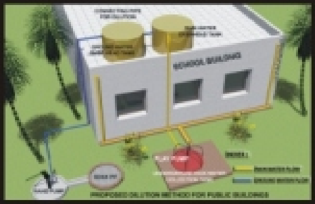

INTEGRATED FLUOROSIS MITIGATION

Guidance Manual

नीरी NEERI

unicef

"Pending International Review"

Guidance Manual

INTEGRATED FLUOROSIS MITIGATION

"Defluoridation reduces fluoride in water, IFM reverses fluorosis in humans"

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Foreword

India is projected to be one of the worst affected by physical water scarcity in the World by 2025, with fresh water available/person/ year of <1000 m^3. Due to the lowering of groundwater in many parts of India, there are significant risks of increased bacteriological and chemical contaminations mainly due to arsenic, fluoride and nitrate. This is also true for many other parts of the world. Therefore, to mitigate these contaminants there is a need for a "holistic" health management approach. This approach should begin with establishing tolerable levels of risk to human health of the specific chemicals followed by appropriate risk management strategies. In this connection, a novel concept of Integrated Fluorosis Mitigation (IFM) has been developed and implemented jointly by UNICEF and NEERI to address the growing problem of fluorosis.

The conventional fluorosis mitigation approach mainly deals with defluoridation of water and, other ways of lowering of fluoride intake, while, an appropriate IFM plan starts with a detailed Quantitative Chemical Risk Assessment (QCRA) leading to identification of key factors actually responsible for the fluorosis, followed by development of an adequate and specific strategy for effective mitigation of fluorosis. This includes- water management solutions, domestic level defluoridation of drinking water as well as nutrition supplementation. This approach addresses the different causes of fluorosis, including intake of high levels of fluoride from various exposure routes and impact of nutritional behaviour viz-a-viz malnutrition towards fluorosis. Accordingly, fluorosis mitigation is dealt with an integrated approach as explained above. The scientific tool such as Quantitative Chemical Risk Assessment (QCRA) has been used for the first time as diagnostic parameter prior to applying appropriate fluorosis mitigation strategy. QCRA, with data on health surveys, provides the basis for use-based separation of water sources. Ground water consumption can also be reduced by creating alternative water resources, such as, rainwater harvesting or re-use of greywater for sanitation/gardening. Development of improved and simple process for defluoridation of drinking water at household level could also be an effective way of defluoridation of drinking water. The IFM concept has been studied and implemented under a systematic study in Dhar and Jhabua districts of Madhya Pradesh, India. Water quality monitoring and surveys along with reported dental/skeletal fluorosis symptoms have been used for identification of fluoride contamination as the problem in the study region. Initial interventions based on the present study have shown excellent results towards actually controlling the fluorosis in study area. A recent dental fluorosis survey has shown a 47% reduction in dental fluorosis, as a result of IFM.

Based on these detailed studies, this guidance manual has been prepared, which may be considered as the first of its kind as it provides and applies Modern Scientific Approaches outlined in WHO GDWQ Vol. 3 (2004) to rural Indian communities. This manual will be 2nd in the series published by NEERI in collaboration with UNICEF, Bhopal and is based on the studies jointly carried out with UNICEF Bhopal in various parts of Madhya Pradesh, India. The Institute is thankful to the UNICEF, and Government of Madhya Pradesh and NGOs in this study region, for their technical cooperation in the implementation of defluoridation schemes for water treatment and related studies. This manual has been written specifically for practitioners involved in the fluorosis mitigation programme, which includes local governing bodies, engineers, water quality analysts, scientists, sociologists and professionals.

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September, 2007

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Background

Provision of water and sanitation services in urban and rural areas has expanded much more slowly than the population growth in most low-income and many middle-income nations. This increase has numerous implications for water management. With 16 percent of world's population, India has only 4 percent of global water resources. Furthermore, water resources of India are not distributed evenly with rainfall varying from an annual average of >10,000 mm in parts of Meghalaya, <500 mm in the semi arid regions of Gujarat to <200 mm in Rajasthan (CWC, 2005, Ministry of Water Resources, 2005. Additionally much of the rainfall is received during the rain intensive monsoon months (from June to September), where flash rains contributing to the majority of rain falling during 100 hours. As a result, India faces scarcity of water in several regions during certain period of the year. The per capita availability of fresh water has dropped from 5177 cubic meter in 1951 to 1869 cubic meter in 2001 (CWC, 2005).

India's water resources are distributed between ground and surface water sources. The total available water resource is 1869 billion cubic meters (BCM) per year (CWC, 2005). Only 60 percent is utilisable resource, which is contributed by 690 BCM of surface water and 432 BCM of groundwater. By 2025, India is projected to be one of the worst affected by physical water scarcity in the World. In the central basaltic geologic formations of India, over exploitation of finite groundwater resources is forcing government authorities to explore deeper (previously un-surveyed) aquifers. Many of these deep aquifers are located in older strata (CGWB), which contain high levels of chemical minerals such as fluorite or hornblende. These pollutants when leached into groundwater sources have significant health affects.

Clearly availability of water is finite. The demand for water is increasing dramatically and is leading to conflicts due to the rapid growth of population. The Global Water Supply and Sanitation Assessment Report by UNICEF/WHO (Joint Monitoring Programme for Water Supply and Sanitation (2000), Global Water Supply and Sanitation Assessment (2000), WHO and WSSCC (2000)) indicates that globally about 1.1 billion population lack access to safe water; additional 3.0 billion population may join in the next two generations. Due to over exploitation, the quality and water resource is being affected by salinity, arsenic, nitrate and fluoride content. The global burden of disease due to fluoride in drinking water was estimated by Fewtrell et al. (2006) by combining exposure-response curves for dental and skeletal fluorosis (derived from published data) with model-derived predicted drinking water fluoride concentrations and an estimate of the percentage population exposed. It has been estimated in the study that in India population of 18,197,000 are affected with dental fluorosis and 7,889,000 are affected with skeletal fluorosis. The study further estimates skeletal fluorosis-attributed DALY of 17 per 1000 population in India.

Therefore, to mitigate these pollutants there is a need for an "Integrated Fluorosis Mitigation (IFM)" approach. This approach needs to begin with better understanding of health impacts of excessive fluoride intake in relation with the nutritional aspects, and establishing tolerable levels of risk to human health followed by an integrated strategy involving water management solutions, new water defluoridation techniques as well as nutritional supplementation. It is now established beyond doubt that fluoride intake is not the only factor responsible for fluorosis, and malnutrition can play crucial role in aggravating the problem. As a consequence, nutritional solutions can also be very effective in fluorosis mitigation. Similarly there seems to be considerable scope for improvement in existing defluoridation techniques for water as they may not be techno-economically very feasible in many rural and less developed areas. The cost-effectiveness of IFM will be comparable to various interventions evaluated by Hutton et al. (2004)) to improve water and sanitation services, with results presented for 17 WHO sub-regions and at the global level. The results of the study indicate that all the water and sanitation improvements were found to be cost-beneficial. In developing regions, the return on a US$1 investment was in the range US$5 to US$28 for various interventions. The main contributor to benefits was the saving of time associated with better access to water supply and sanitation services.

This guidance manual can be used for assessing the problem of fluorosis in any specific area and also for planning and implementing the specific mitigation strategy for fluorosis. The manual is the 2nd in the series published by NEERI in collaboration with Dr. Sam Godfrey of UNICEF Bhopal.

Disclaimer

All the adsorbents/ defluoridation materials used in this study have been developed at laboratory level and evaluated by following the batch studies. Limited evaluation studies using both simulated and actual field waters have been carried out for domestic application. However, detailed long term studies, regeneration studies as well as toxicological studies need to be carried out before these adsorbents can be considered for process up-scaling and practical applications. The present manual restricts to the findings of Project Cooperation Agreement (PCA), including laboratory level R&D studies on adsorbents/ defluoridation materials as an alternative to conventional materials for defluoridation of water.

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Who Should use this Manual?

This manual has been written specifically for practitioners involved in the fluorosis mitigation programme. This includes local governing bodies, engineers, water quality analysts, scientists, sociologists and professionals in developing countries. The manual is designed to provide guidance to the practitioners on how to manage the fluorosis problem using the concept of Integrated Fluorosis Mitigation (IFM). This involves QCRA for the assessment of fluorosis and its causes, followed by a mitigation approach by using dilution technique based on rain water harvesting and overall water management, defluoridation of water at household level and nutritional supplementation. This manual is written exclusively to enable and encourage the service providers to systematically implement an Integrated Fluorosis Mitigation approach as detailed in this manual.

How to use this Manual for Implementation of Integrated Fluorosis Mitigation?

The manual can be used for assessing the problem of fluorosis, and its causes in a specific area, as well as for preparing and implementing suitable strategy for fluorosis mitigation. Case studies and guidance for fluorosis mitigation are given in **Chapter 1**

Structure of the Manual

Chapter 1	Introduction
Chapter 2	IFM I: Quantitative Chemical Risk Assessment
Chapter 3	IFM II: Water Management Solutions
Chapter 4	IFM III: Household Level Mitigation through Defluoridation of Water
Chapter 5	IFM IV: Nutritional Mitigation
Chapter 6	Summary
	References
Annexure I	QCRA: Survey Tool Design
Annexure II	Users' Perception: Forms
Annexure III	Calcium Rich Food
Annexure IV	Vitamin 'C' Rich Food
Annexure V	Iron Rich Food
Annexure VI VI	Antioxidant Rich Food
Annexure VII	Harmful Food Containing Higher Fluoride Contents
Annexure VIII	Peer Reviewed Publications and Patent

Index

Chapter 1: INTRODUCTION

List of Tables

List of Figures

Chapter 1

INTRODUCTION

Excessive fluoride intake results in multidimensional health problems, most common being, dental and skeletal fluorosis. Fluoride in water derives mainly from dissolution of natural minerals in the rocks and soils with which water interacts. High fluoride concentrations are also often found in arid climatic conditions. Here, groundwater flow is slow and reaction times between water and rocks are therefore increased (Ayoob and Gupta, 2006). In tropical countries, like India, problem of excessive fluoride is more severe, particularly in arid parts of the country. Beside natural sources, fluoride ions can also be found in effluents from semiconductor, metal processing, fertilizers, aluminium and glass-manufacturing industries (Liu *et al.*, 1983; Cheng, 1985; Chaturvedi *et al.*, 1990; Sujana 1998; Toyoda and Taira, 2000). However, fluoride intake from other sources is also considerable, especially from food. Traditionally, fluorosis has been directly correlated to the fluoride intake, however, recent studies including our work in Madhya Pradesh has brought out the fact that nutritional habits also play very important role in fluorosis epidemic.

Fluorosis mitigation has been a very active area of research for more than 50 years including some of the earliest studies carried out by the British Geological Survey (BGS). A large number of attempts have been reported, mainly on defluoridation of water, however, it cannot be proposed as the only or most effective solution to mitigate fluorosis. Fluorosis mitigation approach needs to begin with better understanding of health impacts of excessive fluoride intake in relation with the nutritional aspects, and establishing tolerable levels of risk to human health through a systematic Quantitative Chemical Risk Assessment (QCRA). This should be followed by an integrated fluorosis mitigation strategy involving water management solutions, new water defluoridation techniques as well as nutritional supplementation. Therefore, better water management and nutritional supplementation are imperative for fluorosis mitigation, while development of new materials as well as simple domestic level defluoridation techniques can play important role in implementation of fluorosis mitigation strategies, especially in the rural, less developed areas. This manual presents a brief review of fluoride pollution and existing fluorosis mitigation approaches, while the main objective of this manual is to present the comprehensive approach of ***"Integrated Fluorosis Mitigation"*** (IFM) involving QCRA, water management solutions, domestic defluoridation of water and nutritional supplementation. The concept of IFM is further explained in section 1.6 along with a conceptual diagram, while the methodology and details for the implementation of IFM have been given on page 18-19.

Development of new defluoridation materials is a step wise and complex process including laboratory development, bench scale studies, pilot scale and full-scale demonstrations. The present study is limited to only laboratory level development of new materials for defluoridation of drinking water. A limited number of field demonstrations have also been carried out including users' perception studies for domestic level defluoridation of water in study areas of Dhar and Jhabua districts of Madhya Pradesh. These studies, however, clearly demonstrate the acceptability of defluoridation methods to the rural population and their willingness to adopt the same. The case studies involving QCRA and mitigation approach in the study area have shown excellent results, thereby validating the proposed approach of IFM. This has also helped designing the precise protocols for implementation of IFM, which can be practiced by the professionals having adequate knowledge in this field. This work was carried out under the joint research project between National Environmental Engineering Research Institute (NEERI), Nagpur and United Nations Children's Fund (UNICEF), Bhopal on **Technical Strengthening of PHED MP, Collaboration between UNICEF Bhopal and NEERI for Effective Delivery of TSC/SD** (Principal Investigators: Dr. Sam Godfrey, Dr. S. R. Wate and Dr. S. S. Rayalu). The case studies especially related to nutritional supplementation, carried out under this programme show effective control and even the reversal of fluorosis in certain cases.

1.1 Fluoride Pollution: Global and Indian Scenario

In urban areas, surface water is being mainly used, but large number of people in rural areas and lower-income semi-urban communities use groundwater. An estimated 80% of domestic needs in rural areas of India are reported to be met by ground water (Ayoob & Gupta, 2006). These populations are therefore, more vulnerable to waterborne diseases as also there is evidence of contaminated groundwater leading to outbreak of endemic diseases (WHO and UNICEF, 2004). Currently, it is estimated that two third of people in Asia still lives without any proper access to drinking water (WHO, 2004a). In addition, the excess fluoride in groundwater adds much to this problem. Therefore, the water quality problems faced in this region and the proportion of people affected is quite large to assess and tackle (Ayoob and Gupta, 2006).

The other worst affected areas with fluorosis include the arid parts of Asian countries (China and Mongolia), African countries (Algeria, Ethiopia, Ghana, Ivory Coast, Senegal, Kenya, Tanzania and Uganda) and South American countries (Mexico and Argentina). Tanzania, covering some of the highly fluorotic rift valley areas, is one of the most severely fluoride affected countries in the world. Fluorosis incidence (all degrees) amongst the population in Kenya ranged widely from 11.7 to 56.5% in various provinces. In some places, dental fluorosis is found to be substantially higher than would be expected from the levels of fluoride in drinking water. The study by Apambire *et al.*, (1997) established that 62% of the total population of school children in the Bongo area of Ghana was having dental fluorosis.

Recent research from East Africa and China suggests that one reason for the increasing prevalence of fluorosis is lack of knowledge about alternative routes of exposure. Recent studies by Cao *et al., (2006)* and Whyte *et al.,* (2005) identified food as a potential hazard and states that food consumption may increase the risk of fluorosis. Indeed, studies indicate that the establishment of a water quality standard of 1 to 1.5 mg/l for fluoride consumption, through drinking water alone, is not enough to mitigate the adverse health affects of fluoride.

In early 1930s fluorosis was reported only in 4 states of India, in 1986 it was 13, in 1992 it was 15, and in 2006 it was 20, indicating that endemic fluorosis has emerged as one of the most alarming public health problems of the country. Among the affected states, Rajasthan, Andhra Pradesh, Madhya Pradesh and Gujarat are the most endemic.

1.2 Causes and Symptoms of Fluorosis

The fluoride research in the past decades suggests that fluoride concentrations in water below 1 mg/l are beneficial in the prevention of dental caries or tooth decay, but above 1.5 mg/l increase the severity of the incurable chronic disease 'fluorosis'. The optimal level of fluoride intake is not known with certainty. A level of 0.050.07 mg/kg is often thought of as “optimal”, however, even lower levels of intake have been associated with fluorosis (Levy, 1994). It cannot be assumed that because a person resides in a locality where excess fluoride is not present in drinking water, he or she is receiving low levels of fluoride as humans are exposed to fluoride from other sources or from water at locations other than home (e.g., child care centers, schools, workplaces etc.) (Levy *et al.*, 1997; 1998; 2000). Drinking water as a source of fluoride has already been discussed; a brief description of other sources of fluoride exposure is given here.

1.2.1 Fluoride from food and beverages

Virtually all foodstuffs contain at least trace amounts of fluoride (WHO, 2002). Fluoride enters in human food-and-beverage chain in increasing amounts through the consumption of tea, wheat, spinach, cabbage, carrots and other foods items (Susheela, 2003; Lakdawala and Punekar, 1973). The fluoride in these items results from the use of fluoridated water for food and beverage processing. One potentially dangerous source of fluoride is tea. Tea trees accumulate and store fluoride, absorbing it selectively from the air and soil (Cao *et al.*, 2003). Tea plants are found having high fluoride uptake and 97% of it gets accumulated in leaves (Shu *et al.*, 2003). The fluoride content of tea leaves is about 1,000 times the soluble fluoride content of soil and 2 to 7 times the total fluoride content in soil (Fung *et al.*, 1999). Studies by Whyte *et al.* and others showed that instant tea in distilled water has a fluoride concentration of 3.3 mg/l (Michael *et al.*, 2005). This is a key causative factor of dental fluorosis (Cao *et al.*, 1997; 2000; 2003). Furthermore, brick tea prepared in China, which is fermented and then compressed into bricks, has a fluoride content of 590780 mg/kg (Sha *et al.*,1994). In addition some common foodstuff like areca nut (supari), beetle leaves (pan ka patta), tobacco, cardamom and black salt also contain substantial amount of fluoride as detailed in Annexure VII.

1.2.2 Other sources

There are a considerable number of industrial sources of fluoride including industrial plants manufacturing aluminum, hydrofluoric acid, phosphate fertilizer plants, enamel, glass etc. Recently, substantial amounts of industrial effluent containing fluoride are also generated from industries manufacturing semiconductors and integrated circuits. (Ando *et al.*, 1998; Liang, 1993; Datta *et al.*, 1996). Fluoride mouth rinses are generally contraindicated for young children, because pre school children cannot rinse and spit properly. However, self-applied gels, used on a daily basis, could present a considerable risk for over-ingestion. Most of dentifrices contain fluoride, usually at a concentration of 1,000 mg/l. Studies of families with generally higher socio-economic status found that approximately 85% of children were using fluoride dentifrice by 24 months of age (Levy *et al.*, 1997). High fluoride containing toothpastes are also a major source of fluoride intake (Levy *et al.*, 2000).

1.2.3 Role of nutritional aspects in fluorosis

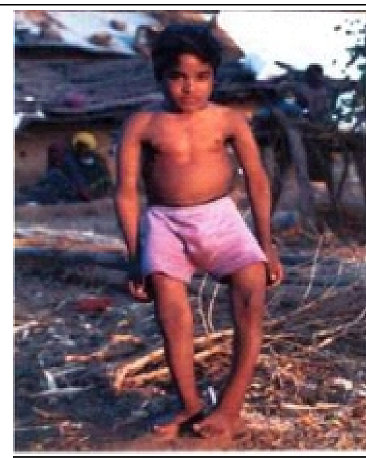
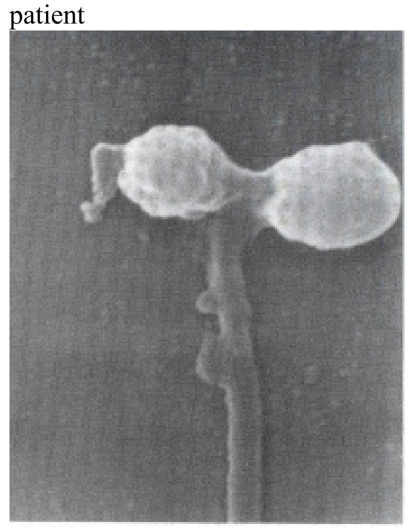
There are already convincing evidence and scientific reasons to justify the important role of malnutrition and dietary habits on severity of fluorosis. Chinoy et al., (2000) indicated that protein supplementation has a beneficial effect on reducing the fluoride induced liver toxicity and is necessary for recovery from fluoride toxicity. Further community based studies strongly suggest that calcium status modifies the type of bone changes seen in fluorosis (Krishnamachari et al., 1986 and Chakma et al., 2000). Clinical trials carried out with therapeutic supplementation of micronutrients in fluorosis affected children of Rajasthan also showed beneficial effect on skeletal deformities (Gupta et al., 1994). Reversal of fluoride induced cell injury through nutritional supplementation of calcium, vitamin C and antioxidants have been reported from Delhi. Over 90% of the persons affected with severe skeletal fluorosis, bone disease and deformities belong to the low socio-economic group, where calcium intake status is low (Teotia et al., 1984). Studies also show that deficiency of vitamin C play significant role in fluorosis. Jolly et al. (1974) has highlighted the role of nutritional factors relative to the different clinical patterns of fluorosis seen in various endemic regions in India. Similarly a study in China shows 43.8% prevalence of skeletal fluorosis with normal nutrition while 69.2% in those with malnutrition, clearly underlining the role of nutritional aspects (Liang et al., 1997). The observations of wide variations in the prevalence of both dental and skeletal fluorosis at the same fluoride exposure level, makes it clear that health and nutritional status play important role in fluorosis (Ayoob and Gupta, 2006).

1.2.4 Symptoms of fluorosis

The most common symptoms of chronic fluoride exposures are skeletal fluorosis, which can lead to the permanent bone and joint deformations and dental fluorosis.

<table>
<tr>
<td>Dental Fluorosis

• Occurs if exposed to high fluoride during permanent dentition
• Chalky white teeth initially
• Yellow to brown pigmentation in the middle of the teeth away from the gums
• In severe form the teeth becomes brittle and the enamel chips off</td>
<td></td>
</tr>
<tr>
<td>Skeletal Fluorosis

In Children
• Pain in the lower limbs
• Knock knee
• Bow leg
• Anterior bowing of the lower limb bones.
In adults
• Stiffness of the back and neck muscles
• Unable to bend forward
• Unable to stand straight</td>
<td></td>
</tr>
<tr>
<td>Non Skeletal/ Soft Tissue Fluorosis
Gastrointestinal system:
• Gas in the stomach
• Loss of appetite
• Constipation
Haemopoetic system:
• Anaemia and tiredness
Endocrine glands:
• Delayed puberty
• Destruction of thyroid gland
Genitourinary system:
• Infertility due to abnormal sperm
Renal system:
• Chronic renal failure
Central nervous system
• Low I Q</td>
<td>Double headed sperm in fluorosis patient
</td>
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</table>

1.3 Standards for Fluoride in Drinking Water

Traditionally, a limit of fluoride (1 to 1.5 mg/l) was established by individual countries based on epidemiological evidence. With the advent of the third edition of the WHO GDWQ, there is a fundamental departure from standard setting, based on dose-response effect, towards risk assessment and risk management. The guidelines advocate for the use of Water Safety Plans, as risk management tool, to help achieve health based risk targets.

1.3.1 WHO risk assessment and risk management approach

The "framework for safe drinking water" comprises six key components:

1. Health-based targets based on evaluation of health concerns
2. System assessment to determine whether the drinking-water supply as a whole can deliver water that meets the health-based targets
3. Operational monitoring of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety
4. Management plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operation and incident conditions
5. Upgrade and improvement, documentation and communication; and
6. A system of independent surveillance that verifies that the above are operating properly.

