

# Solar Energy based Electrolytic Defluoridation Technology



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# Structure of Presentation

- 1. Background**
- 2. Integrated fluorosis mitigation**
- 3. Electrolytic defluoridation technology**
  - **Process**
  - **Components**
  - **Features**
  - **Cost estimates**
  - **Roll over mechanism**
- 4. Conclusion**

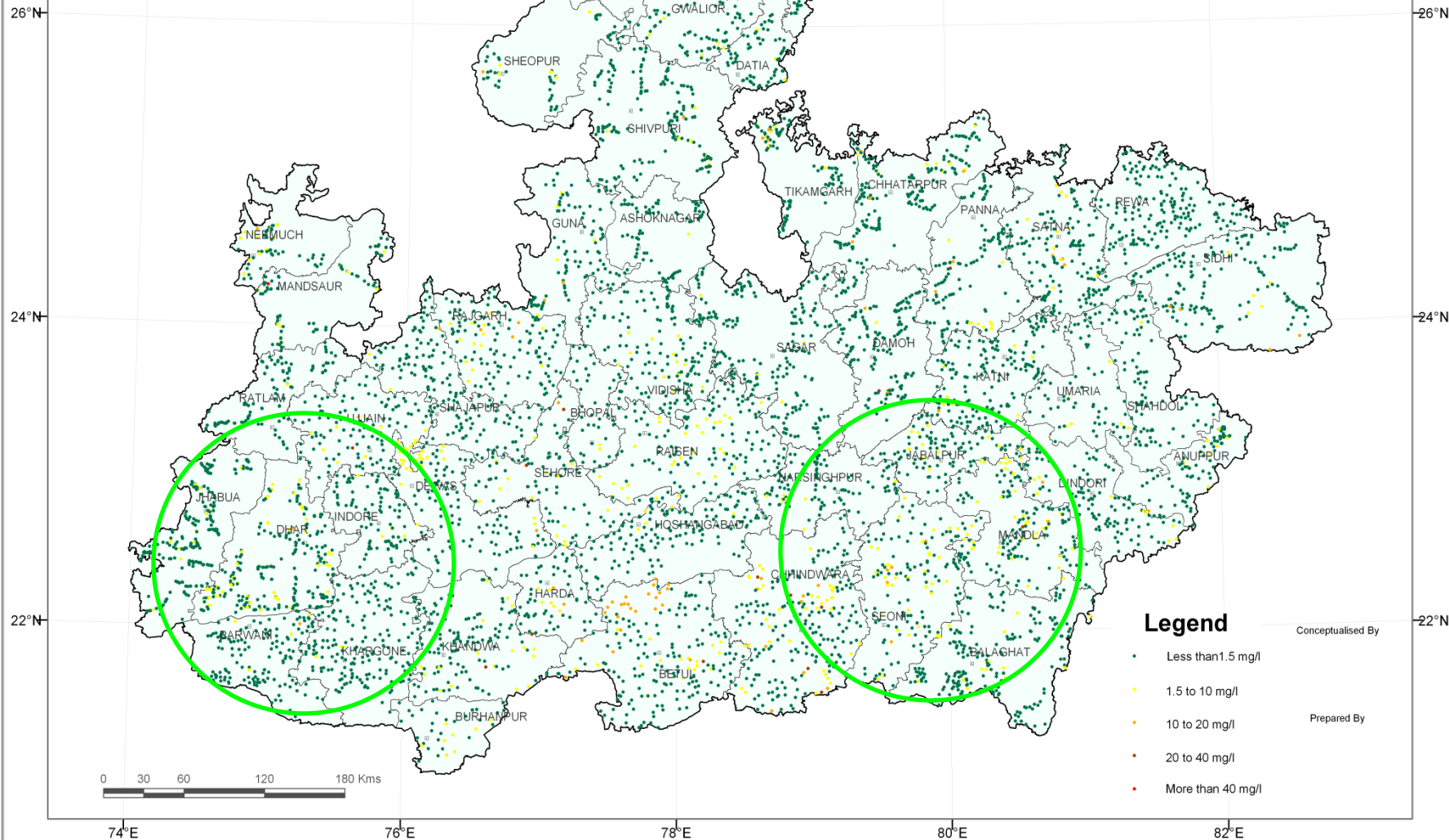
# Background

- **extent of contamination** and **unsustainable sources** impose more demands on **development of water technologies**
- **acceptance** of these technologies by **water supply agencies, community and practitioners** and **field implementation** is **equally important**
- A Google hit on ‘**Fluoride removal technologies**’ return with more than **100,000 results; 33,000 affected habitations** and **25 million persons**
- something **beyond “technology development”** needs to be done

