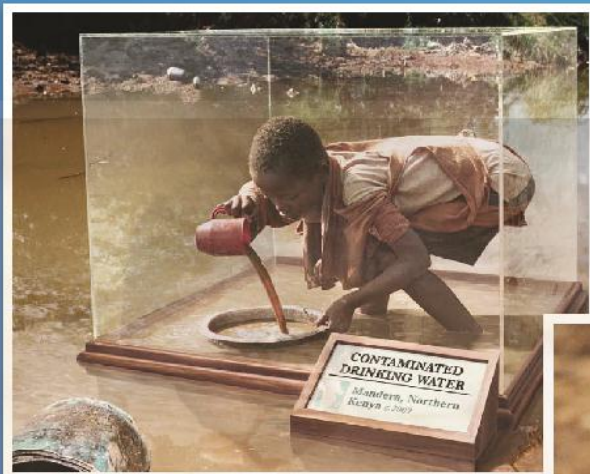


TREATMENT OF FLUORIDE CONTAMINATED WATER IN THE RIFT VALLEY

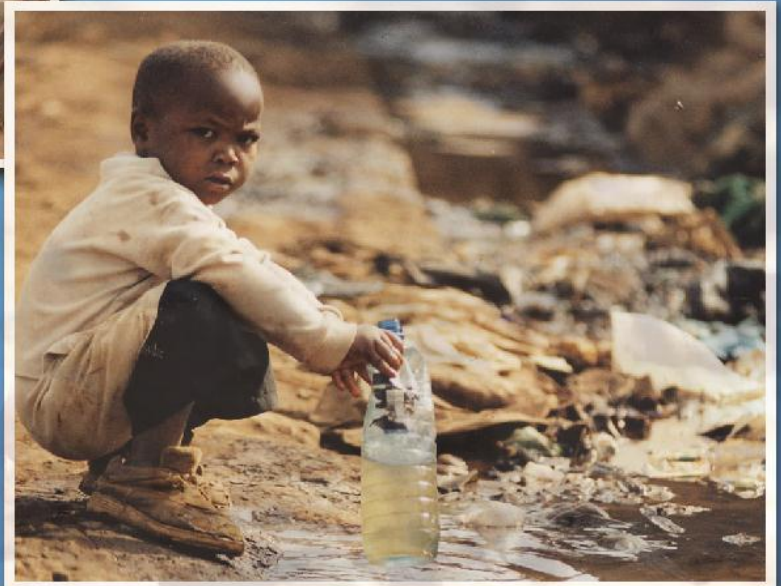
NEJASHI
ETHIO-TURKISH INTERNATIONAL SCHOOLS



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ADDIS ABABA, ETHIOPIA

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Table of Contents

Abstract	1
Introduction	2
Possible Solutions	2
Instruments.....	2
Variables	3
Methodology	3
Results	5
Conclusion	8
References	9

ABSTRACT

In the rift valley, it is not easy to reach drinkable water and this causes serious environmental and health problems. The water found in the regions is polluted by an excessive amount of fluoride. In an area where alternative sources are not easily available, treatment of contaminated water is the most reasonable and best approach.

This will stop dangerous effects on the environment and will bring safely drinkable water to the region at a very low cost when compared to other available methods.

The efficiency of untreated hydrated alumina (UHA) and thermally treated hydrated alumina (THA) obtained from hydrolysis of locally manufactured aluminum sulfate to remove fluoride from aqueous solution has been investigated in batch and continuous operation. The parameters considered were contact time and adsorbent dose, thermal pre-treatment of adsorbent, initial fluoride concentration and pH.

The adsorption was rapid during the initial 20 minutes, but significant amount ($> 90\%$) was removed within one hour at an optimum adsorbent dose of 1.6 g/L for initial F^- concentration of 20 mg/L . The removal efficiency of F^- was increased with adsorbent dosage. Fluoride adsorption efficiencies increase with increase in the thermal treatment temperature up to $200\text{ }^\circ\text{C}$, but further increase in temperature resulted in decreased removal efficiency. For application in continuous packed bed column, treatment at $300\text{ }^\circ\text{C}$ was taken as an optimum value. Fluoride adsorption capacity increases linearly with increase in F^- concentration. High de-fluoridation efficiency was achieved using both UHA and THA within a pH range of 4.0 to 9.0. The adsorption data at ambient pH were well fitted to the "Freundlich" isotherm model with a minimum capacity of $23.7\text{ mg F}^-/\text{g}$ and $7.0\text{ mg F}^-/\text{g}$ for THA and UHA, respectively. The kinetic studies showed that the adsorption reaction of fluoride removal by hydrated alumina can be well described by a pseudo-second-order rate equation. Continuous packed bed column experiment using THA indicated that 4.5 g of THA could treat 6 L of water containing 20 mg/L fluoride before breakthrough.

