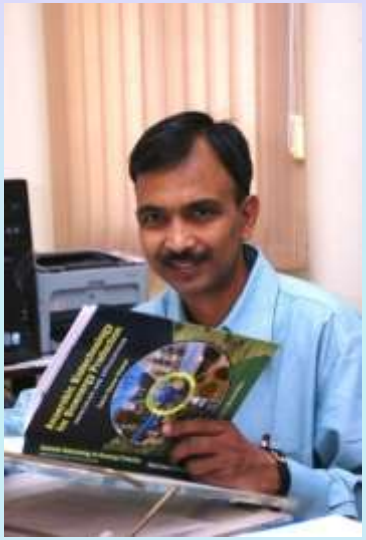
Techno-medical aspects of Water quality issues of Rajasthan-interventions at MNIT



By

Dr. A. B. Gupta, PCE, MNIT Jaipur

November 28, 2018, Alwar

I am indebted to my research team and proud of my students

- Saroj Sharma – IHE Delft, Netherlands
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- Rakesh Gelda- University of Michighan
- Deepak Vashistha- RPI, NY

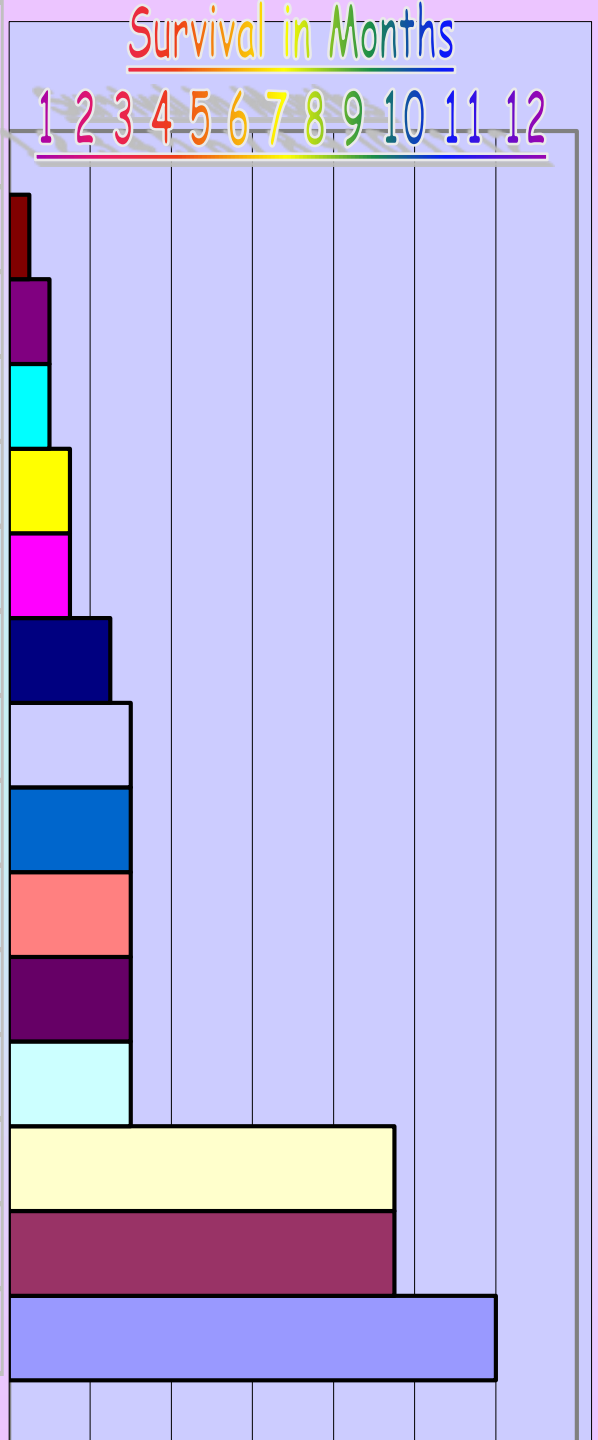
To cure is the word of the past, To prevent is the whisper of the future.

***Swami Vivekanand**

Water⇔ Health

- **Biological contamination- water borne diseases- quick detection**
- **Water as habitat for vectors of disease- Malaria- design of hand pumps**
- **Water transmitting toxic chemicals- As, F, NO_3, pesticides.**
- **Salinity- Solar based VMD process**

ORGANISM	EXCRETED LOAD(no/g)
Champhylobacter spp.	1.00E+07
Giardia lamblia	1.00E+08
Entamoeba histolytica	1.00E+08
Shigella spp.	1.00E+07
Vibrio cholerae	1.00E+07
Salmonella typhi	1.00E+08
Salmonella spp.	1.00E+08
E. coli (path)	1.00E+08
Enteroviruses	1.00E+07
Hepatitis A virus	1.00E+06
Ancylostoma duodenale	1.00E+02
Trichuris trichura	1.00E+03
Taenia Saginata	1.00E+04
Ascaris lunbricoides	1.00E+04



Drinking Water & Sanitation facilities

Hand pump under DPIP

Testing of microbiological quality of water

- Routine MPN testing involves standard plating or multiple dilution tubes tests, which are time consuming and elaborate
- UNICEF has supplied some quick assessment kits (H_2S strip), which were analyzed for sensitivity in our laboratory and corroborated with "Colilert" results

Colilert18

Quanti try sealer

Quanti tray

Bacteriological H_2S Strip Test Kit provided by PHED Rajasthan.

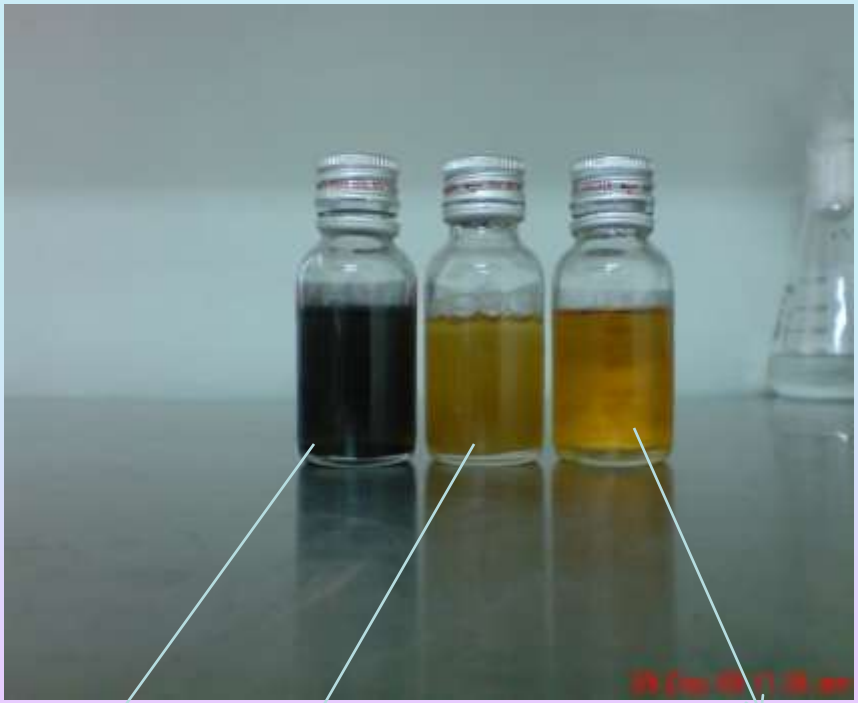
Principle

Preparation of very close dilutions

Bacteriological H_2S Strip Test medium provided by PHED Rajasthan.

