Treatment of arsenic contaminated groundwater: a case study in the south of Sila Massif (Calabria, Italy)

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Fuoco I.[1], Figoli A. [2], Criscuoli A. [2], De Rosa R.[1], Gabriele B. [3], Mancuso R. [3], Vespasiano G.[1], Apollaro C.[1]

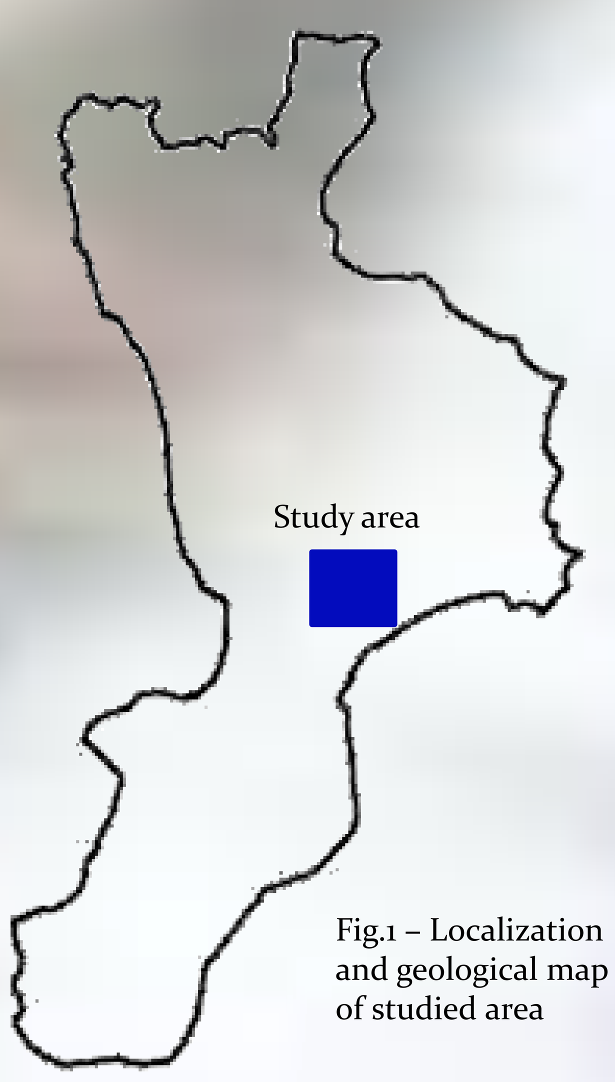
[1] Department of Biology, Ecology and Earth Science (DiBEST)– University of Calabria- Arcavacata di Rende (CS), Italy
2 Institute on Membrane Technology (ITM-CNR), Arcavacata di Rende (CS) Italy.
3 Department of Chemistry and Chemical Tecnologie, LISOC Group, University of Calabria- Arcavacata di Rende (CS), Italy.

INTRODUCTION

Arsenic (As) is a dangerous pollutant present in natural systems. It is found in the atmosphere, rocks and soils and in natural waters and it is mobilized through a combination of natural processes such as weathering, biological activity, volcanic emissions as well as through several human activities (mining and industrial activities, use of pesticides and herbicides). The occurrence of high arsenic concentration into groundwaters of all the world (as Argentina, Chile, China, Bengal, Bangladesh and Vietnam) is one of main environmental **problematics** of present day and the arsenic removal is one of most targets of hydrogeochemical research. In water systems As can occur mainly as oxyanions of trivalent (As(III)) and pentavalent (AsV) inorganic forms. Long exposure times and intake of As in its inorganic forms through food and water causes numerous adverse health effects that occur with skin lesions, circulatory disorder, diabetes, effects that can sometimes become lethal by evolving into bladder, lungs, kidney and skin cancers (National Research Council, 2001). In this regard the Italian government, on the basis of WHO guidelines (WHO, 2001), has established as maximum value in drinking water the concentration 10 μg/L. This study reports the data of 3 arsenic contaminated springs located in the Catanzaro province (southern Sila Massif, Calabria, Italy) where As concentration above permitted limit was found. In order to reach an acceptable concentration value (10 μg/L), the three water samples were treated by nanofiltration (NF)membrane technique. Nanofiltration (NF) has already been proved on synthetic solutions to be able to reach an arsenic value below the drinking water standard (Figoli et al., 2010, Figoli et al. 2016). The innovation of this study is the application of the pressure-driven membrane process for natural As contaminated groundwaters to evaluate the rejection efficiency even in the presence of others ions.