Table 1.1: Standards / prescribed limits for fluoride in drinking water

Agency / Source	Prescribed Limit/ Desired Limit / Guideline value (mg/litre)	Remarks
Indian Standards Drinking Water Specifications 1992, Reaffirmed 1993 ***IS:10500***	1.0 (Desired limit) 1.5 (Permissible limit in the absence of alternate source)	Fluoride may be kept as low as possible. High fluoride may cause fluorosis.
WHO Guidelines Third Edition, Vol. 1 Recommendations 2004	1.5	Volume of water consumed and intake from other sources should be considered when setting national standards.

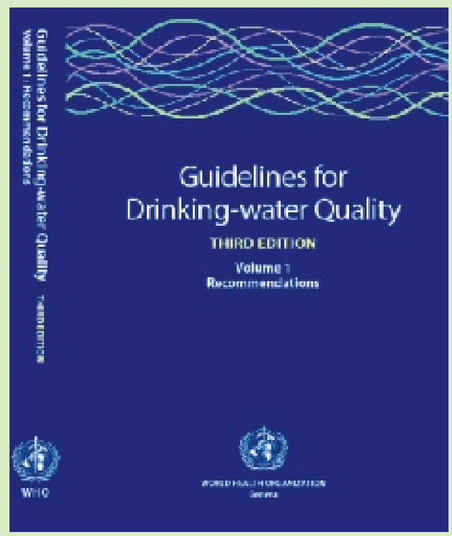
1.3.2 Water safety plan (WSP) and risk based targets

In the framework for safe drinking-water, assessment of risk is not a goal in its own right, but is a part of an iterative cycle that uses the assessment of risk to derive management decisions that, when implemented, result in incremental improvements in water quality. Descriptions of a "reference level of risk" in relation to water are typically expressed in terms of specific health outcomes. A reference level of risk enables the comparison of water-related diseases with one another and a consistent approach for dealing with each hazard. For the purpose of these guidelines, a reference level of risk is used for broad equivalence between the levels of protection afforded to toxic chemicals and those afforded to microbial pathogens. For these purpose, only the health effects of waterborne diseases are taken into account. The reference level of risk is 10-6 disability-adjusted life-years (DALYs) per person per year, which is approximately equivalent to a lifetime excess cancer risk of 10-5. This is described in detail in Chapter 2. A WSP comprises, as a minimum, the three essential following actions in order to ensure that drinking water is safe:

- a system assessment;
- effective operational monitoring; and
- management.

While water can be a major source of enteric pathogens and hazardous chemicals, it is by no means the only source. In setting standards, consideration needs to be given to other sources of exposure including food. There is limited value in establishing a strict target concentration for a chemical in drinking water, as it provides only a small proportion of total exposure (WHO, 2004c). Drinking water may be only a minor contributor to the overall intake of a particular chemical, and in some circumstances controlling the levels in drinking water, at potentially considerable expense, may have little impact on overall exposure. Drinking-water risk management strategies should therefore be considered in conjunction with other potential sources of human exposure.

Water Safety Plan (WSP) approach is described by the World Health Organisation (WHO) as the most effective means of consistently ensuring the safety of freshwater through the use of a comprehensive risk assessment and risk management. WSP is a powerful tool for water quality management and considers health protection as major objective. The third edition of the World Health Organization Guidelines for Drinking Water Quality states that: *"The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchments to consumer"* (WHO, 2004c).



Health-based targets are an essential component of the drinking-water safety framework and takes account of the overall public health situation and contribution of drinking-water quality to disease due to waterborne microbes and chemicals, as a part of overall water and health policy. Health-based targets provide the basis for the application of the Guidelines to all types of drinking-water supply. Due to the range of constituents in water, their mode of action and the nature of fluctuations in their concentration, there are four principal types of health-based targets used as a basis for identifying safety requirements.

This manual describes setting up health-based targets for fluoride in drinking water considering the study undertaken in Dhar and Jhabua districts in Madhya Pradesh, India.

1.4 Existing Practices for Fluorosis Mitigation

Fluorosis mitigation *per se* is mainly addressed through defluoridation of water in most of the cases. In India, defluoridation of water is predominantly applied at community level, mostly using the activated alumina based defluoridation techniques in present scenario. However, water management techniques are seldom used as an effective option for water defluoridation. There are isolated cases where nutritional supplementation has also been used as part of curative measures in fluorosis affected areas. Scientific assessment and quantification of the causes of fluorosis using tools like QCRA has not been reported to the best of our knowledge, which also limits the reported fluorosis mitigation as a general remedial approach, rather than site specific and using the concept of integrated fluorosis mitigation.

1.4.1 Defluoridation of drinking water

Several methods of defluoridation of drinking water are available. Most common methods are based on *precipitation and adsorption/ion exchange.* In addition, a few other techniques, such as membrane separation process, electrolytic defluoridation, electrodialysis etc. have also been reported. The comparison of various treatment methods for defluoridation of drinking water is given in **Table 1.2.**

Sr. No	Treatment method	Advantages	Disadvantages
1	Precipitation	• Established method • Most widely used method particularly at community level	• High chemical dose is required. • Moderate efficiency • Excessive use of aluminum salts produce sludge and adverse health effects through aluminum solubility
2	Adsorption	• Locally available adsorbent materials • High efficiency • Cost effective	• Process is dependent on pH. • Presence of sulfate, phosphate, bicarbonate etc. results in ionic competition • Regeneration is required • Disposal of fluoride-laden sludge
3	Ion Exchange	• Removes fluoride up to 90-95% • Retains the taste and colour of water intact	• Presence of sulfate, phosphate, bicarbonate etc. results in ionic competition • Relatively higher cost • Treated water sometimes has a low pH and high levels of chloride
4	Membrane processes	• Highly effective technique • No chemicals are required • No interference by other ions. • It works under wide pH range	• Skilled labor is required • Relative higher cost • May not be suitable fo r water with high salinity, TDS

1.4.2 Defluoridation and UNICEF

UNICEF in association with Government of India and other partners have worked extensively on defluoridation programmes in India. In the 1980s, UNICEF supported the Government of India's Technology Mission in an effort to identify and address the fluoride problem. The Government of India subsequently launched a big and comprehensive programme to provide safe drinking water in fluoride affected areas. In recent years, the focus of UNICEF in Indian programme has been on strengthening the systems for monitoring water quality, facilitating water treatment by households, and advocating alternative water supplies when necessary. Education - both of households and communities - is key to this strategy. A number of demonstration projects have been initiated in fluorosis-affected areas, with the emphasis currently on introducing household defluoridation. UNICEF has also sponsored research and development on the use of defluoridation materials for removal of fluoride from water.

Since fluoride must now be considered an issue of worldwide importance, the years of experience in India is expected to help UNICEF and its partners provide four types of assistance towards an eventual solution:

- Promoting a better understanding of the problem and its impact on children;
- Raising the awareness of relevant governments and the public on the fluoride issue in particular and the importance in general, of monitoring water quality;
- Demonstrating, through pilot projects, the efficacy of low-cost fluoride removal technologies;
- Strengthening community and government capacity for fluorosis prevention, including a credible system for risk assessment that comprises both water quality and health monitoring.

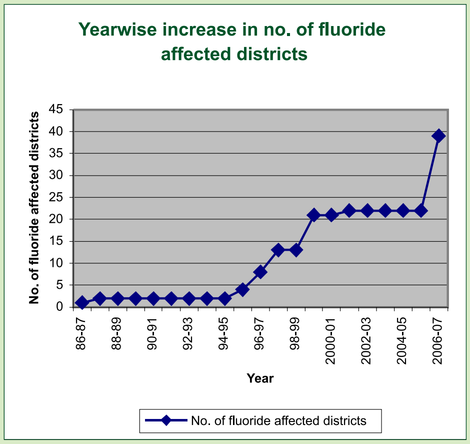
1.4.3 *Fluorosis mitigation in Madhya Pradesh (India)*

Excessive fluoride in drinking water was identified as early as in 1970s but due to lack of adequate documentation, no reliable data are now available. K. Raghva Rao, (1974) reported presence of high fluoride in water from hot springs of Madhya Pradesh (MP). It was the inception of Technology Mission Programme of Government of India, which embarked upon this vital issue of fluorosis control in the same year for all over the country using concerted efforts. Jhabua District was identified as one of the Mini-Mission Districts of Madhya Pradesh. by Govt. of India. NEERI, Nagpur in the year 1986, discovered for the first time that 13 villages of Jhabua District, have excess of fluoride in water. However, no physical manifestations in the villagers were reported by NEERI. Consequently in September 1987, fluorosis disease was suspected by State Health Department in 3 villages of Shivpuri District, which could not be confirmed. This was then followed by analysis of water quality of drinking water sources of these villages for fluoride contents. First report of fluorosis manifestation in human was reported by Chakma *et al.* in 1997 from two villages in Mandla district. At this stage Government of India, specially Rajiv Gandhi Drinking Water Mission and Government of Madhya Pradesh accepted the recommendations made by Dr Tapas Chakma for the control of fluorosis in Mandla, part of which ultimately came as a policy change making fluoride testing mandatory for all hand pumps before installation, which was not in practice earlier.

Since then, PHED started making concerted efforts to prevent and control the problem of fluorosis. The following steps have been taken by PHED to provide safe, potable water supply on a sustainable basis in fluoride-affected areas:

- IEC (Informations, Education and Communication) activity by organizing district level update cum awareness camps as per Guidelines of GOI (Government of India) including one International Workshop on Fluorosis Mitigation in year 2001.
- Co-ordination with related departments/ organisations to facilitate fluorosis mitigation. Water Quality Analysis Facilities and analytical quality control.

  These steps helped PHED in identification of fluoride-affected areas in effective manner. Despite these efforts, there has been steady increase in the number of fluoride affected districts in Madhya Pradesh.



In 1986, there was only one fluoride affected district, while in 2007, this figure has gone up to 39 with 10471 affected sources out of total 398896 sources.
Main attributes to this increment are:-

- **Increased water demand.**
- **Improved analytical facilities for fluoride analysis**

Provision of safe water:

To provide safe water in fluoride affected areas, following strategy is being adopted in the given sequence for providing safe drinking water to the public, which are area specific :

Table 1.3: Fluorosis mitigation by providing safe water

No.	Particulars	Situation	Action taken
1	To check adequacy of source as per population norms	Adequate	• Capped • Or notified affected Tube well (TW) as unfit and keeping its use confined for *Nistar* (sanitation) purposes only
		Inadequate	• Alternative sources explored
2.	To check Dug Well (DW) water quality	DW safe TW unsafe	• Renovation and converting DW into sanitary dug well. • Providing Hand pump or power pump on DW. • Tube well in fluoride free zone. • PWSS from remote ground water or Surface water source
		DW unsafe TW safe	• Hand pump or single or multi village PWSS on tube well.
		Both DW and TW unsafe	• Individual and Group WSS. • PWSS from remote ground water or surface water source. • Defluoridation plant and / or domestic defluoridation filter

Fig. 1.1: Defluoridation plant in Madhya Pradesh

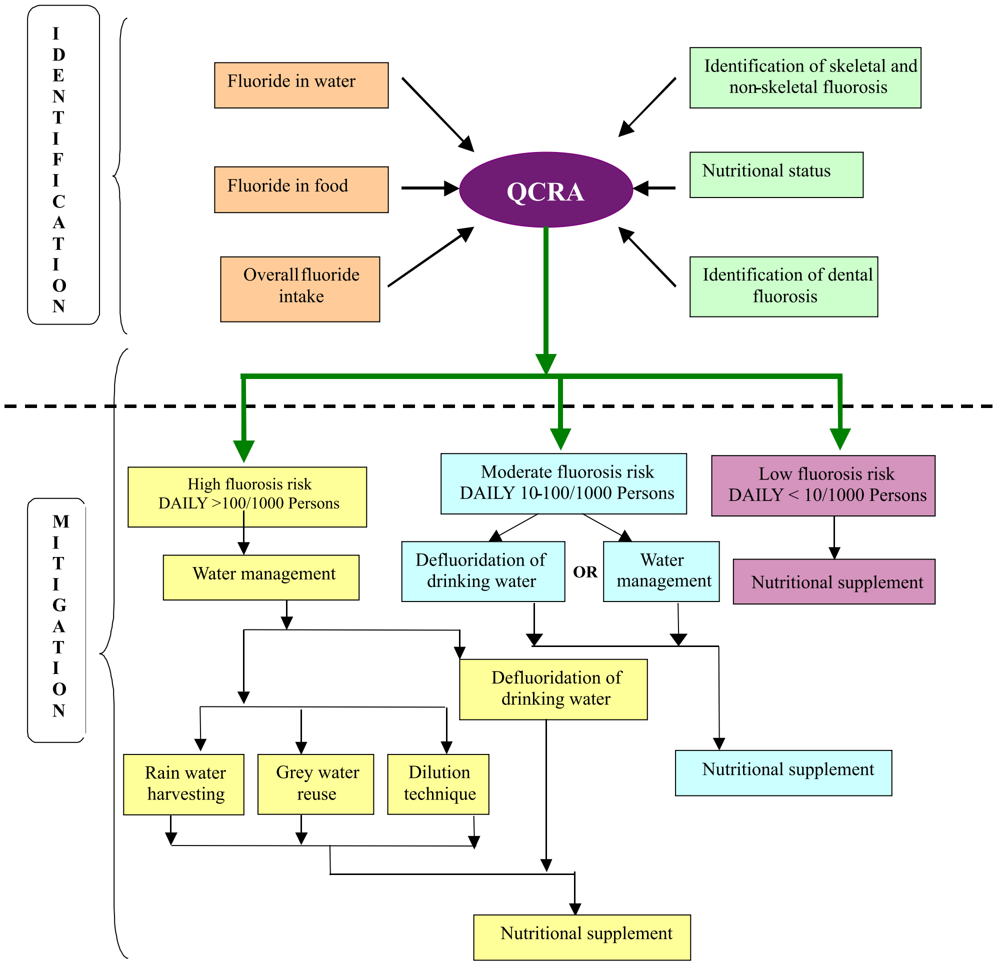
Following defluoridation plants have been installed in Shivpuri District of MP:

Type	Technology	Year of installation	No. of plants	Installed	Working
Fill and Draw type	Nalgonda	1990	2	2	2
Hand pump attachment	Activated alumina	1994 onwards	28	28	11

1.5 Concept of Integrated Fluorosis Mitigation (IFM)

Fluorosis is caused by intake of high levels of fluoride from various exposure routes, while its impact on human health also depends on various factors including the nutritional status. Therefore, fluorosis mitigation needs multidimensional approach, starting with proper identification of the problem and its causes. The scientific tools such as Quantitative Chemical Risk Assessment (QCRA) is used for assessment of health impacts due to excessive fluoride intake in relation with the nutritional aspects, and finally establishing tolerable levels of risk to human health. Water quality monitoring and surveys along with reported dental/skeletal fluorosis symptoms lead to the identification of fluoride contamination as problem in a region. QCRA with data on health surveys provides the basis for use-based separation of water sources. This should be followed by an integrated fluorosis mitigation strategy involving various water management solutions (including rain water harvesting, grey water reuse), improved water defluoridation techniques and nutritional supplementation. This approach also offers a site specific and practically more feasible solution for the effective mitigation of fluorosis.

Concept of IFM



1.6 Objectives of the Manual

The major objective of this manual is to introduce and disseminate a new concept of Integrated Fluorosis Mitigation (IFM) for the effective mitigation of fluorosis in developing countries. This is achieved through the following objectives:

- Provision of information on guidelines for implementation of QCRA for the quantitative assessment of fluorosis and its causes
- Planning an appropriate fluorosis mitigation strategy based on the QCRA results
- Water management solutions through rain water harvesting system for dilution of fluoride containing water and grey water reuse
- Improved processes/techniques for defluoridation of water at domestic level
- Formulation of guidelines and implementation plan for nutritional supplementation
- Preparation and execution of "Integrated Fluorosis Mitigation" strategy for effective mitigation and possibly reversal of fluorosis.

1.7 How to Implement the Concept of IFM

Identification

Health surveys | **Secondary data**

Identification of fluorosis affected areas

Step 1

Assessment of fluorosis problem and causes

QCRA Study — *Please refer to chapter 2*

Step 2

Categorization of the fluorosis (High, moderate or low risk)

QCRA Results — *Table 2.1*

Step 3

Mitigation/Control

Class-A: High risk category

Action I-Water management solution

Grey water reuse — *Please refer to chapter 3*

Design of rainwater harvesting system, water dilution — *Please refer to chapter 3*

Action II- Defluoridation of drinking water — *Please refer to chapter 4*

Action III- Nutritional supplement — *Please refer to chapter 5*

Follow up: Periodic assessment for the impacts of interventions and revision of strategy

Class-B: Moderate risk category

Action I-Water management solution-

Grey water reuse — *Please refer to chapter 3*

Design of rainwater harvesting system, water dilution — *Please refer to chapter 3*

OR

Action I- Defluoridation of drinking water — *Please refer to chapter 4*

Action II- Nutritional supplement — *Please refer to chapter 5*

Follow up: Periodic assessment for the impacts of interventions and revision of strategy

Class-C: Low risk category

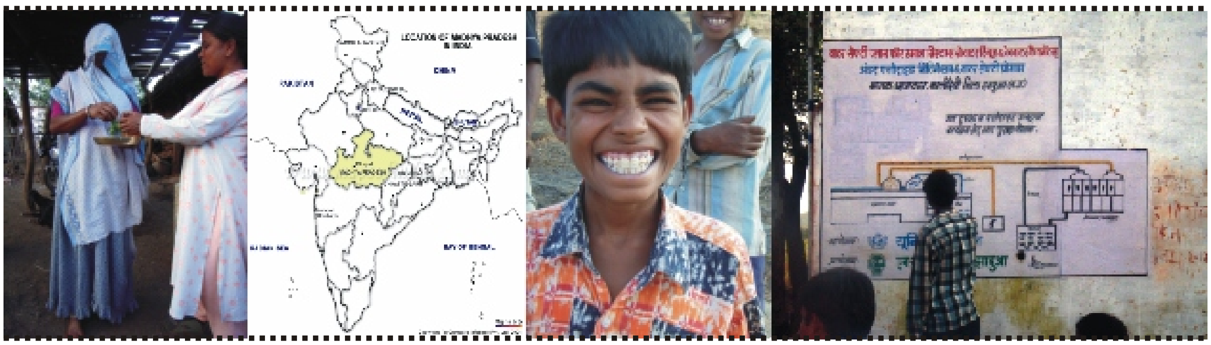
Action I- Identification of Nutritional deficiencies and adequate nutritional supplementation — *Please refer to chapter 5*

Follow up: Periodic assessment for the impacts of interventions and revision of strategy

1.8 Case Study

INTEGRATED FLUOROSIS MITIGATION (IFM) CASE STUDY IN MADHYA PRADESH, INDIA

Madhya Pradesh is a central state in India. It has a population of 66 million with a high tribal population. More than 80% of the 48 districts of MP are affected by elevated levels of fluoride in drinking water.



To mitigate fluorosis, areas with both high fluoride in water and also high prevalence of dental fluorosis were identified. Two districts (Dhar and Jhabua) were taken as implementation sites and a dental survey of 1000 children using the Deans survey and Quantitative Chemical Risk Assessment (QCRA) were undertaken in March 2005. This was followed by the IFM intervention including water dilution and defluoridation, and nutritional supplementation in both schools and communities. The QCRA followed the approach outlined in the WHO Guidelines for Drinking Water Quality volume 3 (2004) and involved hazard identification, exposure assessment, dose response and risk characterization. The results of the QCRA indicated that 60% of the fluoride is being consumed from food and 40% is being consumed from water.

Based on the QCRA, three categories of risk were determined:

1. CLASS A HIGH RISK CATEGORY (DALY >100/1000 persons) where the mitigation included IEC, household defluoridation, nutritional supplementation and water management.
2. CLASS B MODERATE RISK CATEGORY (DALY <100/1000 persons) including IEC, dilution of fluoride containing water and nutritional supplementation.
3. CLASS C LOW RISK CATEGORY (DALY <10/1000 persons) IEC and Nutritional supplementation.

Following the intervention a further dental survey of the same 1000 children was done. Results from the Deans survey indicate a reduction in the prevalence of Grade I fluorosis by 86%, for Grade II fluorosis by 77% and Grade IV by 60%. There was a minor increase in Grade II fluorosis by 21% due to the change in the cohort age of the study group over the two years. Overall the IFM resulted in a drastic reduction in the prevalence of dental fluorosis and increased the number of healthy teeth by 154%.

1.9 Information, Education and Communication (IEC) on IFM

Information, education and communication (IEC) combines strategies and methods that enable individuals, families, and communities to play active roles in achieving, protecting and sustaining their own health and well being. IEC is an important component of any development programme particularly related to water and environmental sanitation. The failure of Central Rural Sanitation Programme of Department of Drinking Water Supply was due to lack of demand, lack of participation in programme implementation and, lack of awareness among the community regarding health and hygiene aspects of safe drinking water and clean sanitation facilities. Therefore, it is proposed to educate the public; create awareness among them regarding health effects of excess fluoride consumption; provide integrated fluorosis mitigation solutions; and create long term success by facilitating community involvement and ownership by integrating IEC with IFM. The available IEC material on fluorosis mitigation concentrates simply on health effects of excess fluoride in drinking water and defluoridation of water particularly using activated alumina filter.

The integrated fluorosis mitigation approach is a new concept and an appropriate IEC material will help to popularize the concept particularly among rural community. The guidance manual on IFM is meant for application in rural areas and IEC will be an important component for making the manual effective. The IEC material will be developed in local language and disseminated to reach panchayat level. The IEC material on IFM will be developed for the following components:

- Identification of fluorosis affected areas
- Categorisation of fluorosis (high, moderate and low)
- Integrated fluorosis mitigation options
- Water management solutions
  - Defluoridation of drinking water
  - Nutritional supplementation.

Techniques for IEC on IFM

There are various techniques of communication, which include mass communication as well as inter personal communication. These techniques can be applied for IEC on IFM.

Mass Communication

Mass Communication technique helps in providing information to large audience in a short time. The communication process is information centered and for awareness creation. In certain case, it results in change in cognitive level but change of attitude for expected behavioural change cannot be achieved through mass communication

Mass Media

- Electronic Media message through radio, television, documentary and short films
- Print Media Information booklets, flash card, posters, flip charts, leaflets, pamphlets, newsletter/bulletins, calendars, wall writing, newspaper, magazine

Traditional Media

- Folk Media Performance attracts audience and reaches all (Folk songs, street plays, puppet shows/drama)

- Rural Resources Wall painting slogans, exhibition, banner display during fairs and festivals, bulletin or public notice boards, drum beater, local entertainment artists.

Interpersonal Communication

Interpersonal communication differs from other forms of communication in that there are few participants involved, the interacts are in close physical proximity to each other and feedback is immediate. The campaigner should introduce himself/herself to local authorities, local leaders and community and brief them about the programme. This will make the work easier and help the programme managers to get adequate support from everybody. Home contact drive, group meetings, focus group discussion, etc are part of interpersonal communication. Some of the individuals and institutions that could be effectively involved for creating awareness are school teachers and children, Anganwadis workers, scout and guides, NSS, NCC, health workers, PHED staff and community based organizations.

