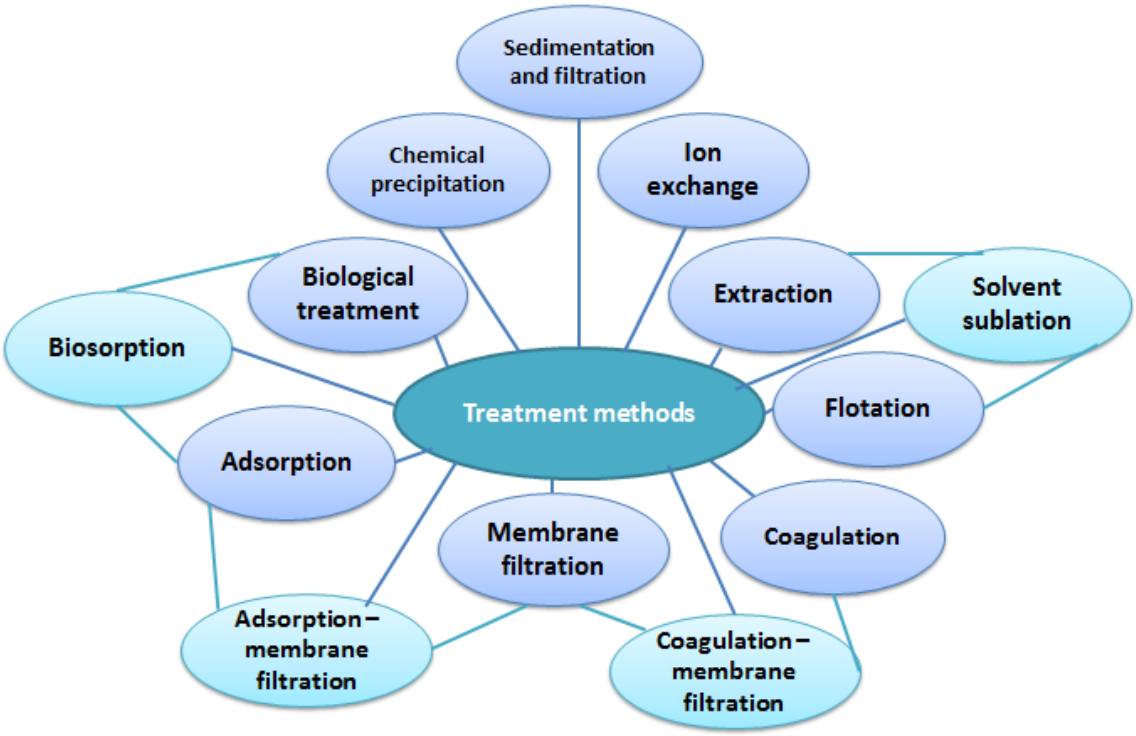

Fig 1. Treatment methods

Thus, ecological assessment is very important in the selection of the treatment method for arsenic removal.

METHOD OF ASSESSMENT

Integral assessment is based on the points of view of the experts and includes evaluation of different criteria. Total score for each evaluated treatment method was calculated by the next formula:

$$MS = \frac{\sum_{i=m}^{m}\sum_{j=1}^{n} C_{ij} \cdot S_{ij}}{m},$$

where ***MS*** is the total score of treatment method; ***m*** is the number of the experts; ***n*** is the number of criteria; C_{ij} is coefficient of criterion importance for each criterion and each expert; S_{ij} is score of the method for each criterion and each expert.

Thus, after calculations by above formula each method has total score on a ten-point scale, where "0" is "very dangerous for environment" and "10" is "completely eco-friendly".

ECOLOGICAL ASSESSMENT

Three experts evaluated some most perspective or most popular methods of arsenic removal (reverse osmosis and nanofiltration, adsorption-microfiltration, adsorption, biological methods, coagulation, coagulation-membrane filtration, lime softening) by different criteria (treatment efficiency, safety of wastes, quantity of wastes, need for chemicals).