# MADHYA PRADESH (INDIA)

## FLOURIDE CONCENTRATION

BIS Standard Less than 1.5 mg/l



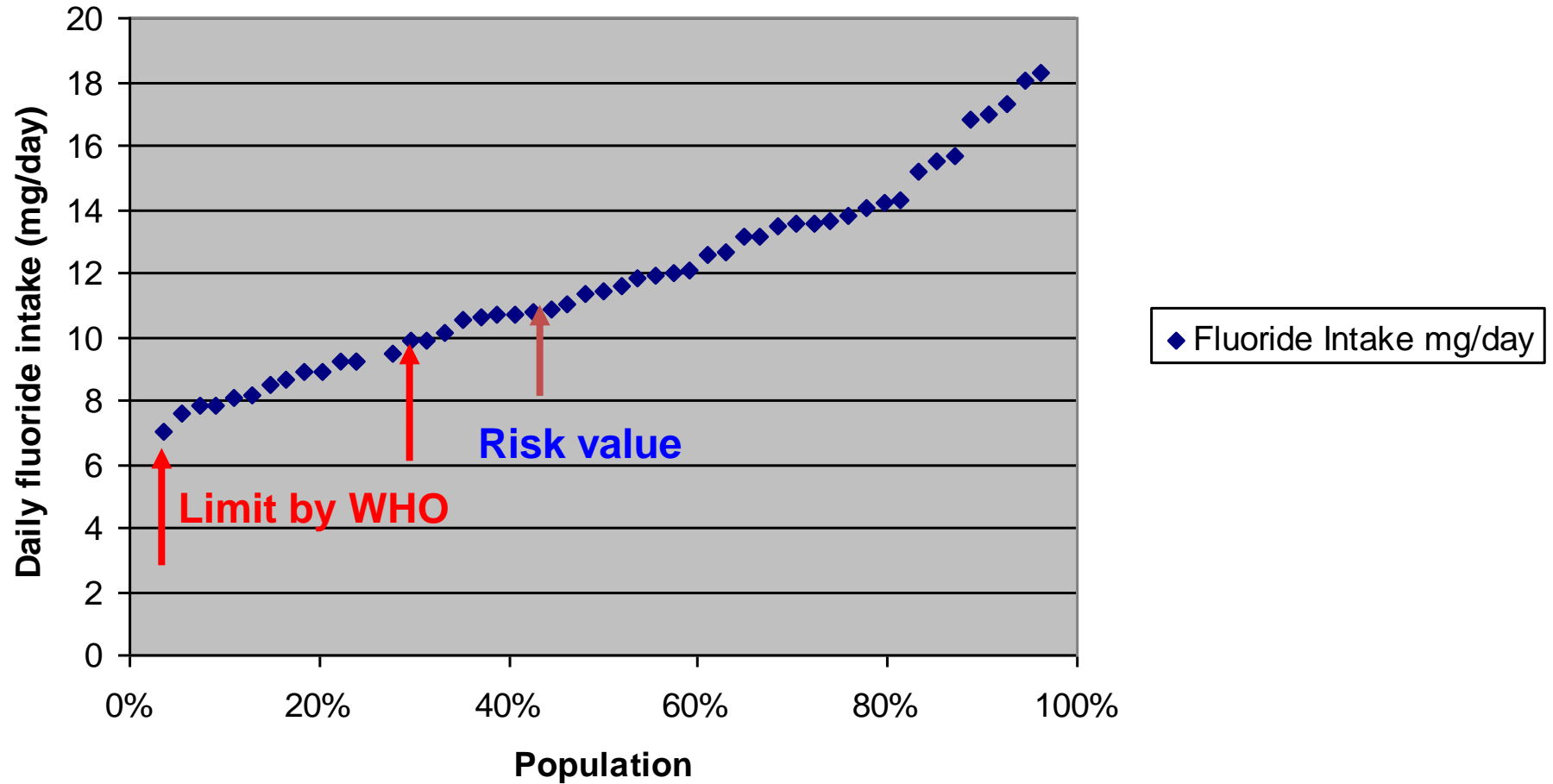
### Legend

- Less than 1.5 mg/l
- 1.5 to 10 mg/l
- 10 to 20 mg/l
- 20 to 40 mg/l
- More than 40 mg/l