Therefore, both UHA and THA can be applied for the treatment of fluoride contaminated water in the Rift Valley.

INTRODUCTION

PURPOSE

In the rift valley, it is not easy to reach drinkable water and this causes serious environmental and health problems. The water found in the regions is polluted by an excessive amount of fluoride. In an area where alternative sources are not easily available, treatment of contaminated water is the most reasonable and best approach.

This will stop dangerous effects on the environment and will bring safely drinkable water to the region at a very low cost when compared to other available methods.

POSSIBLE SOLUTIONS

1. Surface water from rivers and springs
 - Need for development of springs and treatment plants for rivers.
2. Rain water harvesting
 - Need for large expensive storage reservoirs.
3. Low fluoride ground water can be found in the same area as high fluoride wells
 - Need for hydrological information and maps.
4. **De-fluoridation schemes, alone or mixing with surface water.**

EXPERIMENTAL PROCEDURES

INSTRUMENTS

1. A pH/ISE meter (Orion Model, EA 940 Expandable Ion Analyzer, U.S.A.) equipped with combination fluoride-selective electrode (Orion Model 96-09) was employed for the determination of F⁻.
2. The pH was measured with pH/ion meter (WTW Inolab pH/ION Level 2, Germany) using unfilled pH glass electrode.
3. The residual F⁻ concentration was measured according to the procedure described in the instrument's manual by using 1:1 ratio of the samples or standards and TISAB.
4. The electrode was calibrated prior to each experiment over a concentration range of interest. All measurements were made at room temperature (23 ± 2 °C).

VARIABLES/PARAMETERS

- A. Contact time and adsorbent dose
- B. Thermal pre-treatment of adsorbent
- C. Initial fluoride concentration and pH level

METHODOLOGY:

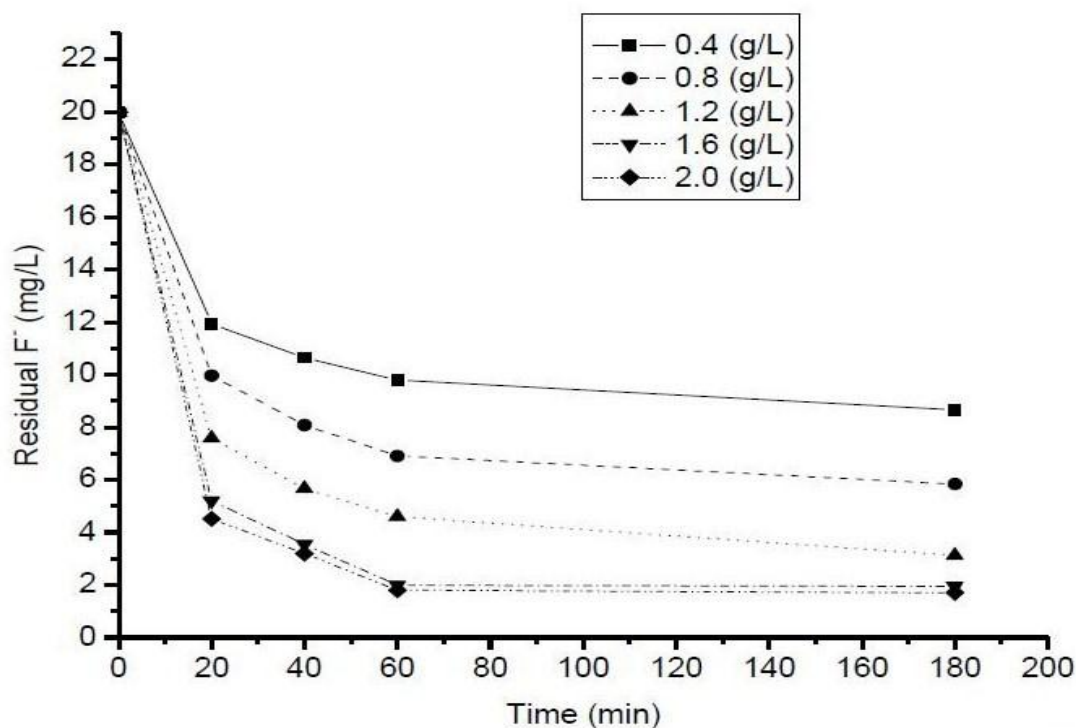
- 1) The adsorbent (aluminum hydroxide, also called hydrated alumina) was prepared from $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ (17 % Al_2O_3).
- 2) The raw material was dissolved in distilled water and the pH was adjusted to 7 with 2 M NaOH.
- 3) The pH was chosen based on the literature value at which hydrated alumina $[\text{Al}(\text{OH})_3]$ become stable. The precipitate (hydrated alumina) was filtered, washed with distilled water and dried, hereafter considered as untreated hydrated alumina (UHA).
- 4) Samples of the UHA were placed in porcelain crucibles and heated at the preset temperature from 200 to 600 °C at 100°C intervals in a furnace (Carbolite, ELF Model) for 1 h.
- 5) At the end of 1 h, the treated samples were taken out from the furnace and kept in a desiccator until further use. This material hereafter was considered as treated hydrated alumina (THA).
- 6) A 1000 mg F^-/L sodium fluoride stock solution (99.0 % NaF) was prepared in distilled water.
- 7) All batch experiments were conducted using 500 ml of distilled water spiked with F^- in 1 L Erlenmeyer flask under continuous mixing condition with magnetic stirrers at room temperature (23 ± 2 °C)
- 8) The effect of adsorbent dose and contact time were studied by varying the dosages of untreated adsorbent from 0.4 to 2.0 g/L at constant initial F^- concentration of 20 mg/L.
- 9) To investigate the effect of thermal treatment on fluoride removal efficiency of THA, 1.6 g/L dose of each adsorbent treated at different temperatures (200 to 600 °C) was mixed with 20 mg/L fluoride solution for a contact time of 1 h.
- 10) The effects of initial F^- concentration and contact time were investigated by varying the fluoride concentrations from 5 to 30 mg/L at constant THA dose of 1.6 g/L.