Principle

Dilution preparation 9+1



Salmonella& Citrobacter

Others

Note safe for drinking

Safe for drinking

Way Forward

- Detection time of 10-12 h needs further reduction
- Simultaneous multiple coliform/pathogen enumeration
- Developing a kit to detect emerging pathogens (*Legionella pneumona, Giardia lambia, Shewanella, Stenotrophomonas…*)
- Assessing effects of emerging pathogens on water quality of existing resources including exposure to farmers, antibiotic resistance development
- Affordable cost

Common Disinfectants

- Ozone
- Ultraviolet Radiations
- Chlorine
- Chloramines
- Chlorine Dioxide

Disinfection…

•During disinfection, chlorine may react with NOM in the raw water, resulting in the formation of various DBPs such as THMs & HAAs. These THMs have some adverse health effects, in particular cancer & reproductive disorder.

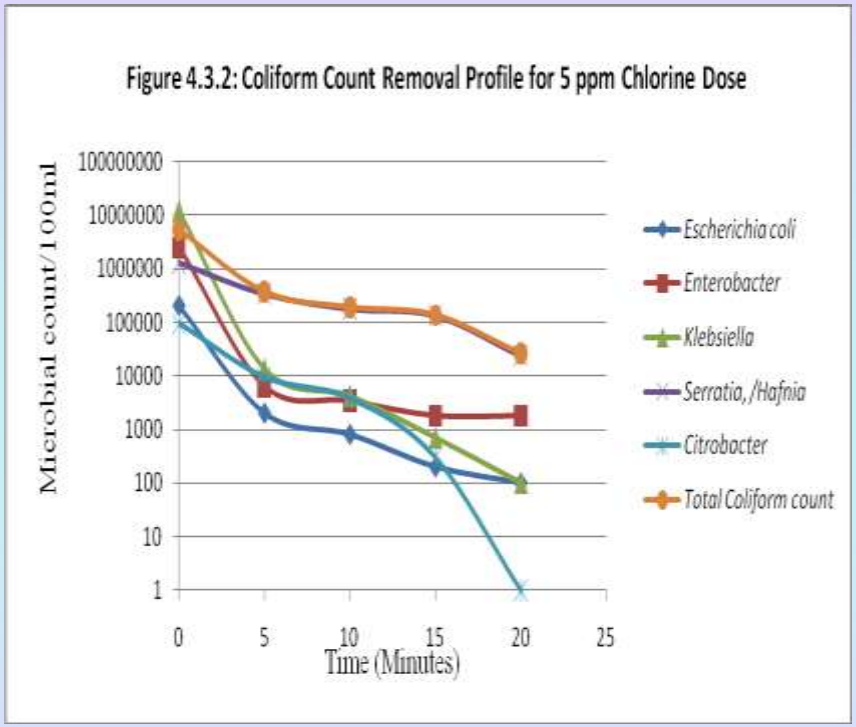
•Hence, disinfection methods using only chlorine are not totally safe and have some environmental consequences.

•Application of a single technology is not recommended and a hybrid system such as using U.V. or Ozone after chlorination can be beneficial to carry out disinfection studies in better ways by reducing the chances of formation of carcinogenic compounds and reducing the use of high doses of chlorine against the remaining resistant bacteria

Research Carried Out at MNIT: Disinfection by Chlorine

- Our research has indicated that a dose of 17.5 and 5 ppm of Calcium hypochlorite was required to conform to the WHO guidelines for fecal coliform (1000 MPN/ 100 ml) for treated sewage from ASP of Delawas, Jaipur and RBC, located in MNIT campus
- The concentration of 6 of the 8 dominant coliform species dropped below aforementioned norm at a dose of only 7.5 ppm and 2.5 ppm respectively
- Two resistant varieties, *Serratia/Hafnia* and *Enterobacter* required 17.5 ppm and 5 ppm to attain the above norm
- Excess chlorination is not only expensive but it can also lead to excessive formation of DBPs, which are proven carcinogens.
- $CHCl_3$ (human carcinogen) was the major THM whose concentration increased substantially as the dose increased [8-12]

Chlorine Disinfection limitation…



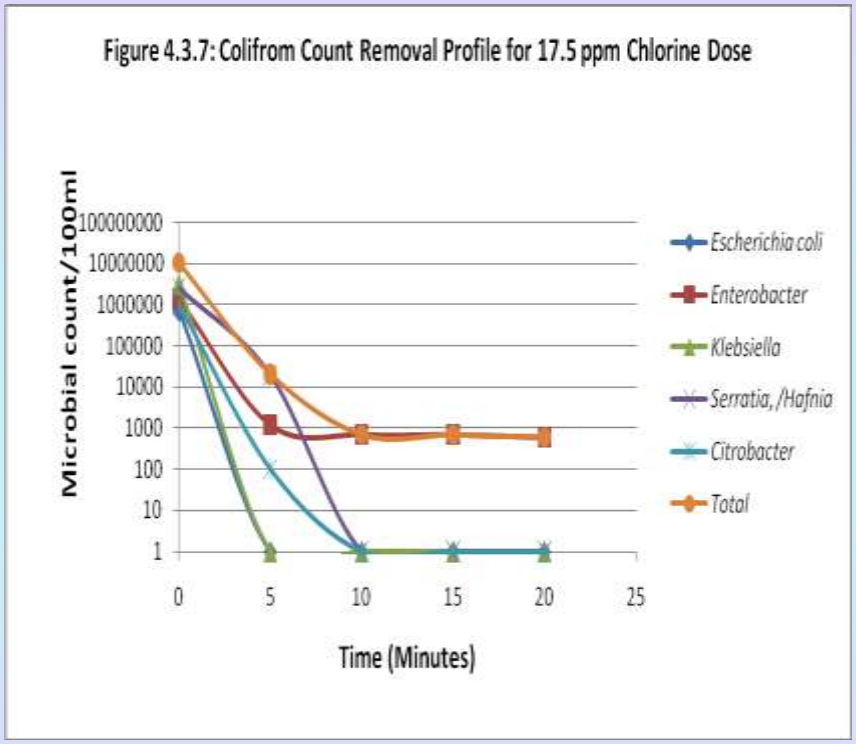


Figure 1: Total Coliform count (per 100ml) removal profile for chlorine dose of 5 ppm & 17.5 ppm (Dinesh et al., 2011)