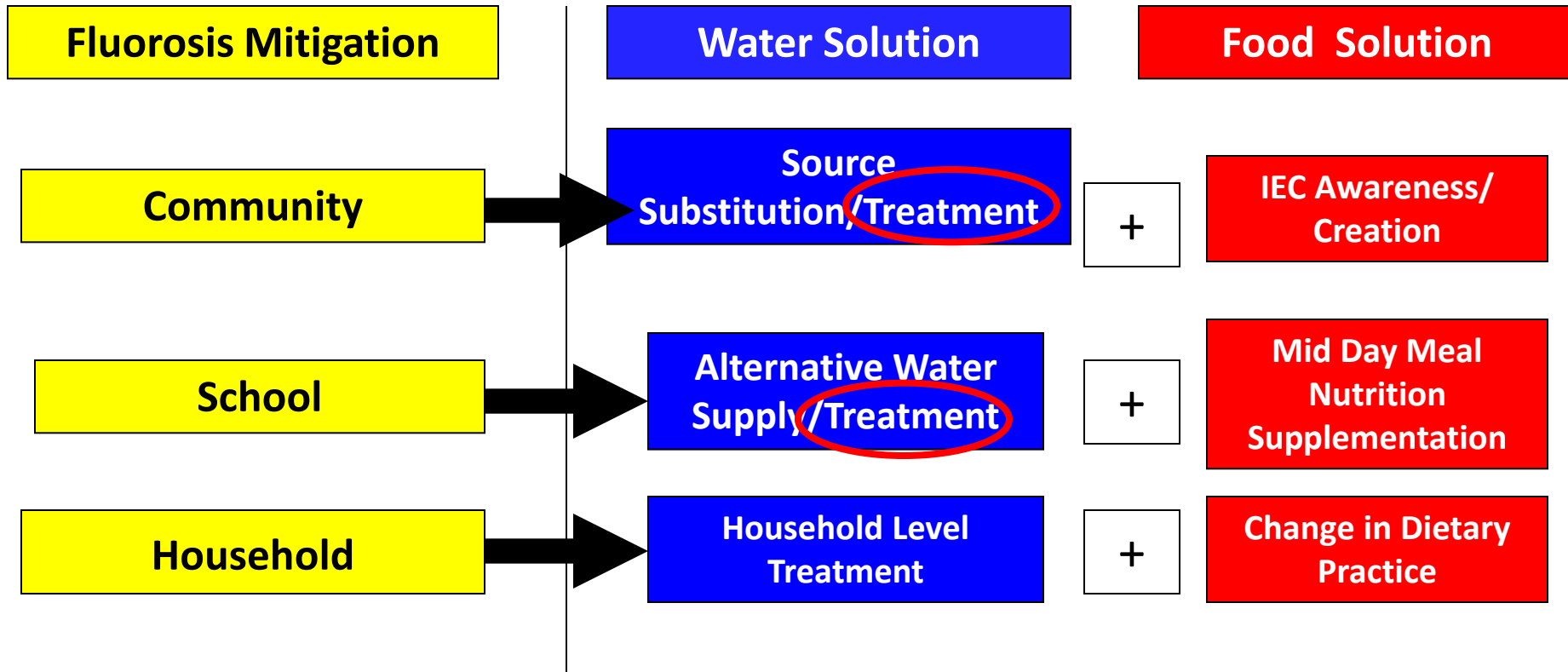
Conceptualised By

Prepared By

# Daily fluoride intake by population



# Integrated fluorosis mitigation measures



## Chakoda

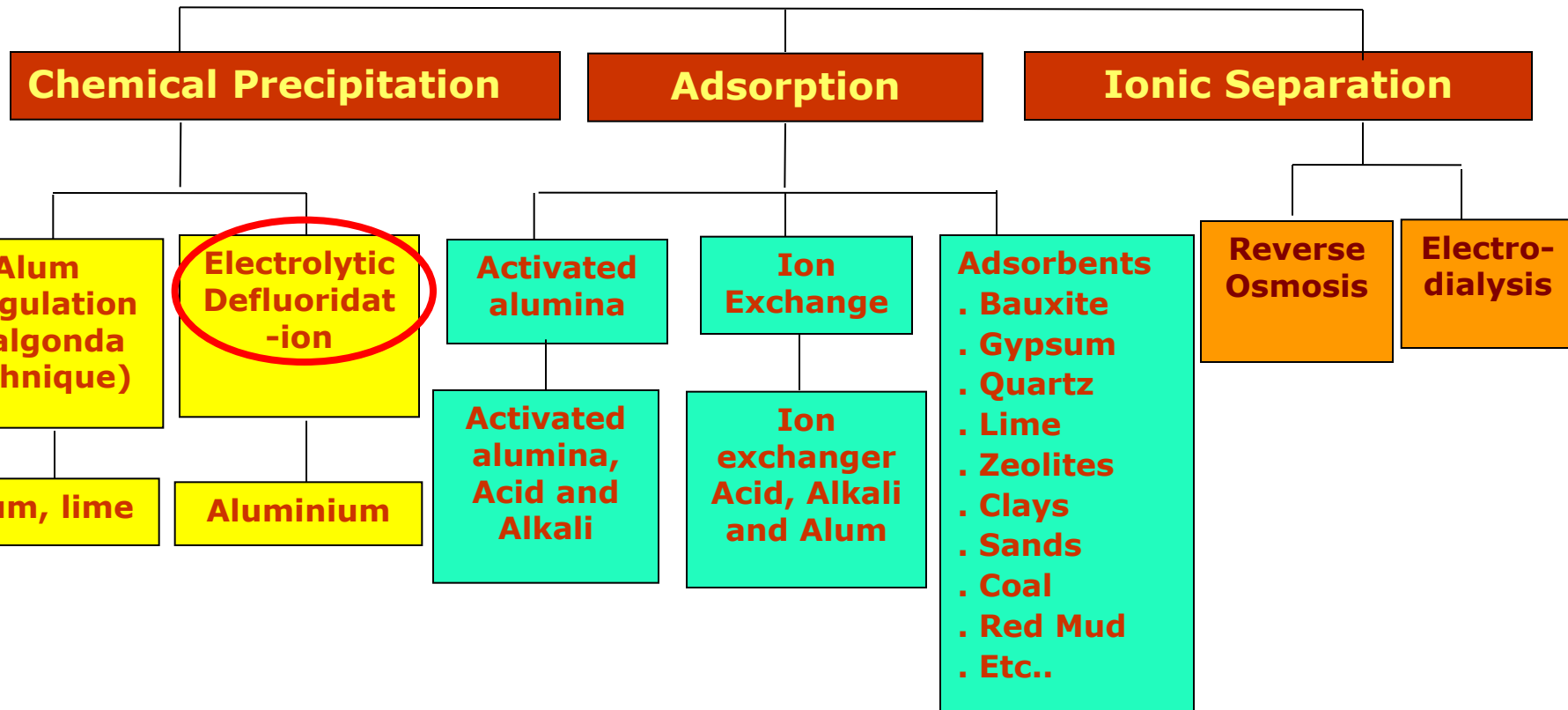
Calcium – 32000 mg/kg

Iron – 124 mg/kg

Vitamin C – 820 mg/kg



# Defluoridation technologies



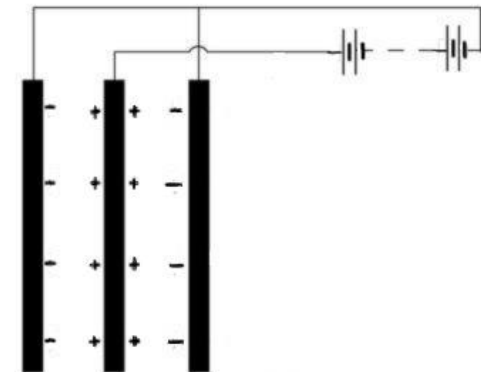
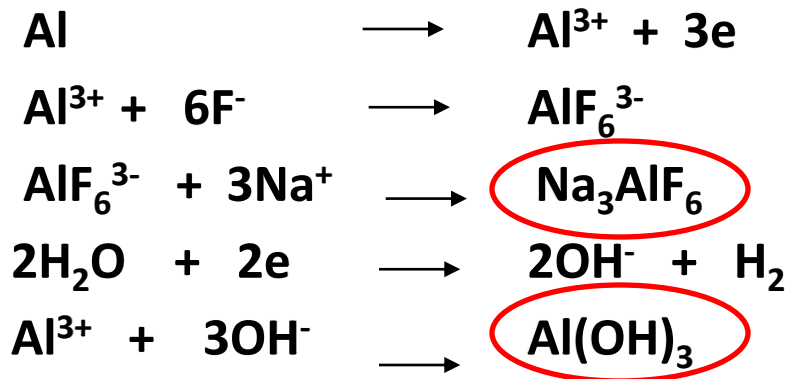
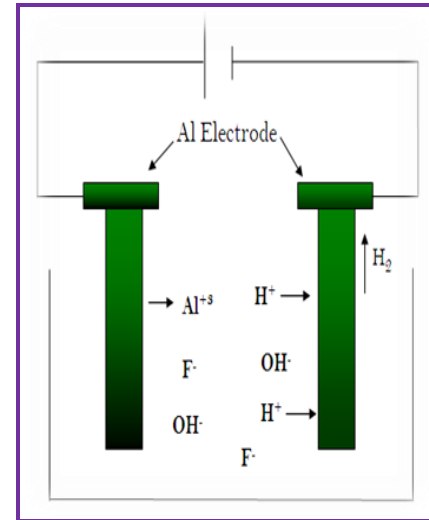
## Limitations of the Present Technologies for Defluoridation of Water

- **High Cost** : costly components, continuous power supply, expensive chemicals, skilled operation or regeneration e.g. reverse osmosis, ion exchange and activated alumina
- **Unobserved break through** : Fluoride concentration in the treated water may rise gradually or suddenly, typically when a medium in a treatment column is exhausted or even when the flow is out of control
- **Limited removal capacity** : bone charcoal or activated alumina
- **Deteriorated water quality**: due to excessively high pH values, high doses of chemicals, poorly prepared medium (bone charcoal) or due to medium escaping from the treatment container, e.g. ion exchange, alumina, Nalgonda sludge, etc
- **Taboo limitations** : in particular, the bone charcoal method is culturally not acceptable