- 11) The effect of pH of raw (F^- spiked) water on the adsorption of F^- onto both UHA and THA was studied by varying the initial pH of the water from 3 to 10.
- 12) The kinetic analysis of the adsorption data is based on reaction kinetics of pseudo-first-order and pseudo-second-order mechanisms.
- 13) The change in pH during adsorption of F^- on THA was determined by first equilibrating constant adsorbent dose of 1.6 g in 490 ml distilled water samples whose pH varies from 3 to 10 for 20 h.
- 14) Continuous flow de-fluoridation study was carried out using a column made from glass with internal diameter and effective bed height of 0.9 cm and 25 cm, respectively.
- 15) The column was packed with 4.5 g of THA sample with particle size range of 1.0 - 2.8 mm. Spiked water containing 20 mg/L F^- was introduced into the column at a flow rate of 4 ml/min with peristaltic pump up-flow direction.
- 16) The fluoride adsorption capacity was determined when the effluent fluoride concentration at the top of the column beds exceeded 1.5 mg/L (the permissible concentration, designated as the break-through concentration) and also at the point of saturation.

RESULTS *(Some additional Data will be provided during the project presentation)*

Effect of adsorbent dose and contact time:

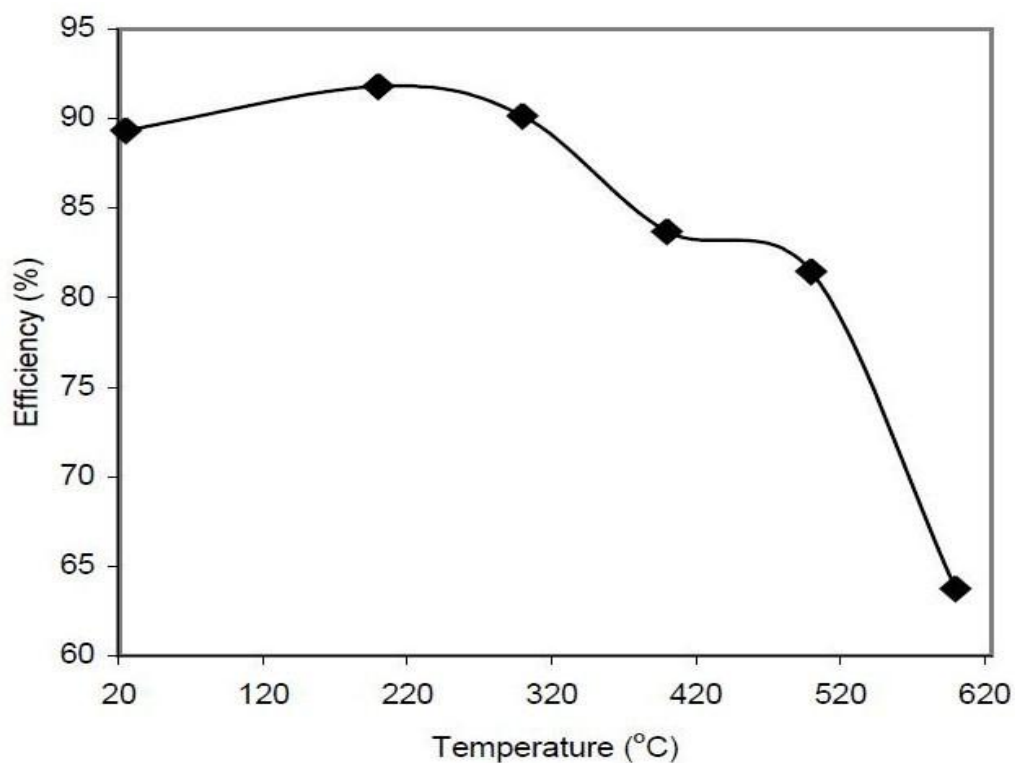
The results show that under the condition specified above, a contact time of about 60 min is enough to remove about 90 % of the fluoride in solution with an adsorbent dose greater than or equal to 1.6 g/L. This indicates that longer contact time did not have much effect.



