Removal of Arsenic from Underground Water to obtain Drinking Water

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Abstract: Scientists found excessive arsenic concentrations is several underground waters in the world. In these areas, hundreds of thousands of people presented serious intoxications due to this element. Billions of people, especially in developing countries, use daily water with an arsenic content several times higher than the limit of 10 µg/L, recommended by the World Health Organization. The main method for the removal of arsenic from water is the physical-chemical treatment. In the present paper is investigated the possibility to remove arsenic from underground water with high arsenic content using filtration on sand filter. Water samples have been collected from wells in an area with high arsenic content. The analyses showed that in some of the samples the concentrations of iron, manganese and arsenic were higher than the maximum values permitted by the legislation. The studies on arsenic removal were carried out on a synthetic solution with a composition similar to the studied waters. This solution has been aerated then passed over a sand layer in order to retain iron, manganese and arsenic. The residual concentrations of iron, manganese and arsenic in the effluent were under the detection limit. We concluded that the insoluble iron compounds resulting during aeration and retained on sand present high adsorption capacity for arsenic. Underground waters with high arsenic content which also contain iron ions can be used as drinking waters after a simple pass on a sand layer.

Keywords: arsenic, pollution, filter layer, sand layer, underground water

1. Introduction

Underground waters are an important resource, taking into account that unlike surface waters they are usually less polluted or even unpolluted. Therefore, underground waters may be made potable using minimal measures, sometimes using only disinfection, or without any treatment.

Following detailed analyses, the scientists found excessive arsenic concentrations is several underground waters in the world. In these areas, hundreds of thousands of people presented serious intoxications due to this element. Billions of people, especially in developing countries, use daily water with an arsenic content several times higher than the limit of 10 µg/L, recommended by the World Health Organization. The most affected areas are in Mexico, Argentina, USA, Canada, Taiwan, Japan, China and Vietnam [1].

In Romania, the concentration of arsenic in surface and underground waters varies between 0.05 and 3.7 mg/L. These concentrations are higher than the maximum permitted value recommended by international standards, both in the Western Plain, as well in the other studied areas. Until now, waters with high arsenic content have been identified in Şaru Dornei area (in Suceava county) and in the Western Plain. In Şaru Dornei, where a mineral water bottling plant used to work, in some mineral water springs have been found concentrations of arsenic higher than 2 mg/L [2].

The effects of arsenic pollution are serious and dangerous to human life. Especially long-term ingestion of contaminated water can cause various forms of cancer.

Therefore, solving these problems raised by water pollution is done by removing of arsenic, ensuring the necessary conditions for consumption, in terms of concentration of arsenic.

Various technologies for the treatment of arsenic contaminated drinking water in both laboratory and natural conditions have been proposed [3-9]. The main method for the removal of arsenic from water is the physical-chemical treatment. Technologies for the removal of arsenic from drinking water include:
- processes of precipitation, coagulation/filtration, direct filtration, coagulation assisted by micro-filtration, intensive coagulation, softening using calcium oxide, intensive softening lime-based;
- processes of adsorption on activated aluminum oxide, activated carbon, iron oxide, manganese oxide;
- ion exchange processes, in particular anion exchange;
- membrane filtration: nano filtration, reverse osmosis, reverse electrodialysis;
- alternative treatment processes, especially filtration on sand filter;
- removal of arsenic in situ (in depth and on the surface);
- biological treatment of arsenic.

Many of these techniques are still in experimental stage, others have not yet been widely demonstrated. Also, even though some methods are technically reliable, cost may mean a barrier.

In the present paper is investigated the possibility to remove arsenic from underground water with high arsenic content using filtration on sand filter.

2. Experimental

Water samples have been collected from 13 family wells in an area with high arsenic content. The water samples have been analyzed according to the legislation [10], in view to determine the quality parameters.