hybrid disinfection

- A large dose of chlorine is needed for disinfection that results in the formation of THMs, especially chloroform besides adding to the cost of dechlorination.
- UV & Ozone are costlier than chlorine and have other environmental issues.
- An attempt to reduce the dosage of chlorine has been made by using it in conjunction of UV/ozone to optimize the process.
- An initial optimized dose of chlorine is given to deactivate susceptible coliforms helping minimize the formation of THMs.
- Removal of the remaining chlorine resistant species is achieved with relatively low doses of otherwise costly disinfectants like UV or O_3 in series to lower the overall cost.
- The effect of the second step brought a big additional benefit of scavenging chloroform formed during the first step significantly adding to the overall benefits of the hybrid strategy

Challenges of treated wastewater reuse, its impact on WQ of surface/ groundwater

- Is it safe to use (Norms of STP effluent)?.
- Develop cost effective methods for screening of potential disease causing bacteria and pathogens.
- Identification of antibiotic resistance mechanism among bacterial communities in wastewater.
- Improvement of disinfection methodology.

  - cost effective

  - less Disinfection by-products (DBPs)

  - inhibition on antibiotic resistance in bacterial community.

Jawahar Circle. Jaipur STP...Recent findings…antibiotic resistance

- Reuse of water is best way to manage the demand of water.

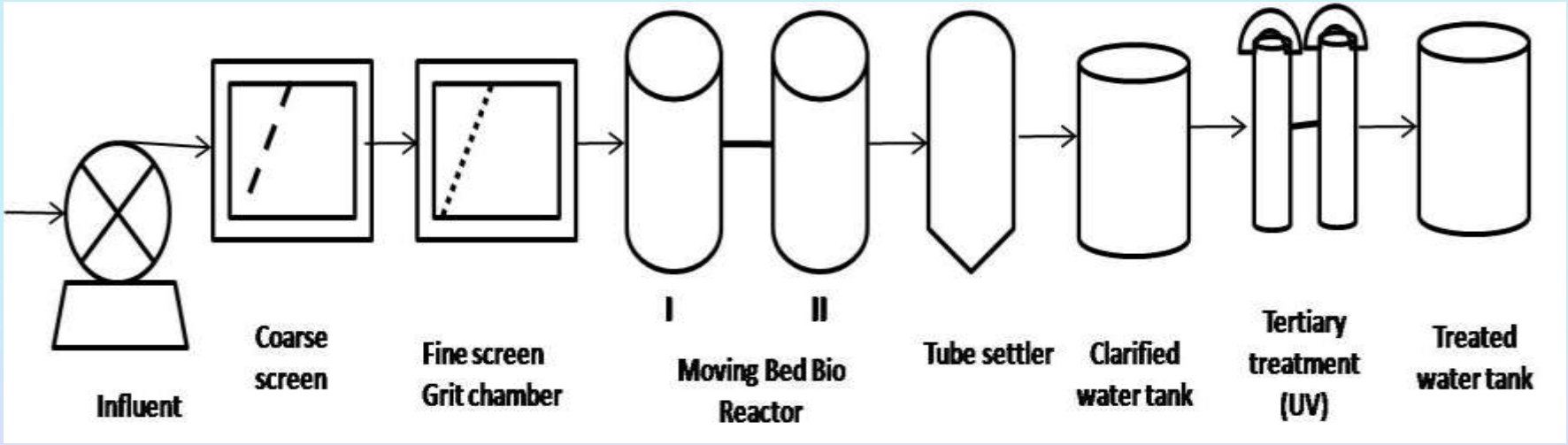
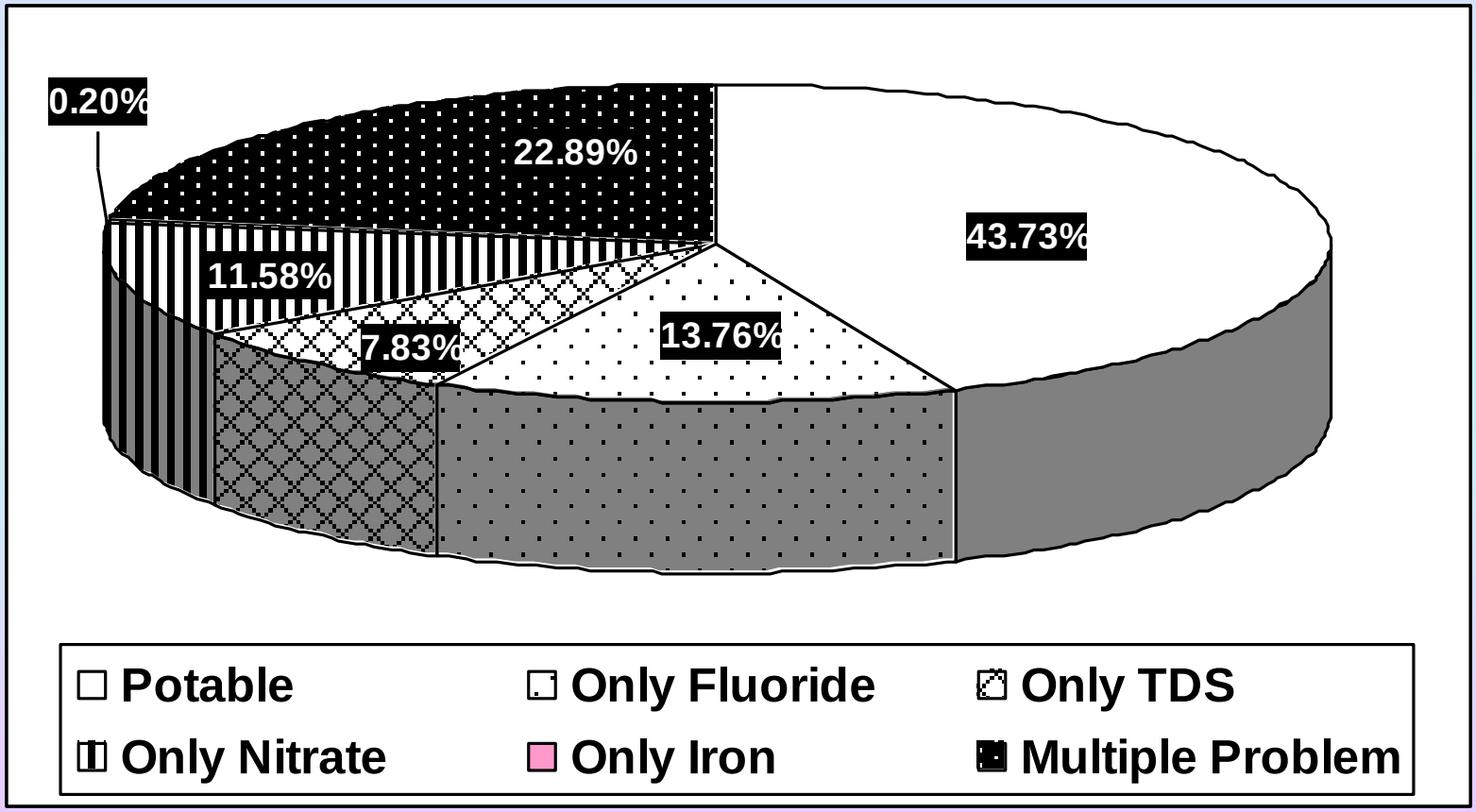


