*Bulletin of Pure and Applied Sciences.*
*Vol.38 B (Botany), No.2.*
*July-December 2019: P.63-67*
**Original Research Article**

*Print version ISSN 0970 4612*
*Online version ISSN 2320 3196*
*DOI: 10.5958/2320-3196.2019.00008.9*
*Available online at www.bpasjournals.com*

# Fluoride Removal from Ground Water Sample by *Pistia stratiotes*

**Sukalpa Karmakar[1*], Joydeep Mukherjee[2], Somnath Mukherjee[3]**

**Author's Affiliation**
[1]Research Scholar, Environmental Engineering Division, Civil Engineering Department, Jadavpur University, Kolkata, West Bengal 700032, India.
E-mail: sukalpa17@gmail.com
[2]UGC Associate Professor, School of Environmental Studies, Jadavpur University, Kolkata, West Bengal 700032, India.
E-mail: joydeep_envstu@school.jdvu.ac.in
[3]Professor, Environmental Engineering Division, Civil Engineering Department, Jadavpur University, Kolkata, West Bengal 700032, India.
E-mail: sukalpa17@gmail.com

***Corresponding Author:**
**Sukalpa Karmakar**
Research Scholar, Environmental Engineering Division, Civil Engineering Department, Jadavpur University, Kolkata, West Bengal 700032, India.

**E-mail:**
sukalpa17@gmail.com

**Received on 30.04.2019,**
**Accepted on 24.06.2019**

**Keywords**:
Fluoride,
Ground water,
*Pistia stratiotes,*
Removal kinetics

**Abstract**

Fluoride in ground water is a well recognized problem in different parts of the earth including India. Various physiochemical separation processes are available which are to be considered as environmental friendly. Phytoremediation technology reported in the literature as a sustainable and cost effective green technology and its availability is ubiquitous in India. An investigation was undertaken in Environmental Engineering laboratory, Jadavpur University Kolkata to examine the potential of *Pistia stratiotes* (water lettuce) for removal of fluoride from a real life groundwater samples collected from fluoride affected tubewell. The initial concentration of fluoride in ground water sample was found to be 8.12 ± 1.26 mg/l. The experimental result showed that for a biomass (*Pistia stratiotes*) of 80 g/L, 29.37% fluoride was removed after an10 days of exposure time following the pseudo first order reaction kinetics.

## INTRODUCTION

Fluorosis is a complex disease which affects millions of people in India as well as a large part of the rest of the world. Fluoride contamination in ground water is mostly emerged as dissolution of rock forming minerals like apatite [$Ca_5(PO_4)_3$ (F,Cl,OH)] and fluorite [$CaF_2$] in addition to profuse withdrawal of ground water[1]. In addition to agricultural runoff, some specific industrial effluent discharge in land also contributes fluoride in groundwater[2]. The maximum permissible level of fluoride in India is 1.5 mg/L in drinking water[3]. In West Bengal, several districts are also exposed with high fluoride level in groundwater[4].

Several conventional treatment methods using different physico-chemical processes are well practiced for defluoridation of water. However, majority of these separation technologies have their limitations individually and most of these are site specific to suit the local condition[5]. Hence a low

cost, sustainable and environment friendly fluoride removal methodology is being searched by scientists and researchers around the world. As a result phytoremediation emerged as an eco-friendly and sustainable technology, since the method is applied earlier for treatment of ground water for treatment of arsenic and other toxic metals[6,7]. In view of above direction a research study was undertaken to assess the potentiality of *Pistia stratiotes* for fluoride removal from groundwater sample.

## MATERIALS AND METHODS

### Collection and acclimatization of plant

Fresh aquatic floating plants (*Pistia stratiotes*) were collected from a pond located within the Jadavpur University campus and brought to the laboratory. The plants were thoroughly washed under tap water and acclimatized in 10% Hoagland solution for 10 days[8].

### Location Study of some important parameters of collected water sample

Groundwater sample was collected from a tube well exist in Kartikdanga in Nalhati Block, Birbhum, West Bengal, India. Water sample was collected into three Tarson bottles of 2L capacity. All these tube wells are used for drinking and other domestic purpose in that locality. Some other important water quality parameters such as pH, Total dissolve solids (TDS), Total hardness and Total iron were also analysed as per methods underlain in Standard Method[9].