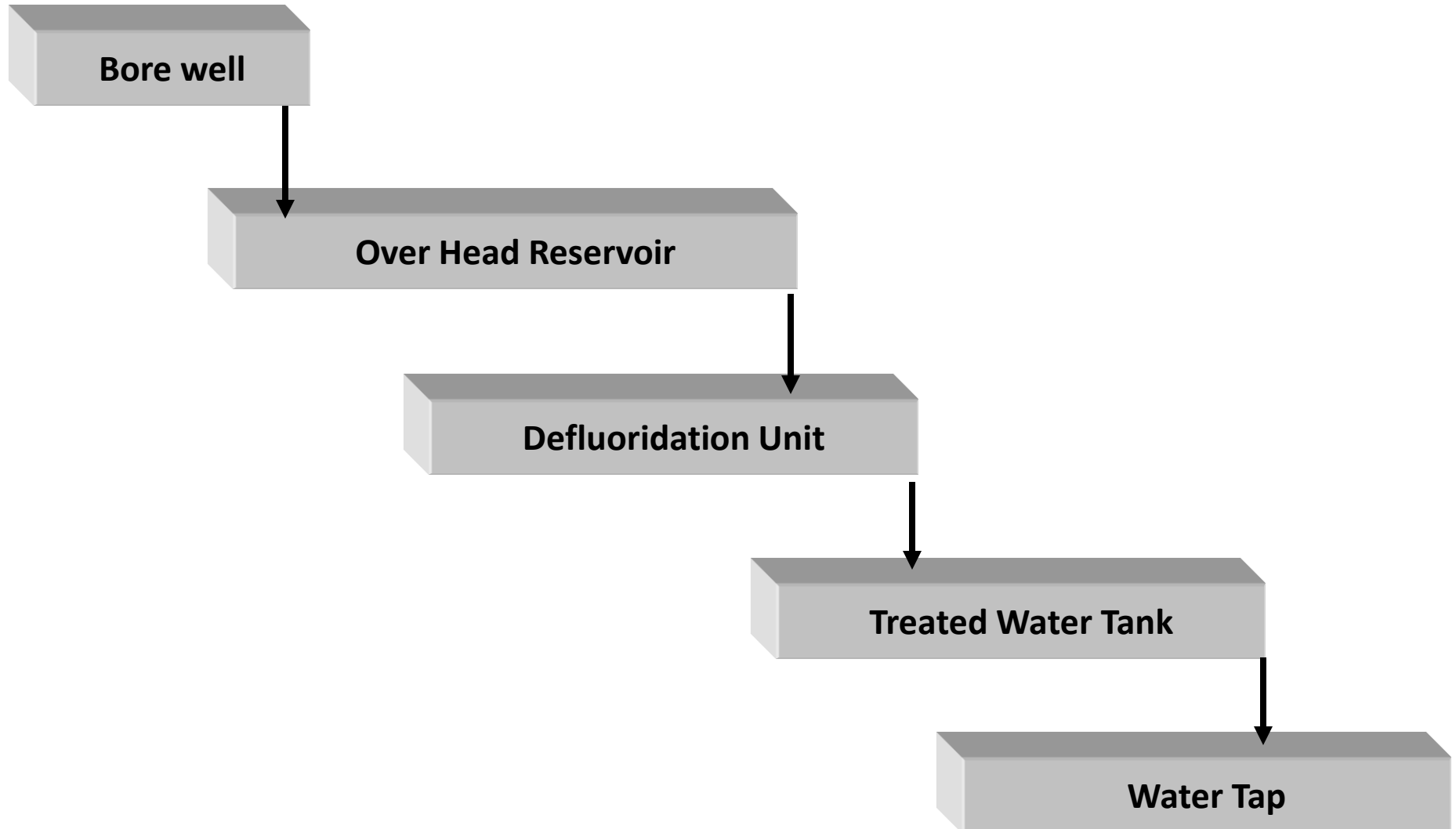


# Electrolytic defluoridation technique

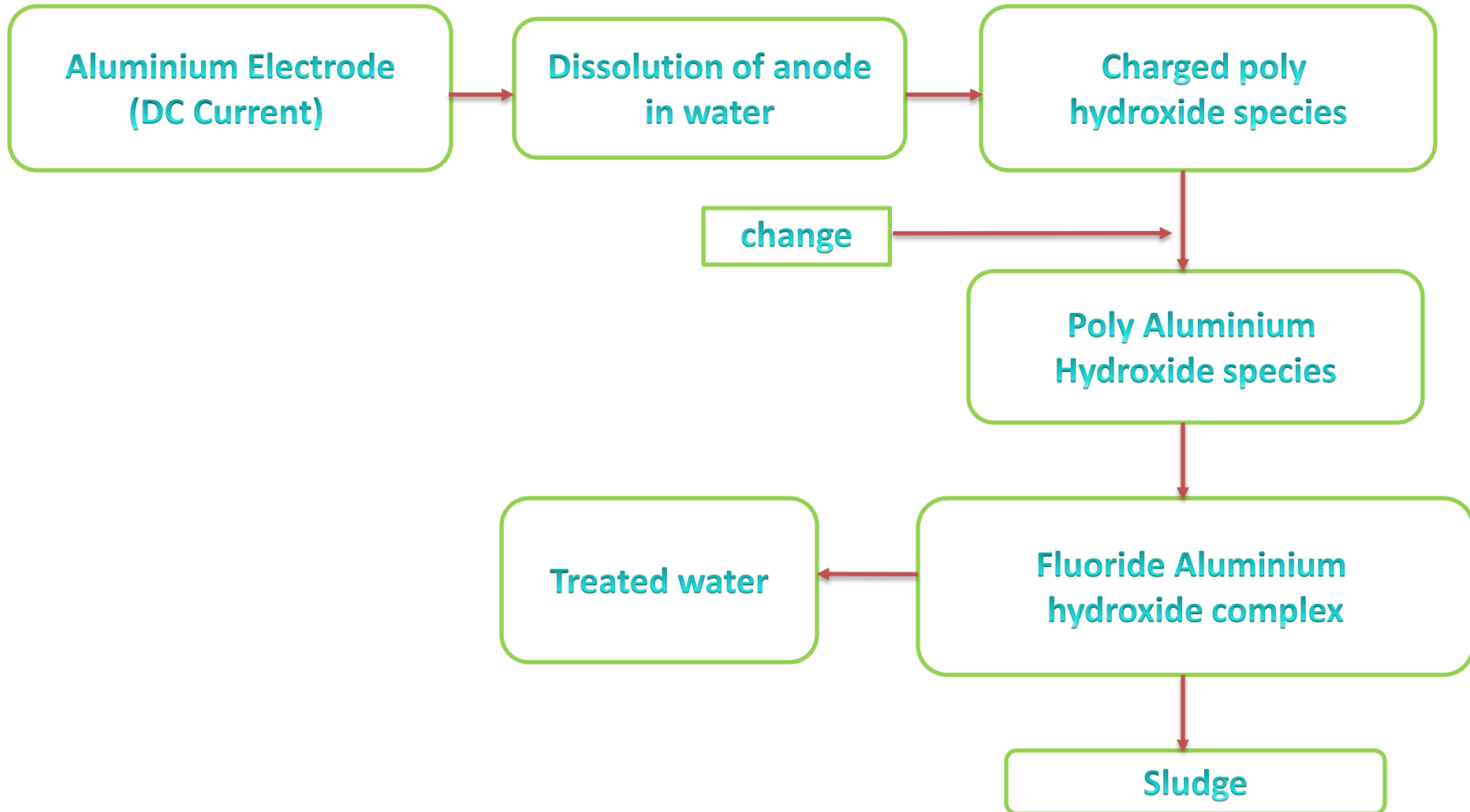
- In Electrolytic Defluoridation process, **active species of hydroxide of aluminium** are produced by passing **direct current** through **aluminium electrodes**
- Reactions involved during electrolytic defluoridation process are as follows:



