Ethiopia is one of the 23 countries in the world affected by high fluoride.
How can one ensure safe water on sustainable basis for the rural population if there is no surface water and if groundwater is contaminated?
HEALTH PROBLEMS OF FLUORIDE IN DRINKING WATER

Fluorides in drinking water, illustrating the impacts of both deficiencies and excesses.

Skeletal fluorosis: excessive deposition of F in bone

Dental fluorosis: mottling of the tooth enamel

The average daily tolerable intake of fluoride recommended by US EPA is 0.05-0.1 mg/kg bw /day
OBJECTIVES OF THIS STUDY

1. To estimate daily fluoride intake by children and adults in selected villages with different fluoride levels, variable nutritional and socio-cultural conditions

2. To evaluate the relative contribution of water and food to the total daily fluoride intake

3. To evaluate the risk of fluorosis in relation to total dietary intake

4. To field test high capacity water defluoridation technology
METHODOLOGY AND APPROACH

1. **Determination of total dietary intake of fluoride**
   - in water, food, and local beverages
   - Survey of water and food consumption through actual measurement for at least 10% of the target population
   - Additional survey through questionnaire

2. **Survey of fluorosis (dental and skeletal)**
   - Identification of dental fluorosis using Deans Index (10% of target population)
   - Identification of skeletal fluorosis using physical exercise method developed in India,
   - Measurement of body weight

3. **Defluoridation technology based on Aluminium Oxide Hydroxide**
   - Synthesis and characterization
   - Laboratory column studies
   - Design, field implementation, and monitoring
   - Assess sustainability (technical, cost, acceptability and use, institutional)
SURVEY OF SKELETAL FLUOROSIS
Determination of Fluoride in Water and Food

- Alkali fusion method for digestion of the food samples was used.
- Fluoride concentration was measured by fluoride selective electrode
- Spiking and recovery analysis for food samples
- Certified reference material (Timothy high-2695) for food samples

<table>
<thead>
<tr>
<th>Reference material</th>
<th>Measured F (mg/kg)</th>
<th>Average F (mg/kg)</th>
<th>Stdv</th>
<th>Certified value (mg/kg)</th>
<th>Measured at NIFES (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy high</td>
<td>262, 258, 298, 308, 295, 284, 269</td>
<td>282</td>
<td>19.36</td>
<td>277±27</td>
<td>277±34</td>
</tr>
</tbody>
</table>

No significant difference between measurement result and certified value at 95% confidence level.  
(Malde et al., 2001)
# Fluoride Intake (mg/person/day) using different water sources

<table>
<thead>
<tr>
<th>Daily intake of F⁻ through</th>
<th>Village 1 (1 ppm)</th>
<th>Village 2 (3 ppm)</th>
<th>Village 3 (11.5 ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>2.61</td>
<td>3.52</td>
<td>3.97</td>
</tr>
<tr>
<td>Enjera</td>
<td>4.63</td>
<td>5.68</td>
<td>8.1</td>
</tr>
<tr>
<td>Shiro stew</td>
<td>0.16</td>
<td>0.24</td>
<td>0.69</td>
</tr>
<tr>
<td>Potato stew</td>
<td>0.34</td>
<td>0.51</td>
<td>0.77</td>
</tr>
<tr>
<td>Kale stew</td>
<td>0.59</td>
<td>0.71</td>
<td>1.3</td>
</tr>
<tr>
<td>Porridge</td>
<td>0.83</td>
<td>0.83</td>
<td>0.63</td>
</tr>
<tr>
<td>Fish stew</td>
<td>0.04</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Total</td>
<td>9.2</td>
<td>11.56</td>
<td>15.58</td>
</tr>
<tr>
<td>Tea</td>
<td>0.17</td>
<td>0.41</td>
<td>1.67</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.24</td>
<td>0.66</td>
<td>1.29</td>
</tr>
<tr>
<td>Drinking water</td>
<td>1.73</td>
<td>4.78</td>
<td>17.35</td>
</tr>
<tr>
<td>Total</td>
<td>2.14</td>
<td>5.85</td>
<td>20.31</td>
</tr>
</tbody>
</table>
RELATIVE CONTRIBUTION OF WATER AND FOOD TO THE TOTAL DAILY INTAKE