UNICEF alongwith PHED, Department of Tribal Welfare and NGO partners organized Children Convention at Dhar and Jhabua in January, 2007 is an example of effective IEC activity. Tribal children depicted IFM in the form of drama, songs, dances and paintings, which helped to raise awareness about IFM in these tribal districts of Madhya Pradesh. The selected photographs of children performing dance and drama on IFM are shown in **fig. 1.2.**

Fig. 1.2: IFM communnication through dance and drama

Chapter 2

INTEGRATED FLUOROSIS MITIGATION-I:

QUANTITATIVE CHEMICAL RISK ASSESSMENT (QCRA)

2.1 INTRODUCTION

Fluoride has spread to 36,988 habitations in India (DDWS, 2004). However the exact exposure-health relationship is yet to be properly established, (Ayoob *et al.*, 2006). Chakma *et al.* (2000) through their study in Madhya Pradesh indicated correlation between malnutrition and increased incidences of fluorosis. However, there are limited studies on exact exposure routes of humans to fluoride.

2.2 Hazard Identification

Fluoride is found in water, food, soil and air. The fluoride content in soil normally ranges from 200 to 300 mg/l (U.S. Department of Health and Human Services, 2003). The defluoridation of soil is not considered feasible particularly in rural areas, hence this option is not dealt in the manual. Fluoride is also found in air. However, the amount of fluoride that a person breathes in a day is usually less than 1.0 $\mu g/m^3$ (U.S. Department of Health and Human Services, 2003). Therefore, soil and air exposure are not considered in this manual.

2.2.1 Malnutrition and fluorosis

Malnutrition or rather lack of good food is the cause of a number of physical ailments. Bone deformities due to fluorosis are also reported to be more prevalent among children having higher grades of malnutrition.

The research in India also provides ample evidence on the critical role of malnutrition and poverty on the incidence and severity of fluorosis (Teotia *et al.,* 1984). Comparison of dietary adequacy, water fluoride levels, and incidence of skeletal fluorosis in several villages in India suggest that vitamin C deficiency (Khandare *et al.,* 2000) and poor nutrition play a major role in fluorosis (Mishra *et al.,* 1992). The study by Jolly *et al.* (1974) addressed the role of nutritional factors relative to the different clinical patterns of fluorosis seen in endemic regions of India. It was observed that in Punjab due to more dietary calcium intake, osteomalacia and rickets are not encountered as in Andhra Pradesh and Rajasthan. Low-calcium intake could also be another factor responsible for aggravating the problem of genu valgum (knock knee a form of skeletal fluorosis) (Zang *et al.*, 1996). Apart from calcium, other nutrients also affect resistance or susceptibility to skeletal fluorosis as reported by Chakma *et al.* (2000) in their study in Mandla district, Madhya Pradesh, India.

2.2.2 Identification of dental fluorosis

Several methods have been developed for quantifying the severity of dental fluorosis (Dean, 1934, Takumori, 1971). Depending on the level of exposure and nutritional status of the child, Dean (1934), developed a scale of from 0 to 4 as follows: class 0, no fluorosis; class 1, very mild fluorosis (opaque white areas irregularly covering about 25% of the tooth surface); class 2, mild fluorosis (white areas covering about 50% of the tooth surface); class 3, moderate fluorosis (all surfaces affected, with some brown spots and marked wear on surfaces subject to attrition); and class 4, severe fluorosis (widespread brown stains and pitting).

A girl with clinical signs of rickets (swelling of the wrist joint)

A boy with skeletal fluorosis (clinically only knock knee)

2.2.3 Identification of rickets and fluorosis

'Skeletal fluorosis' is a condition associated with prolonged accumulation of fluoride resulting in fragile bones having low tensile strength. The earliest clinical sign of skeletal fluorosis is the restrictions in spine movement. The studies in China and India reported an increased prevalence of skeletal fluorosis above the fluoride level of 1.4 mg/l in drinking water (Choubisa, 1997, Jolly *et al.,* 1974, Xu *et al.,* 1997). However, skeletal fluorosis has been reported in India in a village with average fluoride concentration as low as 0.7 mg/l, with range 0.41.4 mg/l (Jolly, 1973). Although the disease is uncommon at such low concentrations, evidence of skeletal fluorosis, with severe clinical manifestations, has been reported in at least 9 studies from 5 countries, where water supplies contain fluoride naturally in the range 0.72.5 mg/l (Diesendorf, 1990).

The severity of muscle stiffness due to fluorosis skeletal fluorosis amongst the different age groups can be determined using the following prescribed physical exercises (*Susheela et al., 2004*) with focused communities in endemic areas. Persons unable to undertake the exercise will be demarcated as having skeletal fluorosis.

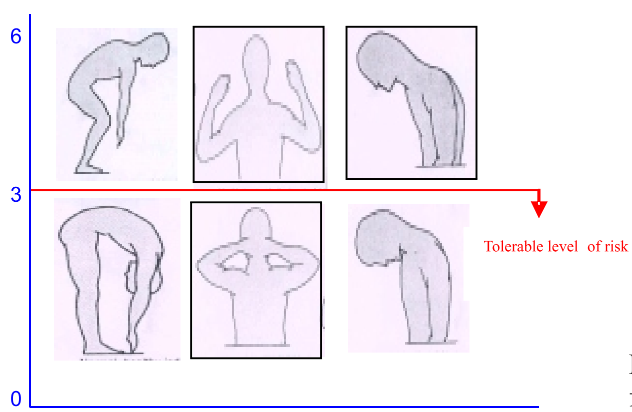
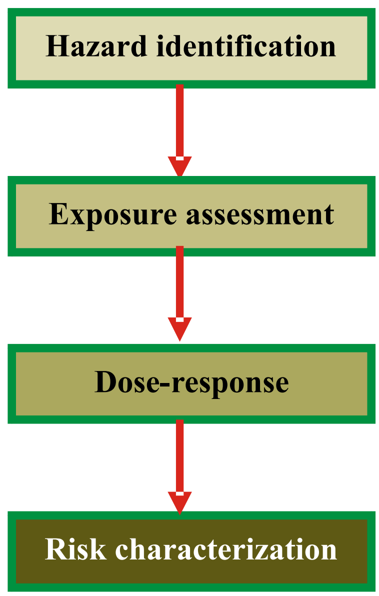


Fig. 2.1: Identification of skeletal fluorosis and tolerable level of risk

2.3 Quantitative Chemical Risk Assessment (QCRA)

To determine an acceptable level of risk and an appropriate water quality target, a Quantitative Chemical Risk Assessment (QCRA) tool may be used. The QCRA is based on the WHO (2004) Health Based Targets methodology. The QCRA systematically combines available information on exposure routes such as food and water and dose-response to produce estimates of the disease burden associated with exposure to chemicals. Results have been published by Godfrey *et al.* (2006). This helps plan appropriate intervention commencing with problem formulation to identify all possible hazards and their pathways from source(s) to recipient(s). Human exposure to the chemicals (environmental concentrations and volumes ingested) and doseresponses of these selected chemicals are then combined to characterize the risks. With the use of additional information (social, cultural, political, economic, environmental, etc.), management options can be prioritized. QCRA has four steps as presented below:



The process of QCRA clearly characterizes low, moderate and high fluorosis risk in terms of Disability Adjusted Life Years (DALY) in a given area for identifying various interventions under integrated fluorosis mitigation. The risk categories and its relationship with DALY are given below:

DALY	Risk Level
<10 per 1000 population	Low
10-100 per 1000 population	Moderate
>100 per 1000 population	High

2.3.1 Hazard assessment

During the hazard assessment, rapid analysis of food and water samples are analysed to determine the concentration of fluoride in both products.

2.3.2 Exposure assessment

During the exposure assessment the populations of interest, the pathways by which exposure may occur, and the magnitude, frequency of these potential exposures are identified to calculate the tolerable daily intake (TDI). The calculation of the tolerable daily intake is required to estimate the total quantity of fluoride consumed by the community. An estimated tolerable daily intake (TDI) is calculated using Equation 1:

$$TDI = \frac{(NOAEL \ or \ LOAEL)}{UF} \qquad \ldots\ldots\ldots\ldots..(1)$$

Where, NOAEL and LOAEL are no observed and lower observed adverse limits respectively, whereas UF stands for uncertainty factor. Findings from the QCRA are used for establishing guideline values for both fluoride intake from food and water.

2.3.3 Dose response

During the dose response, epidemiological and medical screening is done using the Deans dental fluorosis examination and the health based check up (Susheela *et al.,* 2004). In the QCRA, several subgroups in the population, such as children, the elderly and immuno-compromized persons are tested.

2.3.4 Risk characterization

Risk characterization brings together the data collected on the fluoride exposure, doseresponse, severity and disease burden. During the QCRA survey the severity of fluorosis amongst the different age groups and tolerable risks for fluoride has been calculated by undertaking prescribed physical exercises (*Susheela et al., 2004*) with focused communities. These exercises are illustrated in **Figure 2.1.**

The DALY (Disability Adjusted Life Years) were calculated based on methods outlined in Havelaar *et al.* (2003) with background data from Murray *et al.* (1996). A three-step methodology was used in this study to calculate the DALY. Firstly, the number (percentage) of people affected by fluorosis was determined from field data. Secondly, the prevalence of fluorosis was calculated based on median number of years affected by fluorosis per 1000 population. Finally, the susceptibility fraction was calculated as the probability of death per symptomatic case (CFR).

$$\text{Prevalence level} = \frac{\text{No. of People affected above tolerable level (i.e. 3)}}{\text{Total Population}} \times 1000$$

Figure 2.2

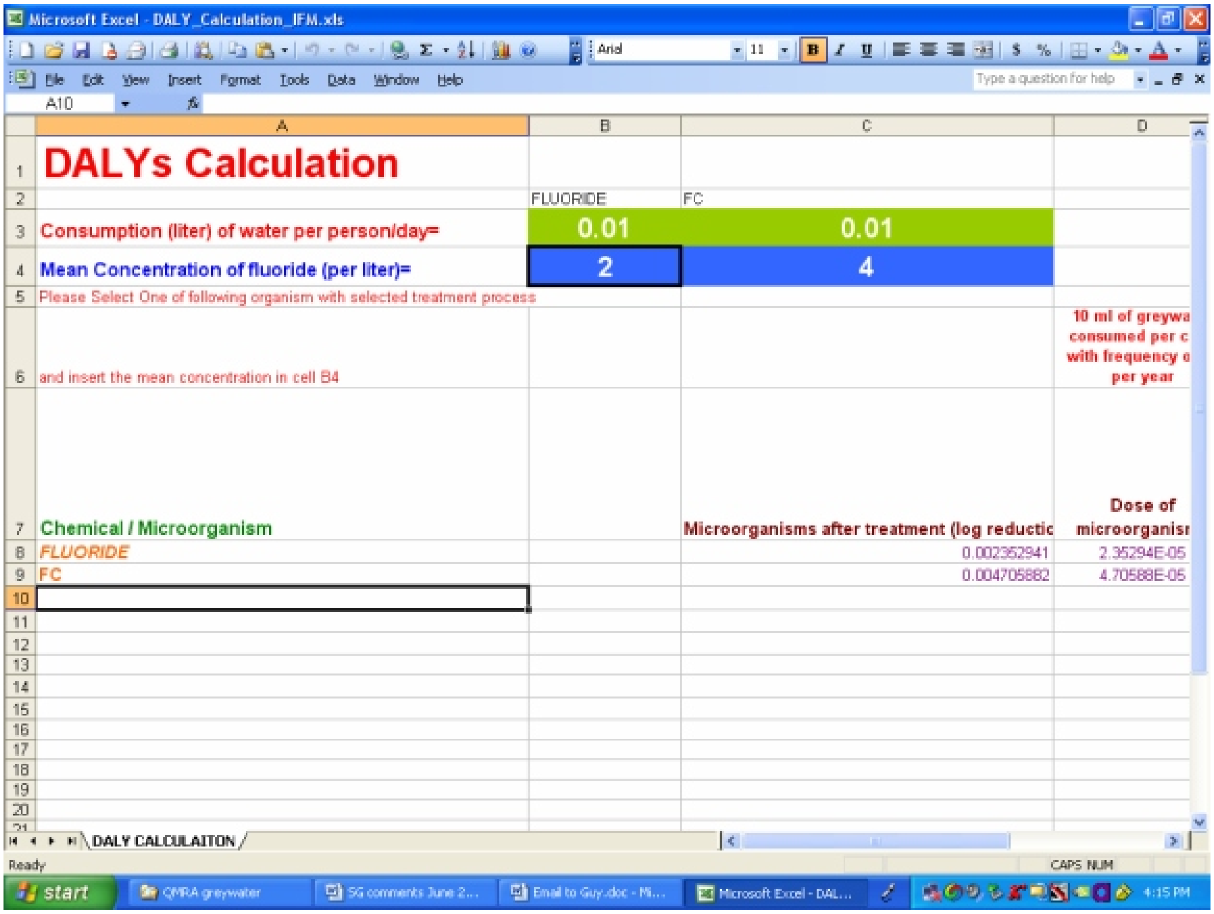


Fig. 2.2 Excel spreadsheet to calculate DALY risk

2.4 Case Study of QCRA

UNICEF and NEERI in Madhya Pradesh, India have undertaken QCRA. It has been applied in the districts of Dhar and Jhabua in Western Madhya Pradesh, India.

2.4.1 Hazard identification

All potential hazards, sources and events that can lead to the presence of these hazards are identified and documented for each component of the exposure routes. These are identified by analyzing samples of water and food for fluoride concentration. The food samples include:

- Cereals (Maize, Wheat, Rice), Pulses (Red, Green and Black grams) were collected from different households, whereas toothpaste, tooth powder, tea, tobacco, local wine, milk powder and pan masala samples of different brands were procured from local markets. Results indicated that fluoride in water was 0.3 to 1.5 mg/l whereas fluoride in food samples was 0.005 to 1.1 mg/kg dry weight (see figure 2.3 and 2.4).

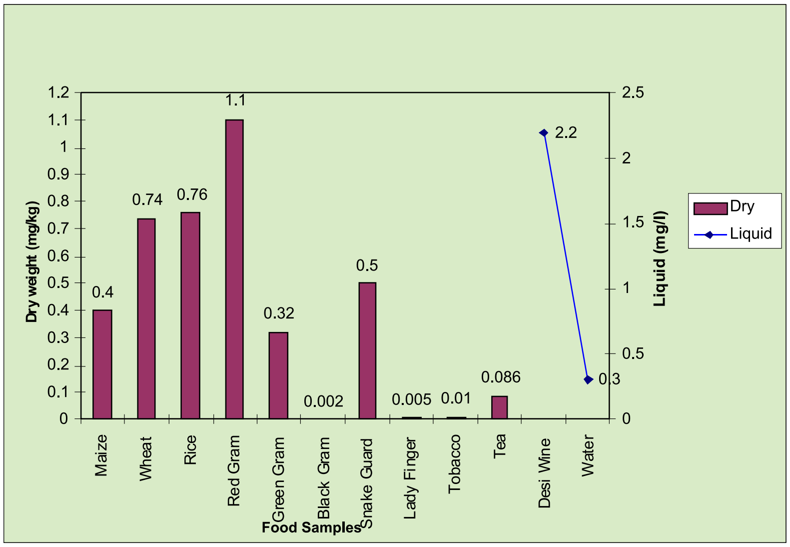


Fig. 2.3: Fluoride in food Items, drinks and drinking water

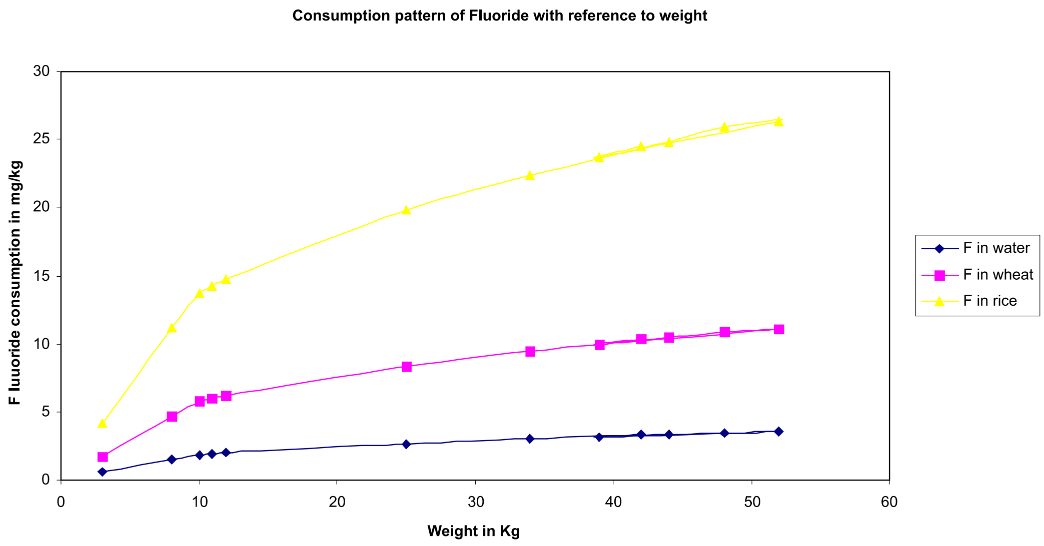


Fig. 2.4: Consumption pattern of fluoride with reference to weight

2.4.2 Exposure assessment

To ascertain what is an acceptable daily intake, the TOLERABLE DAILY INTAKE (TDI) formulae was used. This is calculated using Equation 1:

$$TDI = \frac{(NOAEL \ or \ LOAEL)}{UF} \qquad \ldots\ldots\ldots\ldots(1)$$

Where, NOAEL and LOAEL are no observed and lower observed adverse limits respectively, whereas UF stands for uncertainty factor. Findings from the QCRA highlighted the importance of establishing guideline values for both fluoride intake from food and water.

> **Exposure Assessment at Dhar and Jhabua**
> Maximum TDI value for all exposure routes was observed in the range of 0.4 to 0.6 mg/kg

In this particular study, population is segregated in three different groups i.e. 0-12, 13-20 and >20 and guideline value for different age groups were calculated by using Equation 2:

$$GV = \frac{(TDI \times BW \times P)}{C} \qquad \ldots\ldots\ldots\ldots \qquad (2)$$

GV= Guideline Value

TDI= Tolerable Daily Intake

BW= Body Weight

P= Fraction of TDI fraction allocated to drinking water

C= Daily drinking-water consumption

The calculated guideline values for different age groups are outlined below:

Sr. No	Age groups	Guideline Values, mg/kg
1.	0-12 (Children)	3.44
2.	12-20 (Adolescent)	5.71
3.	>20 (Adult)	5.38

2.4.3 Dose response

The effect of concern is the most common effect of chronic ingestion of fluoride through water and food. In focused communities and in Ashram (boarding) schools tolerable health risk based survey has been carried out to evaluate the prevalence of fluorosis in the region. The health survey reveals that dental and skeletal fluorosis is predominant in the focused communities. A LOAEL/NOAEL analysis indicates that around 90% of affected population with prevalence of 120.7 persons per thousand persons is above the tolerable risk level.

For this study acceptable risk limits based on a point scale methodology adapted from Susheela *et al.* (2004) is considered. A field based health survey was undertaken to ascertain a qualitative estimate of relative levels of acceptable risk.

2.4.4 Risk characterization

The DALY (Disability Adjusted Life Years) were calculated based on methods outlined in Fewtrell *et al.* (2006) and Havelaar *et al.* (2003) with background data from Murray *et al.* (1996).

The average life expectancy in Madhya Pradesh is 55 as a mean value for male and female (Government of India, 2001). The prevalence was calculated as 120.6 per thousand population. The data can be summarized as follows:

- No of healthy life years (55) x the disability weight of full health (0) + life years with disability (25) x disability weight for fluorosis (0.33) + life years lost (30) x the weighting of death (1)
- 55 x 1 + 25 x 0.33 + 30 x 1 = 38.25 per 1000

DALY scores of 38.25/1000 are higher than those recorded in recent studies of Arsenic in South Asia (APSU 2006). Although these should not be compared due to the difference in the control group study.

Fewtrell *et al.* (2006) reported that the disability weight for fluorosis is 0.03 for dental fluorosis, 0.24 for skeletal fluorosis (age 40-59) and 0.5 for skeletal fluorosis in adults >60 years of age. These disability weightings were not used in this study as they were published after the completion of the research.

Observations from the QCRA are useful:

1. For establishing the national standard for fluoride, it is essential to incorporate the QCRA and health risk based approach
2. QCRA also signify the impact of standards on most vulnerable age groups.
3. Consumption of fluoride content through food is as important as through water
4. Results indicate that intake of fluoride in children, adolescents and adults are more from food as compared to water
5. In fluoride affected areas capping of hand pumps is not a sustainable solution as microbial risk will increase due to lack of water for sanitation
6. According to DALY score of 38.25 per 1000, Dhar and Jhabua have high risk of fluorosis and interventions are planned accordingly
7. Rapid health based risk water quality guidelines are required for different states in India.

Chapter 3

INTEGRATED FLUOROSIS MITIGATION II :

WATER MANAGEMENT SOLUTIONS

3.1 INTRODUCTION

As noted in the background and introduction to this manual, a range of mitigation options are required to reduce fluorosis depending on the concentration of fluoride in either the water or the food. These mitigations can be divided into :

a) Water mitigation solutions for fluoride concentrations <3mg/l,

b) Water mitigation solutions for fluoride concentrations >3mg/l

For both levels of mitigations there are a range of different technologies. This chapter will focus on appropriate technological interventions for fluoride concentrations <3mg/l. The subsequent chapter on household level defluoridation techniques will outline solutions for fluoride concentrations >3mg/l.