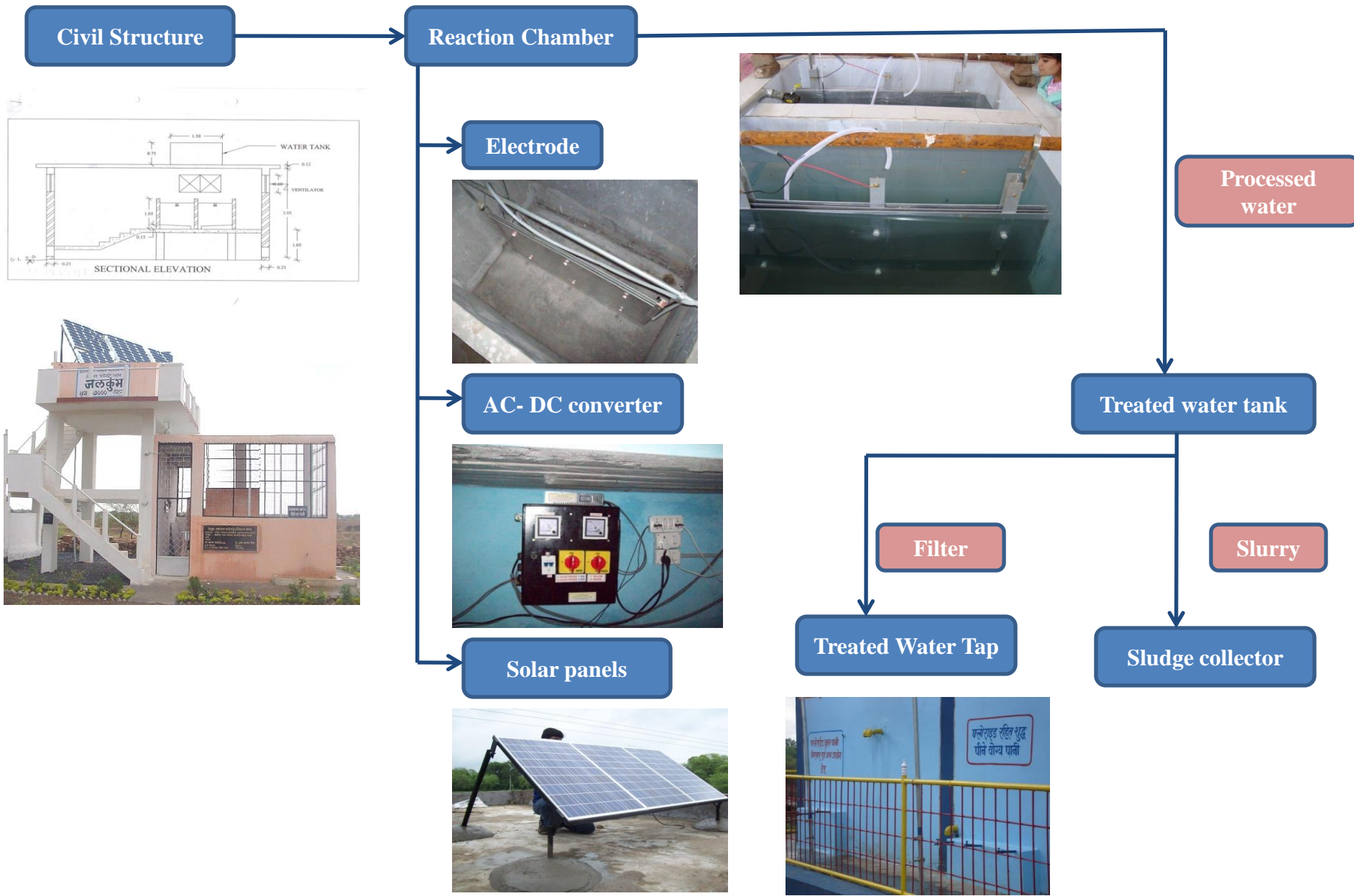
# Treatment Flow Sheet of Electrolytic Defluoridation Plant



# Electrolytic Defluoridation Process



# Flow Diagram for Electrolytic Defluoridation Plant



# Design Details of Electrolytic Defluoridation Plant

- Capacity : 2000 liter per batch (2-3 batches depending on the water demand)
- No. of reactors : 2
- Type of electrode : Aluminium
- DC power supply unit : 0-30 ampere, 0-30 volts
- Period of electrolysis : 60-90 minutes
- Fluoride in treated water : less than 1.0 mg/L

## Specification of Solar Photovoltaic System

- Solar Photovoltaic System with minimum 30 ampere output for 3 hours (220 Watts)
- Charge controller
- SMF Battery (150 AH)
- AC inverter (100-150 watts)
- DC control unit (20-30 A) with display
- AC charger for battery in emergency

# Sludge Management

- **Quantity of sludge per 1000 liter of treated water with raw water fluoride of 5 mg/L : 100 gram**
- **Quantity of sludge is much lower as compared to other techniques**
- **Sludge is not hazardous in nature**
- **Method of sludge disposal : Sand bed**
- **No leaching of fluoride in water in normal pH range of water (6.5-8.5)**
- **Can be used in brick making or sanitary landfill**
- **Currently sludge being land-filled**

# Cost estimates for Electrolytic Defluoridation Plant

**Construction cost (Civil structure): 2000 litre per batch**

**USD 2000-3000**

**Accessories:**

**USD 2500-3000 including Solar Panels**

**Operating cost: per 1000 litre of water**

- Aluminium
- Electric power consumption ( raw water Pumping + EDF process)
- Chemicals (HCl)
- $C_0 = 5 \text{ mg/L}$  : INR (2.04 + 2.0 + 2.16 + 2.0) = INR **8.20** (USD **15** per 1000 liter)
- $C_0 = 10 \text{ mg/L}$  : INR (4.60 + 2.0 + 3.80 + 2.0) = INR **12.40** (USD **20** per 1000 liter)



# Features of Electrochemical Defluoridation



## Advantages

- Useful for safe water supply in fluoride affected area
- Easy to operate even by unskilled persons
- Minimum maintenance
- Low cost
- Less sludge quantity
- Produce potable water with palatable taste
- Reduces the fluoride concentration to  $<1.0$  mg/L
- Simultaneous reduction in hardness, nitrate and bacterial contamination

## Limitations

- pH sensitive process
- Periodic monitoring of residual aluminium
- Power driven
- Effectiveness at higher fluoride concentration ( $>10$  mg/l) to be proven