Fig.1. Sewage treatment plant, Jawahar circle, Jaipur

Water quality scenario in Rajasthan (Dhindsa, 2006)



New mandate

- Government of India mandate under the National Drinking Water Mission states that every individual has to be provided with 8 liters water per day that meets the minimum water quality standards prescribed by the BIS 10500
- Rural water supply coverage in Rajasthan dropped from 98% to 54%.
- Problems of multiple chemical parameters

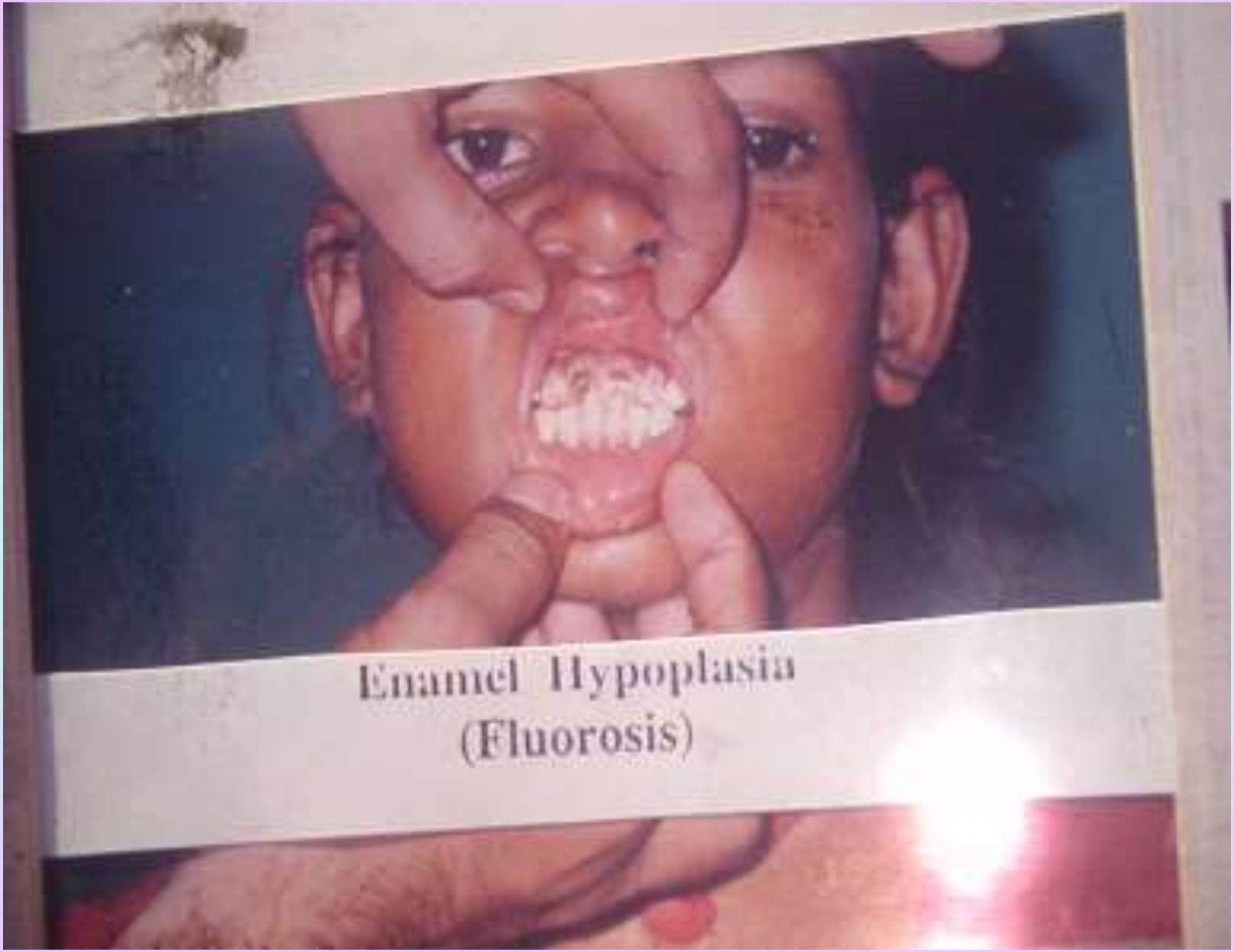
EFFECT OF FLUORIDES

Excess fluoride damages:

- **Teeth**
- **Bones**
- **Joints**

In Final Stages:

- **Premature Aging**


Enamel Hypoplasia
(Fluorosis)

