CEST 2025

19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Performance Of Preoxidation And Coagulation In Arsenic Removal From Groundwater For Human Consumption In A Small Rural Community In Western Romania

Pacala A.[1,*], Neidoni D.-G.[1], Negrea S.-C.[1], Tenea A.-G.[1], Dınu C.[1], Stefanescu M.[1]

[1]National Research and Development Institute for Industrial Ecology ECOIND, Drumul Podu Dambovitei 57-73 Street, 060652 code, Bucharest, Romania

*corresponding author: Pacala Adina
e-mail: adina.pacala@incdecoind.ro

Abstract. Health problems caused by high arsenic concentrations (over 200 µg/L) in groundwater sources in the Pannonian Basin (Hungary, Romania, Croatia, Serbia) have become a major concern for researchers and environmental experts. This paper evaluates the effect of the preoxidation (with hypochlorite)/coagulation process (with commercially available coagulant $FeCl_3$) on the removal efficiency of arsenic (with an initial concentration of 235 ± 0,6 µg/L) from a groundwater source for a small rural community in western Romania, at laboratory scale. The results of this experimental study showed that, through the preoxidation/coagulation process, the arsenic concentration is removed up to 94% from the groundwater used. Since coagulation and flocculation are simple and commonly applied in drinking water treatment plants in most countries of the Pannonian Basin, this work aims to contribute to long-term improvement of drinking water in this geographical area, with groundwater sources naturally contaminated with arsenic.

Keywords: arsenic removal, preoxidation, coagulation, groundwater treatment.

1. Introduction

In Western Romania, part of the European Pannonian Basin, the presence of arsenic in the aquifers are due to the geological composition of soil. Recent studies have reported arsenic concentrations in groundwater used for human consumption of up to 400 µg/L in western Romania and similar arsenic concentrations exist in southern Hungary (210 µg/L), northern Serbia (350 µg/L) and eastern Croatia (610 µg/L) (Habuda-Stanic et al, 2015). Developing feasible technologies for rural areas in Romania is an essential task (Directive (EU) 2020/2184) and the selection of an arsenic removal technology for a particular region depends on the oxidation state of arsenic, the pH of groundwater and a number of other factors. Groundwater of western Romania is characterized by inorganic contaminants, with increased concentrations of iron, manganese, ammonium, organic matter, high water hardness and arsenic ranging between 10 to 400 µg/L (Tudorache et al, 2011). Arsenic exists generally in four oxidation states (-3, 0, +3, +5) and the main species of arsenic in natural environments are arsenite [As(III)] and arsenate [As(V)]. Comparatively, As(III) is more difficult to be removed than As(V) from aqueous solutions by almost all of the arsenic removal techno-logies and preoxidation of As(III) to As(V) using some oxidizing chemical agents like chlorine, ozone, NaOCl and potassium permanganate is critical for achieving optimal performance for most processes (Costa et al, 2024; Kumar et al, 2019). Various technologies are available for the removal of arsenic from contaminated water including chemical precipitation or coagulation, adsorption, lime softening, ion exchange and membrane separation (Nicomel et al, 2016; Raju N.J, 2022, Shaji et al, 2021). The aim of this study was to investigate the effect of arsenic preoxidation on arsenic removal from naturally arsenic-contaminated groundwater from a small rural community in Western Romania (well depth 120 m) using NaOCl as oxidant in various concentrations followed by the addition of $FeCl_3$ as coagulant with the purpose to determine optimal concentration of oxidant and coagulant, in order to develop a process and small system available for rural areas for arsenic removal from drinking water.

2. Material and methods

The laboratory scale of the study was carried out in two separate stages in order to investigate the effect of preoxidation in improving the removal of arsenic by the coagulation process. Firstly, the removal of arsenic was optimized by the coagulation process, and then the effect of the preoxidation process before coagulation was studied to increase the efficiency of the system.

2.1. Coagulation experiment

The coagulant $FeCl_3$ (conc. approx. 40%) was a commercial coagulant available on the Romanian market.

Coagulation experiments were carried out at room temperature (20°C) using Jar-test on a six-paddle gang stirrer (Floculator Jar-test, WiteStir JT M6). The groundwater was stirred rapidly at 150 rpm for 2 min after coagulant dosing, followed by slow stirring at 45 rpm for 10 min. For 20 min after settling, supernatants were collected to measure residual turbidity, total organic carbon (TOC), pH, colour, conductivity and absorbance at 254 nm, etc. The detection technique used for As was Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES Avio 500, Perkin-Elmer) and the concentration of iron and manganese were deter-minated with a Spectrophotometer (sAA-280FS, Agilent). The As species were determined on an Agilent 1260 Infinity II HPLC system coupled to an Agilent 7850 ICP-MS.