### Fluoride estimation method

Collected water samples were filtered with Whatman (42 grade) filter paper and filtrates were analyzed for fluoride estimation by using expandable ion analyzer (EA 940, Orion Research) and fluoride ion specific electrode (Thermo scientific). TISAB-III solution was added to each sample before measuring the samples according to the manufacturer's instruction. Necessary calibration of the instrument was done during the analytical determination of fluoride.

### Removal study for kinetic evaluation

Time concentration study was performed at 30 ± 2 °C room temperature in presence of two 40W fluorescent tubes for a photoperiod of 10 h per day in polyvinyl chloride (PVC) trough of 2 L capacity each for 10 days contact period in each set as batch mode. In each container, one liter (1 L) field sample was taken and treated with 80 g/L floating aquatic plant (*Pistia stratiotes*) biomass. Another identical trough was taken containing 1L field water sample only as control set simultaneously. Sampling was done for each alternate day and evaporation loss was compensated with distilled water. In this study, kinetics including reaction order was also analyzed, based on experimental results.

## RESULTS AND DISCUSSION

### Characteristics of collected groundwater

The area where from the water was collected consists of fine grained, hard, and compact basaltic rocks. These rocks possess negligible primary porosity but acquire secondary porosity by post fracturing and weathering of rock fragments due to redox activities which causes increase in fluoride concentration in ground water in the Nalhati[10]. In the present study average level of fluoride concentrations in the collected ground water sample was 8.12 ± 1.26 mg/L. The pH of collected water sample was determined and found to be 7.87 ± 0.42. Besides, the average value of Total hardness, Total dissolved solids and Total Iron in the field water sample were found to be 28.33 mg/L, 329 mg/L and 48.01 µg/L respectively.

### Batch kinetic study:

Time-concentration study was conducted with real-life groundwater sample containing fluoride of 8.12 ± 1.26 mg/L as initial concentration and 80 g/L of *pistia stratiotes* as biomass. The batch kinetic results are shown in Figure 1. After 10 days of exposure time, 29.37 % fluoride removal by *Pistia stratiotes* was observed, corresponding to initial fluoride concentrations of 8.12 ± 1.26 mg/L. Authors

have reported in their earlier publication that *Pistia stratiotes* has appreciable fluoride uptake capacity which increases with increasing initial concentration of fluoride[11]. In this present study, 0.030 mg/g fluoride uptake capacity of *Pistia stratiotes* was found after 10 days equilibrium exposure time during batch kinetic study. Figure 1 shows that at initial stage there was a rapid intake of fluoride by the plant and the removal data followed an identical trend like batch kinetic study with synthetic water sample which was conducted by the author earlier[12]. This phenomenon was more likely occurred due to the existence of a higher concentration gradient of fluoride in water imparted as dominant driving force which may initiate transfer of fluoride from solution to plants root[13]. Earlier researchers have reported that cell wall contains calcium which binds to the fluoride present in water and removes fluoride from water[14].

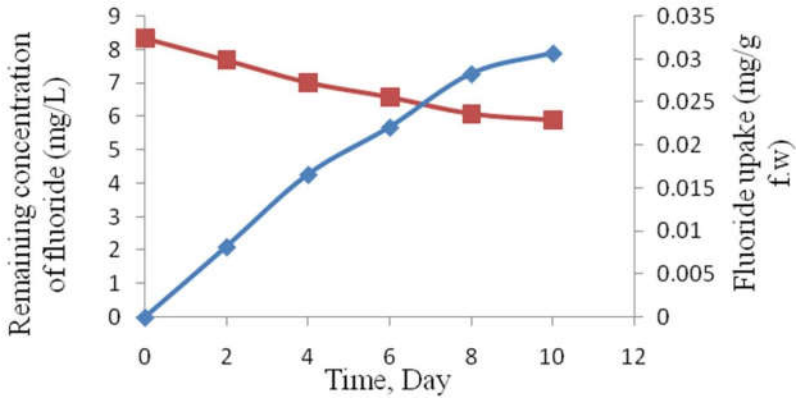


**Figure 1: Fluoride removal and fluoride uptake by *Pistia stratiotes* from real life ground water sample**

**Reaction order for real life ground water**

The experimental results as observed for real life ground water sample were examined for fitting in reaction order model and sorption mechanism with two different kinetic order models, such as pseudo-first order[15] and pseudo-second order reaction models[16]. The pseudo first order kinetic model depends on the sorbent capacity for the sorption analysis. The linearized form of the pseudo first-order kinetic model and pseudo second order kinetic model for real life ground water sample was plotted in Figure 2 and Figure 3 respectively.