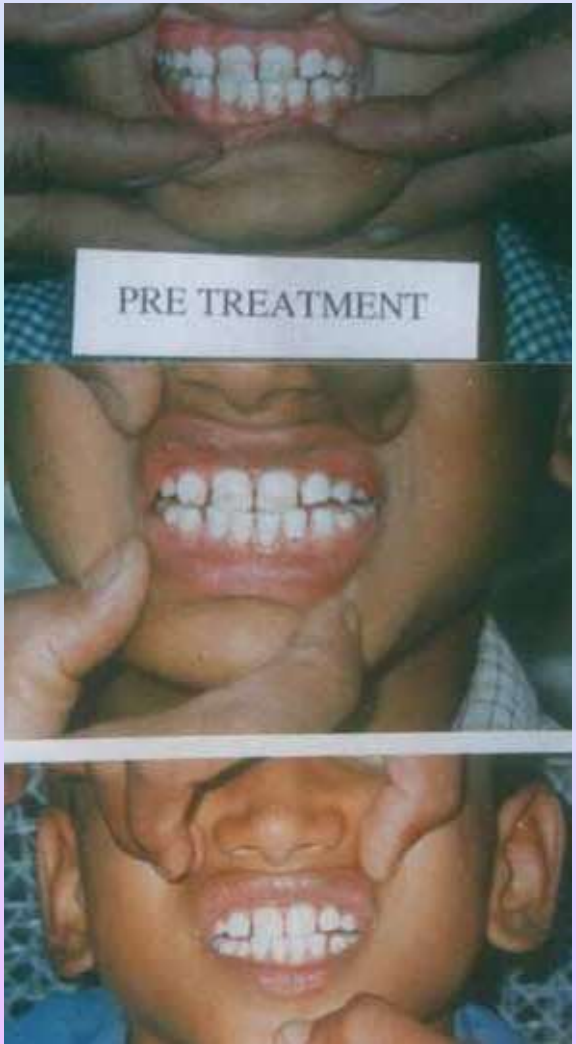
TREATMENT

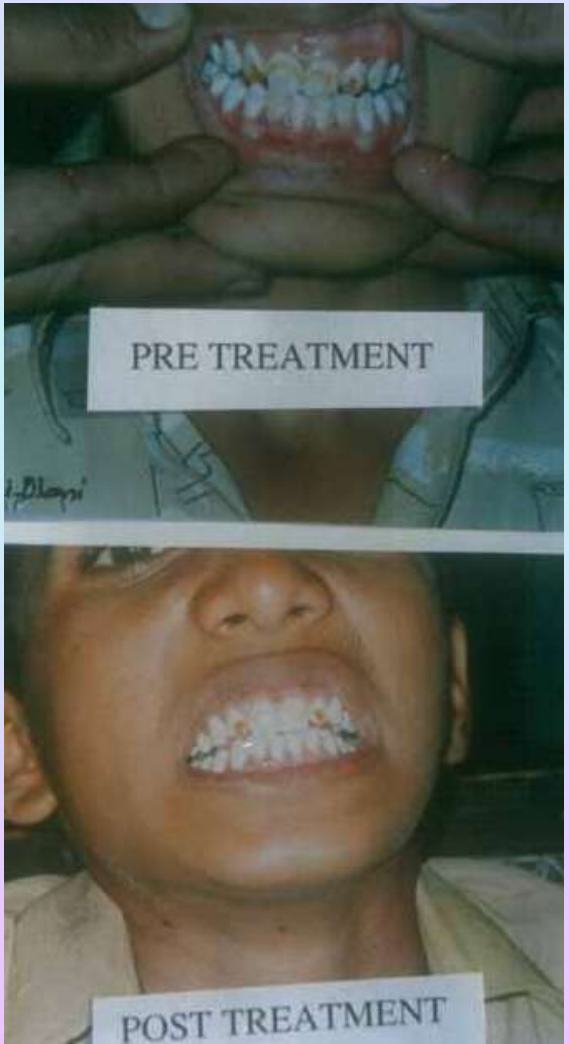
- **Fluorosis *could be reversed, at least in children by Calcium, Vitamin C and Vitamin D supplementation***

  Source: **Gupta et *al.* 1994,1996, 2001a,b, 2009**

Dental fluorosis

(Reversal of fluorosis)





Skeletal fluorosis

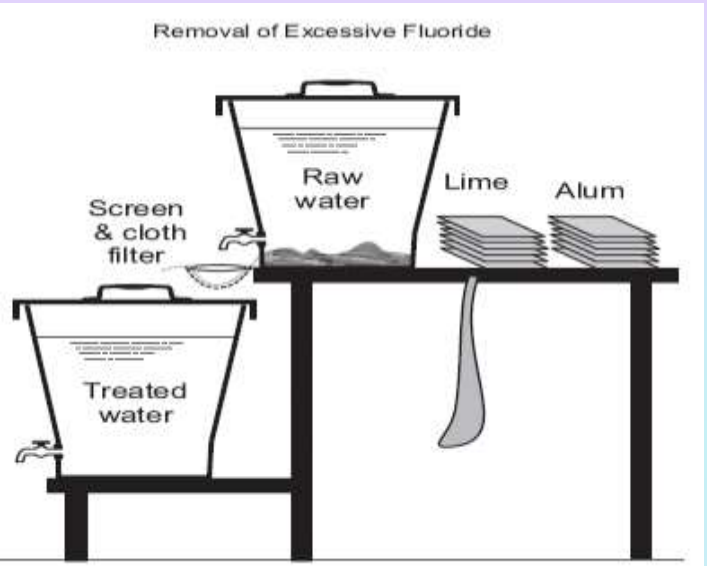
(Reversal of fluorosis)

DEFLUORIDATION METHODS

- ***Precipitation methods - Nalgonda process, Precipitation using Lime, PACl, etc.***
- ***Adsorption or Ion exchange methods –***
- ***Adsorbents- activated alumina, wood, Carbon, petroleum residues, rice husk, jute waste, coconut shell, Fly ash, Defluoron-1, Defluoron-2, Krass (Agarwal et al., 1999; Gupta et al., 1999), bone-char etc.***
- ***Ion exchange materials- Tulsion A27, Amberlite IRA400, Polystyrene etc.***
- ***Electrochemical Method – Electro - coagulation***
- ***Membrane Separation- RO, ED, etc***

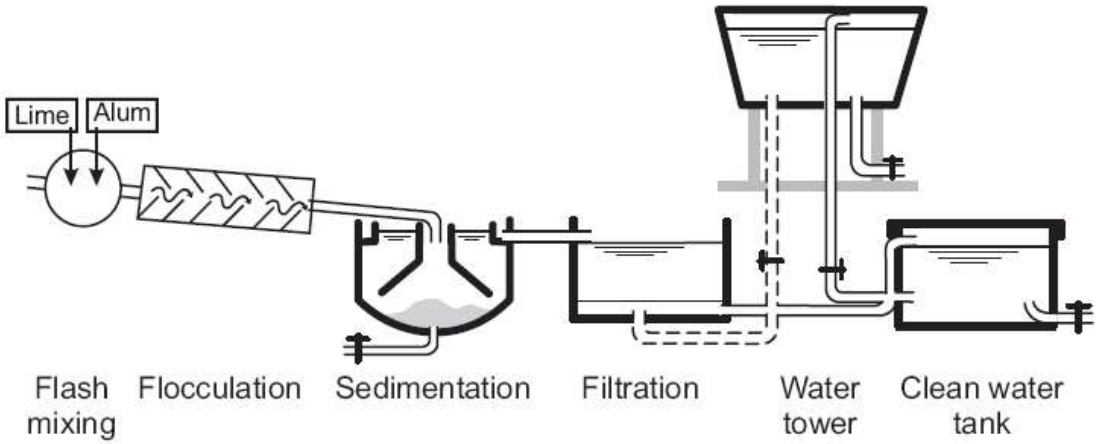
Nalgonda Process – Community Level Unit and Domestic Defluoridation Unit - as adopted for domestic use in the United Republic of Tanzania