3. Results and discussions

The preoxidation step of arsenite to arsenate was performed before the coagulation process by hypochlorite. For this purpose, the effect of preoxidation before coagulation under optimal conditions was investigated for $FeCl_3$ coagulant (30 mg/L optimum dose applied). Therefore, the concentration of 0.1 mg/L and 0.2 mg/L hypochlorite was used at the natural pH of the water samples (pH = 8.07) for $FeCl_3$ coagulant.

Table 1. Comparative analysis for quality parameters of raw groundwater (GW) with/without preoxidation NaOCl and treated with coagulant ($FeCl_3$).

Parameter, unit	GW	Without NaOCl	With 0.1 mg/L NaOCl	With 0.2 mg/L NaOCl
Dose $FeCl_3$,mg/L	-	30	30	30
Turbidity, NTU	0.68	0.60	0.58	0.50
pH	8.07	7.9	7.6	7.4
Conductivity,µs/cm	920	938	961	970
Color, grd. Hz	63	58	50	46
UV_{254nm}, cm^{-1}	0.096	0.082	0.071	0.062
Iron dissolved, mg/L	0.65	0.45	0.16	0.05
Manganese dissolved, mg/L	0.23	0.23	0.23	0.23
Amonium, mg/L	1.26	1,26	1,20	1.16
Arsenite, µg/L	202	112,6	46.2	<1.60
Arsenate, µg/L	33.6	10.4	5.0	<3.00

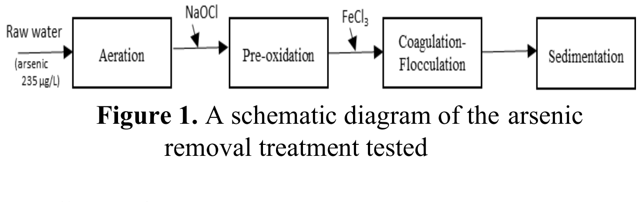

Figure 1. A schematic diagram of the arsenic removal treatment tested

4. Conclusions

The present study showed that for arsenic removal from selected groundwater in western Romania, where the most detected arsenic species is the trivalent arsenic (As(III)) form, efficient arsenic removal requires arsenic preoxidation. Therefore, the evaluation of the capacity of preoxidation of As(III) to As(V) using hypochlorite to enhance the coagulation process with $FeCl_3$ to remove arsenic was presented at laboratory scale.

The initial arsenic of 235 µg/L was reduced to below 2 µg/L (undetectable by AAS) along with the removal of iron to below 0.1 mg/L. Given the promising results found, the novelty of integrating preoxidation, before coagulation, and flocculation as pretreatment into the conventional groundwater treatment process for arsenic removal and obtaining safe drinking water, guarantees increased robustness of the treatment.

5. Acknowledgements

This work was carried out through the "Nucleu" Program within the National Research Development and Innovation Plan 2022-2027 with the support of Romanian Ministry of Research, Innovation and Digitalization, contract no. 3N/2022, Project code PN 23 22 03 03.

References

Shaji E., Santosh M., Sarath K.V., Prakash P., Deepchand V. and Divya B.V. (2021), Arsenic contamination of groundwater: a global synopsis with focus on the Indian Peninsula, *Geoscience Frontiers*, **12**, (3), https://doi.org/10.1016/j.gsf.2020.08.015.

Tudorache A., Marin C., Badea I.A. and Vladescu L. (2011), Determination of arsenic content of some Romanian natural mineral groundwaters, *Environmental Monitoring and Assessment*, **179**, 79-89.

Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast).

Habuda-Stanic M., Nujic M., Romic Z., Loncaric A., Ravancic M.E. and Kralj E. (2015), Arsenic preoxidation and its removal from groundwater using iron coagulants, *Desalination and Water treatment,* **56**, 2105-2113.

Kumar R., Patel M., Singh P., Bundschuh J., Pittman Jr. C. U., Trakal L. and Mohan D. (2019), Emerging technologies for arsenic removal from drinking water in rural and peri-urban areas: Methods, experience from, and options for Latin America, *Science of the Total Environment*, **694**, 133427.

Nicomel N. R., Leus K., Folens K., Van Der Voort P. and Laing G. D. (2016), Review-Technologies for Arsenic Removal from Water: Current Status and Future Perspectives, *International Journal of Environmental Research and Public Health,* **13**, 62.

Costa F.C., Moreira V.R., Guimaraes R.N., Moser P.B., Santos L.V., de Paula E.C. and Amaral M.S.C. (2024), Pre-oxidation and Coagulation-Flocculation as a Pretreatment to UF-RO Applied for Surface Water Treatment and Arsenic Removal, *Desalination,* **586**, 117855.

Raju N.J. (2022), Arsenic in the geo-environment: A review of sources, geochemical processes, toxicity and removal technologies, *Environmental Research*, **203**, 111782.