Defluoridation with Electrocoagulation Followed by Activated Alumina Adsorption for Rural Areas

By

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Mottling of tooth enamel, is a developmental disturbance of dental enamel caused by excessive exposure to high concentrations of fluoride during tooth development. The risk of fluoride overexposure occurs at any age but it is higher at younger ages.
Skeletal Fluorosis

• Skeletal fluorosis is a bone disease caused by excessive consumption of fluoride.

• In advanced cases, skeletal fluorosis causes pain and damage to bones and joints.
Fluoride standards for drinking water

World Health Organization (WHO) guideline value **1.5 mg/L**.

The Requirement (Acceptable limit) of fluoride as per IS 10500:2012 of Bureau of Indian Standard (BIS) is **1.0 mg/L**.

The permissible limit in the absence of alternate source of fluoride as per IS 10500:2012 of Bureau of Indian Standard (BIS) is **1.5 mg/L**.

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES**
Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR) recommended that public water supplies contain fluoride at concentrations between **0.7 and 1.2 mg/L**.
Fluoride removal Technology

Nalgonda Technique:
Alum (aluminum sulphate) and lime (calcium oxide) are added to and rapidly mixed with the fluoride contaminated water. Induced by a subsequent gentle stirring, flocs develop (aluminum hydroxides) and are subject to removal by simple settling.

Activated alumina
Activated alumina, a granular, highly porous material consisting essentially of dehydrated aluminum hydroxide, can adsorb fluoride.

• The use of activated alumina in a continuous flow system is an economical and efficient method for defluoridating water supplies.
• High removal capacity.
Electro coagulation

Electro coagulation process with aluminum bipolar or monopolar electrodes can be used for Defluoridation process.

- The basic principle of the process is the adsorption of fluoride with freshly precipitated aluminum hydroxide, which is generated by the anodic dissolution of aluminum or its alloys, in an electrochemical cell. Aluminum hydroxide can adsorb fluoride from water.

The basic anodic and cathodic reactions:

- \( \text{Al} \rightarrow \text{Al}^{3+} + 3e \) (At the anode)

- \( 2\text{H}_2\text{O} + 2e \rightarrow \text{H}_2 + 2\text{OH}^- \) (At the cathode)

Why Electrocoagulation

- Fluoride removal capacity is high, 95 - 98% percent removal can be achieved.
- It requires simple equipment, easy to operate and less maintenance.
- Flocs formed by EC can be easily separated directly by filtration.
- EC produces effluent with less total dissolved solids.
- And the running cost is low for this operation.
Adopting Two stage Defluoridation System and its Advantages

• The fluoride removal with activated alumina is effective but costly treatment. The removal technique is fast and minimum sludge handling is required.

• Electrocoagulation (EC) system is an efficient, low operating cost system, though requires electrical maintenance. Maintenance can be sometime challenging in rural area.
• Electrocoagulation (EC) system removes part of the fluoride, reducing the challenge to the activated alumina bed and this helps to prolong service life of activated alumina bed.

• In case, when the fluoride level is not too high EC system with sand filter can deliver safe water. However provision of a downstream activated alumina bed will help in case the EC system is temporarily malfunctioning.
FIELD TRIAL
Noapara, Birbhum, WEST BENGAL, INDIA

Defluoridation Unit at Birbhum District Installed on 2008

Fluoride (mg/l) – 5.83
Two Stage Defluoridation System
Chhota Irga village of Bhowridhi GP in Para block of Purulia district, WEST BENGAL, INDIA (2011)
Over head tank with electrocoagulation

Filtered Water Accumulation Tank

1st Filter

2nd Filter

3rd Filter

Tap for Water Collection

**Raw water Characteristics**

<table>
<thead>
<tr>
<th>pH</th>
<th>Conductivity (ms/cm) @ Temperature 33.4°C</th>
<th>TDS (mg/l)</th>
<th>Fluoride (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.8 - 8.1</td>
<td>0.70 - 0.92</td>
<td>480 - 750</td>
<td>3.9 – 5.1</td>
</tr>
</tbody>
</table>