Domestic Level Defluoridation



The Nalgonda defluoridation as adopted for domestic use

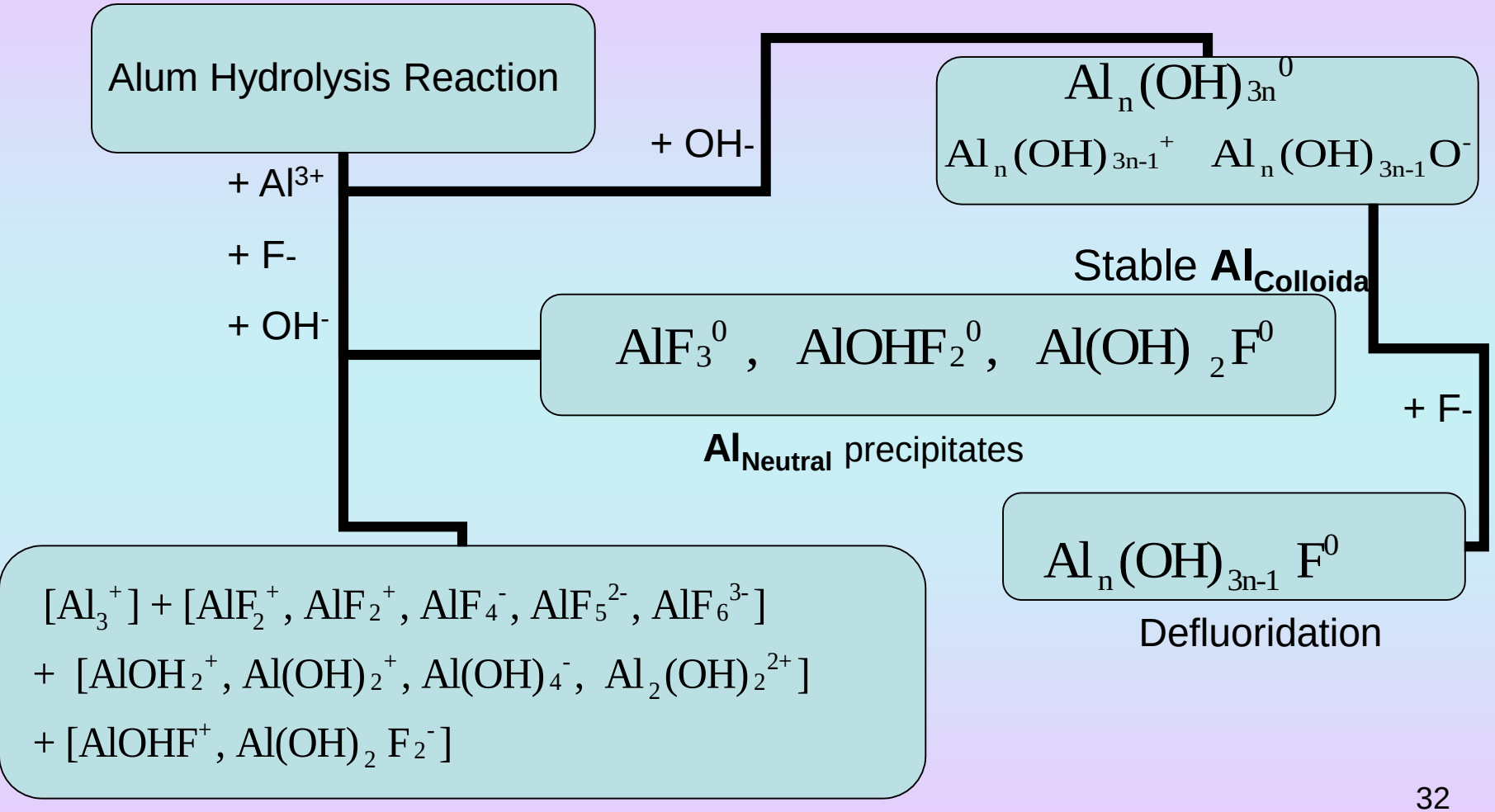
Community Level Defluoridation



Nalgonda Defluoridation Technique - Approximate doses of alum in mg/l required for obtaining the acceptable limit of 1 mg/l fluoride (pH between 6.5 and 8.) (MRD, 1993)

mg F/l	Test Water Alkalinity, mg $CaCO_3$/l															
	125		200		300		400		500		600		800		1000	
	Alum	Al	Alum	Al	Alum	Al	Alum	A l	Alum	Al	Alum	Al	Alum	Al	Alum	Al
2	145	16	200	22	275	30	310	33	350	38	405	44	470	51	520	56
3	220	24	300	32	350	38	405	44	510	55	520	56	585	63	765	82
4	*	*	400	43	415	45	470	51	560	60	600	64	690	74	935	100
5	*	*	*	*	510	55	600	64	690	74	715	77	885	95	1010	108
6	*	*	*	*	610	65	715	77	780	84	935	100	1065	114	1210	130
8	*	*	*	*	*	*	*	*	990	106	1120	120	1300	140	1430	153
10	*	*	*	*	*	*	*	*	*	*	*	*	1510	162	1690	181

NALD-2 MODEL - PATHWAY FOLLOWED BY ALUMINUM IN NALGONDA DEFLUORIDATION



$Al_{Dissolved}$

Colloidal and precipitated Al

George et al. (2009)

Nalgonda_MNIT

DEFLUORIDATION PLANT OF HEALTHCARE

- **Technical Specification As Per The Information Provided By Company:**

- Contact time = 12-15 min
- Flow rate = 10 lit/min
- Duration of each cycle = 15 min
- Daily output capacity = 6,000 litres
- Volume of Activated = 100kg/ reactor Alumina media used.

