4th Workshop on Fluorosis & Defluoridation ISFR, EnDeCo, ICOH

Proceedings of the 4th International Workshop on Fluorosis Prevention and Defluoridation of Water

Colombo, Sri Lanka
March 2-6, 2004

Edited by:
Eli Dahi
In collaborations with:
Sunsanee Rajchagool

Published by:
ISFR
EnDeCo
& ICOH

Proceedings of
The 4th International Workshop
on
Fluorosis Prevention and Defluoridation of Water

March 2-6, 2004
Colombo, Sri Lanka

Edited by:
Eli Dahi
in collaboration with:
Sunsanee Rajchagool

Published by:
ISFR, EnDeCo & ICOH

ISBN
1174-9709

Proceedings of the 4th International Workshop on Fluorosis Prevention and Defluoridation of Water March 2-6, 2004, Colombo, Sri Lanka

Edited by:
Eli Dahi in collaboration with Sunsanee Rajchagool

Published by:
The International Society for Fluoride Research, ISFR
Editorial Office:
17 Pioneer Crescent, Dunedin, New Zealand
URL: http://www.fluoride-journal.com/
E-mail: spittle@es.co.nz

Environmental Development Co-operation Group, EnDeCo
Ngongongare, Usa River P.O.Box 215, Tanzania
URL: http://De-Fluoride.net
E-mail: elidahi@hotmail.com

Intercountry Centre for Oral Health, ICOH
548 Chiang Mai. Lumphun Road, Nong Hoi,
Muang. Chiang Mai. Thailand 50000
URL: http://www.icoh.org
E-mail: icoh@loxinfo.co.th

ISBN 1174-9709
ISFR, EnDeCo & ICOH

Printed by:
Chiang Mai B.S. Publishing
48 Santidhama Rd, Chang Puak, Muang Chiang Mai,
Thailand 50200

PREFACE

The 4th Workshop on Fluorosis Prevention and Defluoridation of Drinking Water gave whoever participated in the event of **March 2-6, Colombo, Sri Lanka 2004**, a genuine impression of the research and the mitigation work going on around the world. This Proceedings is a humble attempt to share and disseminate the exchanged knowledge and experiences. It is meant as another landmark in the "F & Def" landscape, hopefully worth to read for all researchers, health workers and administrators dealing with fluorosis. There is no need to rediscover the wheel, nor to repeat former mistakes.

The first International Workshop was held in **Arusha, Tanzania 1995**, the second in **Nazareth, Ethiopia 1997** and the third in **Chiang Mai, Thailand 2000**. For those of us who have been participating in all four "F & Def Workshops" it was a special pleasure and enrichment to participate in this Workshop. One could observe the development and the overall trends in fluorosis prevention and defluoridation of water:

Firstly, it is noticeable that the numbers of participants and contributors from developing countries has been successively increasing, in compare to those from the industrialised countries.

Secondly, due to the fact that workers from new countries are showing up and reporting about their areas, it is now possible to make steady more proper estimates of the widespread and the seriousness of the fluorosis problem. Our pervious conservative estimates on how many people do suffer from fluorosis have been revised, unfortunately upwards, stepwise for each Workshop.

Thirdly, more research and mitigation are reported with direct reference to actual field conditions and human suffering, less from laboratory and purely academic issues. Committed workers and institutions are no longer just waiting for the authorities to take actions like setting up a new guideline or provision of safe water; They are going ahead with their work in direct interaction with the affected people.

On behalf of the **International Organising Committee** I would like to address our thanks to the **National Organising Committee**, in particular the **Chairman Dr. K.D.G. Saparmadu**, who, in spite of difficult odds, could put Sri Lanka Professionals, the Authorities and press of the Country and an Overseas Donor Organisation (JICA) together, and in this way arrange for an impressive workshop. Thanks to the **Co-Chairman Dr. Adly Mohammed**, the **Scientific-Session Chairperson Dr. Siromani Abayaratna** and the **College of Community Dentistry of Sri Lanka**, who took their lion-share of the organisation of the workshop. Last but not least a special thank to the **Honorary Secretary Mr. J. P. Padmasiri**, who was at first to invite the event to Sri Lanka.

A grand thank to **Dr. Sunsanee Rajchagool**, Director of the **Intercountry Centre for Oral Health**, Chiang Mai, Thailand, for her support and efforts, without which it couldn't have been possible to edit and publish this Proceedings on a volunteer, non-profit basis.

Eli Dahi, Chairman of the International Organising Committee.

International Organising Committee

Kjell Bjorvatn, Professor
Eli Dahi, Professor, Chairman
David Kennedy, Dr
Wim van Palenstein Helderman, Professor
Sunsanee Rajchagool, Director, Vice Chairperson
K. D. G. Saparamadu, Dr
A. K. Susheela, Professor
Handa Yujiro, Professor

National Organising Committee:

S. Abayaratna, Dr, Chairperson-Scientific Sessions
A. A. H. K. Amerasinghe, Dr, Honorary Treasurer
E. A. Fernando, Dr
L. J. T. Fernando, Dr
J. M. W. Jayasundara Bandara, Dr
K. Krishnarasa, Dr, Honorary Secretary
A. Mohammed, Dr, Co-chairman
F. Nazriya Shahim, Dr
I. Ratnayake, Dr
D. de Silvia, Dr
J. P. Padmasiri, Mr, Honorary Secretary
K. D. G. Saparamadu, Dr, Chairman
U. S. Usgodarachchi, Dr, Honorary Secretary

List of Contents

Session 1: Epidemiology

Session 2: Methodology

Session 3: Defluoridation

Session 4: Mitigation

Session 5: Strategies

Session 1

Epidemiology

Epidemiology Study of Dental Fluorosis in China

Y Si * and B Zhang *
China

SUMMARY: The Epidemiology of dental fluorosis in China is studied using the cross-sectional national oral health survey from 1995. 46,904 school children from 11 different provinces, aged 12 and 15 years, are selected randomly by stratification and multistage clustering. Urban-rural and male-female samples are balanced and the modified Dean's index, CFI, is estimated.
It is found the dental fluorosis prevails in all surveyed provinces. However, the majority of the study subjects had the very mild and mild fluorosis. Of the affected subjects about 62 % had the very mild or mild scores and 38 % had the moderate or severe scores.
The prevalence varies to a large extent among the different provinces. Tientsin has prevalence 16.2 times higher than the average prevalence in the 10 other provinces; 49.6 % and 2.6 % respectively. The CFI is 18.5 times higher in Tientsin than in the 10 other provinces; 0.06 and 1.25 respectively. Rural Tientsin has a prevalence as high as 78 %.
The urban-rural differences do not seem to have a general trend. Both in Shanghai and in Guangdong dental fluorosis is slightly higher in urban than in rural areas. However, in 6 of the other 9 provinces, i.e. Beijing, Tientsin, Shandong, Liaoning, Zhejiang and Hubei, fluorosis prevails much more in the rural areas.
The study indicates that dental fluorosis in China is mainly due to excess of fluoride in the drinking water.

Key words: Epidemiology study, fluorosis, dental fluorosis, Deans index, community fluorosis index, CFI, China, China province, Tientsin province, drinking water.

INTRODUCTION

Dental fluorosis: Fluorosis is a kind of enamel hypoplasia caused by intake of excessive fluoride during the period of the enamel maturating. The mechanism is a destruction of the ameloblasts and the production of abnormal mottled enamel 1. The appearance of the damaged enamel would differ depending on the severity and timing of the exposure to fluoride. Endemic fluorotic areas, where excessive fluoride occurs in the environment, are found all over the world. In most cases the endemic fluorosis is due to too high fluoride concentrations in the drinking water. Another type of fluorosis is found is areas where intensive coal burning takes place.

* *National Committee for Oral Health (NCOH), No.22 Zhongguancun Nandajie, Haidian District, Peking University School of Stomatology, Beijing 100081, China.*
ncoh@public.bta.net.cn

Fluoridation and fluorosis: Meanwhile, with the confirmation of the caries preventive effect of fluoride, all countries started using fluoridated toothpaste and some countries even began to fluoridate drinking. Many studies had showed that the prevalence of caries had declined obviously 1-3. But at the same time, the prevalence of fluorosis in many countries had a trend to increase 4-5, whereas, some studies also concluded that the fluorosis prevalence remained the same 6.

Fluorosis in China: The first national oral health survey in China was carried out in 1983, organized by the ministry of health and the ministry of education. 383,265 students from 29 provinces were sampled and their oral health status was evaluated. The subjects were grouped according to age: 7, 9, 12, 15 and 17. The prevalence of the fluorosis varied from 0 to 69.5 % 8.

Chinese data on endemic fluorosis from 1990 to 2000 indicate that the state of the fluorosis had been well under control during these ten years. The prevalence of water-based fluorosis in Huabei, Huadong and Xibei was declining, while the prevalence of fluorosis in Dongbei was increasing. Also the non-water-based fluorosis is reported to have been rising in west of our country 7.

In 1995, a second national oral health survey was conducted by the Center of Diseases Control, Ministry of Health and the National Committee for Oral Health. Now a third oral health survey is in its planning phase, to be carried out probably in 2005.

The present cross-sectional study investigates the fluorosis prevalence in China, the date being withdrawn from the 1995 survey.

MATERIALS AND METHODS

Sampling: The random stratified multistage and clustering sampling methods were used. The oral health status varies among different age, sex and residential area. Thus in the sampling, the number of male (23,452) and female (23,452) were balanced, but the samples in the urban areas was double of that in rural ones. In China, the proportion of population in urban to rural areas was 37.7 % to 62.3 %. All subjects were local residents who have been living in the locality since they were 6 years old.

Altogether 23,452 students aged 12 years old and 23,452 15-year-old students were selected from eleven provinces all over the China. In each province, we selected three typical cities, one was the capital city, another was a local city (a kind of middle city) and a third was a county city (a kind of small city). In every city, one urban area and one rural area were selected.

Clinical investigation: Before the national oral health survey was carried out, the National Committee for Oral Health allotted the work to the local Committee for Oral Health from 11 provinces. A technical instruction team was constituted in each province to take charge of the organization, sampling and training. The leaders of the teams were all experienced dentists. The modified Dean's Index of fluorosis was used. Only a score was obtained from each person, based on the lower of the two most severely affected teeth. The classification is shown in Table 1.