GEOLOGICAL FEATURES

The study area is located in the northern sector of the Calabrian Peloritan Arc (CPA) and fall in the southen part of Sila Massif which represents the major high morphostructural of the Ionian margin of north-eastern Calabria. The CPA is a nappe-structured belt, which was produced during the Europe-Apulia collision in Oligocene-Early Miocene. Literature data recognized three major structural elements that represent different paleogeographic domains: (a) The Apennine Units Complex, made up of Mesozoic sedimentary and metasedimentary successions; (b) The Liguride complex, made up Cretaceous-Paleogene metapelitic-ophiolitic-carbonate assemblage; (c) The Calabride complex, comprising several Paleozoic tectono-metamorphic units made up gneiss, schist, phyllite, and amphibolite affected by various Alpine metamorphic events and intruded by the Late Hercynian Sila Batholith (Van Dijk et al., 2000). The geology of study area (Fig.1) is characterized mainly by granites ,gneiss and schists which underwent intense weathering processes. Mineralogical and petrographic studies of Sila Massif mineralizations highlight the presence of sulphides in metamorphic and crystalline rocks (Bonardi et al., 1982) that could be the geogenic source of arsenic in the environment (Smedley, P.L., Kinniburgh, D.G., 2002).



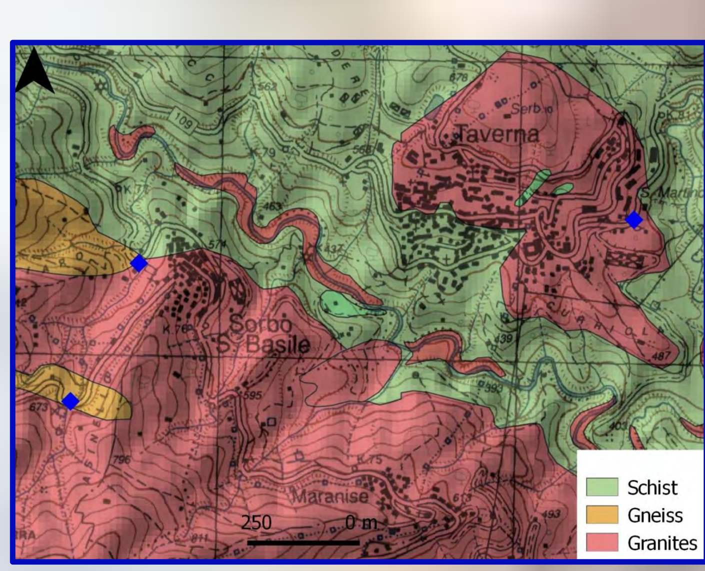


Fig.1 – Localization and geological map of studied area

FIELD AND LABORATORY OPERATIONS

In the field, some parameters as temperature, pH, electrical conductivity (EC), oxidation-reduction potential (Eh) and total alcalinity were measured by means of portable instruments and consistent volumes of three springs studied (S1, S2 and S3), were collected for subsequent membrane treatments.

NF experiments were performed by using a laboratory pilot unit (SEPA CF), consisting of three major components: cell body, cell holder, and feed pump. The experiments were conducted at different operating pressures (3 bar, 7 bar, 11 bar and 15 bar) Four types of membrane modules commercialized by GE Osmonics, named HL (Polyamide), DK (proprietary thin-film) and CK (cellulose acetate) and by Microdyn Nadir, named NP030P (Polyethersulfone), were used. The samples, before and after membrane treatment, have been analyzed, determining the major elements by HPLC (Dionex ICS 1100) and total arsenic by ICP-MS, Perkin Elmer/SCIEX, Elan DRCe.

RESULTS

The three water samples (S1, S2 and S3) have shown a composition that reflects a water-rock interaction with crystalline-metamorphic rocks outcrops in the area, and differ in terms of arsenic concentration, which is about 60, 120 and 430 ppb, respectively.