# Solar Energy Based Electrolytic Plants installed by NEERI



**Dongargaon, Chandrapur District, Maharashtra**



**Sargapur Village, Seoni District, Madhya Pradesh**



**Usarwara village in Durg District, Chhatisgarh**

**UNICEF provided funds for installation of 16 plants in Madhya Pradesh**

# Performance of the EDF plants

Sl. No.	Parameters	Bore Well	Treated Water
1.	pH	7.26 - 7.75	6.9-7.3
2.	Total Dissolved Solids	690 - 720	870-930
3.	Alkalinity, CaCO <sub>3</sub>	290 - 308	280-300
4.	Total Hardness, CaCO <sub>3</sub>	144-170	90-120
7.	Nitrate, NO <sub>3</sub>	5.2 - 11	4-7
8.	Sulphate, SO <sub>4</sub>	42-90	40-88
9.	Chloride, Cl	148 - 180	176-278
10.	Fluoride, F	2.5 – 3.2	0.3-0.6

All values except pH are in mg/L

# Conclusion

- **Electrolytic defluoridation is a useful technology but has certain limitations as other technologies do also have**
- **Though appear simple, operation and maintenance is a challenge**
- **Treatment using electrolytic defluoridation technique is cost-effective**
- **Simultaneous removal of bacteria and nitrate**
- **Roll-over business model will have to be evolved and NEERI is there to support**





# Thank You



**Winner**



**NEERI-ZAR  
Multi Pollutant Water  
Treatment Unit**

**CSIR-NEERI  
bags 2 Prestigious International  
Project Innovation Awards (PIA)  
– Development  
instituted by International Water  
Association (IWA)**



**Honour Winner**



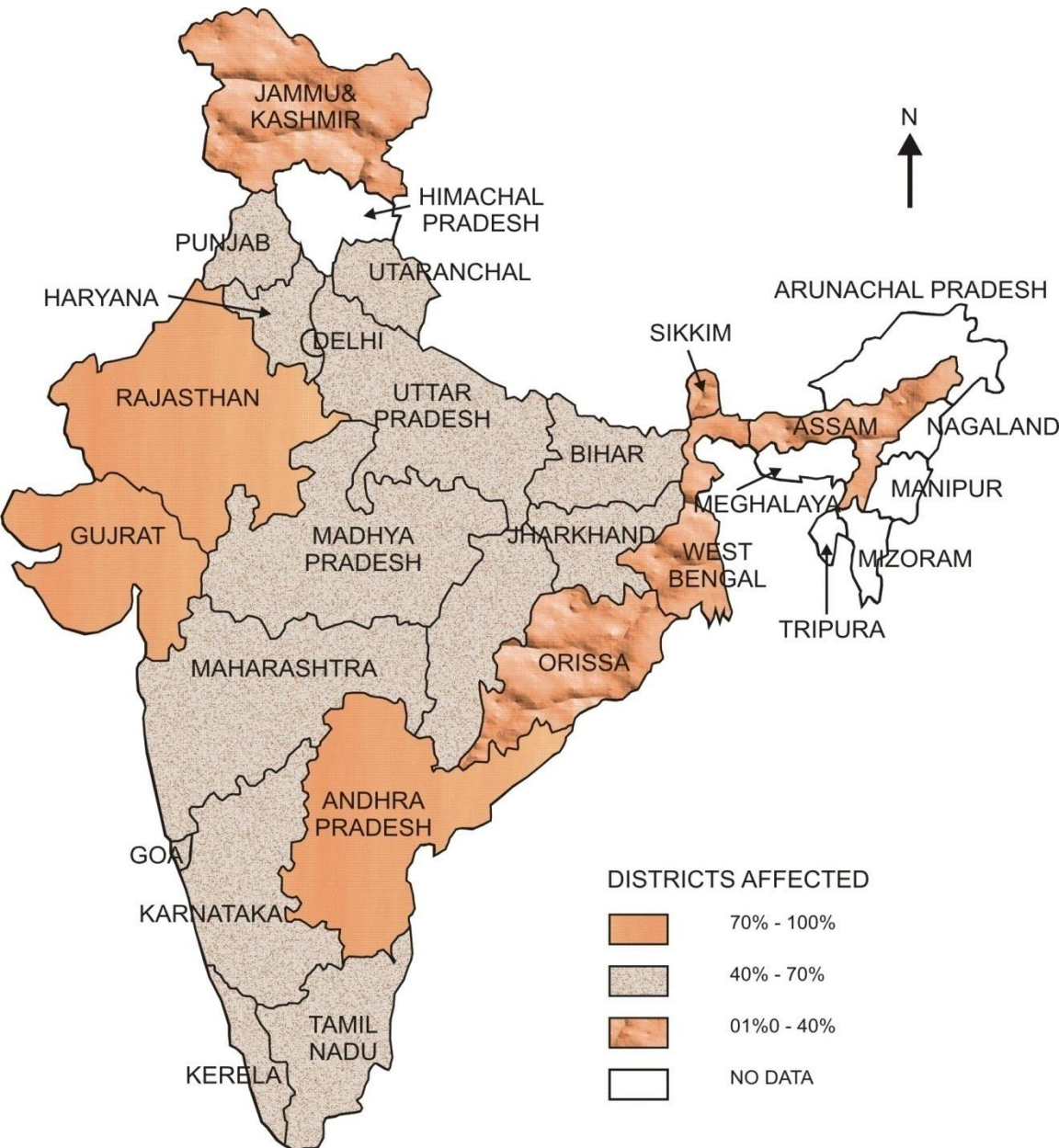
**Solar Energy Based  
Electrolytic Defluoridation  
Plant**

**PIA entries were from various countries such as Sri Lanka, Vietnam, Lebanon, Brazil, Republic of Korea (South Korea), China, Tanzania, South Africa, Kenya, Philippines, Jordan besides India**