TABLE 1: Diagnostic criteria and weighting system for Dean's Index [9].

Classification & Weighting	Diagnostic Criteria
Normal ~0	The enamel presents the usual translucent semi-vitreous type of structure. The surface is smooth, glossy, and usually of a pale creamy white colour.
Questionable~ 0.5	The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is utilized in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" not justified.
Very mild ~ 1	Small, opaque, paper-white areas scattered irregularly over the tooth but not involving as much as approximately 25 % of the tooth surface. Frequently included in this classification are teeth showing no more than about 1-2 mm of white opacity at the tips of the summits of the cusps of the bicuspids or second molars.
Mild ~ 2	The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50 % of the tooth.
Moderate ~ 3	All enamel surfaces of the teeth are affected, and surfaces subject to attrition show marked wear. Brown stain is frequently a disfiguring feature.
Severe ~ 4	All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is the discrete or confluent pitting. Brown stains are widespread, and teeth often present a corroded-like appearance.
CFI =0.5 * number of people of "questionable" + 1 * number of "very mild" + 2 * number of "mild" + 3 * number of "moderate" + 4 * number of "severe")/ the number of people examined	

Nature light was used to examine and the teeth were not dried before the examination. The number of examiners in each province was not more than ten to lessen the bias between examiners.

RESULTS

The data obtained are summarised in Table 1 and 2. Figures 1 & 2 illustrate the fluorosis prevalence and the urban/rural differences in the provinces. Figures 3 & 4 illustrate the Community Fluorosis Index and the 12/15 years-group differences in the provinces. Figures 5 & 6 illustrate the distribution of fluorosis severity among the selected age groups in surveyed provinces all together.

TABLE 1: The prevalence of fluorosis of 12 and 15 years old students in urban and rural areas of the surveyed provinces.

Province	12-year-old			15-year-old		
	Urban	Rural	Both	Urban	Rural	Both
Beijing	2.39	5.90	3.56	1.69	12.64	5.35
Shanghai	5.00	0.00	3.33	5.14	0.00	3.42
Tientsin	41.31	72.75	51.69	32.11	78.09	47.47
Gansu	0.92	1.26	1.03	5.14	3.09	4.46
Shandong	3.17	16.15	7.50	1.55	16.43	6.52
Yunnan	0.42	0.56	0.47	1.06	0.42	0.84
Liaoning	1.34	9.13	3.94	1.76	13.62	5.72
Zhejiang	0.99	4.63	2.20	0.7	8.29	3.24
Hubei	0.42	1.83	0.89	0.35	0.98	0.56
Guangdong	1.41	0.28	1.03	3.45	0.14	3.35
Sichuang	0.14	0.00	0.09	0.00	0.00	0.00
All	5.21	10.23	6.89	4.81	12.16	7.27

TABLE 2: The Community Fluorosis Index (CFI) of the 12 and 15 years old students in the surveyed provinces.

Province	12-year-old			15-year-old		
	Urban	Rural	Both	Urban	Rural	Both
Beijing	0.051	0.140	0.081	0.035	0.247	0.106
Shanghai	0.218	0.000	0.146	0.197	0.000	0.131
Tientsin	1.022	1.830	1.292	0.851	1.923	1.209
Gansu	0.021	0.030	0.024	0.102	0.067	0.090
Shandong	0.059	0.320	0.147	0.030	0.383	0.148
Yunnan	0.010	0.010	0.011	0.024	0.006	0.018
Liaoning	0.028	0.170	0.076	0.030	0.216	0.092
Zhejiang	0.017	0.080	0.038	0.014	0.142	0.057
Hubei	0.011	0.040	0.019	0.008	0.025	0.014
Guangdong	0.032	0.020	0.027	0.079	0.007	0.055
Sichuang	0.004	0.000	0.003	0.000	0.000	0.000
All	0.134	0.240	0.169	0.125	0.274	0.175

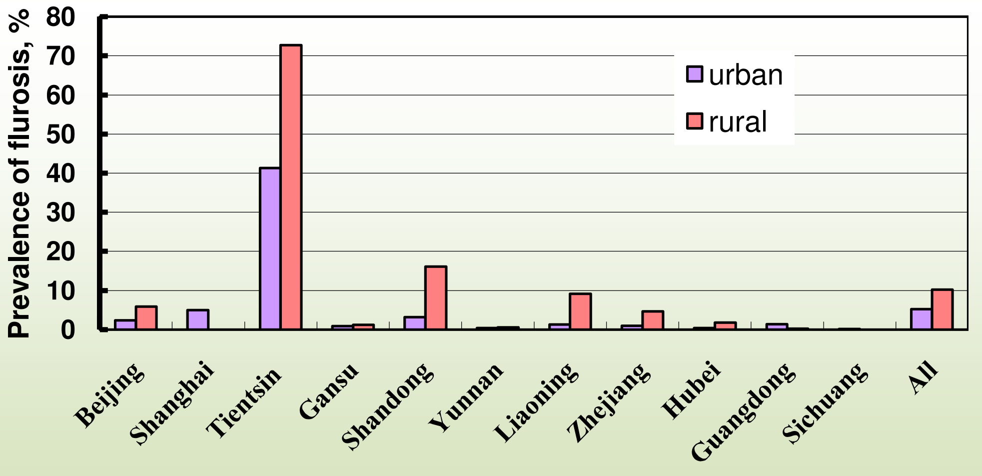


FIGURE 1: The prevalence of fluorosis for 12-years-old students in urban and rural areas.

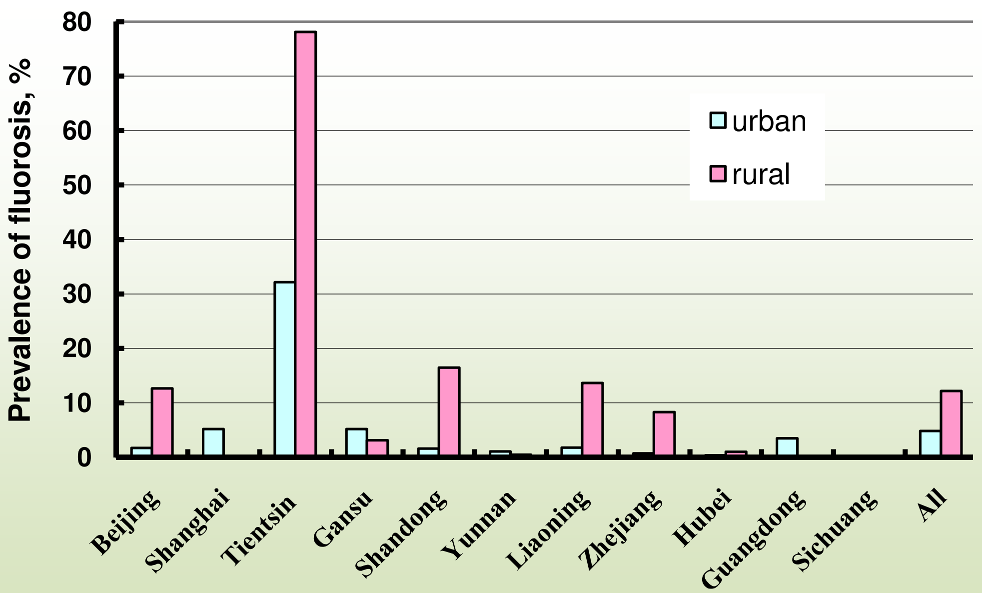


FIGURE 2: The prevalence of fluorosis for 15-years-old students in urban and rural areas.

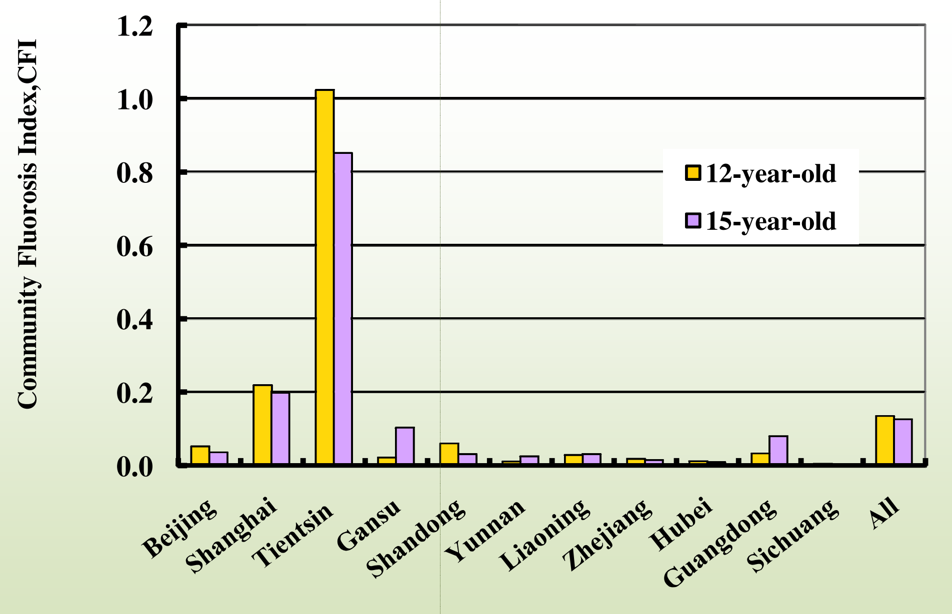


FIGURE 3: The Community Fluorosis Index (CFI) of the 12 and 15 years old students in urban areas.

