OPTIMUM OPERATION OF COUNTER-CURRENT WATER DEFLUORIDATION SYSTEM

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SUMMARY: In many regions of the world, the groundwater and the surface water have higher than permissible fluoride concentration. A system based on the counter-current movement of the sorbent and the sorbate has been discussed as an ideal, most efficient and economical method of water defluoridation. A technique based on experimental runs on a simple column type moving media adsorber is described for evaluating the optimal operating conditions for maximum advantage. The presented defluoridation methodology has vast scope for field application.

Key Word: Water defluoridation, optimal operation, moving medium reactor, fluoride, bone char.

INTRODUCTION

Fluoride may be present in surface or ground water in varying quantities. The sources of fluoride in water can be the Earth's crust, the ocean and industrial activities. The surface or ground waters contain low to medium fluorides. The manufactures of certain products such as glasses, metals, electroplating, manufacturing parts, pesticides, disinfectants, etc., contribute the fluoride bearing waste waters[1-3]. Such industrial effluents contain large quantities of fluoride. The fluoride content of ground waters in certain parts of India have been reported to vary from 1.5 to 6.3 mg-F/L and even as high as 18 mg-F/L[4]. Excessive fluoride in water, unless removed, cause dental or skeletal fluorosis[5,6]. Indian drinking water supply standards recommended an acceptable fluoride concentration of 1.0 mg-F/L and allowable fluoride concentration of 1.5 mg-F/L for potable waters[4].

Defluoridation methods included physico-chemical methods such as adsorption, ion exchange or chemical precipitation[7,8]. In adsorption, the sorbate from aqueous solution concentrates on sorbent surface. The efficiency depends on the mode of contact between the sorbent and sorbate.

The fixed bed continuously operating column reactor is more efficient than batch reactors[9]. Hassler[10] and Weber[9] suggested that a continuously operating expanded bed reactor increases the sorbent effectiveness.

The expanded bed reactor permits the use of small particle size without the associated problems of excessive head loss or air-binding etc., common to packed-bed operation with fine media[11].

In a continuous operation of the expanded bed reactor, the solid sorbent is added at the top of the column and the spent sorbent withdrawn from the bottom. The solution from which adsorption takes place, flows upwards through the regions of partially utilized sorbent to regions of freshly added sorbent material. Natural segregation of sorbent would allow greater sorbent capacity, because individual particles of the porous material became denser with increasing adsorption and therefore, tend to

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concentrate near bottom of the column. The author developed a continuous operating moving media rector to facilitate the fullest utilization of the sorbent capacity.[12-15]

This paper presents a technique to optimize the operation of moving media reactors.

MATERIALS AND METHODS

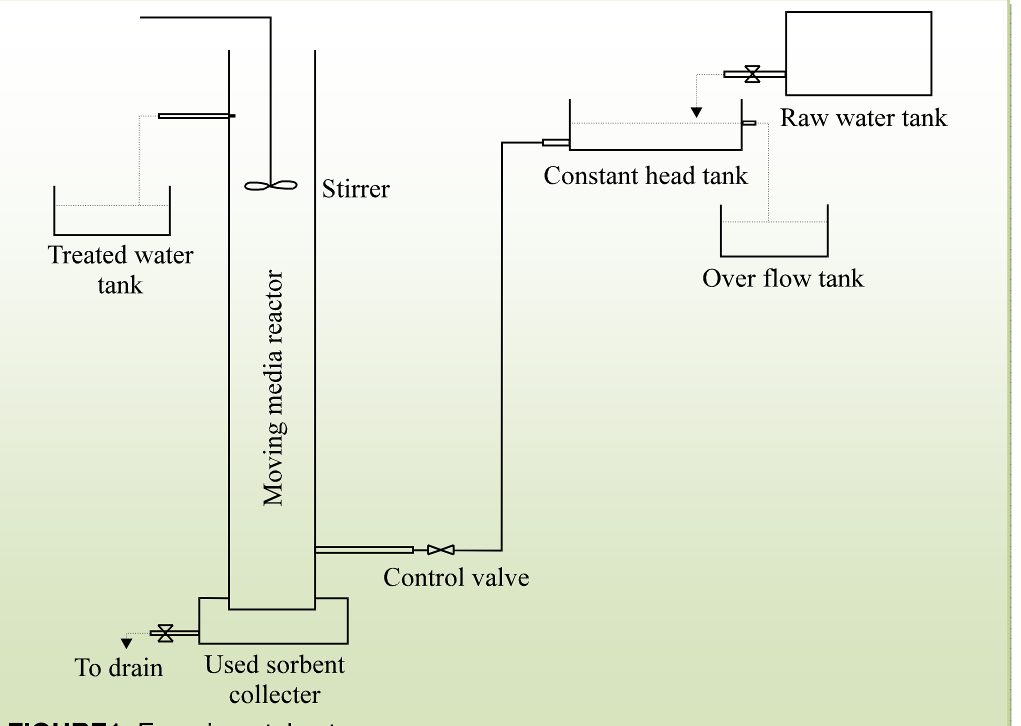

FIGURE1. Experimental setup

The experimental set-up for a moving media adsorber or reactor consisted of a 3.5 cm internal diameter PVC column of 2.0 m in length. The detailed arrangement of this set-up is shown in Figure 1 and consists of an overhead tank, a constant head tank, treated water tank, the adsorption column with necessary accessories, such as a stirrer, a plastic container at the bottom for collecting used adsorbent etc.