Residual F⁻ concentration as a function of time for different doses of UHA (initial concentration = 20 mg/L F⁻, initial pH = 7.0 ± 0.3).

Effect of thermal treatment:

Fluoride adsorption efficiencies increase with increase in the thermal treatment temperature up to 200 °C, but further increase in temperature resulted in decreased removal efficiency. The relatively increasing fluoride removal up to 200 °C may be due to the increased removal of physically adsorbed and/or constitutional water molecules.

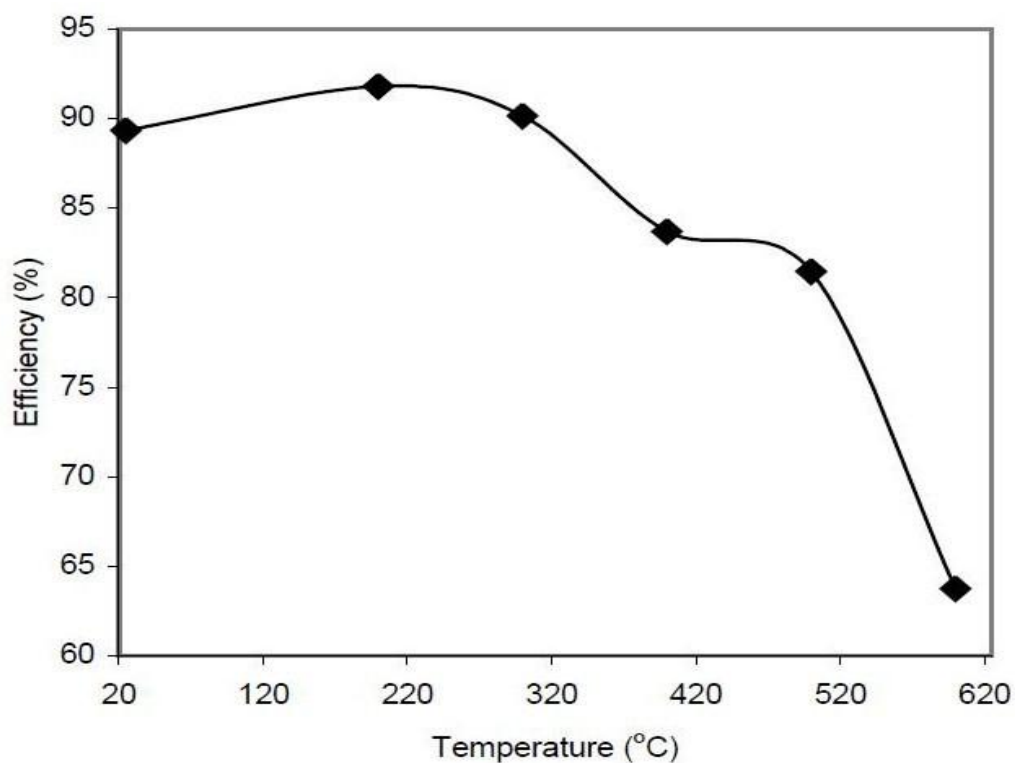


Effect of thermal treatment on F^- removal efficiency of the adsorbent (dose = 1.6 g/L, initial concentration = 20 mg/L F^- , contact time = 60 min, initial pH = 7.0 ± 0.3).