The sodium, potassium, iron, manganese and arsenic contents of the water samples have been determined by atomic absorption spectrophotometry, using a Varian SpectrAA 110 spectrophotometer. For arsenic analysis a hydride VGA 77 system has been used [11-14].

For the studies on the removal of arsenic, a synthetic solution with a composition similar to the studied waters has been used. This solution has been aerated for 10 min then 1 L of solution has been passed over a glass column filled with sand (3.5 cm diameter, 15 cm height of sand layer) in order to retain iron, manganese and arsenic. The effluent has been divided in fractions of 25 mL (0-25; 25-50; 50-75; … ; 975-1000 mL) and the samples have been analyzed to determine the residual concentrations of iron, manganese and arsenic.

3. Results and Discussion

In Table 1 are presented the experimental data regarding the quality parameters determined for the studied water samples. The data show that:

- except well no 1, all wells present sodium concentrations higher than the maximum permitted value;
- for all samples, except 6 and 8, the potassium concentration is under the maximum permitted value;
- all samples have iron concentrations higher than the maximum permitted value;
- for samples 2, 3, 4, 10 and 11 manganese concentration is under the detection limit (UDL); in sample 7 is lower than the maximum permitted value; for all other samples manganese concentration is higher than the maximum permitted value;
- the water samples collected from wells 1-9 have arsenic concentrations higher than the maximum permitted value; for some of the samples the values are four to six times higher than the maximum permitted value, which requires to study the possibility of arsenic removal.

TABLE 1. Water samples quality parameters

Sample	Parameters				
	Sodium, mg/L	Potassium, mg/L	Iron, mg/L	Manganese, mg/L	Arsenic, µg/L
Maximum permitted value	150	12	0.02	0.05	10
Sample 1	105	1.65	2.21	0.41	60.4
Sample 2	433	1.31	1.43	UDL	40.4
Sample 3	505	1.49	0.10	UDL	11.7
Sample 4	367	1.14	0.04	UDL	23.0
Sample 5	328	2.24	2.63	0.05	62.9
Sample 6	433	24.8	1.25	2.78	39.0
Sample 7	420	1.54	2.62	0.09	63.9
Sample 8	239	12.1	0.04	0.25	22.6
Sample 9	560	1.75	0.20	0.31	11.8
Sample 10	377	1.22	0.07	UDL	2.56
Sample 11	489	1.33	0.06	UDL	3.10
Sample 12	413	1.20	0.06	0.18	5.93
Sample 13	452	1.51	0.09	0.25	6.02

TABLE 2. Residual concentrations of arsenic, iron and manganese

Effluent fraction, mL	Arsenic, µg/L		Iron, mg/L		Manganese, mg/L	
	Initial	Residual	Initial	Residual	Initial	Residual
0-25		15		UDL		UDL
25-50		11		UDL		UDL
50-75		6.2		UDL		UDL
75-100		3.4		UDL		UDL
100-125		1.7		UDL		UDL
125-150		0.6		UDL		UDL
150-175		0.09		UDL		UDL
175-200	60	UDL	5	UDL	0.5	UDL
200-225		UDL		UDL		UDL
225-250		UDL		UDL		UDL
375-400		UDL		UDL		UDL
575-600		UDL		UDL		UDL
775-800		UDL		UDL		UDL
975-1000		UDL		UDL		UDL

Detection limit: $DL = 0.01$ mg/L Fe^{n+}; 0.01 mg/L Mn^{n+}; 0.01 µg/L As^{n+}

To study the removal of arsenic a synthetic solution with a composition similar to the studies water samples (60 µg/L As^{3+}, 5 mg/L Fe^{3+} and 0.5 mg/L Mn^{2+}) has been prepared. The solution has been aerated to oxidize Fe^{2+} to Fe^{3+} and Mn^{2+} to Mn^{4+}; insoluble compounds such as $Fe(OH)_3$ and MnO_2 are formed. The solution has been passed over a column filled with sand to retain iron, manganese and arsenic. The experimental data regarding the residual concentrations of arsenic, iron and manganese in effluent fractions are presented in Table 2.