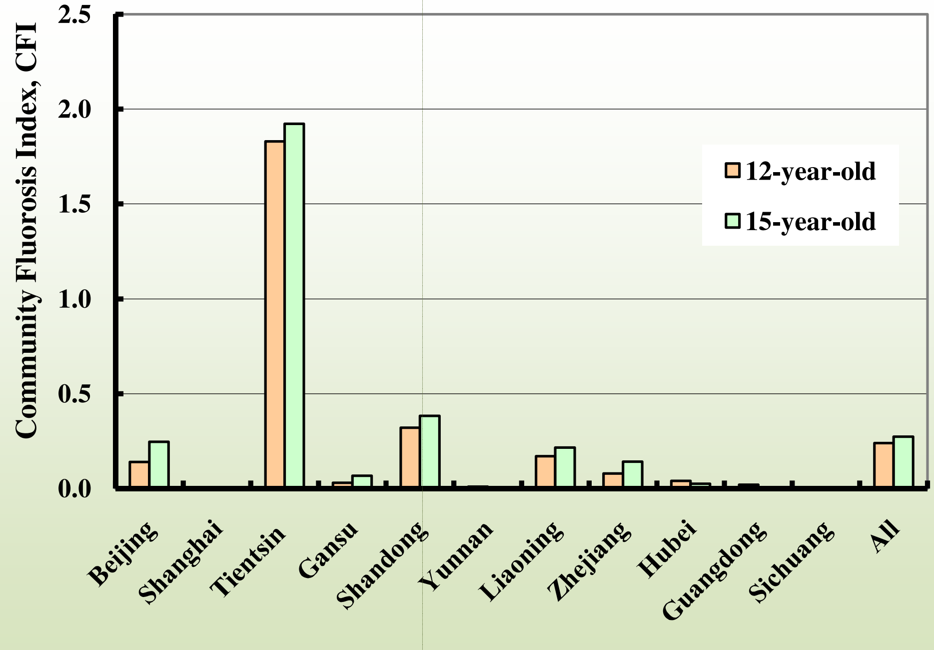


FIGURE 4: The Community Fluorosis Index (CFI) of 12 and 15 years old students in rural areas.

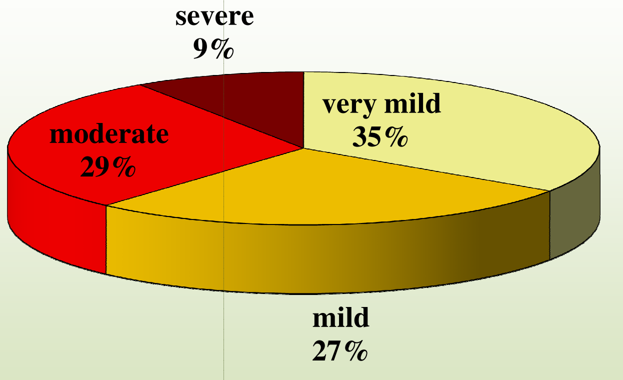


FIGURE 1: THE DEANS SCORES AMONG THE 12-YEARS-GROUPS IN THE 11 SELECTED PROVINCES.

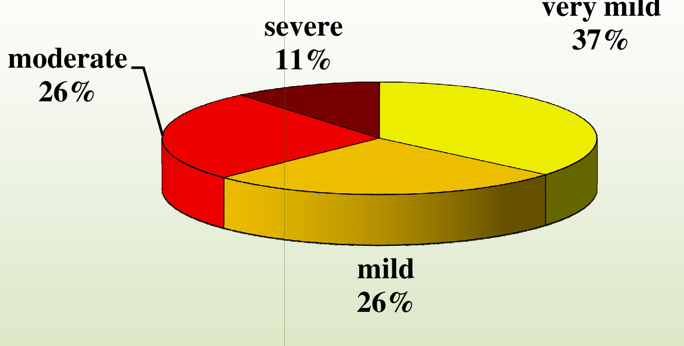


FIGURE 6: The Deans scores among the 15-years-group in the selected provinces in China.

DISCUSSION

Background studies: Many investigations showed that the prevalence of fluorosis was quite associated with the fluoride concentration in drinking water, and the prevalence is directly related to water fluoride concentration [10-11]. Also some studies showed that the prevalence is increasing with the increased water fluoride concentration [12]. A Chinese survey concluded that the relation between the prevalence of fluorosis and the water fluoride concentration appeared is a linear one [13].

Province differences: In China 37.7 % of the1.3 billion population (2002) live in urban areas, while 62.3 % in rural areas. In most urban areas, portable water is made easily available, while well water is the most common source in rural areas. The quality of the portable water is checked up strictly checked, including the fluoride concentration, while well water is often pumped from the deep underground without further control.

This study shows that the dental fluorosis occurs in all 11 surveyed provinces of China. However, the prevalence in Tientsin City appears to be about 16.2 times the prevalence in the 10 other provinces; 49.6 % and 2.6 % respectively. The Deans score is 18.5 times higher in Tientsin that in the 10 other provinces, 0.06 and 1.25 respectively.

This is in agreement with that the fluoride concentration in water sampled in Tientsin varied from 0.5 mg/L to 5 mg/L, while the water fluoride concentrations in other sampling sites were all less than 1 mg/L. Thus Tientsin is a typical fluorotic area, where the fluorosis is related to the drinking water. It constitutes a severe public health problem.

Urban-rural differences: The urban-rural differences do not seem to have a general trend. Both in Shanghai and in Guangdong dental fluorosis is slightly higher in urban than in rural areas. However in 6 of the other 9 provinces, i.e. Beijing, Tientsin, Shandong, Liaoning, Zhejiang and Hubei, fluorosis prevails much more in the rural areas. Probably these differences are similarly associated with the fluoride concentration in water.

Fluorosis severity distribution: Figures 5 & 6 show that the majority of the study students had the very mild and mild fluorosis. Of the affected subjects about 62 % had the very mild or mild scores and 38 % had the moderate or severe scores. This is similar to findings of severity distribution as found by Rozier 1999 [14] in North American areas, by Riodan & Banks in western Australia, and by Clark et al. in Canadian areas [16-18].

Age differences: This study involves only 12 years and 19 years groups. No significant difference could be found between these groups in our survey. This is probably reflecting that the exposure to fluoride has been of the magnitude during the actual 7 years of China's otherwise very long history and changes in environments and social habits.

ACKNOWLEDGMENTS

The authors express acknowledgements to all workers in this national oral health survey.

REFERENCES

1. World Health Organization. Prevention methods and programmes for oral diseases. Report of a WHO Expert Committee. WHO technical report series 713. Geneva, 1984.
2. Ismail AI, Brodeur JM, Kavanagh M, Boisclair G, Tessier C, Picotte L. Prevalence of dental caries and dental fluorosis in students, 11-17 years of age, in fluoridated and nonfluoridated cities in Quebec. Caries Res 1990;24:290-7.
3. McKnight CB, Levy SM, Cooper SE, Jakobsen JR, Warren JJ. A pilot study of dental students' esthetic perceptions of computer-generated mild dental fluorosis compared to other conditions. J Public Health Dent 1999;59(1):18-23.
4. Pendrys DG, Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. J Dent Res 1990;69(Spec Iss):529-538.
5. Clark DC. Trends in the prevalence of dental fluorosis in North America. Community Dent Oral Epidemiol 1994;22:148-152.
6. Heifetz SB, Driscoll WS, Horowits HS, et al. Prevalence of dental caries and dental fluorosis in areas with optimal and above-optimal water fluoride concentrations: a 5-year follow up survey. Jam Dent Assoc, 1988;116(4):490-5.
7. Sun DJ, Shen YF, Zhao XH, et al. Analysis on the disease trend and present state of endemic fluorosis in China mainland. Chinese J Endem 2001;20(6):429-33.
8. Health Ministry, People's Republic of China. Epidemiology study of caries and periodontal diseases of students in China. 1st ed. Beijing: 1987.
9. Dean HT. Classification of mottled enamel diagnosis. J Am Dent Assoc 1934;21:1421-1426.
10. Segreto VA, Camann D, Collins EM, Smith CT. A current study of mottled enamel in Texas. J Am Dent Assoc 1984;108:56-59.
11. Warren JJ, Levy SM, Kanellis MJ. Prevalence of dental fluorosis in the primary dentition. 2001;61(2):87-91.
12. Evans RW. Changes in dental fluorosis following an adjustment to the fluoride concentration of Hong Kong's water supplies. Adv Dent Res 1989;3:154-160.
13. Wang XC, Guo XJ, Kawahara K, et al. A study on the correlative relation between fluoride exposure of groundwater and endemic fluorosis. Chinese J Endem 2001;20(6):434-37.
14. Rozier RG. The prevalence and severity of enamel fluorosis in North American children. J Public Health Dent 1999 Fall;59(4):239-46.
15. Riordan PJ, Banks J. Dental fluorosis and fluoride exposure in Western Australia. J Dent Res 1991;70:1022-1028.

16. Clark DC, Hann HJ, Williamson MF, Berkowitz J. Aesthetic concerns of children and parents in relation to different classifications of the Tooth Surface Index of Fluorosis. Community Dent Oral Epidemiol 1993;21:360-4.
17. Clark DC, Hann HJ, Williamson MF, Berkowitz J. Aesthetic concerns of children and parents in relation to different classifications of the Tooth Surface Index of Fluorosis. Community Dent Oral Epidemiol. 1994;22(6):461-4.
18. Clarke JHC, Mann JE. Natural fluoridation and mottling of teeth in Lincolnshire. Br Dent J 1960;108(5):181-187.

Dental Fluorosis in Anuradhapura District, Sri Lanka

T M M H Tennakoon*
Sri Lanka

SUMMARY: Dental Fluorosis has been recognized as an endemic problem affecting different areas of Sri Lanka with naturally occurring fluoride in drinking water. This study involves a sample of 400 school children in the district of Anuradhapura.

It is found that the prevalence of very mild or greater dental fluorosis is 89.8 % and CFI in Anuradhapura is 1.69. 33.4% of the affected needed treatment. Over two-thirds of the sample is using fluoridated toothpaste. Low awareness was also observed in the sample.

More than 50% of the used water sources contain fluoride over 0.7 mg/L.

It is concluded that dental fluorosis constitutes a major public health problem in Anuradhapura. It is discussed how appropriate measures should be taken in order to solve this long-term problem.

Key words: Anuradhapura, Sri Lanka, community fluorosis index, CFI, fluorosis prevalence, school children.

INTRODUCTION

Reports of other studies have been cited that prevalence of dental fluorosis is 55 % to 77 % in 7 to 20 year old school children in North Central Province [1, 2] and high levels of fluoride in drinking water in Anuradhapura [3]. Communities in Anuradhapura where the Community Fluorosis index, CFI, has been determined are Hidogama 1.89, Galkulama 2.29 and Thalawa 1.85 [4].