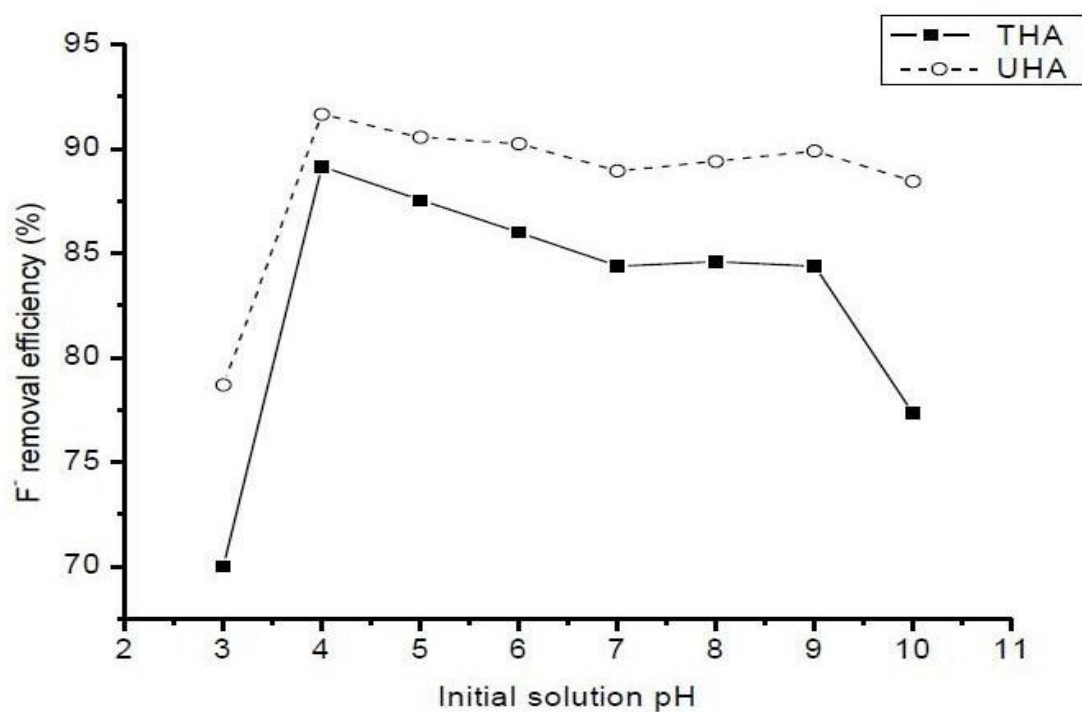
Initial fluoride concentration and pH:

For a given mass of adsorbent, the fluoride removal capacity increases with increasing initial concentration. This can be attributed to the utilization of less accessible or energetically less active sites because of increased diffusivity and activity of fluoride upon the increased concentration.

High de-fluoridation was achieved using both UHA and THA within a PH range of 4.0 to 9.0.



Effect of thermal treatment on F^- removal efficiency of the adsorbent (dose = 1.6 g/L, initial concentration = 20 mg/L F^- , contact time = 60 min, initial pH = 7.0 ± 0.3).



Effect of initial water pH on fluoride removal efficiency of both THA and UHA (initial concentration = 20 mg/L F^- , adsorbent dose = 1.6 g/L, contact time = 60 min).

CONCLUSION

In our work, a simple, fast, and promising method for the treatment of fluoride contaminated water is developed. Both UHA and THA showed a superior adsorption capacity for fluoride ion. Based on the results obtained, it can be concluded that more than 90 % of fluoride was removed within 1 h at an optimum adsorbent dose of 1.6 g/L for initial F⁻ concentration of 20 mg/L. Fluoride adsorption capacity increases linearly with increase in F⁻ concentration. High de-fluoridation efficiency was achieved using both UHA and THA with in a pH range of 4.0 to 9.0. The adsorption data is well fitted to the Freundlich isotherm model with a minimum capacity of 23.7 mg F⁻/g and 7.0 mg F⁻/g for THA and UHA, respectively. Moreover, continuous packed bed column experiment using THA indicated that 4.5 g of THA could treat 6 L of water containing 20 mg/L fluoride before break through.

The fluoride removal capacity of UHA and THA used in the present study was about 7 mg F⁻/g and 23 mg F⁻/g of adsorbent, respectively. Furthermore, it was demonstrated that the adsorbent can be applicable in batch as well as in continuous operations to suit de-fluoridation either at household or small community level. Laboratory results in batch operation indicated that the minimum F⁻ removal capacity of THA was 23.7 mg F⁻/g, which means that 6 L of water containing 20 mg F⁻/L (i.e. 120 mg F⁻) can be treated by about 5 g of THA, which is comparable to the amount required (4.5 g THA) to treat the same amount of water (6 L) with the same F⁻ concentration (20 mg/L) in continuous operation.

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