The sorbent, fishbone charcoal[14,15] was lead into the top of the column at a predetermined rate and the sorbate, the fluoride-containing water, was lead into the bottom of the column at a predetermined rate. The residual fluorides concentration in the effluent samples was determined by an Orion Ion Analyzer, Model 901. The counter-current movement of the sorbent and the sorbate provided ample opportunity for reaction, and the water with the highest concentration of fluoride is in contact with the most exhausted adsorbent while the water which is about to be discharged as effluent is in contact with fresh adsorbent. The set-up manifest a counter-current principle of operation and provides an efficient yet economical system.

RESULTS AND DISCUSSION

Comprehensive studies of water defluoridation using the fishbone charcoal in the dynamic system available in the moving media adsorber, yielded the following performance[12,14,15].

The ratio of the effluent concentration to the inlet concentration of fluoride decreased with an increase in the sorbent mass input flow rate due to larger surface area of the sorbent. This ratio however, increases with the increasing water flow rates due to the decreased reaction or liquid hydraulic residence time. Likewise, the ratio also increases with increasing initial sorbate concentration.

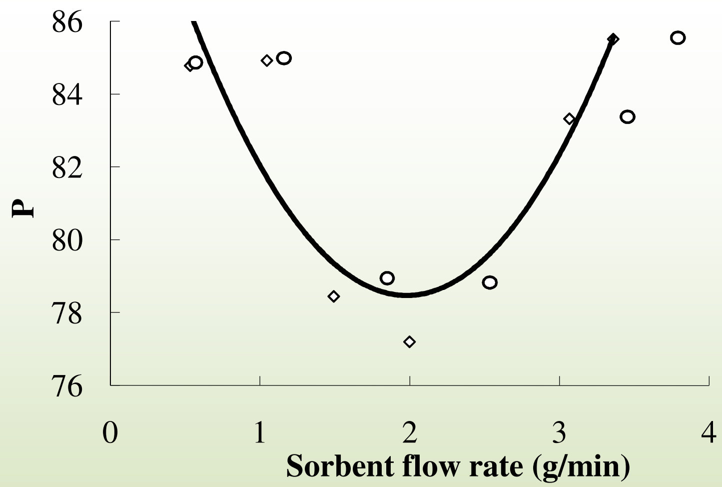

FIGURE 2. Relation between the sorbent flow rate in g/min and the arbitrary chosen parameter P, representing a summation of removal capacity of the sorbent and the percentage fluoride removal from the water. Data for inlet concentration 10 mg-F/L and liquid flow rate 10.0 ml/min.

The fluoride removal capacity of the sorbent expressed in µg-F/g-sorbent decreases with an increases in sorbent mass input rate (in g/min) probably due to an overcrowding and overlapping of sorbent particles reducing the effective surface area available for adsorption. The decrease in capacity is rapid at lower sorbent mass input rates. At greater fluoride removal rates, the fluoride removal per unit mass of sorbent decreases indicating an uneconomical utilization of sorbent. The optimum sorbent mass input rate is where maximum capacity of sorbent, and minimum ratio of effluent to influent fluoride concentration in the water is obtained. The sorbent capacity increases with increasing water flow due to a reduced overcrowding, reduced boundary layer and greater concentration gradient of sorbate. Likewise, the sorbent capacity increases with the initial fluoride concentration in the influent water due to an increased concentration gradient.

The isotherms in the dynamic system were investigated and specific modifications in a conventional isotherm were proposed[15]. Several approaches[13] were used to evolve models for predicting the ratio of effluent to initial sorbate concentration which increased with increasing influent flow rate and increasing initial sorbate concentration. The ratio, however, is decreasing with increasing sorbent input rate.

As the sorbent mass input rate increases, the fluoride removal increases but fluoride removal capacity per unit mass of sorbent decreases. This indicates that higher fluoride removal can be obtained at the cost of fluoride removal capacity of the sorbent. Thus it is critical to decide upon an optimal sorbent mass input rate value to obtain a balance between the percentage of fluoride removal and the fluoride removal capacity of the sorbent on the one hand, and the minimum sorbent mass input rate value on the other. Unitizing the data[14] a plot was prepared (Figure 2) between an arbitrarily chosen parameter P and the sorbent mass input rate. The P values represent a summation of fluoride removal capacity of the sorbent and the percentage fluoride removal. Both the terms summarized in the parameter P represent dimension-less parameters and are in some way (directly or indirectly) functions of the fluoride removal. Fluoride removal capacity of sorbent (q_e) dominate at lower sorbent mass input rates (W), and accounts for optimum utilization of the costly adsorbent, while the percentage sorbate removal (R) dominate at higher W values, and accounts for the systems removal efficiency. The summation of q_e and R thus, represents in some way, the overall removal effect against a W value. This plot of P versus W (Figure 2) indicates that the P value initially decreases with an increase in the W value, reaching a minimum at W = 1.75 to 2.0 g/min beyond which, the P value increases with further increases in the W value.

Thus, it is suggested that for actual operation of the reactor the sorbent mass input rate (W) and the corresponding P value may be taken as design values. The provision of a P value would strike a balance between the fluoride removal and the fluoride removal capacity of the sorbent for the observed test conditions, i.e. it will ensure a fairly high fluoride removal percentage with minimum sacrifice of fluoride removal capacity of the sorbent.

CONCLUSIONS

The methodology for an ideal and most efficient and economical system for water defluoridation has been described. Apart from a discussion of the effects of the various operating variables, a technique to determine the optimal operating conditions in a moving media adsorber has been presented. A few trial experimental runs on a simple column adsorber can establish the most desirable operational requirements for maximum advantage. This can be used for any sorbent-sorbate system. The method and the techniques presented can have immense field and practical applications.

ACKNOLEGMENTS

The data and some material forming a part of this paper has been abstracted from the various papers published in co-autorships of Dr. D.J. Bhatt and Shri D.J. Killedar both of whom worked for their Ph.D. under the author's guidance.

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