In the recent past widespread occurrence of dental fluorosis has been reported from different parts of Anuradhapura. Along with expansion of settlements and resultant destruction of the forests most water tanks were dried. In combating the scarcity of water more and more wells and tube wells were dug and people used to consume underground water rather than rainwater. The other reason is unintentional ingestion of fluoride from variety of sources like fluoridated dentifrices, consumption of food grown and processed in areas of high fluoride concentration and surface water contamination with agro-chemicals containing fluoride.

A study was carried out to assess the present status and future needs of the population. This will also provide reliable baseline data for development of regional oral health programmes in combating endemic problem of dental fluorosis. Prevalence of Dental

* *Office of Deputy Provincial Director of Health Services, Anuradhapura, Sri Lanka*
mahinda@hotmail.com

fluorosis, CFI, treatment needed for fluorosis, awareness of the disease, tooth cleaning material used and fluoride content in drinking water were determined, for Anuradhapura district.

MATERIALS AND METHODS

Twenty clusters from the Anuradhapura district of Sri Lanka were selected for this study. A total of 400 individuals comprising 20 from each cluster was included in the sample. School children, those who have completed their 15th birthday but not reached 16th birthday and those who have lived life time in the area, were subjected to an interviewer administered questionnaire and clinical oral examination.

Their teeth were examined under natural light and scored by Dean's index according to the criteria stipulated by WHO [5, 6]. The treatment need was also recorded.

Prior to the clinical examination, information related to socio-demographic profile, tooth cleaning material, source of water used for drinking, disease awareness (presence/absence of white/ brown patches, causation, prevention), instituting a relevant preventive practice and how an individual's appearance of teeth affects his/her daily life (psychological impact) were obtained using an interviewer administered questionnaire.

Data processing and analysis were done using the statistical software programme SPSS 11.

From the study group a random sample of 300 students were selected to analyse water sources. These sources were later analysed for their Fluoride content by colorimetric method using SPADNS reagent.

RESULTS

The prevalence of dental fluorosis, very mild or greater, was 89.8 % with Dean's index.

Community fluorosis index is 1.69 for Anuradhapura which indicates a major public health problem.

44 % of the water sources analysed contained fluoride less than 0.7 mg/L.

69 % of the sample uses fluoridated toothpaste, despite high fluoride content in drinking water.

Awareness of white/brown patches on teeth was mostly expressed by children with moderate to severe forms of Fluorosis.

44.6 % of the respondents related the problem to water whereas only 9 % of the study group knew fluoride as the causative factor.

Knowledge on methods of prevention was significantly lower.

Only 3 % of the respondents in the group were instituting an effective preventive method.

Psychological impact is more in children with moderate to severe forms of Dental fluorosis.

33.2 % of the affected needed some form of treatment.

DISCUSSION

Present findings confirm that dental fluorosis constitutes a major public health problem to the community and so to the health authorities in Anuradhapura. Low cause awareness, poor knowledge about appropriate preventive measures and poor access to safe drinking water could be some factors implicated for this.

Fluoride content of water sources ranged from 0.03 mg/L to 6.5 mg/L. Even within a small area it showed considerable variation in fluoride concentrations. This opens the possibility of locating water sources with acceptable fluoride concentrations even within high fluoride areas. However additional research in this is warranted to find whether such water sources maintain a low fluoride concentration through out.

69 % of the sample is using fluoridated toothpaste despite high Fluoride content in drinking water. The reason may be due to ubiquitous presence of fluoridated dentifrice in the area and poor availability of non- fluoridated dentifrice.

The earliest study on fluorosis done by Seneviratne et al1974 [1], revealed prevalence of Dental fluorosis was 55 % to 77 % in7 to 20 year old school children in North Central Province of Sri Lanka. As little information is available on prevalence of dental fluorosis in Anuradhapura there was no data for direct comparison. Study done by Abayarathna [4] in three high fluoride areas in Anuradhapura the CFI range from 1.85 to 2.29, when fluoride concentration in drinking water range from <1mg/L to 10.9 mg/L

In a study [7] done in Mexico city children ages 7 to 12 years attending a pediatric dental clinic to measure Dental Fluorosis impact on well-being, 66 % and 81 % of the children reported experiencing at least occasionally distress or being worried respectively because of appearance of teeth.

Thus it is concluded that education of the community about fluorosis and its prevention, introduction of household defluoridation, facilitating collection of rainwater, protection of low fluoride surface water from contamination with agrochemicals and establishment of curative and preventive fluorosis facilities are needed in Anuradhapura .

ACKNOWLEDGEMENTS

The author acknowledges the contributions and assistance of Dr.U. S. Usgodaarachchi, Dr. Priyangika Konthasighe, Mr. L. L. A. Peiris, J. P. Padmasiri, the district PDHS-NCP, DPDHS and DDHSs and Dr. G. P. H.Pathirana.

REFERENCES

19. Senevirathne B.,Thambipillais, Hettiarachchi J., Senevirathna K. Endemic Fluorosis in Ceylon. Transaction of Royal Society of Tropical Medicine & Hygiene 1974; 68 (1): 105-113.
20. Senevirathne B., Senevirathna K., Hettiarachchi J., Thambipillai S. Assessment of fluoride content of water in wells selected randomly and after examining school children for dental fluorosis. Bulletin of World Health Organization.1973; 49: 419-422.
21. Raghva Rao K. V. , Bogoda K. R. Nilaweera N. S. , de Silva P.H.D.S (1987) Mapping high fluoride content in ground water, Sri Lanka, (NWS&DB) WHO Communication.
22. Abayarathna S. Community fluorosis index in 3 schools in the Anuradhapura district. J Sri Lanka Dental 2002; 31: 70-76.
23. World Health organization – Oral Health Survey – Basic methods: 4th edition Geneva: World Health Organization,1987.
24. Dean HT. The Investigation of physiological effects of the epidemiological method. In Moulton FR ed, Fluoride and Dental Health. Washington DC: American Association for advancement of sciences, 1942; 119: 23-31.
25. Soto-rojas A. E., Martez-mier, Manpome G. and Ure-cirett. Impact of Dental Fluorosis on well-being in Mexico city children. Fluorides and Fluorosis. IADR/AADR/CADR 80th General sessions (March 6-9,2002) San Diego.

Relation of Dental Fluorosis to Ground Water Fluoride In South Africa

E J Ncube [a,c] and C F Schutte [b]
Republic of South Africa

SUMMARY: Two sets of data, one of the occurrence of fluoride in ground water and the other of the occurrence of dental fluorosis in South African regions are surveyed and mapped. The percentage morbidity of dental fluorosis varies from province to province, district to district and village to village. Most affected are the Limpopo, Northern Cape, North-West and KwaZulu Natal provinces. The results reveal that most of the local people in these areas suffer from dental fluorosis at varying degrees.

It is shown that dental fluorosis occurs in areas where the fluoride levels in ground water are higher than those recommended for drinking water. The degree and severity of mottling in the subjects studied corresponds with the level of fluoride in drinking water.

It is concluded that fluorosis constitutes a health problem in South Africa and that the problem is related to the occurrence of fluoride in the ground water.

Key words: Dental fluorosis, fluoride, fluoride ion concentration; groundwater, health, morbidity of dental fluorosis, occurrence, South Africa, water quality

INTRODUCTION

The beneficial attributes of fluorides to human health have been known for many years [1]. The fluoride ion is a very important dietary substance. When ingested at specific doses, the fluoride ion is beneficial to both bone and dental development in human beings. At correct intake levels it plays a very important role in the formation of the teeth [2]. Too low fluoride intake levels during childhood may give rise to the occurrence of preventable dental caries in later years. Dental caries is a disease caused by specific bacteria harboured in dental plaque, fermenting carbohydrates to produce acids that can demineralise tooth enamel [3]. If this demineralisation is allowed to continue, the enamel is penetrated permitting bacterial invasion and eventual loss of the tooth by decay in the absence of restorative dental care.

Too high fluoride intake normally gives rise to teeth mottling (dental fluorosis) and related problems. Endemic fluorosis is a condition which is caused by an excess of fluoride in drinking water and which affects the calcification of the teeth, resulting in what is commonly known as dental fluorosis. Maughan-Brown in 1935 and Raubenheimer in 1938 first reported a study of the occurrence of mottled enamel in South Africa.[1]

In 1941, Ockerse produced three reports on human fluorosis in various regions of the former Union of South Africa. At that time 805 areas in which dental fluorosis occurred were known [4]. The majority of the dental fluorosis affected in South Africa

[a] *Rand Water Board, 522 Impala Rd, Glenvista, 2000, South Africa.*
[b] *Department of Chemical Engineering, University of Pretoria, Pretoria, 0002; South Africa.*
[c] *For correspondence: Rand Water, P.O. Box 1127, Johannesburg, 2000, South Africa. E-mail: encube@randwater.co.za*

are the black people living in rural areas. Different studies have shown that the occurrence of dental fluorosis in the majority of cases in South Africa are related to the fluoride content of groundwater used for drinking purposes [5, 6].

The awareness of excess fluoride consumption through water has however been increasing countrywide [7,8]. The issue of whether and at what levels of concentration, to manage the fluoride ion concentrations in South Africa's public water supplies is a contentious one. The Department of Water Affairs and Forestry (DWAF) as the custodian of the country 's water resources, manages the fluoride levels through the criteria set in its guidelines[9]. The guidelines are used by DWAF as a decision support tool to judge the fitness of water for different use. The current target water quality range, (TWQR) which is the concentration range in water necessary to meet requirements for a healthy tooth structure is 0-10 mgF/L. This is a function of daily water intake and varies with the annual maximum daily air temperature. For South African conditions, a concentration of approximately 0.75 mgF/L corresponds to a maximum daily temperature of approximately 26-28ºC. The DWAF works closely with the South African Bureau of Standards (SABS) that is the standard setting body in South Africa. According to the SABS specifications [10] the ideal concentration of fluoride in water that is suitable for lifelong consumption is 0.7 mg/L. In September 2000, the Department of Health proposed compulsory fluoridation of public water supplies [11] to an optimum concentration of fluoride not more than 0.7mg/L.