1.0 mg/L F in water
- Water: 67.1%
- Food: 32.9%

3.0 mg/L F in water
- Water: 58.0%
- Food: 42.0%

11.0 mg/L F in water
- Water: 85.5%
- Food: 24.5%
### AVERAGE DAILY INTAKE OF FLUORIDE IN NINE VILLAGES IN OROMIA AND SNNPR REGIONAL STATES

<table>
<thead>
<tr>
<th>No.</th>
<th>Regional State</th>
<th>Woreda</th>
<th>Village</th>
<th>Fluoride in Water (mg/L)</th>
<th>Fluoride Intake through Food (mg/day)</th>
<th>Total Daily intake of F-(mg)</th>
<th>Observed Risk of Fluorosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oromia</td>
<td>Bora</td>
<td>Malima Beri</td>
<td>11.0</td>
<td>3.89</td>
<td>21.87</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>Sami Berta</td>
<td>12.5</td>
<td>4.38</td>
<td>19.23</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Adama</td>
<td>Dibisa</td>
<td>3.2</td>
<td>4.1</td>
<td>12.0</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Dugda</td>
<td>Gura</td>
<td>11.0</td>
<td>14.95</td>
<td>35.3</td>
<td>88</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>Miskan</td>
<td>3.0</td>
<td>10.73</td>
<td>16.6</td>
<td>51</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>Wayogabriel</td>
<td>1.0</td>
<td>8.37</td>
<td>10.51</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>SNNPR</td>
<td>Duguna</td>
<td>Dimtu</td>
<td>7.4</td>
<td>5.58</td>
<td>15.32</td>
<td>87</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Fango</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Alaba</td>
<td>Kulfo</td>
<td>3.2</td>
<td>6.4</td>
<td>10.07</td>
<td>67</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Mareko</td>
<td>Bidara Fuka</td>
<td>4.2</td>
<td>4.6</td>
<td>12.2</td>
<td>66</td>
</tr>
</tbody>
</table>
OPTIONS FOR MITIGATION

• Alternative low fluoride water?
• Reduce intake through food and other beverages?
• Defluoridation of water for drinking and cooking
  – Different types of defluoridation technologies
    • Commercially available methods are either expensive or have low fluoride removal capacity
    • Adsorption methods are not cost effective if the fluoride in water exceed 10 mg/L
  – We are developing a high capacity material that can produced locally call AO Filter
DEVELOPMENT OF ALUMINIUM OXIDE HYDROXIDE (AO) BASED METHOD

Synthesis

Heat treatment

Characterization

Capacity = 23.7 mg/g

Density = 2.4 g/cm³

SSA = 37.7 m²/g

1 – 2 mm

Batch and column adsorption studies
LABORATORY COLUMN STUDIES WITH AO

![Graphs showing SO₄²⁻ and Ca content (mg/L) vs. EBV over time, with pH and Al/F content (mg/L) also depicted for buffered samples. Key: pH (diamond), SO₄²⁻ (triangle down), Al (triangle up), F (square), Ca (cross).]
WINDMILL ATTACHED COMMUNITY DEFLUORIDATION PLANT BASED ON AO AT TSUCHIGRAGONA (BY AAU/EAWAG)

About 4000 direct beneficiaries

No complaint from the community so far
Fluoride removal efficiency is satisfactory.
Lifespan is limited to few months due to high water demand, high fluoride, and possible effects competing ions.
SULFATE AND ALUMINIUM IN TREATED WATER

We are working to further refine the synthesis of AO to improve material characteristics while maintaining its high fluoride removal capacity and on the possibility to regenerate and reuse.
CONCLUSIONS

• The contribution of food to fluoride exposure is significant

• The water with high fluoride used for cooking further increase the fluoride content of prepared food

• The total daily fluoride intake should be reduced to minimize the risk of fluorosis

• AO filter is effective in removing fluoride on the field and accepted well by the user community

• We need to develop a business plan to ensure sustainability
THANK YOU
Alkali fusion method for digestion of the food samples was used.

Fluoride concentration was measured by fluoride selective electrode.

Sample +5ml 8 M NaOH in Nickel crucibles

Placed on hot plate to dryness

Dried in oven (16h) at 200°C

Ashed in a furnace (3h) at 525°C

Dissolution by adding 10 ml deionized water (2h) on hot plate

Neutralization with Conc. and dil. HCl

Dilution to volume (50 ml) with deionized water

(5 ml - sample + 5 ml TISAB) in plastic beakers

F Conc. measured on calibrated electrode

(Malde et al., 2001)
Daily Fluoride Intake
(mg/person/day)

\[
\text{Consumption of } j = \frac{(\text{Amount of } j \text{ consumed (kg)} \times \text{Frequency of consumption in a week})}{\text{no. of days in a week}}
\]
RESULTS AND DISCUSSION cont’d

- Malde et al., (2004) found total daily fluoride intake of children living:
  - in village A (F⁻ content of water is 2 mg/L) was derived 63% from food,
  - While village K (14 mg/L), got most of fluoride through beverages(60%).