Figure 2 shows the results of treatment tests. The performance (water flux and arsenic rejection) of the membranes has been evaluated changing the operating pressures (3 bar, 7 bar, 11 bar and 15 bar). The following data highlight that all investigated membranes have a linear increase of water flux at higher TMP. In particular, HL membrane type shows much higher water flux compared to the other ones (Fig.2a). Figure 2b shows that all the membranes, except NP030P, are able to reject As very well and As concentrations after the treatment were below 10 μg/L (WHO limit). The figure 2c ,d and figure 2e,f illustrate the best results in terms of flux permeate and As rejections obtained by DK and HL membranes. The permeate flux for water samples treated by the same membrane is comparable but the highest flux was obtained by HL membrane (Fig. 2d). DK and HL membranes showed a similar As rejections for each water samples analysed, as shown in figure 2e and figure 2f, respectively. However, in both cases, the best results were obtained for S1 and S2 samples with As concentration in the permeate (purified water) within the limits established by the law. Furthermore, TDS (Total Dissolved Solids) was measured before and after treatment. Figure 3 shows that the dissolved load remains on acceptable levels even after high pressure treatments.

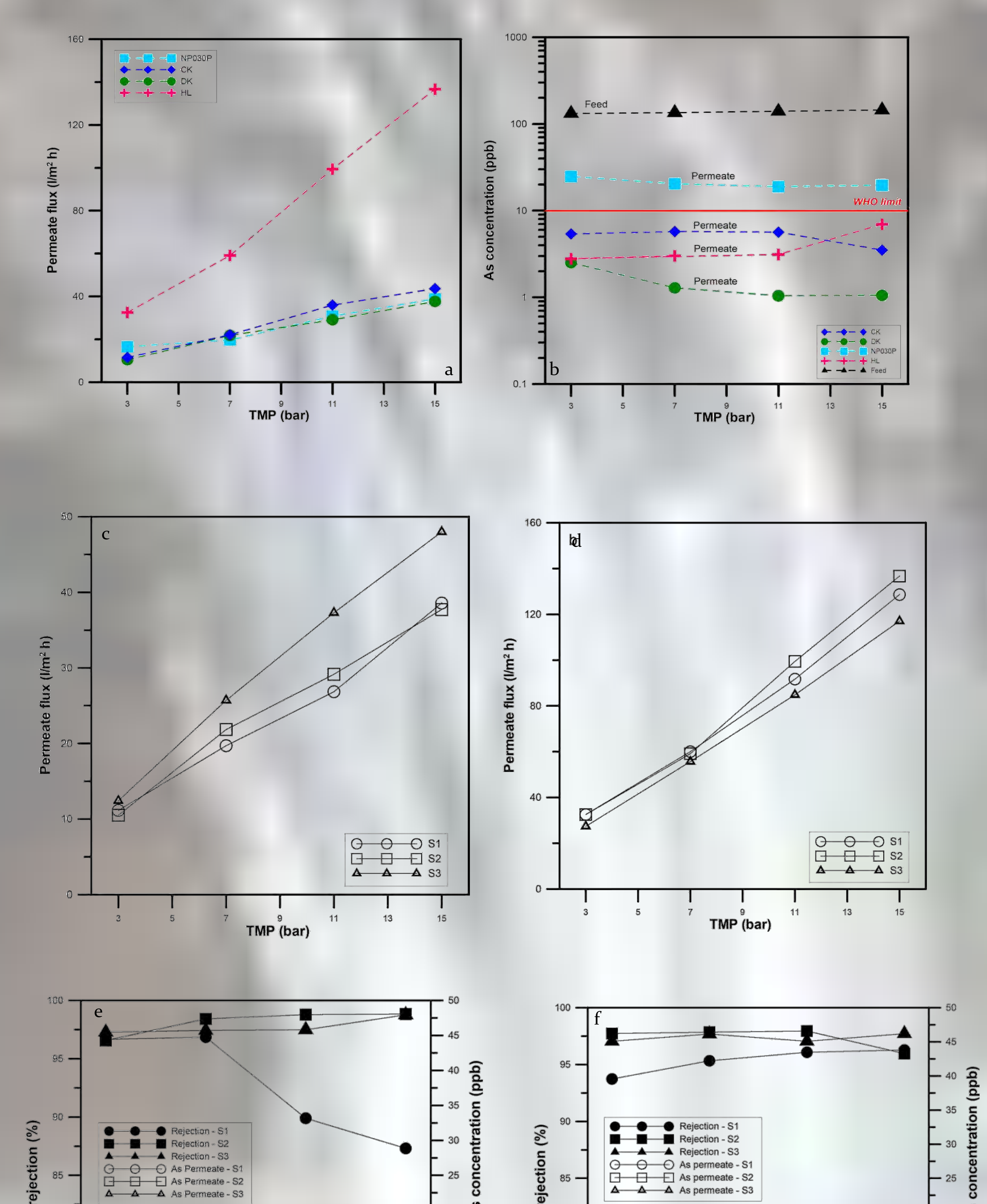


Fig.2 - (a) Transmembrane flux at different TMP for DK,CK, HL and NP030P membranes (S2). (b).As concentration detected in the water before and after the treatment for each membranes (S2). (c,d) Transmembrane flux at different TMP for DK membrane and HL membrane, respectively. (e,f) As rejection and As concentration detected in the purified water by DK and HL membrane, respectively.

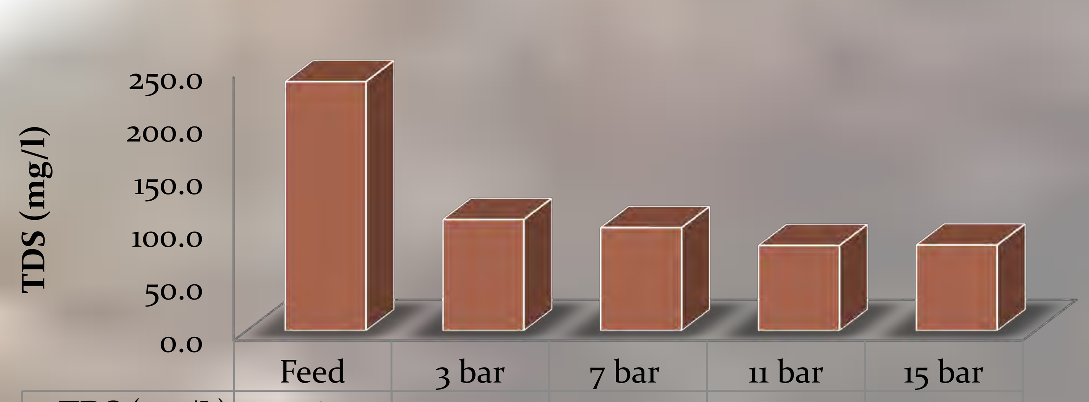


Fig.3- Water TDS of S2 spring before and after the treatment using HL membrane type

CONCLUSION.