The main problem is the lack of adequate information on the environmental and health impacts of fluoride. There is also a lack of accurate information about the current status of fluoride in the country's groundwater resources. This paper addresses these gaps by assessing the groundwater fluoride data for the period 1996-2000 in order to establish the current distribution of fluoride ion concentration levels in groundwater sources and the impact of dietary fluoride on dental health. Areas with fluoride ion concentrations lower or higher than those recommended for drinking water are delineated. The occurrence of dental fluorosis in selected provinces is shown. The degree of the severity of dental fluorosis is shown in terms of the percentage morbidity of dental fluorosis. This is overlain on a water quality map in order to assess the relationship between the occurrence of fluoride in groundwater and the incidences of dental fluorosis. Relevant recommendations based on the results of this study are also made. A detailed analysis of the factors that affect the occurrence of fluoride in groundwater and distribution of fluoride in groundwater is beyond the scope of this paper.

MATERIALS AND METHODS

The fluoride data was extracted from the DWAF's Water Management System (WMS) database housed at the Institute for Water Quality Studies (IWQS). This constituted of 14,509 groundwater samples. This included boreholes and springs. The data was screened for errors incorrect reference codes, incorrect coordinates and number of fluoride ion concentrations reported for the station. A statistical package, STATISTICA, which calculated a fluoride median value for each unique groundwater source was used to process the data. This resulted in a summarized data set comprising of 6042 values. Plotting this data on a map assessed the current status of fluoride ion distribution in the country, cf. Figure 1. The dental fluorosis data was obtained from the National Department of Health (NDOH). These data were processed according to Wang, *et al*., 1999 [12], Table 1, in order to obtain the % morbidity of dental fluorosis. The results for the selected provinces are as shown in Tables 2-5. The results are based on the degree of mottling of the teeth as observed during the dental examinations. A comparison was made between the % morbidity of dental fluorosis and the drinking water quality in selected provinces. The results are shown in Figures 2-5.

RESULTS AND DISCUSSION

The current status of fluoride ion distribution in South African groundwater is provided in Figure 1. The figure shows that the problems of high fluoride ion concentrations are currently being experienced in the Limpopo, Northern Cape, North-West and KwaZulu Natal provinces. A few cases were recorded in other parts of the country. The current situation of the fluoride distribution in the country is such that no clear demarcation can be made of areas deficient in fluoride since some areas have groundwater sources in which the fluoride ion concentrations are higher than the recommended limits for drinking water. This is an indication that the occurrence of low fluoride ion concentrations in groundwater is currently not a national problem. Many sources in the Limpopo, North-West, Northern Cape, Western Cape and KwaZulu Natal provinces are in need of partial de-fluoridation. This must receive serious consideration if the water from those sources is being used for drinking purposes.

The results of the general investigations of fluorosis obtained from the data received from the DOH are as presented in Tables 2-5. The criteria used to interpret the results are as presented in Table 1, adopted from Wang, *et al*., 1999 [12]. The information on the dependency of communities on groundwater for use as drinking water is presented in Table 6. This information was obtained in order to confirm the link between high fluoride levels in groundwater, the consumption of this fluoride contaminated water and the occurrence of dental fluorosis in the same areas. It should be noted that in a province where the communities depend largely on groundwater for drinking water purposes like the North-West Province, the morbidity of dental fluorosis is high.

TABLE 1: Criteria used for the interpretation of Dental fluorosis results.

% Morbidity of dental fluorosis = (B + C)

Class	Dental Fluorosis symptoms
A-Normal	No apparent abnormality
B-Slight (Questionable, Very mild, Mild)	Yellowish teeth with slight erosion
C-Heavy (Moderate and Severe)	Extended erosion or mottling or heavy damage to teeth.

TABLE 2: Dental Fluorosis by level of Severity in the Free State (FS) Province (Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
FS-Region A	34.5%	62.2%	2.5%	64.7%	64.70
FS-Region B	35.6%	62.3%	1.3%	63.6%	63.60
FS-Region C	66.1%	29.1%	3.0%	32.1%	32.10
FS-Region D	66.1%	31.5%	1.7%	33.2%	33.20
FS-Region E	66.5%	29.7%	1.7%	31.4%	31.40
FS-Region F	42.4%	51.4%	4.8%	56.2%	56.20

TABLE 3: Dental Fluorosis by level of Severity in the Western Cape (WC) Province (Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
WC-Boland –Overberg Region	86.0%	13.3%	0 %	13.3%	13.30
WC- Metro	54.5%	42.1%	2.2%	44.3%	44.30
WC- South Cape –Karoo	46.5%	39.2%	10.7%	48.7%	48.70
WC-West-Coast	69.4%	26.5%	1.4%	27.9%	27.90

TABLE 4: Dental Fluorosis by level of Severity in the KwaZulu Natal (KZN) Province (Age group 12)

Name of Place	Class A	Class B	Class C	B + C	% Morbidity
Durban	79.6%	10.9%	1.4%	12.3%	12.30
Jozini	50.7%	34.7%	2.5%	37.2%	37.20
Ladysmith	41.7%	50.8%	7.0%	57.8%	57.80
Newcastle	86.4%	7.6%	3.3%	10.9%	10.90
Pietermaritzburg	72.2%	23.1%	2.1%	25.2%	25.20
Port Shepstone	77.1%	17.5%	1.8%	19.3%	19.30
Ulundi	57.8%	38.2%	1.9%	40.10%	40.10

TABLE 5: Dental Fluorosis by level of Severity in the North-West (NW) Province (Age group 12)

Name of Place	Class A	Class B	Class C	B + C	%Morbidity
NW-Brits	32.8%	61.7%	5.6%	67.3%	67.30
NW-Delareyville	80.7%	5.8%	0%	5.8%	5.80
NW-Mafikeng	97.7%	0.9%	0%	0.9%	0.90
NW-Mogwase	6.7%	93.4%	0%	93.4%	93.40
NW-Moretele	25.6%	35.3%	39.1%	74.4%	74.40
NW-Potchefstroom	82.8%	17.2%	0%	17.2%	17.20
NW-Rustenburg	81.9%	5.8%	0%	5.8%	5.80
NW-Ganyesa	26.7%	54.9%	18.4%	73.3%	73.30
NW-Klerksdorp	82.7%	13.5%	1.8%	15.3%	15.30
NW-Kuruman	42.3%	57.7%	0%	57.7%	57.70
NW-Lichtenburg	86.6%	12.8%	0.5%	13.3%	13.30
NW-Schweizer	71.7%	26.6%	1.6%	28.2%	28.20
NW-Taung	31.6%	60.7%	7.1%	67.8%	67.80
NW-Ventersdorp	73.3%	20%	6.7%	26.7%	26.70
NW-Vryburg	49.7%	43.6%	6.7%	50.3%	50.30
NW-Zeerust	47.8%	48.6%	2.1%	50.7%	50.70
NW-Wolmaranstad	61.1%	33.4%	5.6%	39%	39.00

The distribution of dental fluorosis in selected provinces is shown in the maps in figures 2-5. The maps show the spatial distribution of the current % morbidity of dental fluorosis for the Western Cape, North-West and KwaZulu Natal provinces. The fluoride data is overlain on each provincial map in order to correlate the level of the morbidity of dental fluorosis and fluoride levels in drinking water. It should be noted that there exist differences in the morbidity of dental fluorosis among the investigated and this is true for the fluoride levels in groundwater sources. It was difficult to present the Free State province data using the same format as the dental fluorosis data was reported in regions whose digital data was not present at the time of writing this dissertation.

TABLE 6: Dependency of the communities, Com., on water sources and the water supply potential.

Province	**North-West**		**Free State**		**KwaZulu Natal**	
Source type:	**Com.**	**People**	**Com.**	**People**	**Com.**	**People**
Groundwater	1063	1,411,707	72	122,161	807	2,416,721
Surface Water	221	2,099,461	149	3,097,252	75	212,698
Combined Sour.	13	108,593	30	139,452	48	149,685
None	-	-				
Unknown	-	-			1,563	5,624,304
Total	**1297**	**3,619,761**	**251**	**3340,865**	**2,493**	**8,403,408**
Supply Potential						
Poor	160	48,733	-	-	-	-
Low	207	330,061	24	83,380	-	-
Moderate	341	1,220,101	99	905,112	996	2,590,125
High	266	1,620,011	124	2,271,450	558	1,529,404
Very High	323	400,855	4	80,923	939	4,283,879
Total	**1297**	**3,619,761**	**251**	**3,340,865**	**2,493**	**8,403,408**

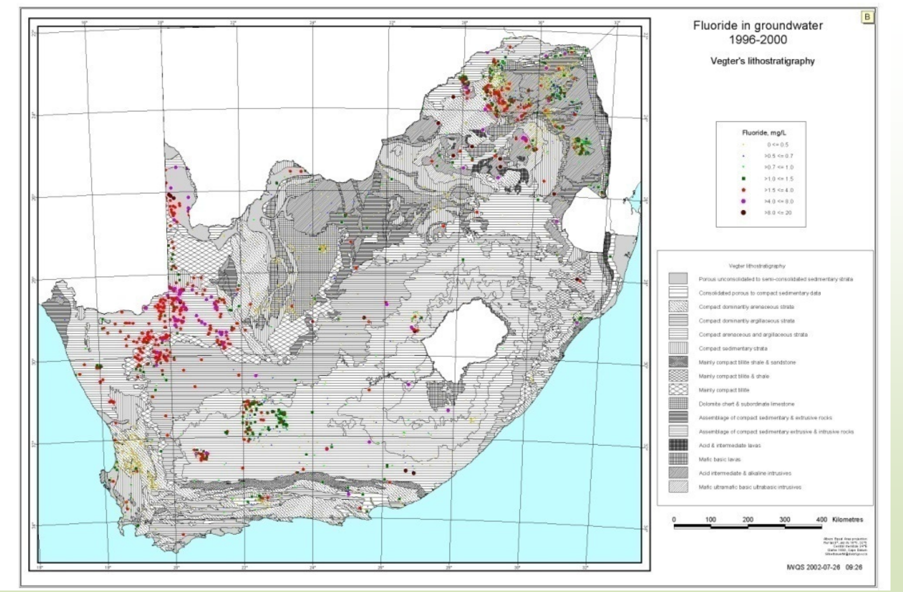


FIGURE 1. Fluoride in groundwater 1996 – 2000.