- Anasuya et al., (1996) studied range of intakes based on consumed foodstuffs and local supplies of drinking water by adults living in rural areas of India and found a daily fluoride intake of 0.84-4.69 mg/day in normal and 3.40-27.1 mg/day in fluorotic areas.

- In a Kenyan study, Opinya et al., (1991) found a total daily fluoride intake of 14·5 mg (range 6–24 mg) in children aged 1–4 years living in an area with 9 mg F⁻ /L in the drinking water.
# POPULATION AT RISK

<table>
<thead>
<tr>
<th>Regional State</th>
<th>Pop. 2002</th>
<th>Pop. 2005</th>
<th>Pop. 2007</th>
<th>Percent of affected population through out the Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afar</td>
<td>1,272,000</td>
<td>1,385,904</td>
<td>1,411,092</td>
<td>1.90</td>
</tr>
<tr>
<td>Oromia</td>
<td>4,139,906</td>
<td>4,510,624</td>
<td>5,011,058</td>
<td>6.78</td>
</tr>
<tr>
<td>SNNP</td>
<td>2,968,448</td>
<td>3,234,265</td>
<td>4,587,645</td>
<td>6.20</td>
</tr>
<tr>
<td>Total</td>
<td>8,380,354</td>
<td>9,130,793</td>
<td>11,009,795</td>
<td>14.88</td>
</tr>
</tbody>
</table>

Population in 2007 is 73,918,505  
Population in 2011 is ~ 80,000,000

How can we ensure 15 L/p/d of **safe water** within 1.5 km of their house on sustainable basis for the rural population?
• Bending body and touch the floor or toes without folding knee.
• Stretch the hands and fold the arms and touch the back of the head
• Touch the chest with the chin (Shusheela et al., 2004).

Figure 3-4 Identification of skeletal fluorosis and tolerable level of risk.
Assessment of Fluorosis

• Dean’s index method of physical examination was used for the assessment of prevalence of dental fluorosis.

• Dean’s 0 (normal), 0.5 (no fluorosis or questionable), Dean’s 1 (very mild), Dean’s 2 (mild), Dean’s 3 (moderate) and Dean’s 4 (Sever).

• In both Kebeles, assessment of dental fluorosis was carried out by dentists.
MILLENIUM DEVELOPMENT GOALS (MDGs)

• To achieve the MDGs, the Ministry of Water and Energy of Ethiopia developed a plan
  – to ensure 15 L/p/d of safe water within 1.5 km of their house on sustainable basis for the rural population
  – Deep wells, shallow wells, and springs are considered as the main safe water supply sources

• However, the level of fluoride in groundwater in the Rift Valley of Ethiopia is very high
THE CHALLENGES OF FLUOROSIS MITIGATION IN ETHIOPIA

• The average daily tolerable intake of fluoride recommended by US EPA is 0.05-0.1 mg/kg bw /day

• In the Ethiopian context
  – Inadequate understanding of the influence of total daily fluoride intake on fluorosis under varying nutritional status and socio-cultural conditions
  – What is the Tolerable daily intake?
  – To what level the fluoride intake should be reduced?

• Sustainability of fluoride removal technologies (Technical, social and economic)
PERCENTAGE CONTRIBUTION OF WATER AND FOOD TO AVERAGE DAILY FLUORIDE INTAKE
FLUORIDE DISTRIBUTION MAP OF ETHIOPIAN RIFT VALLEY AND ADJACENT HIGHLANDS
PROPOSED FLUOROSIS MITIGATION STEPS IN ETHIOPIA

Analysis of water and main diet

F- > 1.5 mg/L?  
N  
Acceptable??

Dental or Skeletal Fluorosis?

F- > 3.0 mg/L?  
Y  
Risk assessment

N  
Health & nutrition surveillance

B  

Alternative water sources?

N  
Fluoride removal required

Y  
Select technology

Y  
Assess feasible supply options

Selection of appropriate technology??