**The awards were presented in the Ceremony held during the 2<sup>nd</sup> IWA Development Congress and Exhibition in Kuala Lumpur, Malaysia on 23<sup>rd</sup> November 2011**



# India

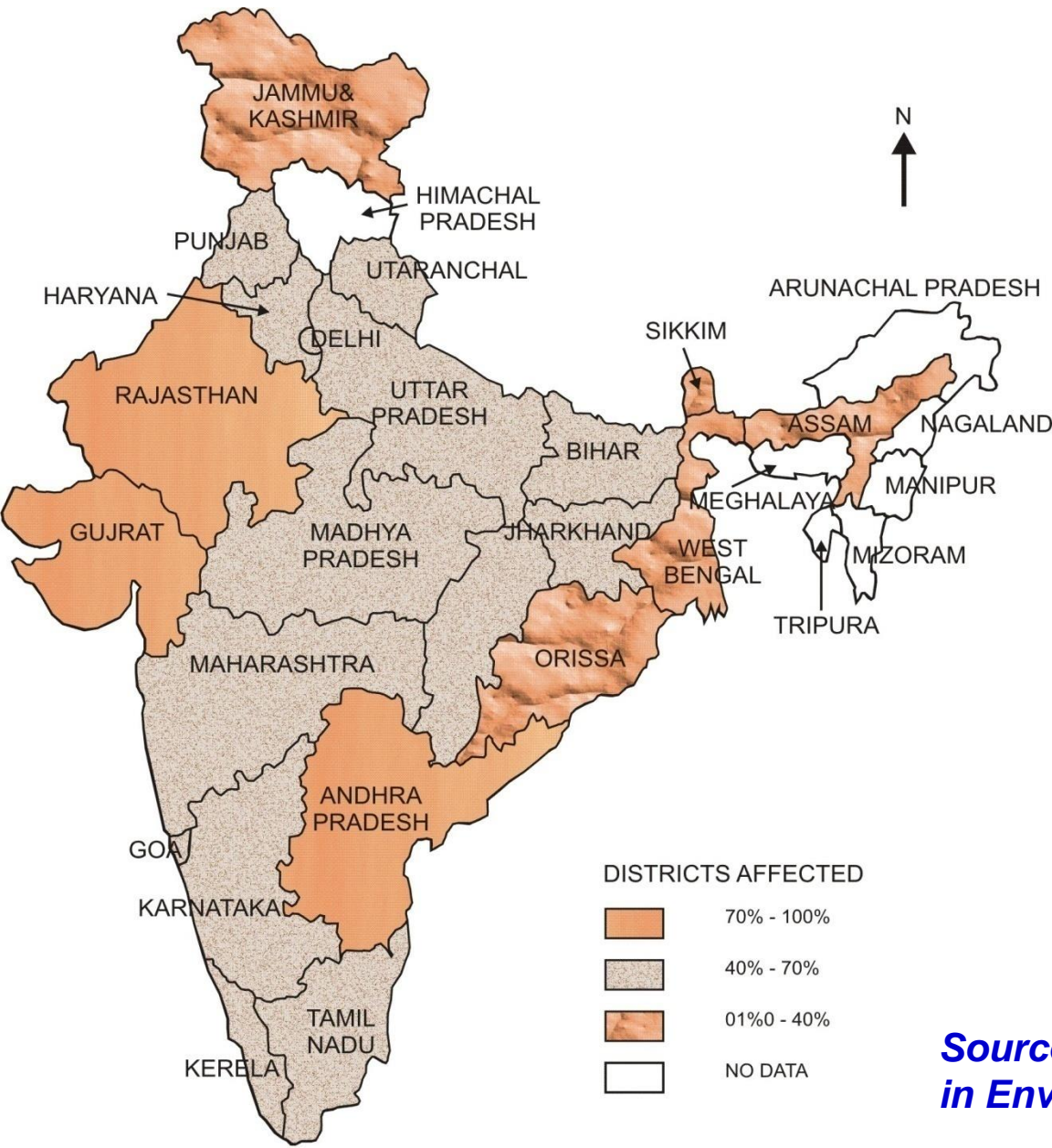


- ❖ 66.62 million people are at “risk”, of which an estimated 6 million are children below the age of 14 years
- ❖ Reported fluoride level in India ranges from 0.5 to 48 mg/l
- ❖ More than 200 districts in 20 states of our country are affected by fluoride pollution in drinking water

**Source: Ayoob and Gupta, Critical Review in Env Sc. And Tech, 2006**



# Fluorosis in India



- ❖ 66.62 million people are at “risk”, of which an estimated 6 million are children below the age of 14 years
- ❖ More than 3.2 million informed and 10 million uninformed drinking water sources
- ❖ Reported fluoride level in India ranges from 0.5 to 48 mg/l
- ❖ More than 200 districts in 20 states of our country are affected by fluoride pollution in drinking water

*Source: Ayoob and Gupta, Critical Review in Env Sc. And Tech, 2006*

# Health Impact of Fluoride

## Dental Fluorosis

- An irreversible toxic effect on the tooth forming cells
- At a fluoride concentration of 3.5 mg/l, over 90% of children of the age group 8–15 years, developed dental fluorosis
- Some studies in India showed 100% prevalence of dental fluorosis at a fluoride level of 3.4 to 3.8 ppm





## Skeletal Fluorosis

- Skeletal fluorosis is a condition associated with prolonged accumulation of fluoride resulting in fragile bones having low tensile strength
- It affects the joints as well as the bones and it is not easily recognizable till advanced stage.
- In its early stages, its symptoms may resemble those of arthritis.
- Skeletal fluorosis affects children as well as adults