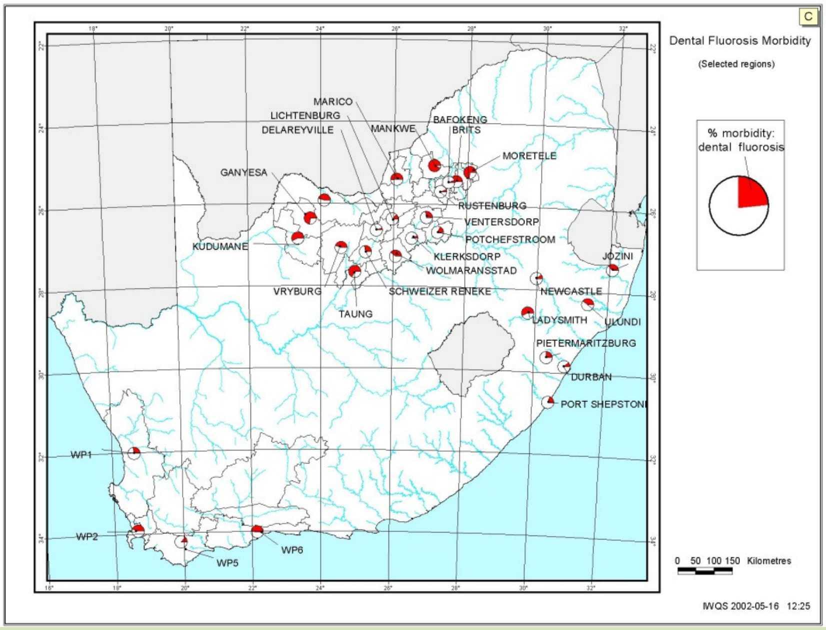


FIGURE 2. The distribution of % morbidity of dental fluorosis.

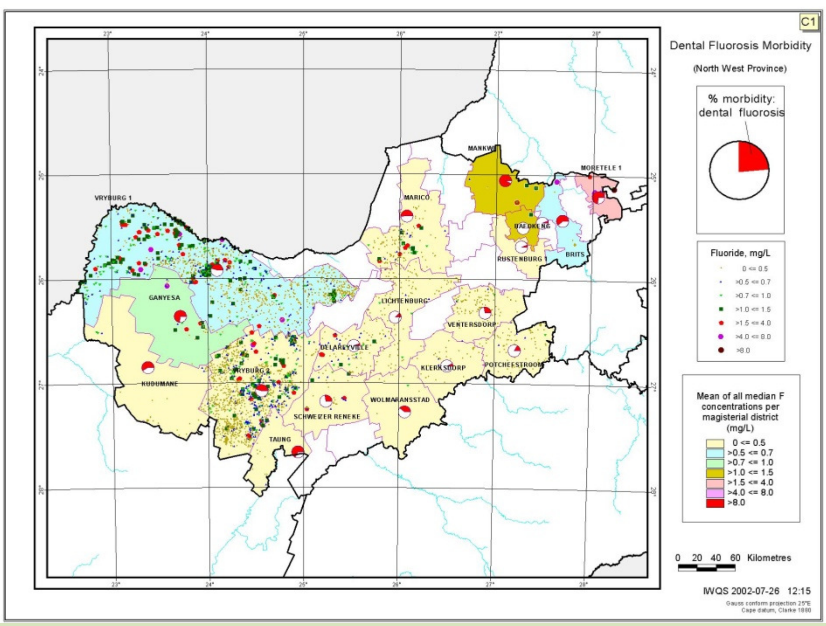


FIGURE 3. Dental fluorosis morbidity (North West Province).

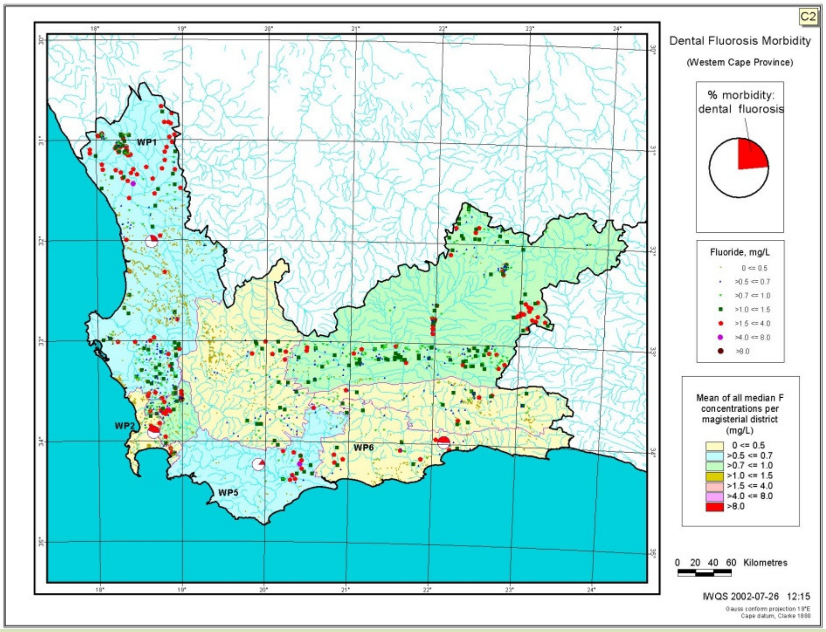


FIGURE 4. Dental fluorosis morbidity (Western Cape Province)

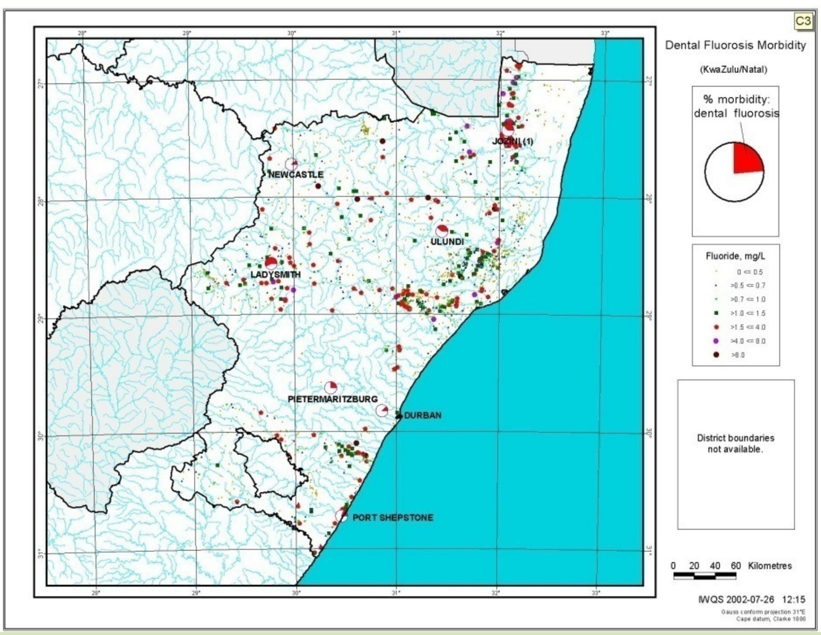


FIGURE 5. Dental fluorosis morbidity (KwaZulu Natal).

From the results, a percentage morbidity of dental fluorosis as high as 97 % was recorded in the North-West province. In comparing the distribution of the % morbidity of fluorosis with that of fluoride concentration in groundwater sources (Figures 2-5), it is apparent that high morbidity of fluorosis occurs in areas where fluoride concentrations are extremely high and in most cases exceeding the limits for drinking water. In towns and villages where the water quality problem in terms of fluoride ion concentration is less serious, the morbidity of fluorosis is comparatively low. It is evident from the maps that the occurrence of dental fluorosis and its morbidity correspond to the levels of fluoride ion concentrations in drinking water. The size of the shaded part (% morbidity of dental fluorosis) in each area gives the idea of the general quality of drinking water consumed by the examined subjects.

CONCLUSION

Areas with high fluoride ion concentrations in their groundwater supplies and high percentage morbidity of dental fluorosis have been identified. Many of these sources require partial de-fluoridation if they are currently being used for drinking water purposes. Proper research needs to be initiated in order to develop cheap and technologically simple processes for small-scale removal of fluoride from fluoride–rich groundwater or developing alternative sources of supply in areas where there is such a problem especially in rural areas.

This study shows that the low fluoride concentration in groundwater is not a national problem. Experiences from other countries where the water fluoride is similarly “low” while the oral health is very advanced, without any fluoridation of water or any medium apart from toothpaste should be considered and much research is needed to test their relevance and feasibility in the South African context.

ACKNOWLEDGEMENTS

Mike Silberbauer and his team have provided unconditional assistance with data extraction, quality control of the data and GIS expertise. Dr Kroon and colleagues at the Department of Health have given the authority to access the dental fluorosis data.

REFERENCES

26. WRC. Distribution of fluoride-rich groundwater in the Eastern and Mogwase regions of the Northern and North-West province South Africa. WRC Report No.526/1/01 2001; 1.1 - 9.85
27. Pontius FW. Fluoride regulation and water fluoridation. Journal American Water Works Association. 1991;83(11): 20-22,96.
28. Hammer, MJ. Need for fluoridation of desalinated water supplies. Aqua London UK. 1986;4:179-182.
29. Ockerse, T. Endemic fluorosis in South Africa a PHD Thesis submitted to the University of Witwatersrand. 1947
30. Du Plessis JB. What would be the maximum concentration of fluoride in water that would not cause dental fluorosis? Fluoride and Fluorosis. The status of South African Research, Pilanesberg National Park, North West Pro*vince*. 1995; 4.
31. M^c^caffrey, LP, Willis JP. Distribution of fluoride-rich groundwater in the eastern parts of Bophuthatswana, relationship to bedrock and soils and constraints on drinking water supplies: a preliminary report, Africa Needs Ground Water. An International Ground Water convention. 1993; 1:1-8
32. Fayazi, M. Regional groundwater investigation on the Northern Springbok flats. Department of Water Affairs and Forestry. Geohydrology, GH Report no. 3684. 1994;108-155.
33. Rudolph, MJ, Molefe, M, Chikte, OME. Dental fluorosis with varying levels of fluoride in drinking water. J Dental Research. 1995;74:1012.
34. DWAF. South African Water Quality Guidelines for domestic use. 1st Edition. 1996.
35. SABS Fluoride standard for drinking water. SABS 241.5th edition. 2001.
36. Anonymous. Notice R797 of 12 June 1998. Regulations under the Health act, 1977 (Act No. 53 of 1977). Schedule: Regulations of fluoridating public water supplies. Republic of South Africa Government *Gazette*. 396, Issue 18960: 1998;7-14.
37. Wang, XC, Kawahara, K, Guo XJ. Fluoride contamination of groundwater and its impacts on human health in Inner Mongolia area, China, *Aqua*. 1999; 48 (4):146-153.