Operate ECL (Electro charge loading) for electrocoagulation System 50-120 Coulombs/liter, 200Kg Activated Alumina bed is split in two columns in a lead-lag type of combination.
Cost of electricity for operation of electrocoagulation systems

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Conversion to USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost @ Al Sheet (Kg)</td>
<td>250.00</td>
<td>$3.77</td>
</tr>
<tr>
<td>Treated water volume by the electrocoagulation system (Liter)</td>
<td>1000.00</td>
<td>$15.08</td>
</tr>
<tr>
<td>Daily cost of aluminum</td>
<td>4.20</td>
<td>$0.06</td>
</tr>
<tr>
<td>Cost of the electricity (@ Rs. 6/- per unit)</td>
<td>6.00</td>
<td>$0.09</td>
</tr>
<tr>
<td>Power consumption for pump per day</td>
<td>1.11</td>
<td>$0.02</td>
</tr>
<tr>
<td>Electricity Cost Pump per day</td>
<td>6.67</td>
<td>$0.10</td>
</tr>
<tr>
<td><strong>Cost per Kilo Liter (1000L)</strong></td>
<td><strong>Rs.17.26</strong></td>
<td><strong>$0.26</strong></td>
</tr>
<tr>
<td><strong>Cost per Liter</strong></td>
<td>0.017</td>
<td><strong>$0.00026</strong></td>
</tr>
</tbody>
</table>

Table Capital Investments for electrocoagulation and Other Maintenance Cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Conversion to USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of the Aluminum electrodes per Kg</td>
<td>250</td>
<td>$3.77</td>
</tr>
<tr>
<td>Cost of Power supply (AC-DC, 24V-20 Amps)</td>
<td>7000</td>
<td>$105.56</td>
</tr>
<tr>
<td>Other electrical equipment cost</td>
<td>1500</td>
<td>$22.62</td>
</tr>
<tr>
<td><strong>Total Capital Cost</strong></td>
<td><strong>Rs.8750</strong></td>
<td><strong>$131.95</strong></td>
</tr>
<tr>
<td>Annual maintenance cost (For Acid cleaning of cathodes, replacing of damaged graphite electrodes)</td>
<td>1000</td>
<td>$15.08</td>
</tr>
</tbody>
</table>

**1 Indian Rupee equals 0.01508 US Dollar (11 September 2015)**
FIELD TRIAL
Nalagola Primary School of Malda district, WEST BENGAL, INDIA (2015)
### Raw water Characteristics

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<th>TDS (mg/l)</th>
<th>Fluoride (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1-8.6</td>
<td>0.45 - 0.55</td>
<td>300</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>0.55</td>
<td>340</td>
<td>2.01</td>
</tr>
</tbody>
</table>

**Operate ECL (Electro charge loading) for electrocoagulation was 200-240 Coulombs/liter**

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**Cost per Kilo Liter (1000 Liter) of treated water** $0.53

**Total Capital Cost for electrocoagulation** $1000.00 – 1200.00$

**Total Cost of the Defluoridation Unit incl. Activated Alumina** 3500 $ – 4000 $
Demonstration of Integrated Fluorosis Mitigation Approaches in Malda West Bengal

Operation Manual
Health Improvements

• At least 17 houses (43 families) were visited and data collected by interview and clinical examination

• Dental, Skeletal and Non-skeletal fluorosis was decreased 2%, 18% and 6% after 3 months of observation
Acknowledgement

• **UNICEF for the funding the projects.**

• **SATHEE (Shibpur Association for Technological, Humanitarian & Environmental Endeavors, An NGO);**

• **Water committee of Noapara, Birbhum, WEST BENGAL, INDIA**

• **Chhota Irga Primary School and All the members of the Purulia water community, WEST BENGAL, INDIA**

• **Nalagola Primary School All the members of the water committee and Nalagola Primary School of Malda district, WEST BENGAL, INDIA**
Thank You