SENIOR DESIGN WORKING PAPER

Defluoridation of Ethiopian Groundwater

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A senior design team from the University of Connecticut recently explored how to replace the activated alumina method of defluoridation with a more cost-effective and sustainable method. Defluoridation of water for human consumption is important because of the deleterious effects of fluoride on the human body. According to the World Health Organization, fluoride consumed in concentrations greater than 1.5 mg/L becomes harmful, resulting in dental, followed by skeletal, fluorosis—a condition in which the calcium found in the human skeleton reacts with the fluoride consumed and causes bones to become much more brittle.

Despite being long known for its capacity for defluoridation, its low cost, and its large reserves in Ethiopia, little research has been conducted on using magnesium oxide for defluoridation. In fact, magnesium oxide added to fluoridated water will, through simple adsorption, form an insoluble byproduct (magnesium fluoride) that settles out of the water. This byproduct can then be filtered out, and the remaining water will be safe to drink.

For sustainability in Ethiopia, the overall process must have no power requirements, so manual methods of stirring must be implemented. After the residence time, the solids can be separated out through the use of a simple filtration system—also requiring no power or fuel—that will yield a large contact area.

An added benefit of using magnesium oxide for defluoridation is that the byproduct of the reaction is nontoxic and can be used as a building material. Magnesium fluoride is difficult to oxidize and requires an extremely high temperature to combust, so it can be used to clad buildings to decrease their flammability.

In short, the use of magnesium oxide to defluoridate water is both more effective and more environmentally friendly than current methods.

Technical analysis

From the literature, we determined defluoridation capacity is dependent on time, reaching equilibrium at 60 minutes, and that the optimal point of fluoride removal from the source is 70%. Removal capacity also depends on the initial concentration of fluoride. The analyses suggest roughly 251.1 kg of magnesium oxide is needed to treat 20,000 L of fluoridated water with 20

mg F/L. To achieve the optimal 70% removal rate and lower the fluoride to the threshold set by the World Health Organization, this must be a three-step process. The process recommended is a three-step flipping method, shown in Figure 1.

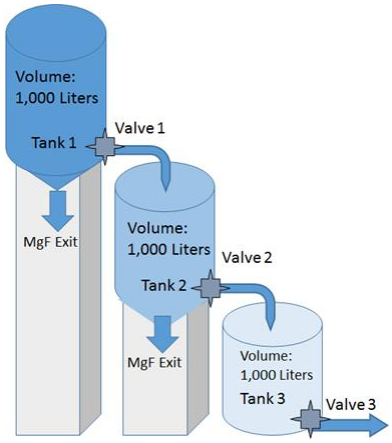

Figure 1: Overall Process

The reactors have magnesium oxide added to the fluoridated water and flipped semi-continuously for an hour to simulate a constantly stirred tank reactor at each step. We validated the process experimentally to determine its feasibility.

Validation methods

To determine its fluoride removal capacity, we added varying amounts of magnesium oxide (see Table 1) to a 20 mg/L fluoride concentration stock and determined the final concentration of fluoride as the percentage removed per gram of magnesium oxide. The removal rate was lower than literature values, most likely due to a less vigorous stirring method of flipping.

Table 1: Final Concentration of Fluoride after Treatment

Added MgO concentration (g/L)	Product fluoride concentration (mg/L)
3	11.73
5	10.42
7	5.76

Economic analysis

Based on a comparison of chemical costs alone, the magnesium oxide defluoridation process is clearly better than the activated alumina process (see Table 2).

Table 2: Defluoridaton Chemical Costs

	Activated alumina	Magnesium oxide
Fluoride adsorption capacity (grams/grams)	0.0011	0.0015
Required chemical (kg/day)	200	250
Cost of method ($/day/person)	0.10	0.03

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The environmental impacts of the defluoridation process life cycle in Ethiopia from start to finish are minimal. The byproduct of the treatment process itself is not harmful and is extremely stable when stored.

Conclusions

The original goal of this project was to replace the current defluoridation method in Ethiopia (activated alumina) with another, more cost-effective method; we accomplished this with magnesium oxide. The largest drawback to this method is that it may require a filtering stage, the duration of which depends on the particle size of the magnesium oxide. It has the advantage, however, that the chemical can be produced in Ethiopia and is readily available from nearby countries, such as Egypt, and the added benefit of producing sellable building material (magnesium fluoride) as a byproduct, instead of toxic waste.

Therefore, we would recommend the use of magnesium oxide to remove excess fluoride from drinking water.

For future work related to this project, further study is needed regarding the particle size of the magnesium oxide used to treat the fluoridated water. This is necessary to create much simpler separation processes and lower the kinetics of the defluoridation reactions.

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