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Defluoridation of groundwater in the south east of Algeria by adsorption

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ABSTRACT

Because of its high reactivity, fluorine does not occur in the elemental state in nature but rather in the form of salts that are grouped under the generic term of Fluoride. Fluorine is one of the natural constituents present in the groundwater of the South-East of Algeria. However, these waters contain high levels of fluoride in excess of the standard recommended by WHO, which is in the range of 1.5 mg/L for water intended for human consumption. These high concentrations can lead to damaging physical effects, especially dental fluorosis and skeletal fluorosis, as well as hypersensitivity reactions and kidney disease. The treatment of these fluorinated waters is, therefore, indispensable, which has prompted us to develop this research in order to be able to propose an adsorbent able to normalize the quantity of fluoride in the groundwater of South-East Algeria, especially the waters destined to human consumption.

Introduction

Fluoride pollution of groundwater in lesser extent surface water, mostly from geogenic sources is a global concern. High or low concentrations of fluoride can occur depending on the nature of the rocks and occurrence of fluoride bearing minerals. Fluoride could be common in groundwater [1].

In the south of Algeria, according to some epidemiological investigations, a problem of health known under the name of endemic fluorosis puts extensively in the oriental zone. It emanates essentially of the ingestion of the excessive quantities of fluoride by the slant of the drinking water [2].

Fluorine is the first element of the halogen family in the periodic table that does not occur in the element state in the environment due to its high reactivity. The presence of Fluoride in drinking water in acceptable concentrations is known as an essential constituent for human health, especially in children below 8 years of age. However, when Fluoride concentration exceed the acceptable level (1.5 mg/l), it leads to serious health problems such as skeletal fluorosis, mottling of teeth, lesions of endocrine glands, thyroid, liver and some other organs [3]. Fluoride compounds are used in industry for a wide range of applications, such as: aluminum production, glass fiber, phosphate fertilizers, bricks, tiles, ceramics, drinking water fluoridation and toothpaste. Weathering of rocks and industrial discharges are the main sources of Fluoride in water, air, and soil. The adsorption of Fluoride mainly depends on the geographical conditions and lifestyles. Potable water is the main source of Fluoride intake in humans. Therefore, treatment of Fluoride-contaminated water to a level below the permissible value that is recommended by the WHO has become a critical health issue [4,5].

Several methods, such as reverse osmosis, ion exchange, adsorption, coagulation, precipitation, and electro coagulation have been used for the removal of excess Fluoride from drinking water. Among these methods, adsorption is the most extensively used and is a promising technique for the removal of Fluoride. A large number of materials have been suggested for the adsorption of this element from water. However, in recent years, studies have been devoted to low-cost materials for the elimination of pollutants from water. These sorbents can be used in natural or modified forms. [6,7].

The objective of this work is the quantification of Fluoride in the groundwater of the South - East of Algeria and the study of the effectiveness of the most used adsorbents for the removal of Fluoride from aqueous solutions in order to facilitate the choice of the most suitable adsorbent for the defluoridation of the studied waters. This study may have positive external effects on the environment and human health.

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Fig. 1. Location of sampling points.

Materials and methods

Materials

The Fluoride concentration in the solutions was determined by expandable ion analyses (Orion EA 940 ion meter).

Sampling

Great importance is given to the sampling operations, so the operator must have a precise knowledge of the sampling conditions (sampling and conservation) and their importance for the quality of the analytical results.
Samples must be homogeneous, representative and obtained without modification of the physicochemical characteristics of the water because the errors likely to make the interpretation of the results difficult are most often related to an unsatisfactory sampling rather than to analytical errors [8].
In this study, samples were taken from boreholes of two aquifers in 4 regions of the South-East of Algeria namely: Ouargla, El Oued, Biskra and Ghardaia as shown in Fig. 1.

Adsorbate

For the experimental studies, sodium fluoride solution in distilled water was used. From a stock solution of 1000 mg/L. working solutions were prepared and stored in polythene containers in a refrigerator for further experimental studies [5].

Adsorbents

In this research work, the adsorbents proposed are :
- Adsorbent 1: Pumice stone functionalized by hexadecyltrimethyl ammonium.
- Adsorbent 2: Coconut fiber ash impregnated with Aluminum.
- Adsorbent 3: Lignite coal.
- Adsorbent 4: Fine coke coal
- Adsorbent 5: Bituminous coal
- Adsorbent 6: Activated carbon produced by wet coconut shell
- Adsorbent 7: Activated carbon produced by dry coconut shell.
- Adsorbent 8: Activated carbon derived from rice straw modifed with potassium permanganate.