Coefficients of criterion importance were parts of 1 and their sum for all criteria of each expert was equal to 1.

Treatment efficiency was evaluated by the ten-point scale, where "0" was "absolutely ineffective" and "10" was "completely removed arsenic". Other criteria also were evaluated by the ten-point scale. For criterion "safety of wastes" "0" was "very dangerous" and "10" was "completely safe". For criterion "quantity of wastes" "0" was "a lot of waste" and "10" was "wasteless method". And for criterion "need for chemicals" "0" was "very high need" and "10" was "method doesn't need chemicals".

Table 1 demonstrates coefficient of criterion importance for each criterion and each expert and score of the method for each criterion and each expert. In the table 1 criteria and scores of different experts were divided by slash (/).

Table 1. Ecological assessment of different treatment methods

Methods\ Criteria	**Treatment efficiency** 0.7/0.5/0.8	**Safety of wastes** 0.1/0.25/0.07	**Quantity of wastes** 0.1/0.15/0.07	**Need for chemicals** 0.1/0.1/0.06
Reverse osmosis and nanofiltration	9/10/10	2/1/2	2/2/2	8/7/9
Adsorption-microfiltration	10/10/10	5/5/6	5/5/4	4/3/3
Adsorption	10/10/10	5/5/6	5/5/5	3/3/3
Biological methods	4/3/5	4/5/4	5/4/3	8/8/8
Coagulation	8/9/9	5/5/6	3/2/3	2/1/1
Coagulation-membrane filtration	8/9/9	5/5/6	4/3/3	1/1/1
Lime softening	4/4/3	4/3/4	5/3/3	2/1/2

Figure 2 showed integral ecological assessment of each treatment methods by three experts. A similar trend was observed in the evaluation of different methods by each expert. All experts decided that reverse osmosis, adsorption-microfiltration and adsorption were the most eco-friendly methods.

The simplest method was to decide that points of view of each expert had the same importance and use the above formula for the calculation of the total score of each treatment method.

According to this formula, adsorption-microfiltration and adsorption were the most environmental friendly methods with total scores 8.19 and 8.18 on a ten-point scale. Reverse osmosis and nanofiltration were a little less eco-friendly (7.52). Coagulation-

membrane filtration and coagulation demonstrated middle-high scores (6.93 and 6.88). Biological methods and lime softening showed scores below middle (4.54 and 3.40).

This approach is the simplest method of ecological assessment of different arsenic removal methods. More accurate approach includes different importance of experts, take into account the location of treatment plants, influence of water quality, number of affected people, sensitivity of water bodies, etc.