This chapter will address mitigation solutions for the majority of fluoride affected water sources with a low level concentration of fluoride of <3mg/l. It is divided into two sections as shown in Fig 3.1.

a) Household level defluoridation of water - including dilution/water supplementation techniques

b) School/community level defluoridation of water including sanitary wells, wisewater management and rainwater harvesting/dilution techniques (Fig 3.1 & 3.2),

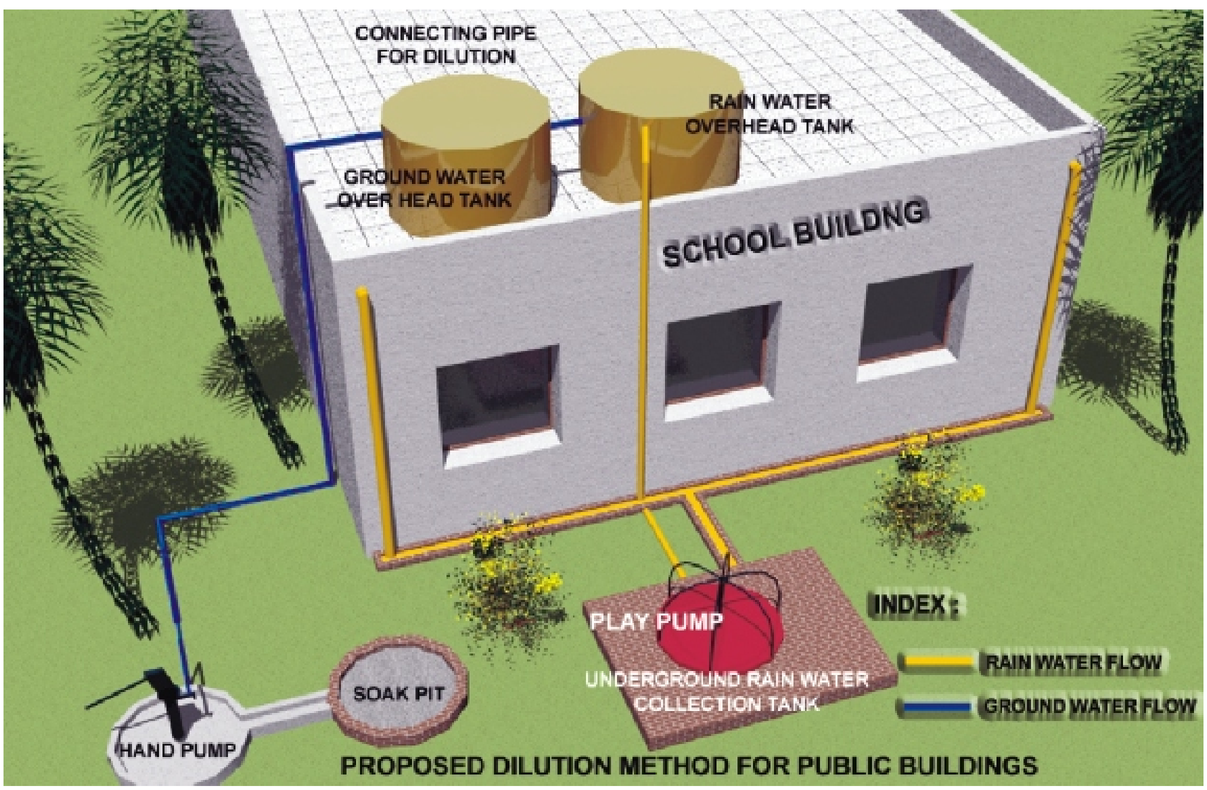


Fig. 3.1: Schematic of dilution technology at school level

3.2 Household Level Dilution of Water

To effectively reduce low concentrations of fluoride in water, UNICEF and NEERI have developed a household level dilution technology (Figure 3.2). The technology comprises of:

1. 7000 l ferro-cement rainwater storage tank
2. 50 l clay household level dilution storage tank.

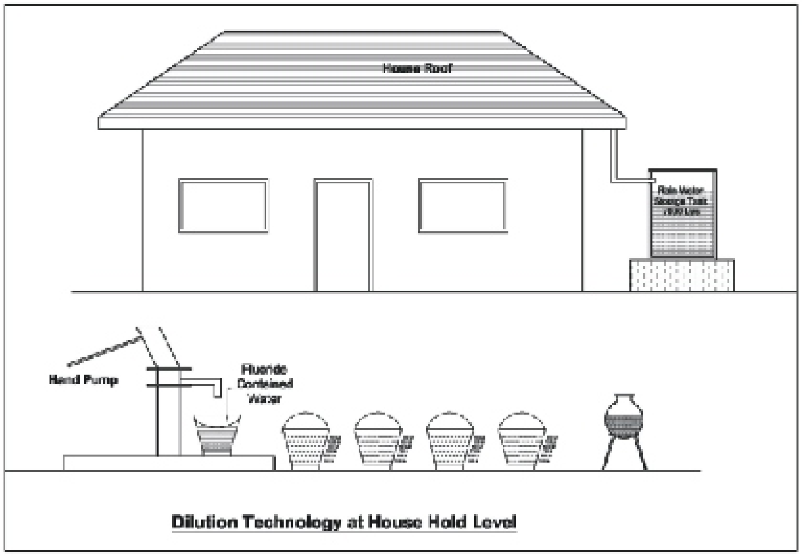


Fig. 3.2: Schematic of dilution technology at household level

The method being promoted involves the collection of rainwater from individual households in a 5000 l storage tank. In order to reduce the demand on the contaminated groundwater and to increase the recharge, individual greywater reuse systems may be used. Complete details of definitions of greywater and of appropriate treatment units can be found in *"Greywater Reuse for Schools in Rural Areas of India" published jointly by NEERI & UNICEF.*

An individual water reuse system recycles between 100 to 150 l per rural household of greywater per day. This reduces the demand on the groundwater by 60% resulting in decreased levels of fluoride during the drier summer months. The household level greywater reuse system is designed as in Figure 3.3.

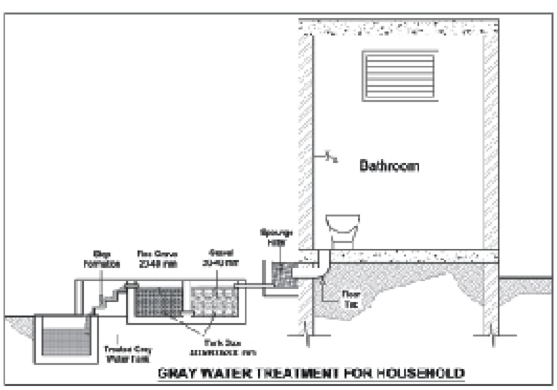


Fig. 3.3: Schematic of greywater treatment for household

The total length of the system is 1.8 m and it is constructed to collect, treat and distribute treated greywater for irrigation and toilet flushing. The system comprises of the following treatment unit processes:

a) Sponge filter to remove surfactants and soaps
b) Gravel (10 to 20mm) to remove sediments
c) Fine gravels (6-10mm) to purify the water
d) Aeration to remove odour
e) Collection tank and pumping.

The systems constructed by UNICEF-NEERI in Madhya Pradesh cost approximately $US 25 (INR 1000=00).

The individual household greywater reuse system reduces the demand of groundwater and increases the availability of greywater for irrigation of calcium rich plants such as "*cassia tora.*"

3.3 School/Community Level Defluoridation of Water

The majority of attention has been placed on household defluoridation of water using absorbents such as activated alumina. Although potentially appropriate for water sources contaminated with high concentrations of fluoride, this manual presents selected alternative, groundwater rainwater solutions to low concentrations of fluoride. These solutions include:

a) Exploration and protection of uncontaminated shallow groundwater sources,
b) Rooftop rainwater harvesting collection and dilution technologies,
c) Source supplementation using greywater reuse/recycling.

3.3.1 Sanitary wells

Experience in Madhya Pradesh and in other states of India, indicate that the majority of fluoride contamination occurs in deep aquifers constructed in fluoride laden geological strata. Due to the increased demand on groundwater, many shallow aquifers are being over exploited for irrigation purposes. Consequently, tubewells are being drilled to deeper depths. One potential solution to this problem is to upgrade and protect shallow aquifers. Outlined below are examples of sanitary well upgradation.

Sanitary Wells in Madhya Pradesh

Surveys undertaken by the Public Health Engineering Department (PHED) of Madhya Pradesh indicate that fluoride concentrations increase in water sources deeper than 25mbgl. Where shallow wells are available, it is recommended that all shallow wells should be:

1. Lined with brick masonry,
2. Covered with a reinforced concrete (RCC) slab
3. Equipped with a IM2/3 handpump
4. Provided with a drainage and soakaway.

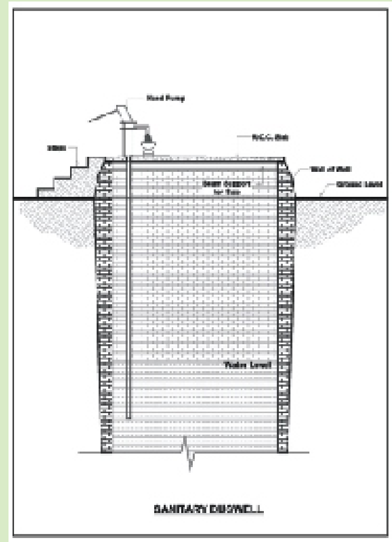


Fig. 3.4: Sanitary wells in Madhya Pradesh

3.3.2 Rainwater harvesting system/dilution

Rooftop rainwater harvesting may not be sufficient to supply potable water for 365 days in a year. It is therefore, advisable to use the rainwater to dilute the fluoride affected groundwater. The design of the rooftop rainwater harvesting system for 50 students includes

Roof area of hostel	:	*150 m^2*
Average rainfall	:	800 mm
Run-off	:	100% (Frequency)
Total availability of water	:	1,27,000 liter
Water collection and storage	:	72,000 liter
Groundwater recharge	:	55,000 liter

3.3.3 Design of roof-water harvesting system

Rooftop rainwater harvesting systems have three main components as depicted in **figure 3.5:**

1. *Catchments surface (roof) for collection of rainwater*
2. Delivery system to transport the water from the roof to the storage reservoir (gutters and drainpipe)
3. Reservoir to store the rainwater until it is used. The storage tank has an extraction device that depending on the location of the tank may be a tap, rope and bucket or a pump.

In addition, filter and first flush systems are also integrated parts of roof-water harvesting system as depicted in the **Figure 3.5.**

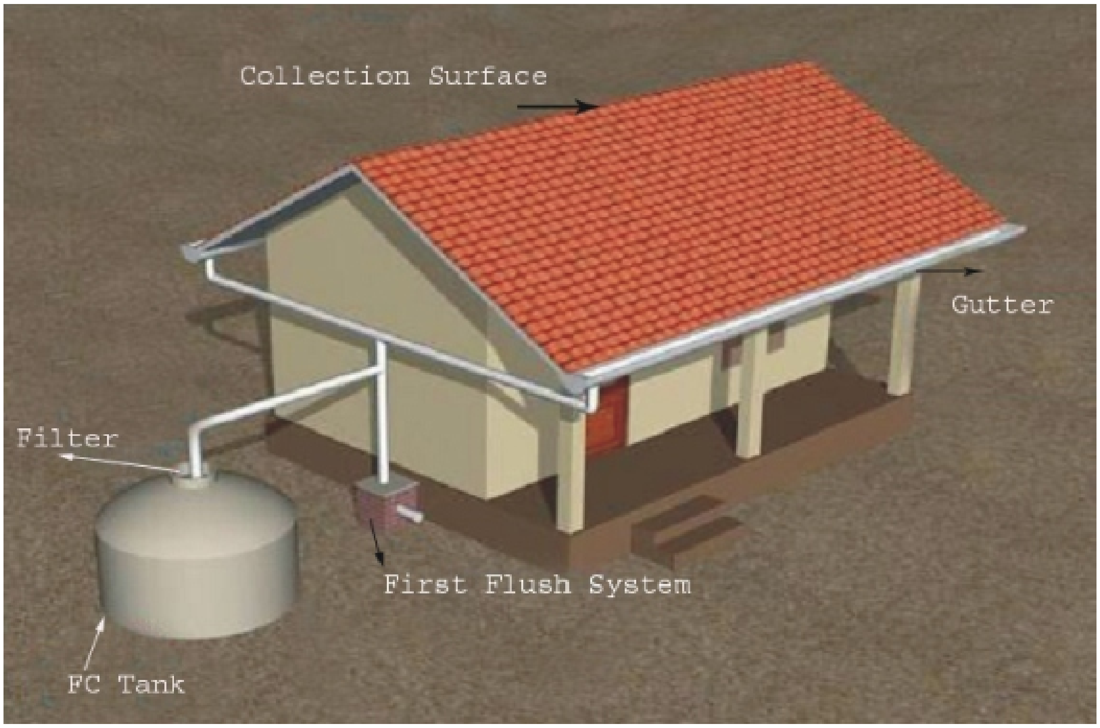


Fig. 3.5: Components of roof water harvesting system

The annual yield of runoff and runoff coefficient for various roof materials are given in Table 3.1.

Table 3.1: Estimation of runoff

Annual yield of runoff Q = K x I x A	**Run off coefficient**
Where Q = Annual yield in liters	GI sheet - 0.9
I = Annual rain fall in mm	Asbestos - 0.8
A= Catchment area in m^2	Tile - 0.75
K= Runoff coefficient	Concrete - 0.7

3.3.4 Design of water collection system

Volume (V) = P x Q x D

Where P - No. of users

Q - Daily per capita consumption rate (liters)

D - Number of critical dry days

The cost of water collection tanks of different materials is given below:

Table 3.2: Cost of water collection tanks of different materials

Material of construction	Cost per liter
Concrete	Rs 4.00 to 5.00
Fiber Glass	Rs 4.00
HDPE	Rs 3.00 to 4.50
Brick masonry	Rs 3.00 to 4.00
Steel	Rs 5.00
Ferro cement	Rs 1.25 to 1.50

3.3.5 Design of dilution system

Dilution technique is applied to mix rainwater collected through rainwater harvesting and groundwater containing fluoride to ensure availability of safe water for drinking and cooking purposes. The dilution technology uses the results of the Quantitative Chemical Risk Assessment (QCRA) to estimate the percentage concentration of groundwater and rainwater to reduce the fluoride concentration. In schools this may include a 1:2 dilution to reduce the concentration of fluoride of 32mg/l to 1mg/l. The main components of the dilution system are depicted in fig. 3.6.

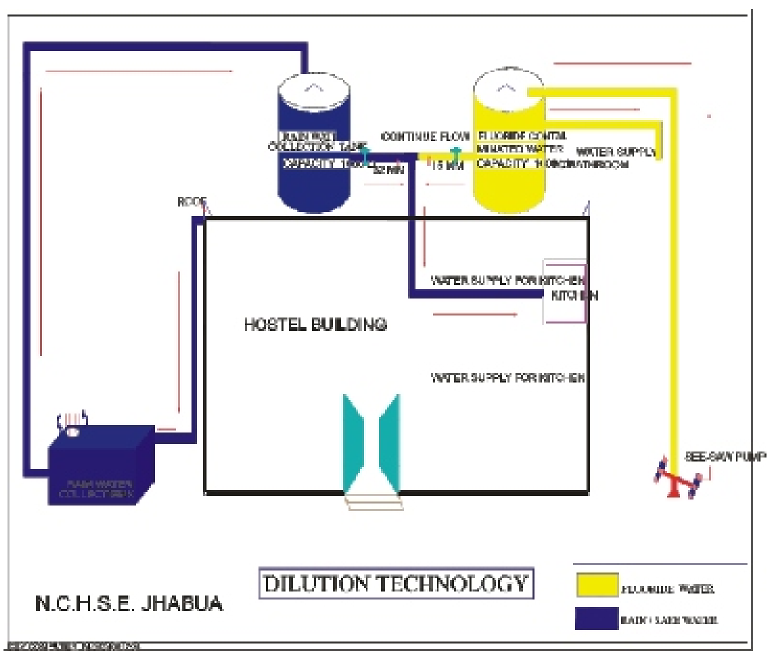


Fig. 3.6: Scheatic of dilution technology

To dilute the contaminated groundwater, the groundwater and rainwater are blended in two overhead tanks. The following equipment are required for undertaking the dilution technique in household or schools:

a) 2 x 1000l pvc storage tank
b) 63mm GI riser pipe from tubewell to overhead tank
c) 63mm GI riser pipe from rainwater tank to overhead tank
d) 32mm GI connecting pipe from rainwater tank
e) 15mm GI connecting pipe
f) t joint with 32 to 15mm reducer
g) 15mm GI riser pipe to 15mm bip tap.

3.4 Pumping Requirements

There are several types of pumps available, which can be used for lifting water. However, it is useful to use play-pumps in school as India Mark II and III hand pumps are source of drinking water. Therefore, the idea of 'play pump technology' emerged as an ideal alternative to provide both joyful space and meeting the water needs of the school. The idea is to use children's play as energy resource to draw water from hand pumps up to the storage tank. This not only reduces the 'burden' of water on children but also creates joyful learning space in the school. The children push the merry-go-round again and again. As they run, a device in the ground beneath them begins to turn. With every rotation of the merry-go-round, water is pumped out of a well, up through a pipe, and into a tank high above the playground. Similarly sea-saw pump can also discharge water in to the tank above with every up and down movement it makes.

The rainwater harvesting and dilution systems are developed as part of water management solutions in boarding schools in Madhya Pradesh. Greywater treatment and reuse is another important part of water management solutions. The guidance on greywater treatments and reuse can be obtained in the Manual "Greywater Reuse for Schools in Rural Areas of India" published jointly by NEERI & UNICEF.

3.4.1 Piped water supplies

In areas where surface water is accessible, water can be collected treated and pumped to fluorosis affected communities. The limitation in this approach is the cost of the system and the increased potential of microbiological contamination due to intermittence of pumping regulations.

Chapter 4

INTEGRATED FLUOROSIS MITIGATION III:

HOUSEHOLD LEVEL MITIGATION THROUGH DEFLUORIDATION OF WATER

4.1 INTRODUCTION

As water has been identified as one of the potential sources of fluoride (F) intake, a great deal of scientific efforts have been put in towards defluoridation of water. Common techniques used to remove fluoride from water can be divided into two categories namely *Precipitation based techniques and Adsorption and Ion exchange based techniques.*

In addition, a few other techniques have also been reported to be effective, such as membrane based techniques, reverse osmosis, electrodialysis, Donnan dialysis and limestone reactor. The efficiency of these techniques depends on several factors and conditions of use. Recently more attention has been focused towards development of effective adsorbent materials for defluoridation due to the several advantages of the adsorption technique. A range of adsorbent materials such as zeolites, modified aluminas, bauxite and bone char have been studied for defluoridation of contaminated water. However, some of these are not found to be cost effective, while other adsorbents are reported to show significant potential for defluoridation of water. Still, there remain at least a few concerns related to the use of existing materials for defluoridation of water:

- Cost of water treatment
- Removal of low concentration of F, and effect of pH and other water quality parameters
- Effective regeneration of adsorbents and handling of waste water/sludge
- Safe disposal or utilization of F loaded adsorbents
- Quality of treated water e.g. release of undesired element from adsorbent
- Community acceptance of fluoride removal.

In view of this, NEERI and UNICEF jointly carried out the following activities:

- Development of new materials for defluoridation of water at domestic level
- Development of simple, low cost domestic level defluoridation techniques for rural areas
- Laboratory and field evaluations of the defluoridation materials and techniques
- Users' perception studies, to infer about the technical requirements and acceptability of household defluoridation technique, especially in the rural/ tribal areas
- Ranking of defluoridation materials based on their potential for defluoridation of water in target areas.

Household vs Community Level Defluoridation of Water

Most of the defluoridation techniques in-vogue have been designed for the community level water treatment. This kind of centralized treatment is usually done considering the advantages related to better control over the complex treatment process, while such a treatment is rather essential when water contamination has adverse impacts even through skin contact e.g. dearsenification of water. As the health effects of fluoride are only through its ingestion, it may be more practical to treat only the water required for drinking. This can save considerable treatment cost as a small portion of water is only used for the drinking purpose. However, many of the water defluoridation techniques in vogue are beset with the limitations related to their cost and complex regeneration processes and requirement of electricity etc. In view of this, efforts have been made in the present study to explore the feasibility of household level defluoridation of drinking water. The major challenge was its affectivity, acceptibility, and feasibility in relatively less developed rural areas of Madhya Pradesh, India, while it was also not easy to convince and train the households for various other options designed for the domestic level defluoridation of water.

4.2 Development of Defluoridation Materials / Media:

Development of new defluoridation technique is a step wise and complex process including laboratory development, bench scale studies, pilot scale and full-scale demonstrations. The present study is limited to only laboratory level development of new defluoridation materials/ media for defluoridation of drinking water. However, a limited number of field demonstration have also been carried out including users' perception study for domestic level defluoridation of water in the areas of Dhar and Jhabua districts of Madhya Pradesh.

Wide array of materials based on following matrices have been synthesized and evaluated for removal of fluoride:

1. Modified alumina based adsorbents
2. Modified zeolites
3. Clay and claypot based adsorbents
4. PoP (Plaster of Paris) based adsorbents
5. Biopolymer based composite **adsorbents.**

The defluoridation materials have been developed by following two approaches: (i) Modification of existing potential defluoridation materials like alumina, clays, to overcome their limitations and (ii) Development of new materials with better properties for defluoridation of water. More emphasis was given towards development of low-cost defluoridation materials, which can be applied for domestic level defluoridation of water in target rural areas.

4.3 Laboratory Evaluations of the Defluoridation Materials:

4.3.1 Adsorption experiments

All chemicals used in the present study were of analytical reagent grade. A stock solution containing 1000 mg/l fluoride was prepared by dissolving appropriate amount of sodium fluoride in double distilled water. Experimental solutions for adsorption and analysis were then prepared diluting the stock solution. A required quantity (50 ml) of the fluoride solution was taken in a PVC conical flask and known weight of adsorbent material was added and then kept on a rotary shaker for 24 hr in order to attain the equilibrium. The solution was then filtered through Whatman filter paper No. 42 and the filtrate was analyzed for residual fluoride concentration by ion selective electrode method as well as spectrophotometrically using SPANDS dye. The release of any undesired elements from adsorbent after the equilibrium adsorption study was estimated by ICP-AES method. Most of the experiments were repeated thrice for better accuracy. The experimental error was observed to be within 2 %. All adsorption experiments were conducted at room temperature of 30 ± 2C.

The specific amount of fluoride adsorbed was calculated from:

$$q_e = (C_0 - C_e) \times \frac{V}{W} \qquad (1)$$

where q_e is the adsorption capacity (mg/l) in the solid at equilibrium; C_0, C_e are initial and equilibrium concentrations of fluoride (mg/l), respectively; V is volume of the aqueous solution and W is the mass (g) of adsorbent used in the experiments.

Batch adsorption experiments were conducted to investigate the effect of various parameters like contact time, adsorbent dose, initial concentration, presence of interfering ions, pH etc. The effect of solution pH on fluoride removal was studied by adjusting the pH of the solution by using 0.1N HCl or 0.1N NaOH. The adsorption was carried out over the pH ranges of 5-9. The effects of the presence of cations and anions were studied in a batch mode experiments, which were carried out by taking 50 ml of fluoride-ions-spiked aqueous solution of initial concentration of 5 mg/l and an optimum dose of adsorbent. In the study of the effect of presence of co-existing ions, the pH of the aqueous solution was not controlled. Actual water samples collected from fluoride affected area (Tarapur, Dhar, Madhya Pradesh) were also tested for fluoride removal.

The selectivity of the adsorbent for fluoride removal has been demonstrated in the presence of other anions like sulphate, nitrate, carbonate and bicarbonate. Fast kinetics has been achieved using simple stirring of the adsorbent for a time ranging between 10-20 min to reduce the levels of fluoride from 10.2 mg/l to <1.5 mg/l. The composite materials developed as part of NEERI-UNICEF joint research overcomes the problem of low adsorption capacity of the conventional materials. Cost-effective regeneration of this material is being explored and initial results are promising.

4.4 Development of Domestic Level Defluoridation Techniques:

As already mentioned, the domestic level defluoridation has several advantages specially with respect to the cost, however, it is important to develop a defluoridation technique, which is effective as well as acceptable to the rural population. The technique has to be extremely simple to use, low cost, manual and also socially acceptable. The following simple techniques have been developed for the application of defluoridation materials in the rural areas of Madhya Pradesh:

Technique 1 : Direct contact or loose sorbent (Fig. 4.1)

Step 1: Take one litre fluoride containing water in a suitable container

Step 2: Open the packed adsorbent pouch and add into the water

Step 3: Stir the contents with the help of wooden stick for 10 minutes

Step 4: Remove the adsorbent by decantation/filtration through cloth.