Adsorption studies

Batch adsorption studies were conducted to evaluate the amount of Fluorine removed from solution using a known mass of each adsorbent. The Fluorine adsorption capacity by the adsorbent material was calculated using following equation:

$$q = (C_0 - C_e)\,\frac{V}{m}$$

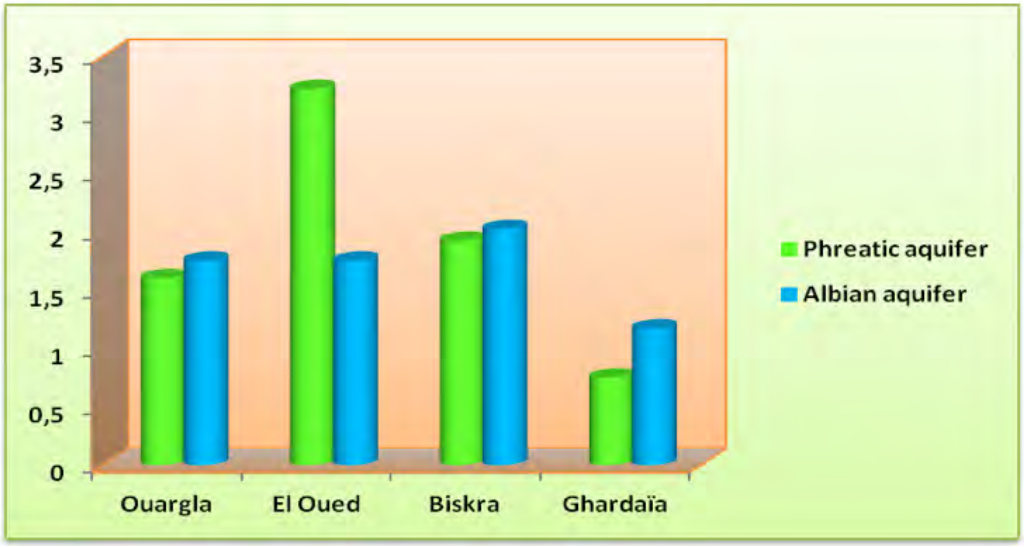

Fig. 2. Average rate of fluoride in groundwater in the South East of Algeria (mg/L)

Where q is the amount of fluorine removed from solution (mg/g); C_0 is the initial concentration of Fluorine before mixing with adsorbent (mg/l), C_e is the equilibrium concentration of Fluorine left in the solution after the experiment (mg/L), V is the solution volume (l) and m is the weight of adsorbent (g).

Results and discussions

Fluoride in groundwater of the South -East of Algeria

The Fluoride analyzes contained in the groundwater of 04 different regions in the South-East of Algeria are illustrated in the Fig. 2.
The amount of Fluoride in the waters under study varies from 0.75 mg/L to 3.22 mg/L, ie:

- From 1.60 mg/L to 1.75 mg/L in the region of Ouargla.
- From 1.75 mg/L to 3.22 mg/L in the region of El Oued.
- From 1.92 mg/L to 2.02 mg/L in the region of Biskra.
- From 0.75 mg/L l to 1.17 mg/L in the region of Ghardaia.

Adsorption of Fluorine

In the Fig. 3 below, we present the adsorption capacity of each adsorbent proposed in this study.
According to the fluoride concentrations observed in the groundwater of the study region, we can use all the adsorbents proposed. However, pumice stone functionalized by hexadecyltrimethyl ammonium gives the best results because of its high adsorption capacity about 41 mg/g.

Conclusion

The amount of fluoride in the groundwater of the South East of Algeria is very important it varies from 0.75 mg/L to 3.22 mg/L.
The adsorption technique is recommended in this type of situation in order to normalize the observed excesses. Several adsorbents can be easily exploited because of the simplicity and ease of implementation of the technique.
The comparative study evoked in this research unveiled the preferential use of pumice stone functionalized by hexadecyltrimethyl ammonium as adsorbent for the defluoridation of the waters of the study region.

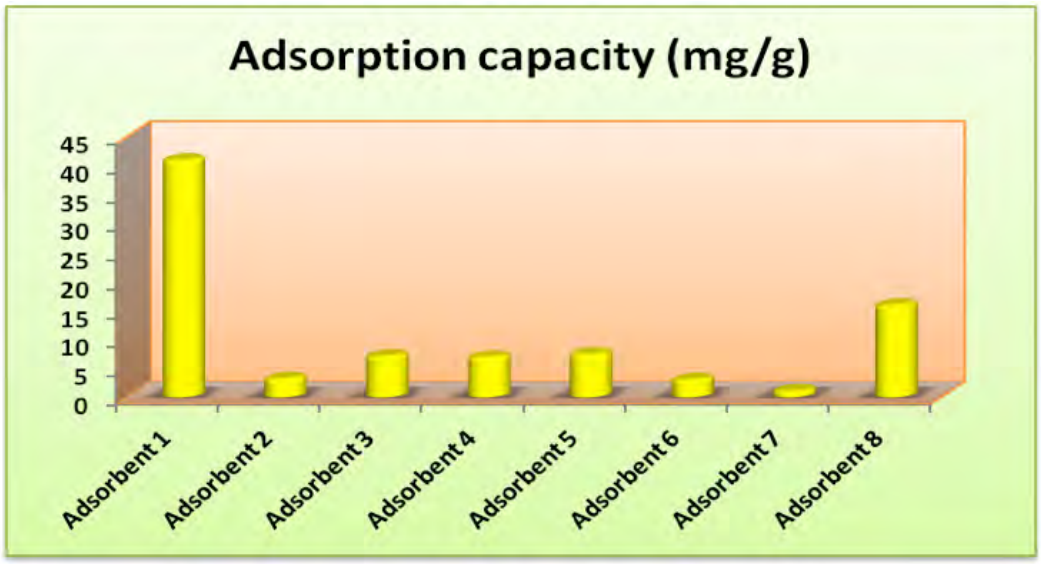

Fig. 3. Effect of the nature of adsorbent on the adsorption capacity of fluorine [4-7].

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Conflicts of interest

Authors declare no conflict of interests.

Notes

The authors declare no competing financial interest.

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