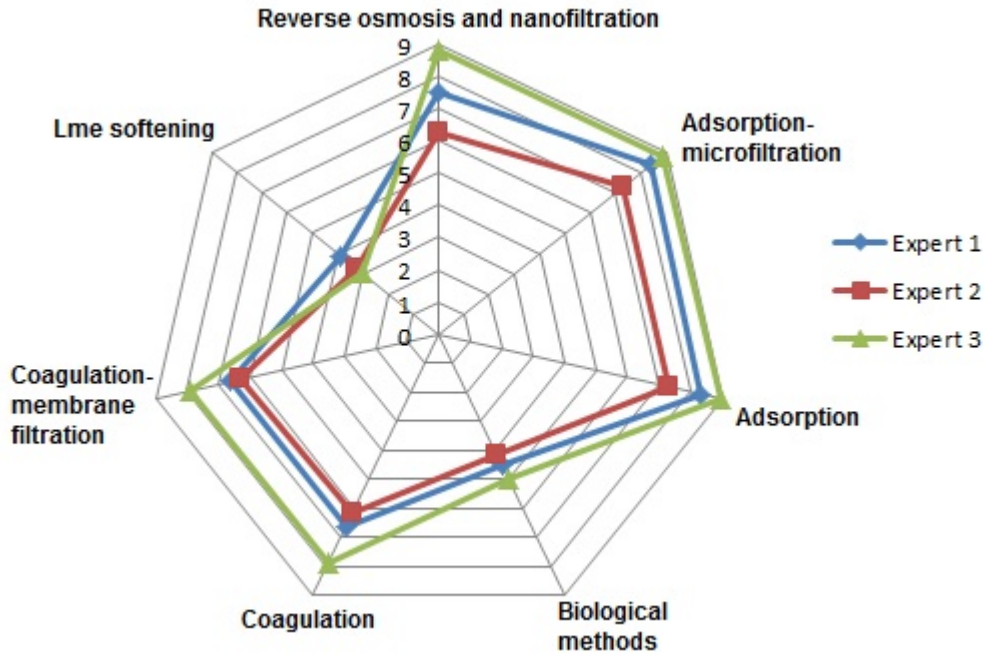

Fig. 2. Evaluation of arsenic removal methods by three experts

CONCLUSIONS

High arsenic level in drinking water is very big problem for many countries in the world. In some regions of Ukraine, especially in the Carpathians, groundwater also has high concentration of arsenic.

There are a lot of different methods of arsenic removal from water, but main part of these approaches is not eco-friendly due to producing of toxic waster during treatment process. Thus, ecological assessment is very important in the selection of the treatment method for arsenic removal.

Integral assessment was based on the points of view of the experts and includes evaluation of different criteria. Three experts evaluated some most perspective or most popular methods of arsenic removal (reverse osmosis and nanofiltration, adsorption-microfiltration, adsorption, biological methods, coagulation, coagulation-membrane filtration, lime softening) by different criteria (treatment efficiency, safety of wastes, quantity of wastes, need for chemicals).

According to the calculations, adsorption-microfiltration and adsorption were the most environmental friendly methods with total scores 8.19 and 8.18 on a ten-point scale. Reverse osmosis and nanofiltration were a little less eco-friendly (7.52). Coagulation-membrane filtration and coagulation demonstrated middle-high scores (6.93 and 6.88). Biological methods and lime softening showed scores below middle (4.54 and 3.40).

Thus, adsorption-microfiltration and adsorption could be recommended as the most eco-friendly methods of arsenic removal in water treatment. Reverse osmosis and

nanofiltration had a little less total score due to higher toxicity of soluble arsenic compounds (in concentrate from membranes) compared to insoluble arsenic compounds (immobilized on adsorbents).

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RISK OF CHEMICAL PLANT IMPACT ON THE ENVIRONMENT

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РИЗИК ВПЛИВУ ХІМІЧНОГО ПІДПРИЄМСТВА НА НАВКОЛИШНЕ СЕРЕДОВИЩЕ

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РИСК ВЛИЯНИЯ ХИМИЧЕСКОГО ПРЕДПРИЯТИЯ НА ОКРУЖАЮЩУЮ СРЕДУ

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This paper present an algorithm that allows quantitatively evaluate chemical risks of environmental changes caused by an industrial facility to the hydrosphere and atmosphere as component of the environment during its scheduled operation.

***Keywords**: ecological risk, chemical risk, anthropogenic object, pollutants*

В статті представлено алгоритм який дозволяє кількісно оцінити хімічний ризик змін навколишнього середовища під впливом промислового підприємства, при його регламентній роботі, для гідросфери та повітря як компонентів навколишнього природного середовища.

***Ключові слова**: екологічний ризик, хімічний ризик, техногенний об’єкт, забруднюючі речовини*

В статье представленно алгоритм который позволяет количественно оценить химический риск изменений окружающей среды под воздействием промышленного предприятия, при его регламентной работе, для гидросферы и воздуха в качестве компонентов окружающей природной среды.

***Ключевые слова**: экологический риск, химический риск, техногенный объект, загрязняющие вещества*