Out of the data in Table 2, one may notice that for all effluent fractions the values for iron and manganese concentration are under the detection limit, meaning that these species were practically completely removed from the solution. One may conclude that the insoluble compounds of manganese and iron resulting during aeration were retained on sand. In the case of residual arsenic concentration, the values decrease as the volume of the solution passed over the sand layer increases. The amount of insoluble iron compounds retained on sand increases as the volume of solution passed over the sand layer increases. In this way on the sand particles was gradually formed an adsorption layer which presents high adsorption capacity for arsenic. Materials containing iron are known as having affinity towards arsenic [5-7]. In this particular case the adsorbent material was formed from the iron present in the solution.

In the case of a ground water, retention of iron, manganese and arsenic ions is naturally possible if water passes a sand layer. If ground water is high, as in the studied area, filter layer thickness does not provide an efficient removal of arsenic. In this case is necessary to monitor the arsenic content of underground water, or to achieve an artificial filter layer. Underground waters with high arsenic content which also contain iron can be used as drinking waters after a simple pass on a sand layer.

4. Conclusions

In the present paper is investigated the possibility to remove arsenic from underground water with high arsenic content using filtration on sand filter.

Water samples have been collected from 13 family wells in an area with high arsenic content. The water samples have been analyzed through atomic absorption spectrophotometry to determine the concentrations of sodium, potassium, iron, manganese and arsenic.

The experimental data showed that the concentrations of iron, manganese and arsenic in some of the samples were higher than the maximum values permitted by the legislation.

The studies on arsenic removal were carried out on a synthetic solution with a composition similar to the studied waters. This solution has been aerated then passed over a

column filled with sand in order to retain iron, manganese and arsenic. The residual concentrations of iron, manganese and arsenic in the effluent were under the detection limit. We concluded that the insoluble iron compounds resulting during aeration and retained on sand present high adsorption capacity for arsenic.

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Due to their iron content, underground waters with high arsenic content can be used as drinking waters after a simple pass on a sand layer.

REFERENCES

1. World Health Organization, *Guidelines for Drinking-water Quality. Third Ed. vol.1. Recommendations*, Geneva, **2008**.
2. Ministry of Waters, *Forests and Environmental Protection of Romania on the state of environmental factors in Romania in 1993*, Bucharest. **1994**.
3. Maji S.K., Pal A. and Pal T., *J. Hazard. Mater.*, 151. **2008**, 811- 820.
4. Partey, F., Norman, D., Ndur, S., and Nartey, R., *J. Colloid Interface Sci.*, 321, **2008**, 493-500.
5. Thirunavukkarasu O.S., Viraraghavan T. and Subramanian K.S., *Water SA*, **2003**, 161-170.
6. Guo H., Stuben D. and Berner Z., *J. Colloid Interface Sci.*, 315, **2007**, 47 - 53.
7. Zeng L., *Water Res.*, 37, **2003**, 4351-4358.
8. Lenoble V., *Elimination de l'arsenic pour la production d'eau potable: oxydation chimique et adsorption pur des substrats solides innovants*, Ph.D. Thesis, Univ. De Limoper, **2003**.
9. Pinisakul A., Polprasert C., Porkplan P. and Satayarirod J., *Water Sci. Technol.*, 46, **2002**, 247-254.
10. Law 311/28.04.2004, *Drinking water quality parameters*.
11. Niedzielski P., *Anal. Chim. Acta.*, 551, **2005**, 199-206.
12. Krachler M., Shotyk W., and Emons H., *Anal. Chim. Acta*, 432, **2001**, 303-310.
13. Akter K.F., Chen Z., Smith L., Davey D. and Naidu R., *Talanta*, 68, **2005**, 406-415.
14. Negrea P., Negrea A., Lupa L. and Mitoi L., *Proceedings of the International Symposium on Trace Elements in the Food Chain*, Budapest, **2006,** 92-96.