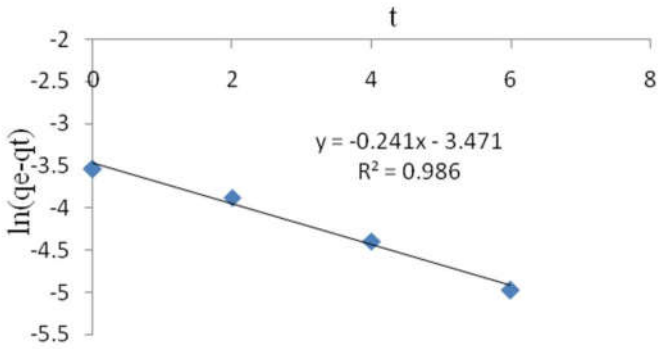


**Figure 2: Pseudo-first order reaction model for fluoride removal by *Pistia stratiotes* from real life ground water sample**

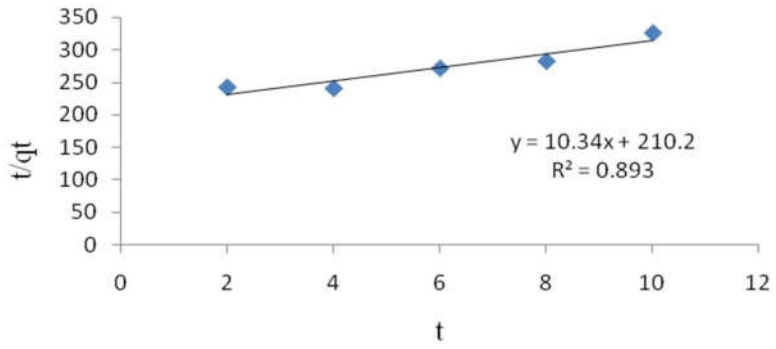


**Figure 3: Pseudo-second order reaction model for fluoride removal by *Pistia stratiotes* for real life ground water sample**

**Table 1: Constants of pseudo-first-order and pseudo- second-order kinetics models for real life ground water treatment**

| $q_{e,exp}$ (mg $g^{-1}$) | Pseudo-first-order constants | | | Pseudo-second-order constants | | |
|---|---|---|---|---|---|---|
| | $K_1$ ($day^{-1}$) | $q_{e,1}$ (mg $g^{-1}$) | $R^2$ | $K_2$ (g $mg^{-1}$ $day^{-1}$) | $q_{e,2}$ (mg $g^{-1}$) | $R^2$ |
| 0.030 | 0.241 | 0.031 | 0.986 | 0.516 | 0.096 | 0.893 |

Table1 shows the kinetic parameters and the equilibrium uptake capacity ($q_e$) values. The $R^2$ values of both pseudo first-order and pseudo second-order equations were found to be different from each other and were calculated as 0.986 and 0.893, respectively. The $q_e$ value of the pseudo first-order model was 0.031 mg/ g fresh weight where as $q_e$ value of pseudo second-order model was calculated as 0.096 mg/ g fresh weight. However, the calculated values of $q_e$ based on the pseudo first-order kinetic model agreed reasonably well with the experimental data. So both the $R^2$ and $q_e$ values indicate that the pseudo first-order model is better fitted than pseudo second order model.

## CONCLUSION

The present study revealed that water lettuce (*Pistia stratiotes*) would be a good natural candidate for the attenuation of fluoride contains in groundwater. The maximum removal efficiency of the plant at 8.12 mg/L of initial fluoride concentration was found to be 29.46 % after 10 days of contact period with 80 g/L plant biomass. The removal kinetic study followed pseudo first-order reaction model. Hence, this green technology can be applied as low cost optional tool for treatment of fluoride in ground water if contact period is to be reduced. The uptake capacity of plant is comparable to other biosorbents and easily be grown in the tropical region which replaces the cost of chemical treatment. However, further study is needed to explore the application of this process to solve fluoride contamination in ground water on pilot scale study along with effect of plant physiological stress studies.

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