The As-rich groundwaters collected in the present study are the result of natural contamination and not of anthropic one. The levels of arsenic detected in the three groundwater samples were above the threshold value established by the WHO but the NF membranes treatment permits to obtain purified water with As concentration below 10 ppb and a dissolved load acceptable for potability . In this study HL membrane was the most performing one.

The application of this technique could allow the use of water resource in the studied contaminated area.

REFERENCES

Bonardi G., De Vivo B., Giunta G., Lima A., Perrone V., Zuppetta A., 1982. Mineralizzazionidell'Arco Calabro Peloritano.Ipotesi genetiche e quadro evolutivo. Boll.Soc.Geol.It. 101 141-155.
Figoli A., Cassano A., Criscuoli A., Islam Mozumder M.S. , Tamez Uddin M., Akhtarul Islam M., Drioli E., Influence of operating parameters on the arsenic removal by nanofiltration. Water Research 44 (2010) 97-104.
Figoli A., Hoinkis J., Bundschuh J. 2016. Membrane Technology for Water Treatment, Removal of toxic trace elements with emphasis on arsenic, fluoride and uranium, CRC Press, Taylor and Francis Group, ISBN978-1-315-73523-8.
National Research Council,2001.Arsenic in Drinking Water. National Academy of Sciences, Washington, DC, USA.
Smedley, P.L., Kinniburgh, D.G., 2002. A review of the source, behaviour and distribution of arsenic in natural waters. Applied Geochemistry 17, 517-568.
Van Dijk, J.P., Bello, M., Brancaleoni, G.P., Cantarella, G., Costa, V., Frixa, A., Golfetto, F., Merlini, S., Riva, M., Torricelli, S., Toscano, C., Zerilli, A. 2000. A regional structural model for the northern sector of the Calabrian Arc (southern Italy). Tectonophysics, 324: 267–320.
WHO, 2001. Environmental Health Criteria 224: Arsenic compounds 2nd edition. World Health Organisation, Geneva.

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