Dimensional specification:-

- Length =70 cm
- Breadth = 70 cm
- Height = 65 cm
- Volume = 318.5L

Fig.3: Defluoridation Plant Of Healthcare

- ***Location:*** ***MAAL (DHULA BARGOT)***
- ***Coordinates:*** ***N 23o 51' 15.2"***
  E 74o 05' 56.0"

BIOFILTER (Bio-F)

- HAP based adsorption, regenerated through alum impregnation
- High efficiency of F removal, with residual Al within the drinking water norms
- High temperature tolerance and short contact time (3-5 min)
- Regeneration produces no hazardous material
- Cost of HAP prohibitive
- Regeneration requires improvement
- Safe disposal of spent bed requires research

Way Forward

- Electrocoagulation Using Aluminium Electrodes
- Membrane Integrated Modified Nalgonda Technique
- Ca-Mg –HAP combinations for defluoridation
- Low cost adsorbents
- Permeable reactive barriers (PRB) for in situ Fluoride immobilization?
- Zero valent iron for in situ immobilization of Arsenic (NDSU)
- In situ Arsenic immobilization (Loughborough, UK)
- Understanding nexus between use of high fluoride/ Arsenic containing groundwater for irrigation and its incorporation in specific edible crops

Nitrate toxicity

- **WHO Standards (45 mg/l)**
- **Methaemoglobinaemia**
- **GIT cancers**

New dimensions

- **Methaemoglobinaemia – A problem of all age groups**
- **Cytochrome b_5 reductase adaptation**
- **Recurrent Stomatitis**
- **Recurrent Diarrhea in children**
- **Recurrent Respiratory Tract Infection in children**

In situ denitrification using *Thiosphera pantotropha*

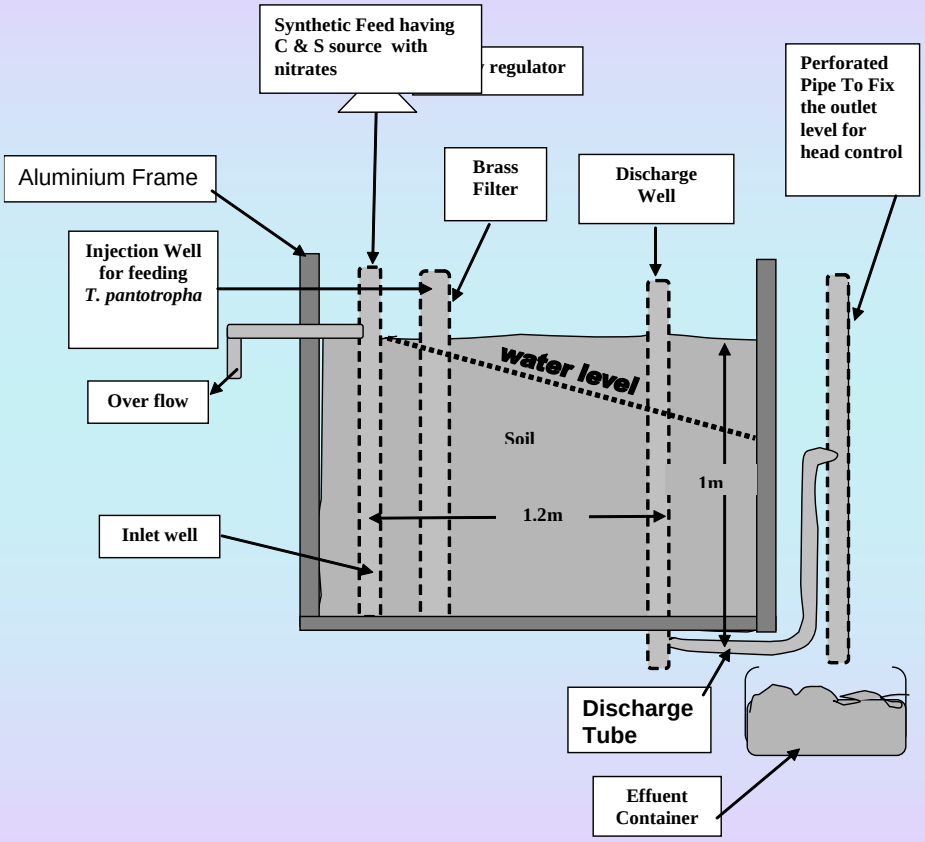


Fig. 1 Line diagram of *In situ* denitrification model

Way Forward

- In the Western world there are strict limits for N and P discharges through treated sewage
- In situ denitrification to be further developed
- Developing bio-adsorbents having affinity for nitrates
- Understanding effect of high nitrate groundwater used for irrigation and its effect on some edible food varieties
- Affordable cost

Emerging pollutants

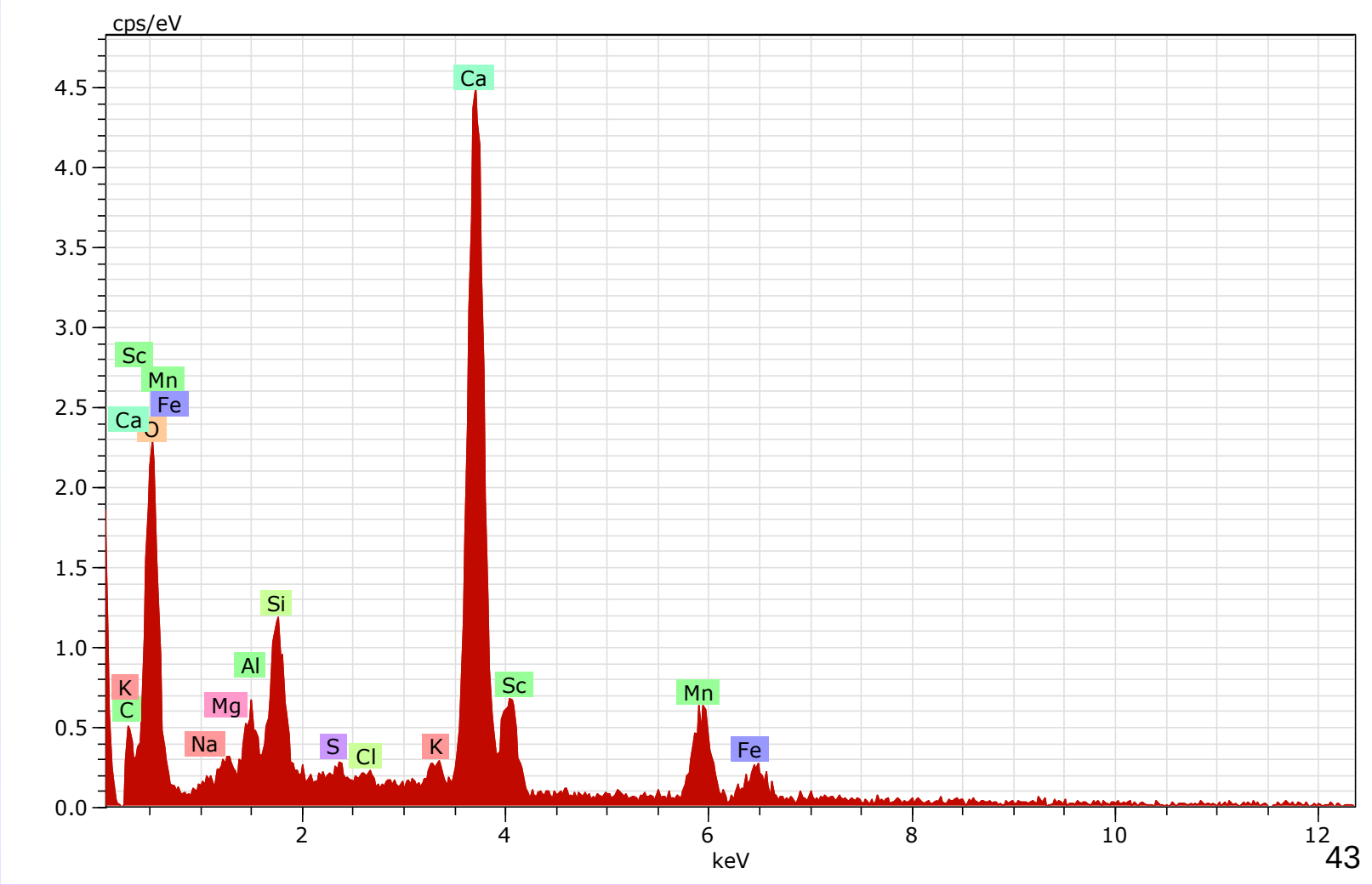
- Heavy metals
- Pesticides
- Presence of EDS and PCPP in treated sewage used for irrigation and their entry to food chain has to be understood deeply in order to avoid massive ill effects
- Research inputs are needed to evolve cost effective strategies