Risk Factors of Dental Fluorosis in Thai Children

S Mongkolnchai-arunya[1], S Chanduaykij [1], P Pukrittayakamee[1],
W Visalseth[1], and P Suntorntam[2]
Thailand

SUMMARY: **In total 840 school children, age 6-12 years, in two districts of Songkhla province of Thailand are examined for dental fluorosis. The children's drinking water are collected and analysed for the contents of fluoride. The results show that 30.5 % of the selected children had dental fluorosis characterised as preliminary or higher degree, about 4.8 % had dental fluorosis of moderate or higher degree and only few, 0.5 % of the children, had severe dental fluorosis. In parallel 28 % of the children's drinking waters had fluoride concentrations more than the Thai standard of 0.7 mg/L. About 22 % of the drinking waters contained fluoride in concentrations that were more than double the standard and about 15 % of the children's drinking water was more than 3 times the Thai standard. Interviews were conducted and six parameters were case-control analysed for eventual association with the dental fluorosis. This revealed that dental fluorosis prevailing in Thai children was highly associated with the fluoride in excess to this standard, Odds Ratio being 3.49. Also the age of start tooth brushing, the age of start using toothpaste and the habit of eating toothpaste were all found to be moderately associated to the prevalence of dental fluorosis, OR were between 1.8 and 2.9. The relations seem to be significant independent of whether the fluoride concentration in the water was more or less than 0.7 mg/L. Also the type of utilised toothpaste seem to be associated to the prevailing dental fluorosis, however, the association was statistically relatively week, OR was 0.35 and 0.49, respectively for the high and low fluoride concentrations in the drinking water. The type and the amount of toothpaste used for brushing and the use of other fluoride supplies did not seem to be associated to the prevailing fluorosis.**

Key words: Dental fluorosis, risk factors, Thailand, Songkhla province, fluoride occurrence, toothpaste, eating behaviour, fluoride supplements.

INTRODUCTION

Many parts of Thailand, cf. figure 1, are reported to be potentially fluorotic due to geological formations that contain fluorite (fluorspar~CaF_2) and cryolite ($NaAlF_3$), which in same cases are mined [1]. In some areas the fluoride is also in excess in the drinking water and dental fluorosis is endemic. Apart for this "background pollutional exposure" people are using fluoridated toothpaste and other fluoride supplement. The children have their own habits of using the toothpaste and in some cases even to eat it. Literature review shows that factors associated to dental fluorosis as often stated are excessive fluoride in drinking water, the use of fluoride supplement, the use of

1 Dental Health Division, Department of Health, MOPH Thailand, surat@health.moph.go.th
2 Food and Drug Administration Committee Office, MOPH Thailand

fluoride toothpaste and taking infant formula [2]. Some study revealed that dental fluorosis in permanent teeth related to the resident in water fluoridation area and the use of fluoride adult toothpaste [3]. Other factors related to dental fluorosis in permanent incisors teeth were the use of fluoride toothpaste in children before 14 months and taking fluoride supplement regularly [4]. While another study that children got fluoride only one source from toothpaste showed that dental fluorosis was related to the use of toothpaste before six years old and the age of start brushing teeth before 2 years old [5].

The objective of this study was to identify the risk factors of the dental fluorosis as it prevailed in Thailand.

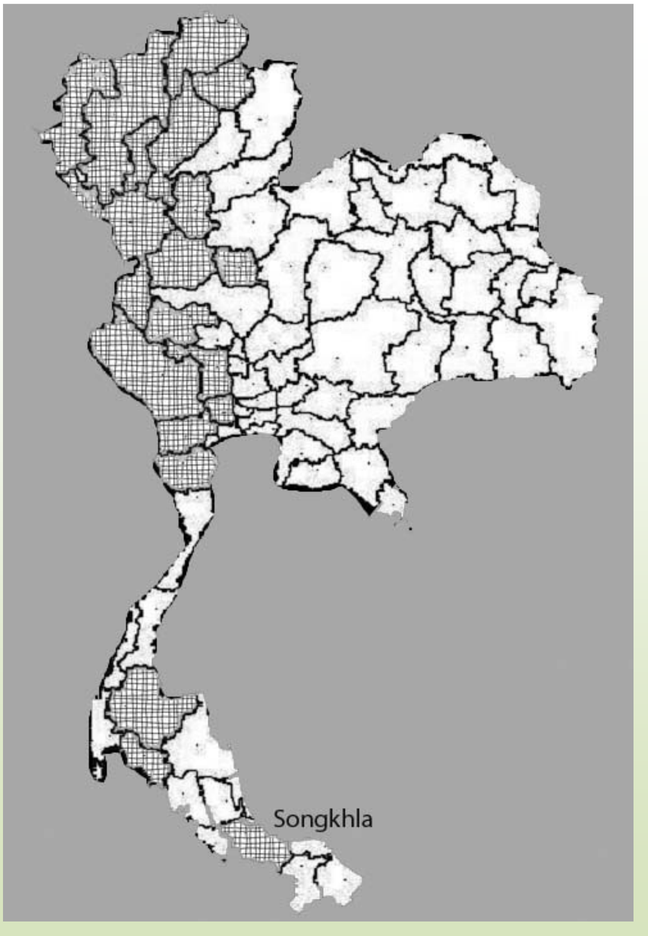


FIGURE 1. Map of Thailand. Grey provinces are potentially fluorotic

MATERIALS AND METHODS

Two districts of Songkhla province in the southern part of Thailand were selected. The study sites were purposively selected according to the number of dental fluorosis cases and variation of fluoride concentration in water supply. In total 840 children in 6 primary schools in the age of 6-12 years were examined by calibrated dentists for dental fluorosis according to modified Dean's Index. The Dean's score 1 was given to cases of preliminary fluorosis instead of to questionable. The children's drinking water was collected from their respective households and the samples were examined in the laboratory for contents of fluoride using the Orion Selectrode.

The households of the school children were interviewed by trained and standardised workers form the village. In the interview the children's parents or the principal responsible family member was requested to give information about the following:

- Age of start brushing teeth.
- Age of start using toothpaste.
- Quantity of toothpaste use.
- Type of toothpaste; fluoridated, not-fluoridated.
- Toothpaste eating behaviour.
- Use of fluoride supplement i.e. fluoride drops or tablets.

The children who have not been in the community for the last 5 years were sorted out and a case-control analysis was made including 662 remaining children.

RESULTS

Out of the 840 examined children in the two districts of the Songkhla province 256 children had dental fluorosis, indicating a prevalence of 30.5 %. The children were consuming drinking water with a fluoride concentration of 0.02 – 5.45 mg/L. Figures 2 and 3 illustrate the distribution of fluoride in the drinking water samples and the corresponding distribution of fluorosis.

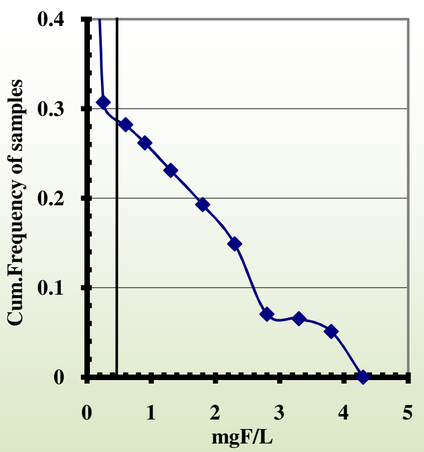


FIGURE 2. Cumulative frequency of drinking water sample versus the fluoride concentration.

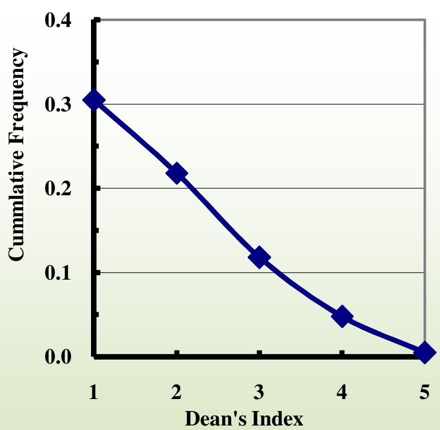


FIGURE 3. Cumulative frequency of dental fluorosis in the school children versus Dean's Index.

TABLE 1. The Odds Ratio, OR, and the 95 % Confidence Interval, CI, for the investigated fluorosis risk factors among Thai Children.

Risk Factor /Criteria		Case	Control	OR	95 %-CI
Drinking water fluoride					
	> 0.7 mg/L	130	101	3.49	2.49-4.89
	≤ 0.7 mg/L	116	315		
Age of start brushing teeth					
> 0.7 mg/L	≤ 2 yrs	60	25	2.61	1.48-4.60
	> 2 yrs	70	76		
≤ 0.7 mg/L_	≤ 2 yrs	53	95	1.95	1.26-3.02
	> 2 yrs	63	220		
Age of start using toothpaste					
> 0.7 mg/L_	≤ 2 years	47	17	2.79	1.49-5.26
	>2 years	83	84		
≤ 0.7 mg/L	≤ 2 years	37	65	1.8	1.12-2.90
	> 2 years	79	250		
Habit of eating toothpaste					
> 0.7 mg/L	Do	43	30	1.15	0.64-2.08
	Don't	67	54		
≤ 0.7 mg/L	Do	56	95	2.47	1.54-3.96
	Don't	42	176		
Type of toothpaste					
> 0.7 mg/L	Adult T.P.	45	61	0.35	0.20-0.59
	Child T.P.	85	40		
≤ 0.7 mg/L	Adult T.P.	44	174	0.49	0.32-0.76
	Child T.P.	72	141		
Amount of toothpaste					
> 0.7 mg/L	≥ ½ brush	38	20	1.68	0.90-3.13
	¼ brush	88	78		
≤ 0.7 mg/L	≥ ½ brush	33	94	0.94	0.59-1.50
	¼ brush	82	219		
Fluoride supplement					
> 0.7 mg/L	Yes	48	34	0.92	0.40-2.09
	No	20	13		
≤ 0.7 mg/L	Yes	38	79	1.01	0.53-1.90
	No	22	46		

By excluding the children who have not been using the same water for 5 years and those whose parents could not provide required information, the total number of study children was reduced to 662. Among those the dental fluorosis prevalence was 37.2 % and the consumed water had fluoride concentration of 0.02 – 4.38 mg/L. The results of the case-control analysis of the study parameters are shown in table 1.