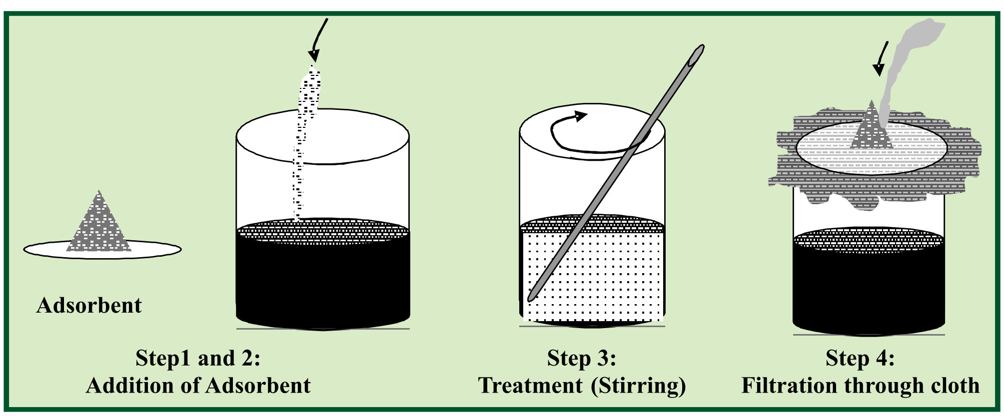


Fig. 4.1: Direct contact or loose sorbent method for defluoridation of water

Technique 2: Bamboo column (Fig. 4.2)

Step 1: Prepare the bamboo column as shown in Fig. 4.2

Step 2: Wash the column and add the pre-weighed quantities of adsorbent

Step 3: Fill the column with fluoride containing water and collect the treated water at bottom.

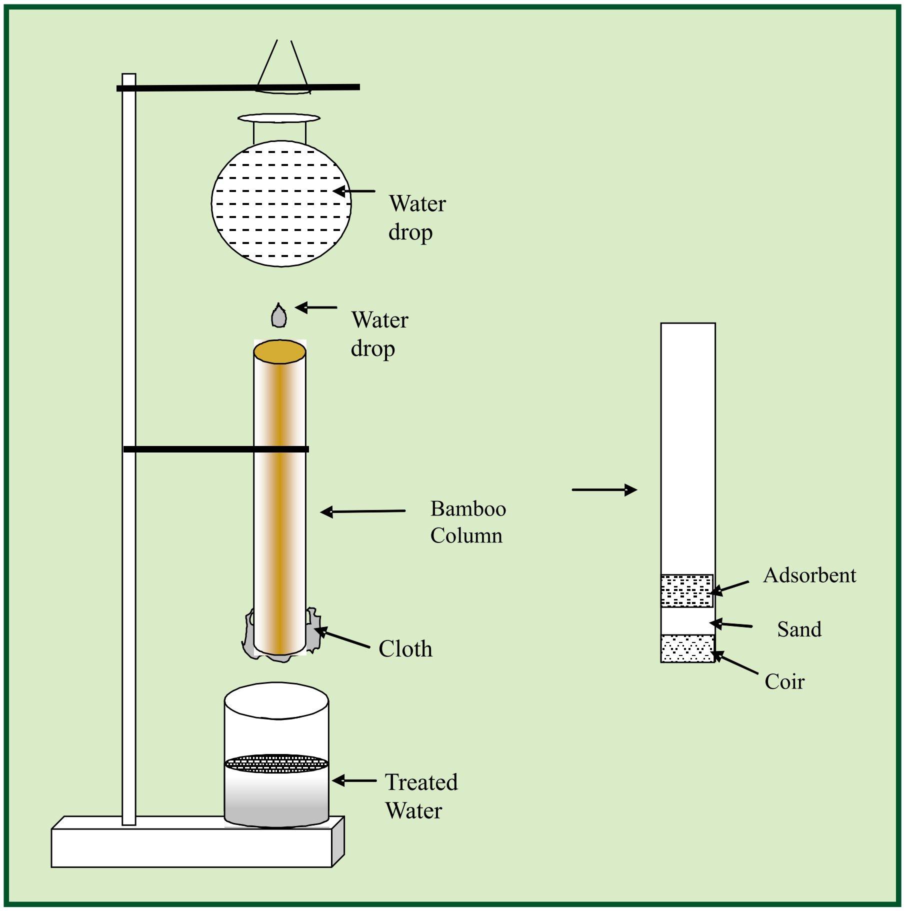


Fig. 4.2: Bamboo column method for defluoridation of water

Technique 3: Stacked Matka (earthen pot)

Step 1: Take two Matkas. Make a fine whole in Matka-1. Make 3-4 small Holes in Matka 2.

Step 2: Add fluoride containing water in Matka-1

Step 3: Prepare Matka-2 as shown in Fig. 4.3.

Step 4: Stack the Matka-1 and Matka-2 as shown in Figure 4.3 and collect the treated water coming out of Matka 2.

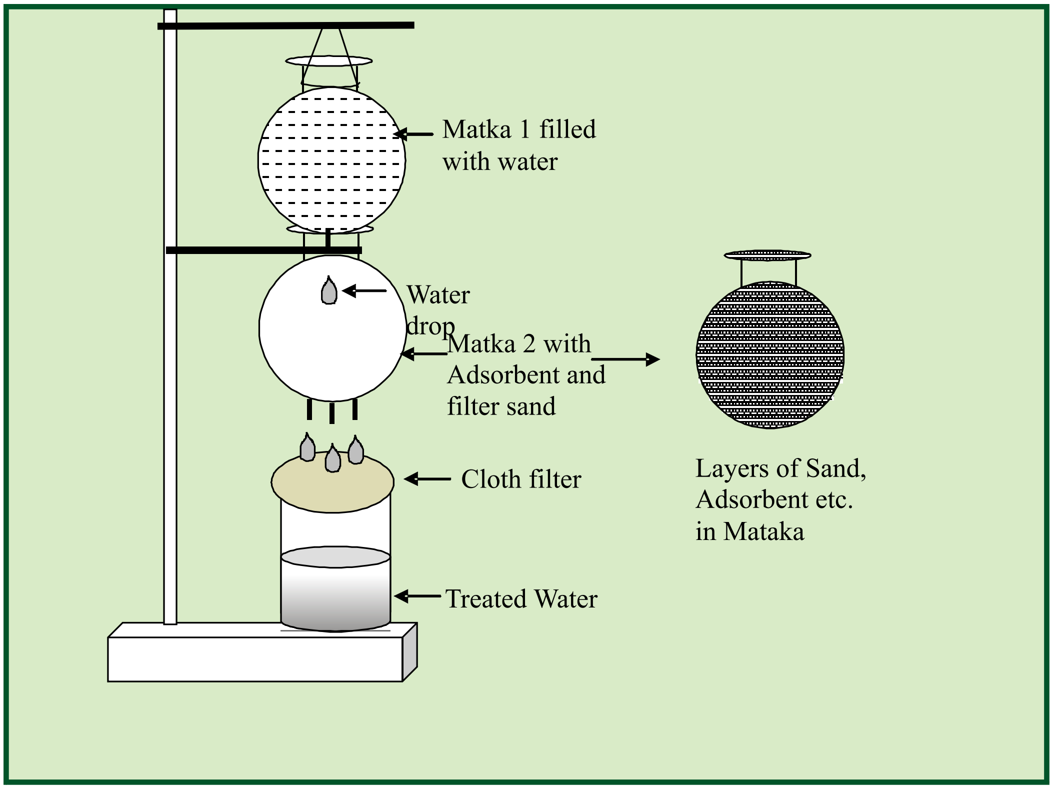


Fig. 4.3: Stacked matka method for defluoridation of water

Technique 4: Defluoridation Pudiya ("DF-Pudiya")

For small quantity of water

Step 1: Prepare the fluoride **DF-Pudiya** as shown below in Fig. 4.4A.

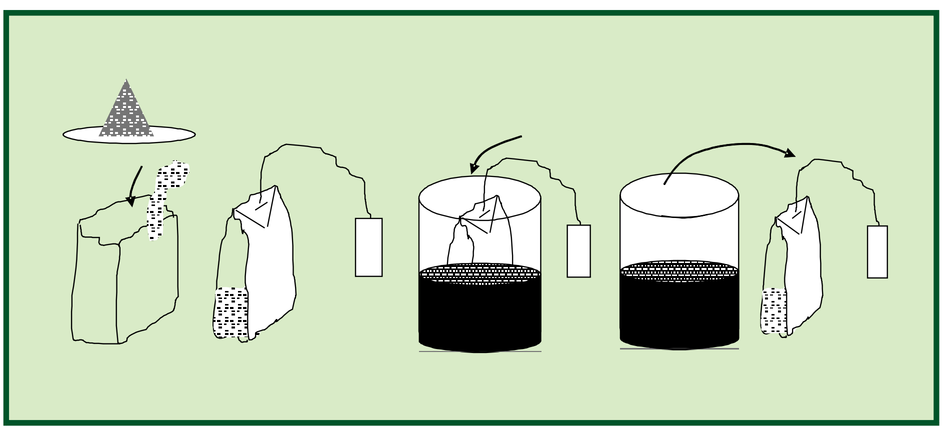


Fig. 4.4A: Use of DF-Pudiya for defluoridation of water

Step 2: Take fluoride containing water in a suitable container

Step 3: Take one **DF-Pudiya** prepared for desired amount of water and stir in the fluoride containing water for 10 minutes

Step 4: Remove the **DF-Pudiya** and use treated water.

For larger quantity of water (Fig. 4.4B)

Step 1: Prepare the **DF-Pudiya** as shown in Figure 4.4A.

Step 2: Take one litre fluoride containing water in a suitable container

Step 3: Take multiple number of **DF-Pudiyas** prepared for required amount of water and tie on wooden stick as shown in Fig. 4.4B. Step 4: Stir the fluoride containing water for 10 minutes with stick having **DF-Pudiyas**

Step 5: Remove the stick and use the treated water.

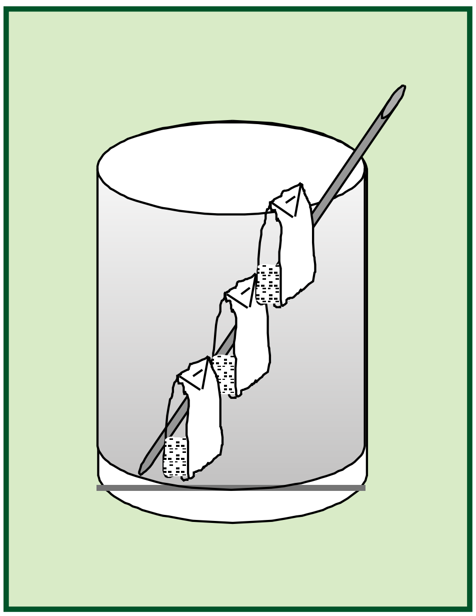


Fig. 4.4B: Use of DF-Pudiya for defluoridation of large quantity of water

4.5 Field Evaluation and Users' Perception Studies

Field evaluations as well as users' perception study was conducted at two villages in Dhar districts of Madhya Pradesh, India, through demonstration of four household methods of fluoride removal, namely loose sorbent, DF-pudiya (Sachet method), bamboo column and stacked matka as detailed in **4.4.** Two questionnaires (**Annexure II**) were designed to survey the users' perception and population characteristics.

4.5.1 Population Surveyed

Two questionnaires were designed to survey the users' perception and population characteristics. The study area was rural and the local population was mostly farmers or labors on farms. 38 families have participated in the survey on users' perception. Adults are mostly illiterate and children are school students in most of these families. **Fig. 4.5** shows distribution of families with number of literate members. Prevailing trend of education was significant and 95% of the families were of the opinion that they can afford education for children. 54% of the respondents expressed high satisfaction level with education facility whereas 46% were reasonably satisfied. Information on source of water for the population was obtained and presented in **Fig. 4.6A;**

- 60% population is dependent on several hand-pumps in localities
- 35% uses open wells
- 5% have access to bore wells fitted with water-lifting motorized pumps.

4.5.2 Users' Perception about Type of Treatment Method

Due to several awareness programs by UNICEF, PHED, other organizations and NGOs in these areas, people are aware of health problems associated with high fluoride levels in ground water. The survey reveals that children are more severely affected (78%) as compared to adults (22%). A large section of the respondents (64%) expressed favorable opinion as regards to acceptance of defluoridation technique if offered to them. The unwilling population was about 25% and 11% of the population did not express their opinion (**Fig. 4.6B**). The household methods developed for rural areas were demonstrated to the local population and feedback on simplicity, cleanliness, suitability and safe nature of methods was derived by personal interview with the respondents.

Analysis was carried out for assessing the simplicity of method, and is represented in **Fig. 4.7A.** About 57 % of the respondents were of the opinion that loose sorbent method is the simplest approach. 24% users opted for sachet and 8% opted for bamboo column method as per as simplicity of the method is concerned. 8% of the respondents did not show any preference while 3% of the respondents opted for all the methods. Loose sorbent treatment was identified as the cleanest method by nearly 48% of the users (**Fig. 4.7B**) in spite of direct addition of adsorbent to water. This may be attributed to the use of filtration step for separation of adsorbent, which offers a feel of adsorbent separation and physical cleaning of water. 27% of the respondents opined that the next cleaner method is bamboo column (**Fig. 4.7B**). A relatively small percentage of respondent (16%) opted for Sachet method, while no respondent was of the opinion that none of these methods is clean. 9% of the respondents were of the opinion that all the methods are clean to be used for drinking water treatment. Similarly, taking into account safety and health considerations, the respondents have identified loose sorbent method followed by bamboo column method as safe methods, relatively free of health hazards (**Fig. 4.7C**). Findings with respect to suitability are presented in **Fig. 4.7 D, which inferred the following:**

- 38% users opted for loose adsorbent treatment.
- 28% users opted for bamboo column method
- 21% opted for sachet method.
- 10% of users were expecting alternate, more suitable method for fluoride removal.
- 3% of users did not show any preference and opted for all the methods.

Thus, according to respondents /users' perception, loose adsorbent treatment emerges out to be the most favoured method based on different criteria including suitability, simplicity, cleanliness and safety as depicted in **Fig. 4.7**.

Respondents/users have also been interviewed for their perception regarding individual treatment method with specific reference to change in smell, colour and turbidity in treated water as compared to raw water. Most of the respondents were of the opinion that there is no significant odour in the treated water using loose sorbent and sachet methods (**Fig. 4.8**). Some of the respondents /users opined even improvement in odour in case of loose sorbent /sachet method, whereas bamboo column treatment was imparting bad odour as expressed by about 33% of respondents/users. Regarding observations pertaining to change in colour, majority of the respondents (93.5%) were of the opinion that the colour of water remained unchanged using loose sorbent treatment. A few users had unfavorable opinion regarding the colour of treated water wherein 3.23% of the respondents/ users opined that colour was unacceptable (or bad). An equal percentage (3.23%) of users were of the opinion that the treatment resulted in improvement in colour.

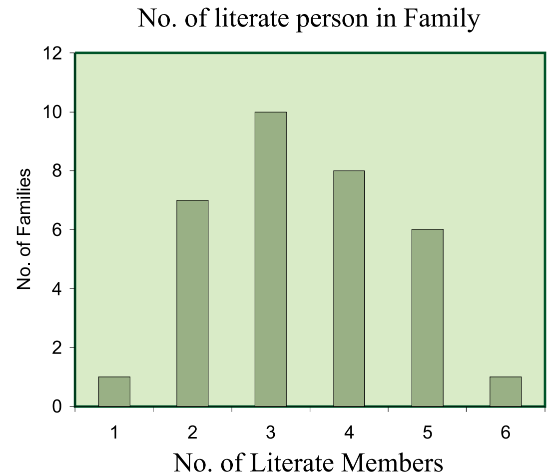
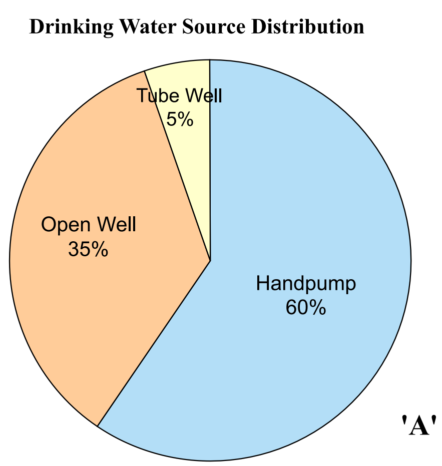


Fig. 4.5: Distribution of families in study area based on number of literate persons in a family



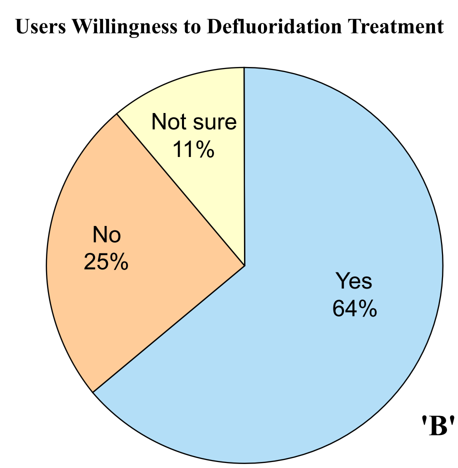


Fig. 4.6: A) Source of water used for drinking/cooking and B) acceptability of users for defluoridation treatment

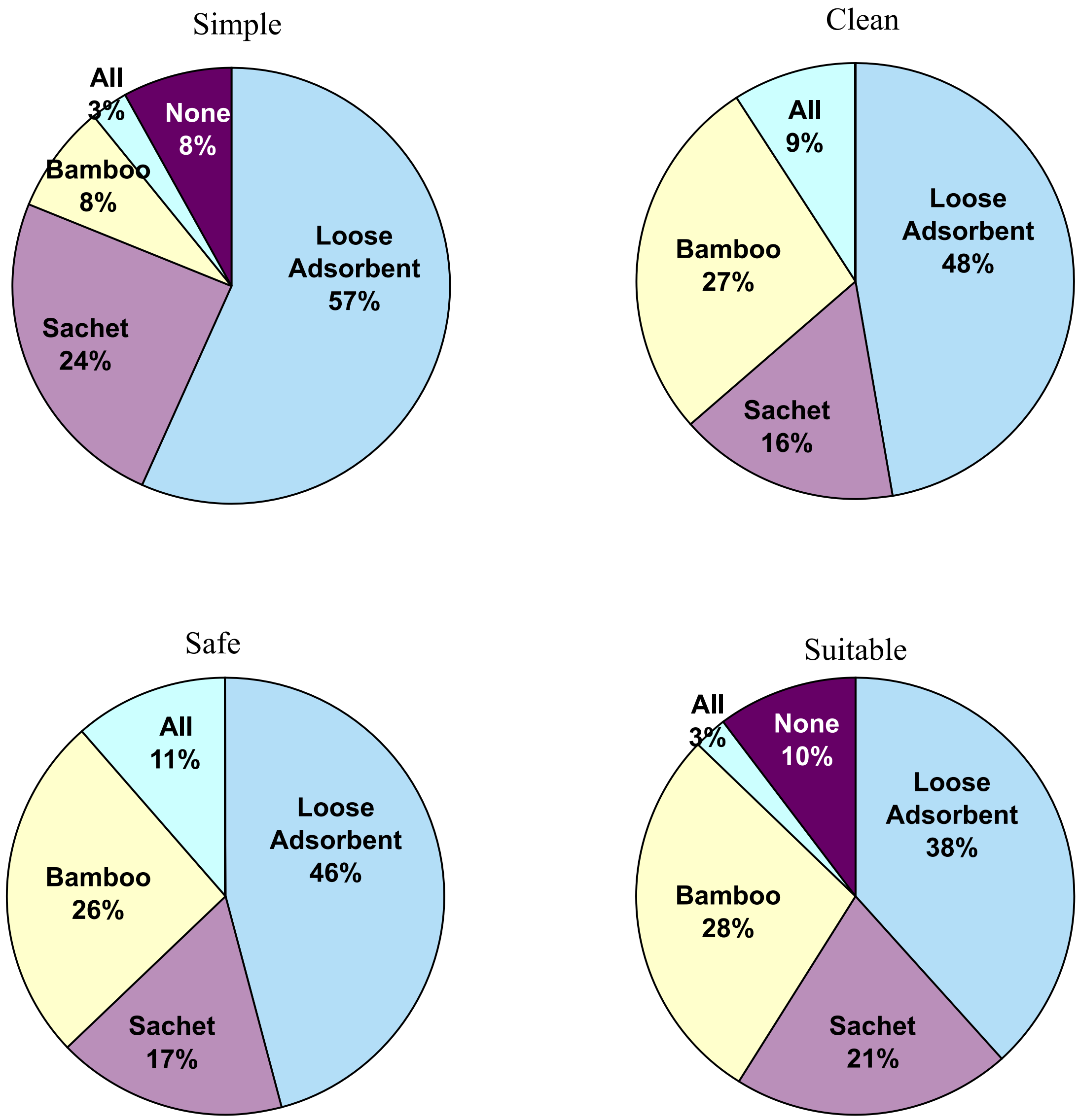


Fig. 4.7: Perception of users regarding various methods for defluoridation of water

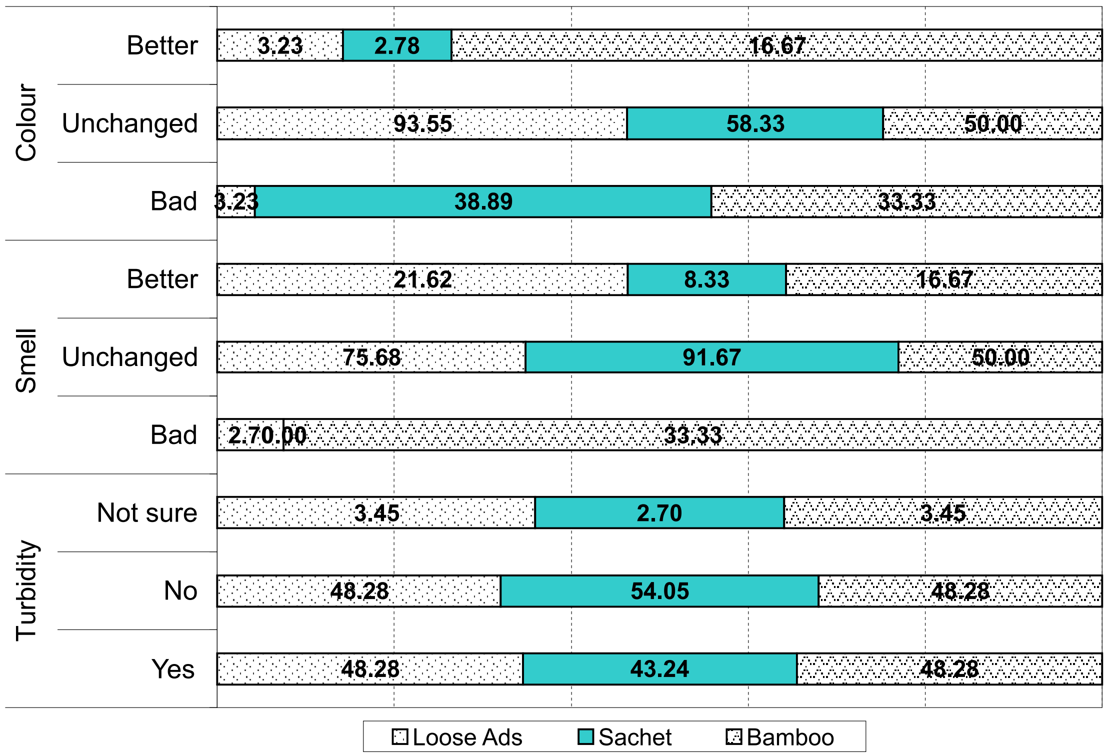


Fig. 4.8: Users' perception about quality of treated water with various methods of defluoridation

It is apparent from the users' perception study that the household treatment of water is appropriate and acceptable for treatment of small quantities of water required for drinking and cooking. This can also substantially reduce the cost of defluoridation of water, as only a small portion of total water requirement needs to be treated. Three potential methods have been developed using proprietary adsorbents (developed under the present study) for application in rural households. The users' perception study conducted on these methods reveals that population in the study area is willing to accept the fluoride removal treatment and would prefer loose adsorbent method over other methods. This method was most preferred even under the criteria of suitability, simplicity, cleanliness and safety of the methods.