Salinity and Desalination- ongoing projects

- Rajasthan Govt has already installed about 2700 RO plants in villages and plans more than 1000 plants every year. Major issues- cost, electricity supply, concentrated waste
- Development of a Solar Energy based Vacuum Membrane Distillation System for rural drinking Water applications in Rajasthan
- Recovery of useful water from RO rejects using VMD process
- Integrated solar and electrical energy operated VMD systems for desalination of water (Indigenously manufactured Microfiltration Membranes from IITD)

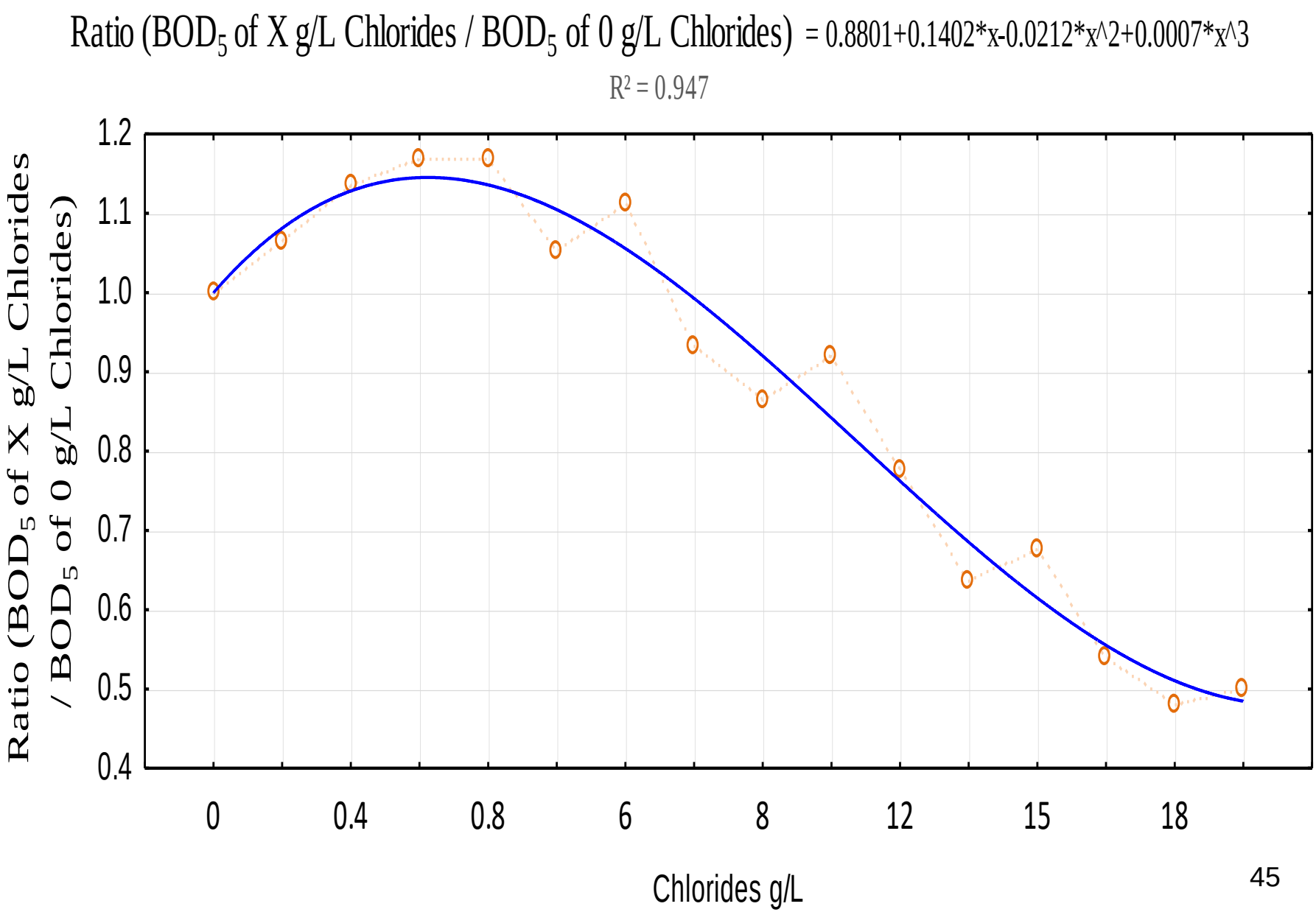
PERFORMANCE STUDY OF COMMUNITY REVERSE OSMOSIS DESALINATION PLANT; issues and solutions

SEM-EDX of reject membrane



VMD_MNIT

FIGURE: Curve between BOD_5 exertion ratios & chloride concentration.



Way Forward

- RO membranes get fouled in a few months beyond repair in Rajasthan compared to a life of few years in the Southern India or Gujarat due to high concentration of hardness
- Anti scalants, chemicals to be used for cleaning membranes require special approach
- RO is commonly used in the Western world for both water as well as industrial wastewater treatment and we can derive solutions by working together
- Functionalized adsorbents to be developed for treatment of specific contaminants
- Reject management from treatment streams
- Cost to be brought down

Conclusion

- Pollution of drinking water can have large scale ramifications on human health.
- Understanding the nature of the biological/ chemical pollutant and its reactivity with other substances is key to optimize its removal
- Recent findings of multi drug resistance among pathogens calls for a detailed study to understand the impact of sewage irrigation on DW quality
- In case of multiple impurities being present, membrane processes have immense applications as they would reject all pollutants almost uniformly
- Management decisions should be taken on a robust technological base for sustainable solutions

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