4.6 Ranking of Materials and Cost Effectiveness

Various materials have been evaluated in batch studies to estimate their adsorption capacity for fluoride removal from simulated water**.** Mass of adsorbent required for reducing fluoride concentration from 5 to 1 mg/l for volume of 1 m^3 of water is compared and presented in **Table 4.1**. It is apparent from the results that the biopolymer-based composite adsorbent (NEE-CEF1) shows high adsorption capacity of 4.1 mg/g when allowed to attain equilibrium. This particular adsorbent is a composite of naturally occurring biopolymer and titanium hydroxide/oxide. Some other materials also appear potential for defluoridation of water.

Table 4.1: Adsorption capacities of different adsorbents and mass of adsorbent required for reducing fluoride concentration from 5 to 1 mg/l for 1 m^3 of water

Sr. no	Adsorbent	Adsorption capacity (mg/g)	Adsorption intensity (n)	Mass of Adsorbent (kg)	Ref.
1.	NEE-CEF1	4.11	0.785	0.97	Present study
2	NEE-CEF2	2.56	0.275	2.31	Present study
3	PoP-chitosan	2.33	0.256	1.72	Present study
4	Meso-alumina	2.03	1.143	1.97	Present study
5	La-Bentonite	0.205	0.314	19.51	Present study
6	La-V-GL-Alumina	1.2	1.02	3.33	Present study
7	PoP	0.38	2.075	10.53	Present study
8	Chitin	0.33	0.774	12.12	Present study
9	AIC-300	0.54	-	7.41	Ramos *et al.* (1999)
10	α-Alumina	0.82	-	4.88	Ramos *et al.* (1999)
11	β-Alumina	2.25	-	1.78	Ramos *et al.* (1999)
12	Activated Alumina	1.31	-	-	Present study

The cost of treatment including the regeneration cost and life of adsorbent will be the governing factors for their techno-economic feasibility in the field. The treatment cost may be compared with the cost of supply of potable water to the community. Prevailing cost of treatment of surface water and supply through municipal water system in India is around Rs. 35 to 40 (approx. US$ 1) per m^3. Whereas, local level transportation of surface or well water through tankers of 3 to 5 m^3 capacity would typically cost about Rs. 70 to 80 per m^3. In case of scarcity of water resources it may be unavoidable to use ground water and the treatment cost targeted is Rs. 50 to 60 per m^3. The cost may be justifiable, as the defluoridation treatment will result in concomitant benefit of fluorosis mitigation. Regeneration studies have been conducted for the adsorbent using different regenerating media. The results obtained are promising and further studies are in progress for optimization of regeneration processes. A detailed cost-effectiveness analysis of adsorbents/treatment considering production cost, reuse and regeneration will provide the basis for final ranking of adsorbents.

4.7 Performance Evaluation of Materials using Field Water

The process developed for the synthesis of biopolymer-based composite adsorbent is highly reproducible. Nearly 50 sets of samples have been synthesized in the laboratory with excellent reproducibility in material synthesis and its fluoride uptake properties. The performance of these samples has also been evaluated for ground water collected from Kanya Ashram, Tarapur, Dhar district, Madhya Pradesh. It is apparent from the results presented in the **Table 4.2** that the levels of pH, TDS, conductivity and fluoride meet the prescribed standards for each of these parameters. Turbidity was less than 5 NTU for nearly all the treated samples. The biopolymer-based composite adsorbent has also been tested for different field water samples as well as diluted field water samples. The samples have been subjected to third party substantiation and the results are presented in **Table 4.3**, which further substantiate the excellent defluoridation properties of this material with no adverse effect on water quality.

Table 4.2: Fluoride removal from field water using biopolymer based composite adsorbents and activated alumina

Contact time: 20 min, Dose: 8 g/l,

Material	Sample	Initial F^- Concentration (mg/l)	Final F^- Concentration (mg/l)	TDS (mg/l)	Conductivity (μS/cm)	pH
NEE-CEF1	Field Water (Kanya Ashram, Tarapur, Dhar district)	9.04	1.63	621	922	7.1
NEE-CEF2	Field Water (Kanya Ashram, Ukara, Dhar district)	4.67	0.54	304	454	6.8
NEE-CEF1	Diluted Field Water (Kanya Ashram Tarapur, Dhar district)	5.10	0.55	495	739	6.5
Activated alumina	Diluted Field Water (Kanya Ashram Tarapur, Dhar district)	5.10	1.72	464	691	7.1

Table 4.3: Water quality test report obtained from third party

- Date of sample collection : 28.09.2006
- Date of receipt : 28.09.2006
- Date of report : 03.10.2006
- Nature of sample : Water Sample -
  - i) Sample**NEE-CEF1** (Treated with biopolymer based composite adsorbent)
  - ii) Sample**NEE-CEF2** (Treated with another biopolymer based composite adsorbent)

Sr. no.	Parameter	Unit	Untreated water	NEE-CEF1	NEE-CEF2
1	Colour	-	Colourless	Colourless	Colourless
2	Odor	-	Odourless	Odourless	Odourless
3	pH	-	7.0	6.3	7.4
4	Turbidity	NTU	<1	0.5	1.2
5	Total Dissolved Solids (TDS)	mg/l	477	478	560
6	Alkalinity as ($CaCO_3$)	mg/l	37	96	144
7	Total Hardness	mg/l	60	64	100
8	Residual Chlorine	mg/l	BDL	BDL	BDL
9	Chloride	mg/l	292	4.86	11.6
10	Fluoride	mg/l	10.2	0.01	0.01
11	Calcium as Ca	mg/l	14.4	17.6	19.2
12	Total Coliform	MPN/100	11	0	0
13	*E.coli*	MPN/100	7	Absent	Absent

Case Study: Users' Perception Study on Household level Defluoridation Techniques in Rural Areas

Location : **Dhar, M.P., India**
Year of study : **2006**

People in the study area are willing to accept the fluoride removal treatment

Loose adsorbent method is the most preferred treatment by end-users

Fluoride concentrations in ground water have been monitored in rural areas of Dhar and Jhabua districts in Madhya Pradesh, India. Further, fluoride removal from drinking water has been achieved by using adsorbents specially developed for domestic applications. These adsorbents have been evaluated using three different methods namely; loose adsorbent, pre-packed sachet and packed bamboo column. Comparative evaluation of these methods has been demonstrated in the laboratory and field. The stringent limit of 1 mg/l for fluoride concentration in drinking water has been achieved by use of specially designed adsorbents. A feedback from end-users in Tarapur and Ukala villages of Dhar districts Madhya Pradesh regarding the defluoridation methods and their acceptability has been collected. Users' perception regarding these household treatments reveals encouraging response for defluoridation methods. The users' perception study conducted on these methods reveals that population in the study area is willing to accept the fluoride removal treatment and would prefer loose adsorbent method over other methods. Even considering the criteria of suitability, simplicity, cleanliness and safe methods, the loose adsorbent treatment method emerges out to be the most favored method.

A number of materials have been reported for defluoridation of water, however, most of these materials show certain limitations for their techno-economic feasibility for the field applications specially in the rural areas. It will be therefore, useful to either modify the existing defluoridation materials with respect to their limitations or to develop new materials with better properties. Our users' perception studies confirm that it is possible to apply domestic level defluoridation of water in rural and tribal areas as well, with certain preferences towards particular methods for defluoridation of water. Most of the defluoridation techniques in-vogue have been designed for the community level water treatment. As the health effect of fluoride is only through its consumption, it may be more practical to treat only the drinking water requirement. This can save considerable treatment cost as a small portion of water is only used for the drinking and cooking purpose. A range of new as well as modified defluoridation materials has been developed under the present study. Some of the adsorbents developed in this study show potential for their practical use in view of the relatively small amount of adsorbents required for treatment of water. In particular biopolymer-based composite adsorbent appears to be more promising considering their fluoride uptake properties.

4.8 Recommended Procedure for Defluoridation of Water under IFM

Considering the methodology of Integrated Fluorosis Mitigation, method for defluoridation of water can be selected based on the estimated level of risk of fluoride as explained in section 1.5 and 1.7. In case of high and moderate risk, the defluoridation method may be followed after treatment of water using the dilution technique. The defluoridation methods suggested in this manual are based on adsorbents and for household applications. The recommended procedure includes estimation of fluoride risk using approach delineated in IFM concept, followed by selection of defluoridation method. Two different methods are recommended based on the users' need. If the requirement of water is for house hold consumption for cooking and drinking, then loose adsorbent treatment is recommended. This will facilitate to treat water in sufficient quantities for fluoride removal useful for entire family. The treated water can be stored for the entire day's requirement. The defluoridation treatment may be more useful for water having fluoride in the range of 3-10 mg/l.

In case the requirement of water is outside the home or on field then the method recommended is sachet or F-pudiya method. This method facilitates carrying prescribed dose of adsorbent in ready-to-use pack for a limited quantity of water. The method is applicable to water with fluoride concentrations of >3mg/l similar to loose adsorbent method.

Both the methods are described in detail in this chapter. It is essential for both the methods that the used adsorbent is collected and sent to centralized regeneration facility. In no case the fluoride containing used adsorbent should be disposed in such a way that may lead to leaching of fluoride to water.

The defluoridation of water can also be done by using any other standard material for which, the design estimates can be worked out in similar way to achieve the targeted concentration of fluoride in drinking water.

Chapter 5

INTEGRATED FLUOROSIS MITIGATION IV:

NUTRITIONAL MITIGATION

5.1 INTRODUCTION

Like other diseases, nutritional status and dietary intake pattern of an individual is an important means of prevention of fluorosis. The chapter on QCRA clearly indicates occurrence of fluorosis at lower levels of fluoride intake in communities having malnutrition. A recent study carried out by Chinoy et al. (2000) presented in XXIIIrd ISFR Conference indicated that nutrient supplementation has a beneficial effect on reducing the fluoride induced liver toxicity, and is necessary for recovery from fluoride toxicity. Further community based studies strongly suggest that calcium status modifies the type of bone changes seen in fluorosis (Krishnamachari et al. 1986). Clinical trials carried out with therapeutic supplementation of micronutrients in fluorosis affected children of Rajasthan also showed beneficial effect on skeletal deformities (Gupta et al., 1994). Reversal of fluoride induced cell injury through nutritional supplementation of calcium, vitamin C and antioxidants have been reported from Delhi. Over 90% of the persons affected with severe skeletal fluorosis, bone disease and deformities belong to the low socio-economic group where calcium status is low (Teotia et al., 1984).

5.2 Nutritional Requirement

Minimum requirement of nutrients particularly calcium, vitamin C, vitamin D and iron for adults and children are given below.

Table 5.1: Recommended dietary allowances of micronutrients

S.No/	Nutrition Element	Recommended dietary allowances (mg/day)	
		Adult	Children
1	Calcium	400	600
2	Vitamin C	40	40
3	Vitamin D	Not available	Not available
4	Iron	28	28

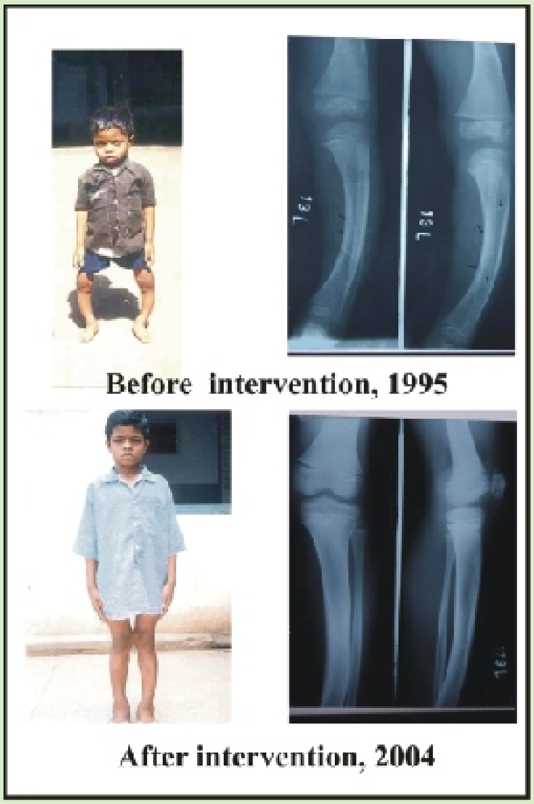
Several studies reported that adequate nutrition intake combat and minimize fluorosis. Food rich in calcium, vitamin C, iron and antioxidant are given in Annexure III to VI. Fatty fish and fish oils, meat, liver and dairy products are good sources of vitamin D but may be costly to procure for community in rural area. Similarly, there are food items which contain high concentration of fluoride and should be avoided particularly in fluorosis risk areas (Annexure VII).

5.3 Evidence of Fluorosis Mitigation due to Nutritional Supplementation:

Case Study: Fluorosis Mitigation Due to Nutritional Supplementation

Location: **Mandla, India** Year of study: **1995- 2004**

Complete reversal of the bone deformities due to fluorosis in mild cases and partial reversal in severe cases observed through nutrition supplementation.



Before intervention, 1995

After intervention, 2004

In epidemiological study was carried out by RMRCT Jabalpur in 1995 in Tilaipani and Hirapur villages of Mandla district and fluorosis was found to be the cause of endemic genuvalgum. Following this, intervention was initiated with nutritional supplementation and safe drinking water in 1997. Nutritional supplementation was given mainly through change in the diet pattern. Micronutrient rich foodstuffs like *Cassia Tora* (Chakoda Bhaji) was advocated repeatedly for increase in use as it contains high amount of calcium, vitamin C and iron, which are required for the bone mineralization, and excretion of fluoride.

Evaluation carried out in 2004 revealed that there was complete reversal of the bone deformities due to fluorosis in mild cases and partial reversal in severe cases. The reversal was not only in clinical pictures but also in biochemical and radiological parameters.

5.4 Practice of Nutrition Supplementation

It is reported in Annexure III that Chakoda Bhaji (*Cassia tora*), a vegetable commonly found in rural area, is very high in calcium content (3200 mg/100 g of dry leaves) and contain other nutrients as well. It is reported by Chakma *et al.* (2000) that consumption of chakoda bahji has resulted in reversal of fluorosis.

Consumption of chakoda bhaji is promoted as part of integrated fluorosis mitigation due to the following reasons:

1. High content of calcium, iron, vitamin C and other nutritional elements
2. Commonly grown in rural areas
3. Easy to grow in rural areas without any additional requirement of fertilizer
4. Chakoda bhaji after drying can be used for consumption
5. Side effects are not reported of Chakoda bhaji consumption
6. Chakoda bhaji can be grown by using treated greywater in rural households.

It is worked out that about 12 20 g of dry Chakoda bhaji or 80 100 g of green Chakoda bhaji should be consumed by an adult to meet minimum requirement of calcium i.e. 400 mg per day. Considering other sources of calcium consumption in normal diet, it is suggested that the consumption of chakoda bhaji can be limited to 10 g in dry state or 50 g of fresh leaves. Therefore, chakoda bhaji can be consumed as food accompaniment as the quantity to be consumed is low. The land and water requirement of chakoda bhaji is worked out for a family of 5 members and presented below:

Chakoda bhaji requirement = 5 persons x 50 g of Chakoda bhaji per day x 365 days

= 91.2 kg

It is proposed that annual requirement of Chakoda bhaji will be about 200 kg considering factor of safety of 2. The land requirement for cultivating 200 kg of chakoda bhaji will be approximately 6 x 6 m to grow about 200 chakoda plants. Chakoda is not water intensive plant and crop duty is about 0.5 litre per day. Therefore, daily irrigation water requirement is 100 l which can be met from household treatment and reuse of greywater. The detail of household greywater treatment and reuse is given in Chapter 3: Water Management Solutions.

Chapter 6

SUMMARY

Summary

- ***QCRA and categorization of fluorosis risk**:* Quantitative Chemical Risk Assessment (QCRA) has been successfully used for assessment of health impacts due to excessive fluoride intake in relation with the nutritional aspects, and finally establishing tolerable levels of risk to human health. Water quality monitoring and surveys along with reported dental/skeletal fluorosis symptoms lead to the identification of fluoride contamination as problem in a region. QCRA with data on health surveys provided the basis for use-based separation of water sources as well as for planning the appropriate fluorosis mitigation strategy.

Based on the QCRA, three categories of risk were determined:

CLASS A HIGH RISK CATEGORY (DALY >100/1000 persons) where the mitigation included IEC, household defluoridation, nutritional supplementation and water management.

CLASS B MODERATE RISK CATEGORY (DALY <100/1000 persons) including IEC, dilution of fluoride affected water and nutritional supplementation.

CLASS C LOW RISK CATEGORY (DALY <10/1000 persons) IEC and Nutritional supplementation

The salient observation from QCRA are as follows :

- For establishing the national standard for fluoride, it is essential to incorporate the QCRA and health risk based approach
- QCRA also signify the impact of standards on most vulnerable age groups.
- Consumption of fluoride content through food is as important as through water
- Results indicate that intake of fluoride in children, adolescents and adults are more from food as compared to water
- In fluoride affected areas capping of hand pumps is not a sustainable solution as microbial risk will increase due to lack of water for sanitation
- According to DALY score of 38.25 per 1000, Dhar and Jhabua have high risk of fluorosis and interventions are planned accordingly
- Rapid health based risk water quality guidelines are required for different states in India.

- ***Water management practices :*** Proper water management can significantly reduce the water consumption, while also generating additional water through measures like greywater reuse and rain water harvesting. Dilution of fluoridated water using collected rainwater proved to be an effective method for reducing fluoride intake from water in household and institutions like residential schools. The ease of implementation and low cost make them effective tools even in the rural areas.

  The dilution technology uses the results of the Quantitative Chemical Risk Assessment (QCRA) to estimate the percentage concentration of groundwater and rainwater to reduce the fluoride concentration. In schools this may include a 1:2 dilution to reduce the concentration of fluoride of 32mg/l to 1mg/l.

  The rainwater harvesting and dilution systems have been developed as part of water management solutions in boarding schools in Madhya Pradesh. Greywater treatment and reuse is another important part of water management solutions. The guidance on greywater treatments and reuse can be obtained in the Manual "Greywater Reuse for Schools in Rural Areas of India" published jointly by NEERI & UNICEF.

- ***Defluoridation*** **:** Defluoridation of water has been the most active area as fluorosis mitigation measure, however, there is a clear possibility of following:

- Development of new materials / media with faster kinetics and better selectivity for defluoridation
- Defluoridation of drinking water at domestic level by simplistic approach of stirring the adsorbent in water
- Lowering the quantum of water being treated, and in turn the cost of defluoridatiion and
- Some of the materials developed under this study show excellent defluoridation of groundwater samples from Dhar region and deserve further trials at larger scales for their acceptance.

Mass of adsorbent required for reducing fluoride concentration from 5 to 1 mg/l for volume of 1 m3 of water is compared and presented. It is apparent from the results that the biopolymer-based composite adsorbent (NEE-CEF1) shows high adsorption capacity of 4.1 mg/g when allowed to attain equilibrium as compared to 2.1 mg/g for activated alumina. This particular adsorbent is a composite of naturally occurring biopolymer and titanium hydroxide/oxide. The users' perception study conducted on these methods reveals that population in the study area is willing to accept the fluoride removal treatment and would prefer loose adsorbent method over other methods. Considering the criteria of suitability, simplicity, cleanliness and safe methods, the loose adsorbent treatment method emerges out to be the most favored method.

- ***Nutritional supplementation*** **:** Inferior nutritional status of a significant population in less developed countries has emerged as one of the most important cause for fluorosis epidemic. This demands for a major change in fluorosis mitigation. Nutritional supplementation has been ignored in most of the fluorosis mitigation strategies. It is possible to pursue this approach cost effectively by providing low cost nutritional supplements like chakoda bhaji for effective fluorosis mitigation. It is worked out that about 12 20 g of dry Chakoda bhaji or 80 100 g of green Chakoda bhaji should be consumed by an adult to meet minimum requirement of calcium i.e. 400 mg per day. Considering other sources of calcium consumption in normal diet, it is suggested that the consumption of chakoda bhaji can be limited to 10 g in dry state or 50 g of fresh leaves. Therefore, chakoda bhaji can be consumed as food accompaniment as the quantity to be consumed is low.

- ***Futuristic recommendations :***

- Although IFM is a very effective approach for fluorosis mitigation, its validation through pilot studies and full scale projects under different conditions possibly in various parts of the world will be useful to further strengthen this approach for its maximum benefits.
  - The concerns about the availability of potable water and depleting ground water level will remain an important challenge to meet the water requirement in near future. Alternate sources of water and water conservation should be implemented more aggressively in the areas of concern.

References

Ando, M., Tadano, M., Asanuma, S., Tamura, K., Matsushima, S., Watanabe, T., Kondo, T., Sakurai, S., Ji, R., Liang, C. and Cao, S., (1998) Health effects of indoor fluoride pollution from coal burning in China. *Environ. Health Perspect.* 106, 239244.

Apambire, W.B., Boyle, D.R. and Michel, F.A., (1997) Geochemistry, genesis, and health implications of fluoriferous ground waters in the upper regions of Ghana. *Environ. Geo.* 33(1), 1324.

Arsenic Policy Support Unit (2006) www.apsu.org

Ayoob, S. and Gupta, A.K., (2006) Fluoride in Drinking Water: A Review on the Status and Strss Effect. *Critical Reviews Environ. Sci. Tech.* 36, 433-487.

Cao, J., Zhao, Y. and Liu, J.W., (2000) Fluoride in the environment and brick-tea-type fluorosis in Tibet. *J. Fluoride Chem.* 106, 9397.

Cao, J., Zhao, Y., Li, Y., Deng, H. J., Yi, J. and Liu J.W., (2006) Fluoride levels in various black tea commodities: Measurement and safety evaluation. *Food Chem. Toxicology* 44, 11311137.

Cao, J., Zhao, Y., Liu, J., Xirao, R., Danzeng, S., Daji, D. and Yan, Y., (2003) Brick tea fluoride as a main source of adult fluorosis. *Food Chem. Toxicology* 41, 535542.

Cao, J., Zhao, Z. and Liu, J.W., (1997) Brick tea consumption as the cause of dental fluorosis among children from Mongol, Kazak and Yugu Populations in China. *Food Chem. Toxicology* 35(8), 827833.

Central Water Commission (CWC) 2005, Water data pocket book 2005 Ministry of Water Resources, Government of India, New Delhi

Chakma T., Singh S.B., Godbole S. and Tiwary R.S. (1997): Endemic Fluorosis with Genuvalgum Syndrome in a Village of District Mandla, Madhya Pradesh. **Indian Paediatrics. 34, 232-236.**

Chakma T., Rao V.P., Singh S.B. and Tiwary R.S., (2000) Endemic Genuvalgum and Other Bone deformities in two villages of Mandla District in Central India. Fluoride. 33, 4, 17-195.

Chaturvedi, A.K., Yadava, K.P., Pathak, K.C. and Singh, V.N., (1990) Defluorination of water by adsorption on flyash. *Water Air Soil Pollut.* 49 4169.

Cheng, L.S., (1985) Electrochemical method to remove fluorine from drinking water. *Water Supply* 3, 177186.

Chinoy N.J., Dipti M., (2000) Beneficial effects of a protein-supplemented diet on fluoride-induced toxicity in liver of male mice. XXIIIrd ISFR Conference abstracts. *Fluoride* 33 (1).

Choubisa, S.L., Choubisa, D.K., Joshi, S.C., and Choubisa, L. Fluorosis in some tribal villages of Dungapur district of Rajasthan, India. *Fluoride* 30, 223228, 1997

Cooper, R. Osotimehin, B, Kaufman, J. Forester, T. (1998) Disease burden in sub-saharan Africa: what should we conclude in the absence ofdata. *The Lancet*, Vol. 351, pp 208-210

Datta, P.S., Deb, D.L. and Tyagi, S.K., (1996) Stable isotope (O-18) investigations on the process controlling fluoride contamination of groundwater. *J. Contam. Hydrol.* 24, 8596.

Dean, H.T. Classification of mottled enamel diagnosis, *J. Am. Dent. Assoc.* 21, 14211426, 1934.

Department of Drinking Water Supply (2004), Ministry of Rural Development, Government of India, First report: Standing Committee on Rural Development, Presented to the Fourteenth Lok Sabha, Lok Sabha Secretariat, New Delhi, India, 2004.

Diesendorf, M. The health hazards of fluoridation: A re-examination, *Int. Clin. Nut. Rev.*10(2), 304321, 1990b.

Fewtrell L., Smith S., Kay D. and Bartram J. (2006) An attempt to estimate the global burden of disease due to fluoride in drinking water, Journal of Water and Health, 04.4, 533-542.

Fung, K.F., Zhang, Z.Q. and Wong, J.W.C., (1999) Fluoride contents in tea and soil from tea plantations and the release of fluoride into tea liquor during infusion, *Environ. Pollut.* 104, 197205.

Global Water Supply and Sanitation Assessment (2000).

Godfrey S., Wate S.R., Kumar P., Swami A., Rayulu S., Rooney R. (2006), Health-based risk targets for fluorosis in tribal children of rural Madhya Pradesh, India, Proceedings of 32nd WEDC International Conference, Colombo, Sri Lanka

Government of India (2001), National Human Development Report, Planning Commission, New Delhi

Gupta S.K, Gupta R.C. Seth and A.K. Reversal of clinical and dental fluorosis. Indian Pediatrics. 1994, 31: 439-443.

Havelaar, A, Melse, J, (2003) Quantifying public health risk in the WHO Guidelines for Drinking Water Quality A burden of disease approach. RIVM Report 734301022

Hutton G. and Haller L. (2004), Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level, Water, Sanitation and Health Protection of the Human Environment, World Health Organisation, Geneva

Jolly, S.S., Singla, V.P., Sharma, R., Ralhan, S.M., and Sandhu, S.S. Endocrine aspects of endemic fluorosis, *Fluoride* 7(4), 208219, 1974.

Jolly, S.S., Prasad, S., Sharma, R. and Chander, R., Endemic fluorosis in Punjab skeletal aspects, *Fluoride* 6, 418, 1973.

Kaimenyi, T.J., (2004) Oral health in Kenya, *International Dental J.* 54(6), 378 382.

Khandare A., Kumar Uday P., Nakka Lakshmaiah. (2000) Beneficial effects of tamarind ingestion on fluoride toxicity in Dogs. Fluoride 33,1, 33-38.

Krishnamachari K.A.V.R. (1986). Skeletal fluorosis in humans: a review of recent progress in the understanding of the disease. Progress in Food and Nutrition Sciences 10(3-4): 279-314.

Lakdawala, D.R., and Punekar, B.D., (1973) Fluoride content of water and commonly consumed foods in Bombay and a study of the dietary fluoride intake. *Indian J. Med. Res*. 61, 16791687.

Levy, S.M., (1994) Review of fluoride exposures and ingestion. *Community Dent Oral Epidemiol* 22(3), 17380.

Levy, S.M., Kiritsy, M.C., Slager, S.L. and Warren, J.J., (1998) Patterns of dietary fluoride supplement use during infancy. *J Public Health Dent* 58(3), 22833.

Levy, S.M., Kiritsy, M.C., Slager, S.L., Warren, J.J. and Kohout, F.J., (1997) Patterns of fluoride dentifrice use among infants. *Pediatr Dent* 19(1), 505.

Levy, S.M., McGrady, J.A., Bhuridej, P., Warren, J.J, Heilman, J.R. and Wefel, J.S., (2000) Factors affecting dentifrice use and ingestion among a sample of U.S. preschoolers. *Pediatr Dent* 22(5), 38994.

Liang, C.K., (1993) Study on dose-effect relationship in coal combustion fluorosis endemic area population. *Hygienic Res.* 22(3), 110.

Liang, C.K., Ji, R., and Cao, S.R. Epidemiological analysis of endemic fluorosis in China, Environ. Carcinogen. Ecotoxicol. Rev. 15(2), 123138, 1997.

Liu, M., Sun, R.Y., Zhang, J.H., Bi, N.Y., Wei, L., Liu, P. and Kei, C.F., (1983) Elimination of excess fluoride in potable water with coarcervation by electrolysis using aluminium anode. *Fluoride* 20(2), 5463.

Michael, P. Whyte, M.D., Kevan Essmyer, M.S., Francis, H., Gannon, M.D., William, R. and Reinus, M.D., (2005). Skeletal fluorosis and instant tea. *The American J. Medicine* 118, 78-82

Mishra U.K., Gujral R.B., Sharma V.P. and Bhargava S.K., (1992) Association of Vitamin D deficiency with endemic fluorosis in India. Fluoride 25(2), 65-70.

Murray, C, Lopez, A. (1996). The global burden of disease, Cambridge Massachusetts. Harvard School of Public Health, WHO/World Bank

Raghava Rao K V. (1974). Incidence of Fluoride in ground water. Proceedings of the Symposium on fluorosis, Hyderabad. Pp 163-173.

Sha, J.Q. and Zheng, D.X., (1994) Study on the fluorine content in fresh leaves of tea plant planted in Fujian Province. *J. Tea Sci.* 14, 3742.

Shu, W.S., Zhang, Z.Q. and Lan, C.Y., (2003) Fluoride and aluminium concentrations of tea plants and tea products from Sichuan Province, PR China. *Chemosphere* 52, 14751482.

Shusheela 2004, Endemic fluorosis in India

Sujana, M.G., Thakur, R.S., and Rao, S.B., (1998) Removal of fluoride from aqueous solution by using alum sludge. *J. Colloid Interf. Sci.* 206, 94101.

Susheela, A.K., (2003) *A Treatise on Fluorosis*, revised 2nd ed., New Delhi, India: Fluorosis Research and Rural Development Foundation.

Takumori, T. Recent studies on fluorosis. II. The new method for classifying mottled teeth based on fluoride content of drinking water, *Fluoride* 4, 154161, 1971.

Teotia S.P.S., Teotia M., Singh D.P., Anand V., Singh C.V., Tomar Singh N.P., (1984) Environmental fluoride and metabolic bone disease: an epidemiological study (fluoride and nutrient interactions). Fluoride. 17 (1): 14-22.

Toyoda, A. and Taira, T., (2000) A new method for treating fluorine wastewater to reduce sludge and running costs. *IEEE Transactions on Semiconductor Manufacturing* 13(3), 305309.

UNICEF/WHO Joint monitoring programme for water supply and sanitation (2000). Global water supply and sanitation assessment 2000 report, WHO, Geneva and WSSCC (2000).

U.S. Department of Health and Human Services (2003), Public Health Service, Agency for Toxic Substances and Disease Registry, Report on Toxicological Profile for Fluorides, Hydrogen Fluoride and Fluorine, ATSDR, 2003

Water Data Pocket Book (2005).

WHO [World Health Organization, Geneva, Switzerland], (2004a) FACTS Water, Sanitation.

WHO [World Health Organization, Geneva, Switzerland], (2004b) Guidelines for Drinking Water Quality, Third Edition, Vol.1 (2004c).

WHO and UNICEF, (2004) Meeting the MDG Drinking Water and Sanitation Target: A midterm Assessment of Progress, WHO Geneva and UNICEF, New York.

WHO (2004) Guidelines for Drinking Water Quality Geneva, Switzerland

WHO (2002), Fluorides, Environmental Health Criteria Number, 227, 2002

WHO and WSSCC (2000).

Whyte, M.P., Essmeyer, K., Gannon, F.H. and Reinus, W.R., (2005) Skeletal fluorosis and instant tea. *Fluoride* 38(1), 7681.

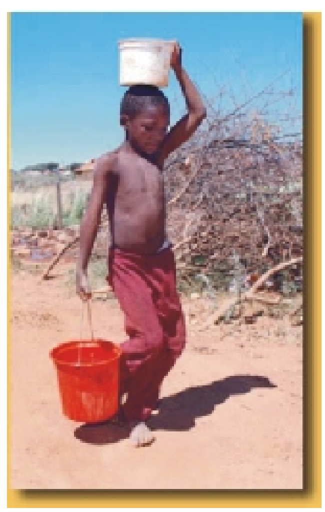
Xu, R.Q., Wu, D.Q., and Xu, R.Y. Relations between environment and endemic fluorosis in Hohot region, Inner Mongolia, *Fluoride* 30, 2628, 1997

Zang Z.Y., Fan J.Y., Yen W., Tian J.Y., J G Wang, Li X.X. and. Wang E.L. (1996) The effect of nutrition on the development of endemic osteomalcia in patients with skeletal fluorosis. Fluoride. 29(1), 20-24.

Annexures

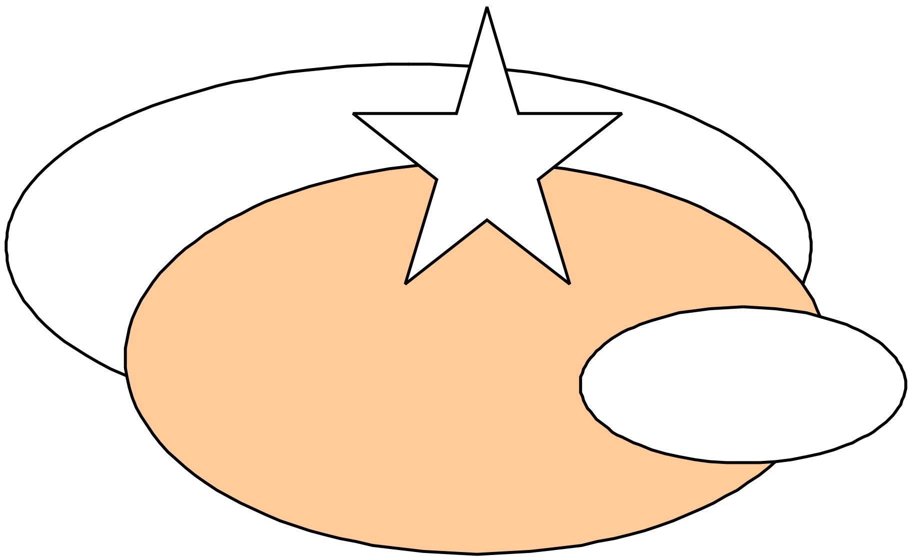
QCRA

SURVEY TOOL DESIGN



Dr Samuel Godfrey
UNICEF
Bhopal

INFORMATION MATERIAL ON QCRA - SURVEY TOOLS

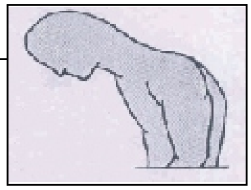
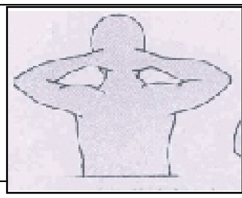
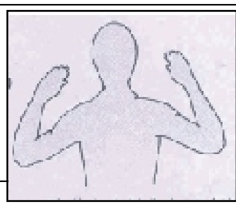
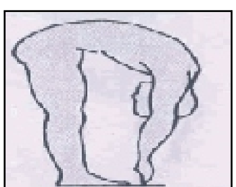
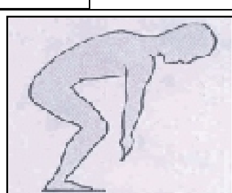
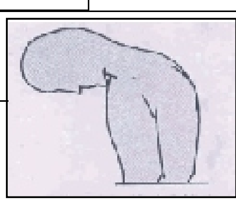


Family Survey
Health Survey
Guiding Formula
Example

QCRA-OAEL

Health Analysis

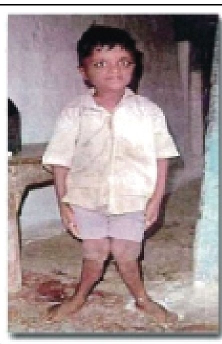
Family Name & Code

		*	Mem-1	Mem-2	Mem-3	Mem-4	Mem-5	Mem-6
				* Use similar code as family sheet				
1 								
2 								
3 								
4 								
5 								
6 								

QCRA-OAEL

Health Analysis

Family Name & Code

		*	Mem-1	Mem-2	Mem-3	Mem-4	Mem-5	Mem-6
				* Use similar code as family sheet				
 7								
 8								

1.Details of fluorosis affected patients

S. No.	Name	Age	Sex	Type of illness[a]	Symptoms

a. Type of Illness: 1. Dental 2. Skeletal 3. Non-skeletal
(Check medical prescription/advise).

QCRA

Name of Surveyor

Place

Date

Format for family analysis :

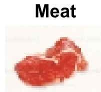
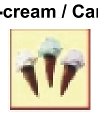
Family Sr. no.	No of persons						Remarks (symptoms of fluorisis)	
1.	M	Age	Wt	F	Age	Wt	M 1- 2-	F 1- 2-
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								

Consumption

Sr. no.	Food	gm	Summer Weekly frequency	Winter Weekly frequency	Average	NOAEL	LOAEL	%
1.	Roti/Rice							
2.	Millet roti							
3.	Dal/cereals							
4.	Pulses							
5.	Vegetables							
6.	Fruits							
7.	Salt							
8.	Milk							
9.	Black Tea							
10.	Sharbat							
11.	Salty snakes chat Garm Masala pickles etc.							
12.	Ice cram							
13.	Candies							
14.	Fish							
15.	Canned fish							
16.	Meat							
17.	Fruit juice (FI preservative)							
18.	Tobacco							
19.	Chuna							
20.	Supari							
21.	FI. Tooth past							

QCRA

	mg/l	Summer	Winter	Average	% allocation		
Potable Water						mg/l/w	%
Bucket					Water		
Any other					Food		
Food		Weekly Frequency	Weekly Frequency		Other		
Roti / Paratha 							
Rice 							
Pulse 							
Vegetables 							
Fruits 							
Fish 							
Canned Fish 							
Black Tea 							

QCRA							
	mg/l	Summer	Winter	Average	% allocation		
Potable Water						mg/l/w	%
Bucket					Water		
Any other					Food		
Food		Weekly Frequency	Weekly Frequency		Other		
Supari 							
Fl. Toothpaste 							
Fruit-Juice 							
Salty Snakes-Chat Garm Masala Pickles etc 							
Tobacco 							
Meat 							
Ice-cream / Candy 							
Powder Milk 							
Other							

Consumption

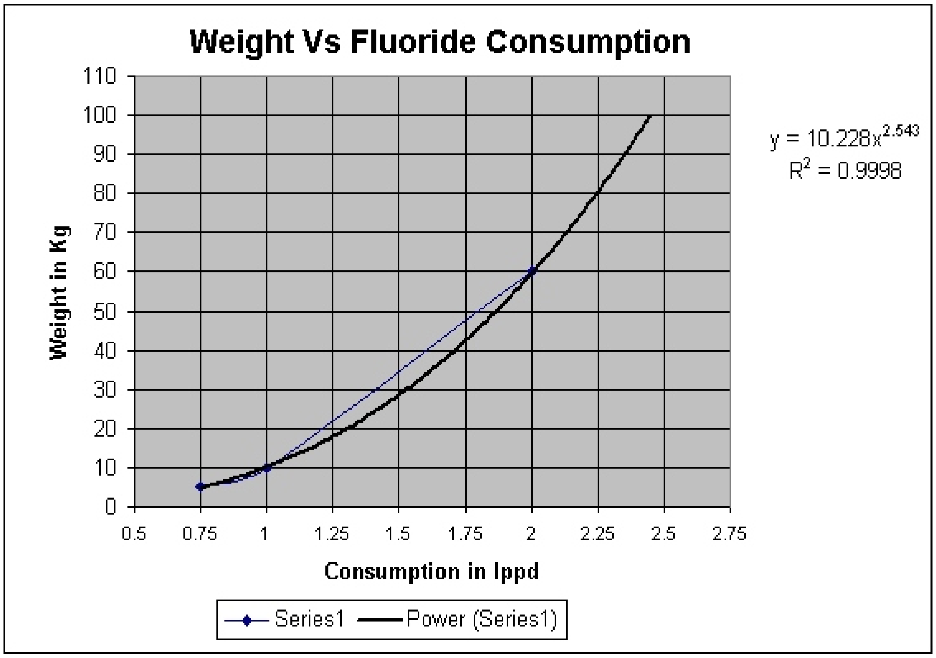
lts/per adult/day		lts/child/day	
For Adults	0.03	For Child	0.1
weight (kgs)	consumption (its/day)	weight (kgs)	consumption (its/day)
100	3.33	10	1
95	3.17	9	0.9
90	3	8	0.8
85	2.83	7	0.7
80	2.67	6	0.6
75	2.5		
70	2.33		
65	2.17		
60	2		
55	1.83		
50	1.67		
45	1.5		
40	1.33		
35	1.17		
30	1		
25	0.83		
20	0.67		
15	0.5		

weight	consumption
60 kg	2 lppd
10kg	1lppd
5kg	0.75lppd

Standard Deviation
Mean Deviation
Moad Deviation

weight	consumption
60 kg	2 lppd
10kg	1lppd
5kg	0.75lppd

standard Deviation 23.22485



weight	lppd
10.2	1
13.0	1.1
16.3	1.2
19.9	1.3
24.1	1.4
28.7	1.5
33.8	1.6
39.4	1.7
45.6	1.8
52.3	1.9
59.6	2
67.5	2.1
76.0	2.2
85.0	2.3
94.8	2.4
105.1	2.5

Analysis/Result

Concentration of Fluoride in the following items

Sr. No.	Item
1.	Water used for
a.	Drinking
b.	Cooking
c.	Hand washing of children
2.	Food
a.	Roti
b.	Dal/cereals, pulses
c.	Rice
d.	Vegetables
f.	Fruits
g.	Meat
h.	Fish
3.	Soil
a.	Agricultural land

QCRA

TDI -Tolerated Daily Intake

$$TDI = (NOAEL \text{ or } LOAEL) / UF$$

NOAEL no-observed-adverse-effect level
LOAEL-Lowest -observed-adverse effect level
UF-Uncertainty factor

TDI is mg per kg of body weight

GV-Guideline Value

$$GV = (TDI \times bw \times P)/C$$

Bw-Body weight
P-Fraction of TDI allocated to drinking Water
C-Daily Drinking Water Consumption.

Annexure II
परिशिष्ट II

नीरी-यूनिसेफ/NEERI-UNICEF

उपयोगकर्ता के मत का अध्ययन, भाग - 1, प्रश्नावली

Questionnaire for Users Perception Study -Part I

घरेलू सर्वेक्षण-वैयक्तिक सूची

(Household Survey Personal Inventory)

दिनांक/Date:
समय/Time:
दिन/Day:

अ) पहचान
A) Identification

1.गांव का नाम/ Name of the village :
2. विकास खंड/तहसील/Block/ Taluka :
3. उत्तरदाता का नाम/ Name of respondent :
4. आयु/ Age :
5. लिंग/ Sex : पुरुष/ Male / महिला/ Female
6. शिक्षा/ Education Level : अनपढ़/चौथी कक्षा से कम,
चौथी से आठवीं कक्षा के बीच
आठवीं से दसवीं कक्षा के बीच
ग्यारहवीं से बारहवीं कक्षा के बीच
Illiterate, < 4th Class, 4-8th Class,
8-10th Class, 11-12th Class

ब) परिवारिक, घरेलू पृष्ठभूमि
B) Family Background
Household Information

(अत्सं/ HS = अत्यधिक संतुष्ट/Highly Satisfactory, सं/SA = संतुष्ट/Satisfactory, सा/ NE = सा/पता नहीं/Neutral/Don't know, असं/ NS असंतुष्ट/Not Satisfactory, अअ/ HU = अत्यधिक संतुष्ट/Highly Unsatisfactory)

1) मलकियत/ Ownership : अपना/ own/किराये का/rented/ अन्य/others (मित्र/सम्बंधी friends / relatives)
: यदि किराये का तो मासिक किराया/ If rented monthly rent (Rs.)
: कब से रह रहे हैं(वर्ष लिखें)/ Occupied since when (Year)
2) प्रकार/Type : संयुक्त/ Tenement/ स्वतंत्र/ Independent/ अन्य/ Others
3) आकार/ Size of House : (i) Size (स्के. फी. /sq. feet) : 100/ 300/ 500 1000
(ii) कुल कमरे/ No. of Rooms : 1 / 2 / 3 / 4 / >4
4) घर सम्बंधी संतुष्टता/Satisfaction about housing :
अत्सं/ सं/ सा/ असं/ अअसं
HS / SA / NE / NS / HU

परिवार/ Size of family

व्यस्क पुरुष/ Adult Male	व्यस्क महिलाएं/ Adult Female	लड़के(14 वर्ष से कम) Children Male >14Years	लड़कियां(14 वर्ष से कम) Children Female >14Years	बच्चे(14 वर्ष से अधिक) Children <14 Years

शिक्षा/Educational Status

परिवार में पढ़े-लिखों की संख्या

No. of literate in the family__________

परिवार में पढ़े-लिखों की स्तरानुसार जानकारी

No. of persons by literacy level__________

अनपढ़ Illiterate	<4th श्रेणी Class	4th-8th श्रेणी Class	8th-10th श्रेणी Class	11th-12th श्रेणी Class	महाविद्यालय/तकनीकी College/ Technical

च. क्या आर्थिक रुप से बच्चों को शिक्षा दिलाने में समर्थ हैं हां/नहीं

c. Can you afford to educate your childrenYes/ No

ड. वार्षिक शिक्षा खर्च (रु. में)

d. Annual expenditure on education (Rs)

कुछ नहीं/None/ 100-500/ 500-1000/ >1000

इ. शिक्षा सुविधाओं से संतुष्टता अत्सं/ सं/ सा/ असं/ अअसं

e. Satisfaction about education facilitiesHS / SA / NE / NS / HU

रोजगार/Employment

i. **परिवार के रोजगार प्राप्त व्यक्ति**

No. of persons employed in the family__________

ii. **परिवार के रोजगार न करने वाले व्यक्ति**

Persons unemployed in the family__________

	रोजगार का प्रकार/Type of Employment					
	कृषि/Agriculture		नौकरी/ Service	व्यवसाय/ Business	श्रमिक/ Labor	पशु पालन/मछुआरा Live Stock fisherman
	कृषक/ Farmer	श्रमिक/ Labour				
मासिक/वार्षिक आय(रु.) Monthly/ Annual income (Rs.)						

- **गैर कृषि कार्यों में कार्यरत श्रमिक**

  Engaged as labours in other than agriculture activities

iii. **आमदनी से संतुष्टि अत्सं/ सं/ सा/ असं/ अअसं**

Satisfaction regarding level of incomeHS / SA / NE / NS / HU

कुल सम्पत्ति की अद्यतन स्थिति

Assets as on today

कुल भूमि (एकड़ में) Total land in (acre)	कृषि प्रयोज्य भूमि(एकड़) Land cultivated (acre)	घर कच्चा/पक्का House Kutcha / pucca	मवेशी Cattle	वाहन Vehicle	अन्य Other

च) व्यवसाय विशेष

C) Occupation Specific

कृषक

Cultivator

क्या सिंचाईकी सुविधा है ?

Is irrigation facility available?

यदि हां तो सिंचाई-सुविधा का प्रकार

If Yes, type of irrigation facility

(नदी/नहर/बांध/तालाब/झील/कूआं/भू-जल/अन्य)

(River/Canal/Dam/Pond/Lake/Well/Ground water/Other)

क्या खेती के अतिरिक्त भी आपकी आय का कोईअन्य स्रोत है

Do you have any other income generating source besides farming

पशु पालन/**Live stock and fishery**

Nature of activities

(मछली/झींगा/मुर्गी पालन/गाय-बैल चराना)

(Fishing activity/ Prawn culture/ Poultry farm/ cattle grazing)

क्या यह कार्य पैतृक है ?

Is this traditional activity : हांYes/ नहींNo

क्या यह कार्य पैतृक है ?

ड) जलापूर्ति

D) Water Supply

1) पेयजल स्रोत : नगर निगम नल/खुला कूआं/स्टैंड पोस्ट/सरकारी हैंड पम्प/निजी हैंड पम्प/नदी/झील/अन्य(स्पष्ट करें). . . . .

Source of drinking water : Municipal Corp.tap / Open well / Stand post /

Hand pump / Pvt. Hand pump / River / Lake Tank / Others / (Specify)…..

2) पेयजल स्रोत : नगर निगम नल/खुला कूआं/बोर-वेल/हैंड पम्प/नदी/झील/अन्य(स्पष्ट करें). . . . . . .

Source of cooking water : Municipal Corp. tap / Open well / Bore well /

Hand pump / River / Lake / Tank / Others / (Specify)…..

3). जल की मात्रा (कितने गलास) व्यस्क (पुरुष/महिला) बच्चे
Quantity of water (how many glass of water) Adults (Male/Female)Children

4). परिवार के लिए आवश्यक जल की मात्रा (लीटर में) :
Quantity of water required for family : 5 / 10 / 20 / 40 lit.

5). क्या आप पेय जल की उपलब्धता से संतुष्ट हैं : हां/नहीं

Satisfaction about availability of drinking water : Yes / No
गुणवत्ता तथा माथा : अत्सं/ सं/ सा/ असं/ अअसं
Quality and quantiy : HS / SA / NE / NS / HU

इ) स्वास्थ्य

E) Health

1) पिछले एक वर्ष से परिवार में होने वाले रोगों की सूची : मियादी बुखार / मलेरिया/ पेचिश/दस्त/अन्य

List of common ailment in the family over last one year : Viral fever/ Malaria/ Dysentry/ Diarrhoea/ others

2) गंभीर/व्यवसाय सम्बंधी रोग से पीड़ित परिवार के सदस्य : तपेदिक(टीबी) दमा/चर्म रोग आंख सम्बंधी विकार/फ्लोरोसिस

Family members with permanent/ occupational Disease : TB/ Asthama/ Skin disease/ Eye disease / fluorosis

3) क्या आपके परिवार का कोईसदस्य दांतों के गिरने/बदन दर्द/हाथ-पैर की विकृति से पीड़ित है : हां/नहीं
Is anybody in your family having health problem such as tooth decay, body ache, deformatted feet/hands : Yes/ No

4) आपके परिवार के कितने व्यक्ति प्रश्न सं.1 से 3 के अनुसार, उपरोक्त में से किसी भी रोग से पीड़ित हैं :
How many persons in your family are suffering from any of the above disease in question 1 to 3 : _______

5) सबसे अधिक कौन पीड़ित है : बच्चे/व्यस्क/वृद्ध/सभी
Who is suffering most : Children/ Adult/ Elders/All

6) क्या आप जानते हैं कि यह रोग पेय जल में फ्लोराईड से सम्बंधित हैं
Do you know the cause of these health problem related

to fluoride in drinking water : हां/नहीं/शायद Yes/ No/ Not sure

७) इन रोगों से सम्बंधित किए गए घरेलू उपचार
Any house hold remedy being used : इमली/आंवला/पत्तियां आदि Tamarind / Awla / Leaves etc.

फ) सामाजिक सुरक्षा

F) Social Security

1) बचत का प्रकार : बैंक/डाकघर/आवर्ती/स्वयं सहायता समूह योजना
Type of saving : Bank/ Post office/ Recurring deposit/ Self help group scheme

2) वार्षिक बचत : रू. 1000 से कम/1000 -10,000/10,000 से अधिक
Amount of saving per annum Rs. : <1000/ 1000-10,000/ >10,000

ग) पर्यावरणीय समस्याएं

G) Environmental Problems

1) क्या आपने निम्न में से किसी समस्या को अनुभव किया है :
Is any of the following problems experienced by you? : हांYes/नहीं No

(i) कूओं में लवणीय जल Saline water in wells ____________________
(ii) रंग, स्वाद, गंध-समस्याColour, taste and odour problem______________
(iii) पानी जमा होनाWater logging ____________________
(iv) विज्ञ पशु-चारे की कमीLack of fodder for cattle ______________
(v) वनस्पति की कमीLoss of vegetation ____________________
(vi) औद्योगिक जल प्रदुषणWater pollution by industries_________________
(vii) औद्योगिक वायु प्रदुषणAir pollution by industries ____________________
(viii) ध्वनि प्रदुषणNoise pollution ____________________
(ix) वाहन पद्रूषणVehicular pollution ____________________
(x) कचरा निपटानGarbage disposal ____________________
(xi) अन्य कोईAny others ____________________

2) आपके समाज के लिए विकास के महत्वपुर्ण मुद्दे क्या हैं ?
What are the most important developmental issues for your community?

जन संचार के प्रभावी माध्यमों का निर्धारण

Identification of Effective Means of Mass Communication

1) आपका मनोरंजन का प्रिय माध्यम कौन सा है?
What is your most favorite entertainment means?

2) क्या आप सामूहिक बैठकों में भाग लेते हैं, कितना?
How frequently you participate in group meetings?

3) मनोरंजन के साधनों की उपलब्धता?
Availability of entertainment means?

उपयोगकर्ता के मत का अध्ययन, भाग - 2, प्रश्नावली

Questionnaire for Users Perception Study-Part II

(उपचार सम्बंधी)

(Treatment Specific)

अ) जल-उपचार-प्रयोग सम्बंधी सामान्य जानकारी

A) General Acceptance of Water Treatment Experiment.

1) क्या आप जानते हैं कि पानी में फ्लोराइड स्वास्थ के लिए हानिकारक है ?
Do you know 'Fluoride' in water is a cause of health problem?

हां Yes	नहीं No	पता नहीं Not sure

2) यदि फ्लोराइड हटाने हेतु सामग्री आपको दी जाए तो क्या आप इसका प्रयोग करेंगे?
If a fluoride removal solution is offered to you, will you use it?

हां Yes	नहीं No	पता नहीं Not sure

3) आपको दिखाईगईविधियों में से आपको कौन सी उपयुक्त लगती है ?
Out of the methods demonstrated to you which one you find suitable?

फ्लोराइड पुड़िया F-Pudiya	जलीय सामग्री Material in water	बांस-कालम Bamboo Column	मटका Matka	सभी All	कोई नहीं None

4) इनमें से कौन सी विधि आपको प्रयोग में आसान लगी?
Which method you find simple to use?

फ्लोराइड पुड़िया F-Pudiya	जलीय सामग्री Material in water	बांस-कालम Bamboo Column	मटका Matka	सभी All	कोई नहीं None

5) आपके अनुसार इनमें से कौन सी विधि अधिक स्वच्छ है?
Which method you find cleanest?

फ्लोराइड पुड़िया F-Pudiya	जलीय सामग्री Material in water	बांस-कालम Bamboo Column	मटका Matka	सभी All	कोई नहीं None

6) आपके अनुसार इनमें से कौन सी विधि अधिक सुरक्षित है?
6) Which method you find safest?

फ्लोराइड पुड़िया F-Pudiya	जलीय सामग्री Material in water	बांस-कॉलम Bamboo Column	मटका Matka	सभी All	कोई नहीं None

ब) फ्लोराइड हटाने सम्बंधी सामान्य मत
B) General opinion about defluoridation

1) क्या आप समुदायिक स्तर के उपचार को प्राथमिकता देंगे?
Would you prefer community level treatment?

हां Yes	नहीं No	सामान्य Neutral

2) क्या आप घरेलू स्तर के उपचार को प्राथमिकता देंगे?
Would you prefer domestic household treatment?

हां Yes	नहीं No	सामान्य Neutral

3) उपचार प्रक्रिया की लागत(भारतीय पैसों में) : 10/50/100 प्रति लीटर
Cost of defluoridation treatment (in Indian paise):10 / 50 / 100 per litre

हां Yes	नहीं No	सामान्य Neutral

च) फ्लोराइड-पुड़िया प्रयोग

C) F-Pudiya Experiment

1) क्या आपको उपचार किए गए पानी में गदलेपन में वृद्धि प्रतीत हुई?
Have you noticed any increase in turbidity in the treated water?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

2) उपचार किए गए पानी का स्वाद आपको कैसा लगा?
How you find taste of treated water?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

3) उपचार किए गए पानी की गंध आपको कैसी लगी?
How is the smell in treated water?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

4) उपचार किए गए पानी का रंग आपको कैसा लगा?
How is the colour of the water after treatment?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

5) कुल मिलाकर इस विधि से फ्लोराइड हटाने के बाद स्वच्छ व स्वस्थ पानी के बारे में आप कैसा महसूस करते हैं?
Over all how you feel water treated for fluoride removal by this method for your health?

अच्छा Good	निश्चित नहीं Not sure	खराब Bad

ड) जलीय सामग्री ( ) विधि

D) Material in water (loose sorbent) technique

1) क्या उपचार किए गए पानी में आपको गदलेपन में वृद्धि प्रतीत हुई?
Have you noticed any increase in turbidity in the treated water?

हां Yes	नहीं No	सामान्य Neutral

2) उपचार किए गए पानी का स्वाद आपको कैसा लगा?
How you find taste of treated water?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

3) उपचार किए गए पानी की गंध आपको कैसी लगी?
How is the smell in treated water?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

4) उपचार किए गए पानी का रंग आपको कैसा लगा?
How is the colour of the water after treatment?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

5) कुल मिलाकर इस विधि से फ्लोराइड हटाने के बाद स्वच्छ व स्वस्थ पानी के बारे में आप कैसा महसूस करते हैं?
Over all how you feel water treated for fluoride removal by this method for your health?

अच्छा Good	निश्चित नहीं Not sure	खराब Bad

इ) बांस कॉलम

E) Bamboo column

1) क्या उपचार किए गए पानी में आपको गदलेपन में वृद्धि प्रतीत हुई?
Have you noticed any increase in turbidity in the treated water?

हां Yes	नहीं No	सामान्य Neutral

2) उपचार किए गए पानी का स्वाद आपको कैसा लगा?
How you find taste of treated water?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

3) उपचार किए गए पानी की गंध आपको कैसी लगी?
How is the smell in treated water?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

4) उपचार किए गए पानी का रंग आपको कैसा लगा?
How is the colour of the water after treatment?

बेहतर Better	प्हले जैसी Unchanged	खराब Bad

5) कुल मिलाकर इस विधि से फ्लोराइड हटाने के बाद स्वच्छ व स्वस्थ पानी के बारे में आप कैसा महसूस करते हैं?
Over all how you feel water treated for fluoride removal by this method for your health?

अच्छा Good	निश्चित नहीं Not sure	खराब Bad

फ) मिट्टी का घड़ा

F) Stacked Matka

1) क्या आपको उपचार किए गए पानी में गदलेपन में वृद्धि प्रतीत हुई?
Have you noticed any increase in turbidity in the treated water?.

हां Yes	नहीं No	सामान्य Neutral

2) उपचार किए गए पानी का स्वाद आपको कैसा लगा?
How you find taste of treated water?

बेहतर Better	पहले जैसा Unchanged	खराब Bad

3) उपचार किए गए पानी की गंध आपको कैसी लगी?
How is the smell in treated water?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

4) उपचार किए गए पानी का गंध आपको कैसा लगा?
How is the colour of the water after treatment?

बेहतर Better	पहले जैसी Unchanged	खराब Bad

5) कुल मिलाकर इस विधि से फ्लोराइड हटाने के बाद स्वच्छ व स्वस्थ पानी के बारे में आप कैसा महसूस करते हैं?
Over all how you feel water treated for fluoride removal by this method for your health?

अच्छा Good	निश्चित नहीं Not sure	खराब Bad

Annexure III

Calcium Rich Food

Sr. No	Botanical Name	English name	Local name	Calcium content/100gm
1.	Eleusine coracana	Ragi	Mudua	344 mg
2.	Phaseolus vulgaris	Rajmah	Rajmah	260 mg
3.	Milk	Milk	Dudh	210 mg
4.	Cassia tora (Fresh Leaves)	Fetid cassia	Chakoda Bhaji	520 mg
5.	Cassia tora (Dry Leaves)	Fetid cassia	Chakoda Bhaji	3200 mg
6.	Amaranthus gangeticus	Amaranth leaves	Chulai sag	397 mg
7.	Beta vulgaris	Beet leaves	Chukandar ka sag	380 mg
8.	Brassica oleracea var-botrytis	Cauliflower	Phool gobee	326 mg
9.	Spinacia oleracea	Spinach	Palak	73 mg
10.	Cyamopsis tetragonoloba	Cluster beans	Guar ki phalli	130 mg
11.	Solanum melongena	Brinjal	Baingan	18 mg
12.	Prunus amygdalus	Almond	Badam	230 mg
13.	Musa paradisiacal	Banana (ripe)	Kela	17 mg
14.	Psidium cattleyanum	Guava	Jam fal	50 mg
15.	Saccharum offinarum	Jaggery	Gud	80 mg

Annexure IV

Vitamin 'C' Rich Food

Sr. No	Botanical Name	English name	Local name	Vitamin C Content/100gm
1	Emblica officinalis	Amla	Amla	600 mg
2	Physalis Peruviana	Cap gooseberry	Rasbari	49 mg
3	Psidium guajava	Guava	Jamphal/Bihi	212 mg
4	Citrus aurantium	Orange	Santra	64 mg
5	Citrus limon	Lemon	Nimbu	39 mg
6	Carica papaya	Papaya	Papita	57 mg
7	Amarahthus gangeticus	Amaranth	Chaulai bhajee	99 mg
8	Brassica oleracea var. capitata	Cabbage	Band gobee	124 mg
9	Moringa oleifera	Drumstick leaves	Sajan/Munga ke patte	220 mg
10	Cassia-tora	Fetid cassia	Chakoda Bhaji	82 mg
11	Brassica rapa	Turnip	Shalgam	180 mg
12	Moringa oleifera	Drumstick	Sajjan ki phalli	120 mg
13	Momordica charantia	Bitter gourd	Karela	99 mg
14	Brassica oleracea var, botrytis	Cauliflower	Phul gobi	56 mg
15	Lycopersicon esculentum	Tomato	Tamatar	27 mg
16	Trigonella foenum graecum	Fenugreek leaves	Methi bhajee	52 mg

Annexure V

Iron Rich Food

Sr. No	Botanical Name	English Name	Local Name	Iron content/ 100gm
1.	Cassia-tora	Fetid cassia	Chakoda Bhaji	12.4 mg
2.	Spinacia oleracea	Spinach	Palak	1.14 mg
3.	Peninsetum Typhoideum	Bajra	Bajri	8.0 mg
4.	Beta Vulgaris	Beet root	Chukandar	16.2 mg
5.	Brassica oleracea var. botrytis	Cauliflower	Phul gobi	40.0 mg
6.	Mentha Spicata	Mint	Pudina	15.6 mg
7.	Brassica campetris var sarason	Mustard leaves	Sarson Ka Sag	16.3 mg
8.	Nelumbium Nelumbo	Lotus stem	Kamal lakdi	60.6 mg
9.	Guizotio	Niger Seeds	Kalatil	56.7 mg
	Curcuma Domestica	Turmeric	Haldi	67.8 mg
10.	Annona squamosa	Custard apple	Sitaphal	4.31 mg
11.	Saccharum offinarum	Jaggery	Gud	2.64 mg
12.	Vigna Catjang	Cowpea	Lobia	8.6 mg

Annexure VI

Antioxidant Rich Food

Sr. No	Botanical Name	English name	Local name
1	Allium cepa	Onion	Pyaz
2	Allium sativum	Garlic	Lehsun
3	Zinziber officinale	Gingers	Adrak
4	Daucus carota	Carrot	Gajar
5	Ipomoea batatas	Sweet potato	Shakarkand
6	Cucurbita maxima	Pumpkin	Kaddu
7	Carica papaya	Papaya	Papita
8	Malus sylvestris	Apple	Sev
9	Citrullus vulgaris	Water melon	Tarbuj
10	Lycopersicon esculentum	Tomato	Tamatar
11	Spinacia oleracea	Spinach	Palak
12	Cassia tora	Fetid cassia	Chakoda

Annexure VII

Food Containing Higher Fluoride Contents

Sr. No	Botanical Name	English name	Local name	Fluoride content/100gm
1.	Camellia sinensis	Tea (Dry leaves)	Chay	39.8-68.59 mg/l
2.	Areca catechu	Areca nut	Supari	3.8 – 12.0 mg/l
3.	Piper beetle	Beetle leaves	Pan ka patta	7.8-12.0 mg/l
4.	Nicotiana tabacum	Tobacco	Tamaku (Khaini)	3.1 – 38.0 mg/l
5.	Elettaria cardamomum	Cardamom	Ilaichi	14.4 mg/l
6.	Black and rock salt	Salt	Kala Namak	14.4 mg/l

Annexure VIII

Peer Reviewed Publications and Patent :

Godfrey, S. (Ed.). (2006) *Water Safety Plans: Madhya Pradesh State Strategy*: UNICEF, Bhopal, India.

Godfrey, S., Howard G. (2005 A) *Water Safety Plans: Book 1 Planning Water Safety Management for Urban Piped Water Supplies in Developing Countries.* Water, Engineering and Development Centre, Loughborough University, UK.

Godfrey, S., Howard, G. (2005 B) *Water Safety Plans: Book 2 Planning Water Safety Management for Urban Piped Water Supplies in Developing Countries*. Water, Engineering and Development Centre, Loughborough University, UK.

National Environmental Engineering Research Institute, Nagpur, India (2006 B) *"Wisewater Management Greywater Reuse in Rural Schools: Guidance Manual from India."* NEERI.

United Nations Children's Fund. (2006) *Water Safety Plans: Madhya Pradesh State Strategy*:
UNICEF, Bhopal, India.

S. P. Kamble, S. Jagtap, N. K. Labhsetwar, D. Thakare, S. Godfrey, S. Devotta, and S. S. Rayalu, (*2006),* Defluoridation of Drinking Water Using Chitin, Chitosan and Lanthanum Modified Chitosan. In Press, *Chemical Engineering Journal.*

S. P. Kamble, S. Jagtap and S. S. Rayalu (2006), Removal of fluoride from drinking water by adsorption onto low cost chitin. Accepted in *Twenty-Second International Conference on Solid Waste Technology and Management*.

Amit Bansiwal, N. K. Labhsetwar, D. Thakare, S. Godfrey, S. Devotta, and S. S. Rayalu, *(2007),* Fluorosis crisis and Defluoridation: Emerging scenario and challenges ahead, *Environmental International, Under Review.*

S. P. Kamble, P. Dixit, S. S. Rayalu, S. Godfrey, S. Devotta, and, N. K. Labhsetwar (2007), Defluoridation of Drinking Water Using Modified Bentonite Clay. Under review, *Water Research.*

Patent:

An Improved Phase of Plaster of Paris for Defluoridation of Water, Indian patent application No. 0183NF, 2006)

Abbreviations

UNICEF	:	United Nations Children's Fund
NEERI	:	National Environmental Engineering Research Institute
PHED	:	Public Health Engineering Department
WHO	:	World Health Organization
IFM	:	Integrated Fluorosis Mitigation
QCRA	:	Quantitative Chemical Risk Assessment
NGOs	:	Non Governmental Organizations
ICMR	:	Indian Council of Medical Research
NCHSE	:	National Centre for Human Settlement and Environment
VVS	:	Vasudha Vikas Sansthan
WHO GDWQ	:	World Health Organization Ground water Quality
MP/CH	:	Madhya Pradesh / Chhatisgarh
TSC/SD	:	Total Sanitation Campaign / Swajaldhara
WSP	:	Water Safety Plan
PCA	:	Project Cooperation Agreement
CGWB	:	Central Ground Water Board
CWC	:	Central Water Commisssion
BCM	:	Billion Cubic Meters
BGS	:	British Geological Survey
DALYs	:	Disability-Adjusted Life-Years
RMRC	:	Regional Medical Research Centre
UNDP	:	United Nations Development Programme
INR	:	Indian Rupee
RCC	:	Reinforced Concrete
DF-pudiya	:	Defluoridation Pudiya
EMU	:	Environmental Materials Unit
EIRA	:	Environmental Impact & Risk Assessment
mg	:	Milligram
g	:	Gram
l	:	Liter
kg	:	Kilo Gram
ppm	:	Part Per Million
cm	:	Centimeter
μS	:	Micro Siemons
mm	:	Millimeter
g	:	Microgram
n	:	Adsorption activity
TDS	:	Total Dissolved Solids
Chakoda Baji	:	<u>Casia</u> <u>tora</u>