DISCUSSION

Figure 3 shows that 30.5 % of the selected children had dental fluorosis characterised preliminary or higher degree, about 4.8 % had dental fluorosis of moderate or higher degree and only few, 0.5 % of the children, had severe dental fluorosis. These findings correspond to the occurrence of fluoride in excess to Thai standard of 0.7 mgF/L [6] in 28 % of the Children's dinking waters, figure 2. About 22 % of the drinking waters contain fluoride in concentrations that are more than double the standard and about 15 % of the children's drinking water is more than 3 times the Thai standard.

It is seen from table 1 that the fluoride concentration in water of 0.7 mg/L was used as a cut point for grouping the subjects in the study. This is in agreement with the Thai Health Department that uses this concentration as a standard for drinking water. The study confirms that dental fluorosis prevailing in Thai children is highly associated with the fluoride in excess to this standard, OR is 3.49 and the 95 % CI 2.49-4.89.

Of the other investigated factors the age of start tooth brushing, the age of start using toothpaste and the habit of eating toothpaste are all found to be moderately associated to the prevalence of dental fluorosis, OR are between 1.8 and 2.9. The relations seem to be significant independent of whether the fluoride concentration in the water is more or less than 0.7 mg/L. Also the type of utilised toothpaste seems to be associated to the prevailing dental fluorosis, however, the association is statistically relatively week, OR is 0.35 and 0.49, respectively for the high and low fluoride concentrations in the drinking water.

Table 1 shows that the type and amount of toothpaste used for brushing and the use of other fluoride supplies do not seem to be associated to the prevailing fluorosis, OR being between too close to 1 (0.9-1.6).

Thus this study reveals that dental fluorosis does prevail among children in the examined area and that especially the fluoride concentration in the children's drinking water is a strongly related risk factor. Also the age of start tooth brushing, the age of start using toothpaste and the habit of eating toothpaste are all found to be moderately associated risk factors of the prevailing dental fluorosis.

ACKNOWLEDGEMENT

The author appreciates the contribution and assistance from the Thai Dental Council, the Office of Food and Drug Administration Committee and the Songkhla Provincial Health Office.

REFERENCES

38. Kumarnchan, P et al. (1997) Manual of the Mineral Mine Map and Natural Fuel Sources in Thailand. (in Thai) Geological Department. p114-115.
39. Mascarenhas, A K, Risk factors for dental fluorosis: a review of the recent literature. Pediatric Dentistry, 2000 Jul-Aug; 22(4):269-77.
40. Tabari, E D, Ellwood, R, Rugg-Gunn, A J., Evans D J and Davies, R M. Dental fluorosis in permanent incisor teeth in relation to water fluoridation, social deprivation and toothpaste use in infancy. Br Dent J, 2000 Aug; 26; 189(4): 216-20.
41. Wang, N J, Groupen, A M, and Øgaard, B. Risk factors associated with fluorosis in a non fluoridated population in Norway. Community Dent Oral Epidemiol 1997 Dec; 25(6): 396-401.
42. Mascarenhas, A K and Burt, B A. Fluoride risk from early exposure to fluoride toothpaste. Community Dent Oral Epidemiol 1998 Aug;26(4): 241-8.
43. The water quality standards for piped drinking water of the Health Department in Jitchamnong, P, Visalseth, W, Tanthulavese, M. (eds) Proceeding of the seminar on maximum fluoride content in bottled water. pp 50 (1999) Dental Health Division Nonthaburi. Thailand.

Session 2

Methodology

False-Indication of Non-Dental Fluorosis in Per See Physical Tests

E Dahi *
Denmark and Tanzania

SUMMARY: On the contrary to dental fluorosis, skeletal and non-skeletal fluorosis are very difficult to diagnose and almost impossible to quantify. This study elaborates on the three physical tests recently proposed by Susheela & Bhatnagar as indicators of non-dental fluorosis: 1) Bending the body to touch the floor. 2) Bending the neck to touch the chest with the chin and 3) Stretching the hands and folding the arms to touch the back of the head.

Twenty-eight severely affected young residents of the highly fluorotic Ngongongare, the Arusha Region that is a part of the Rift Valley, are interviewed and tested using these three physical tests + a new "squatting test". Furthermore, they were checked for the knock-knees symptom.

It is concluded that people are very well aware of having dental fluorosis. They are also very conscious about fluoride being the reason of the fluorosis and that it stems from the water. In spite of the fact that the subjects were clearly heavy affected with respect to dental fluorosis, only 30 % of them had pain in their joints or muscles. None of them thought they could get crippled if they continued to consume the same drinking water. The Susheela-Bhatnagar tests classified all patients as "healthy" and the study shows that these tests are of no use and can be directly misleading. Only 10 of the 28 patients could do the squatting test satisfactorily, suggesting some kind of relationship with the non-dental fluorosis. Yet it is concluded that also this test can give false indications. Only 14 % of the study subjects showed no sign of knock-knees; 64 % showed this manifestation clearly and the rest, about 21 % were classified as questionable. It is discussed that knock-knees may well be a trustworthy symptom of the non-dental fluorosis, though it still may involve risk for false-indication.

Key words: Fluoride symptoms, fluorosis diagnosis, dental fluorosis, skeletal fluorosis, non-skeletal fluorosis, physical test, perception, prevention, knock-knees, indicators.

INTRODUCTION

Dental fluorosis is often directly visible to naked eyes and easily to detect even to lay people. Skeletal and non-skeletal fluoroses, on the contrary, are difficult to diagnose even to professionals assisted by appropriate equipments. Radiography is often needed to identify manifestations like enlargements in joints or minor deformations in the bones. The other symptoms are diffuse and disperse making it difficult to conduct a clear diagnosis, not to mention a qualified quantitative judgement of the extent of intoxication.

* *Environmental Development Co-operation, EnDeCo, Denmark & Tanzania.*
Email: elidahi@hotmail.com

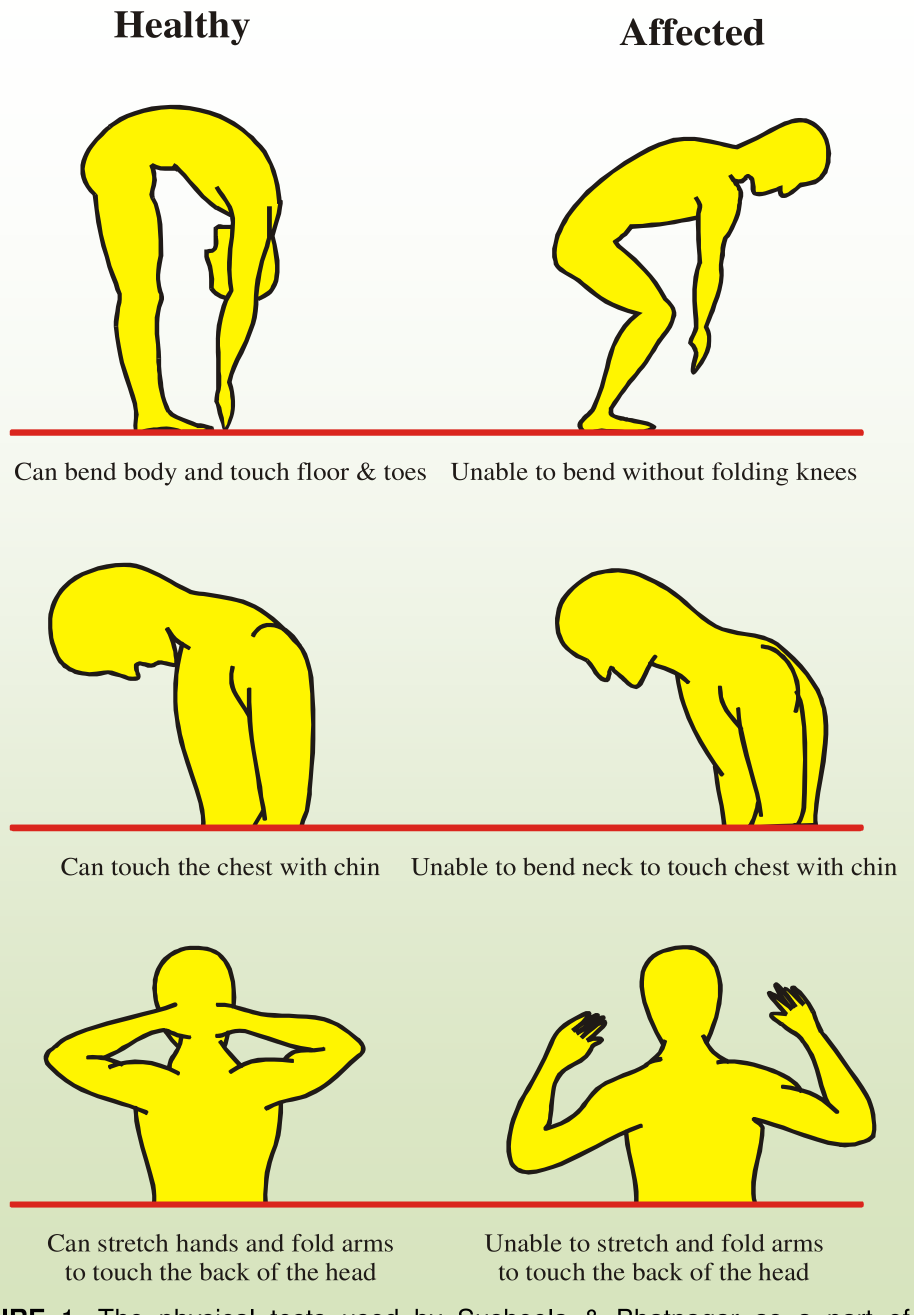


FIGURE 1. The physical tests used by Susheela & Bhatnagar as a part of the diagnosis of fluorosis. The tests were included in the present study, subject to validation or rejection.

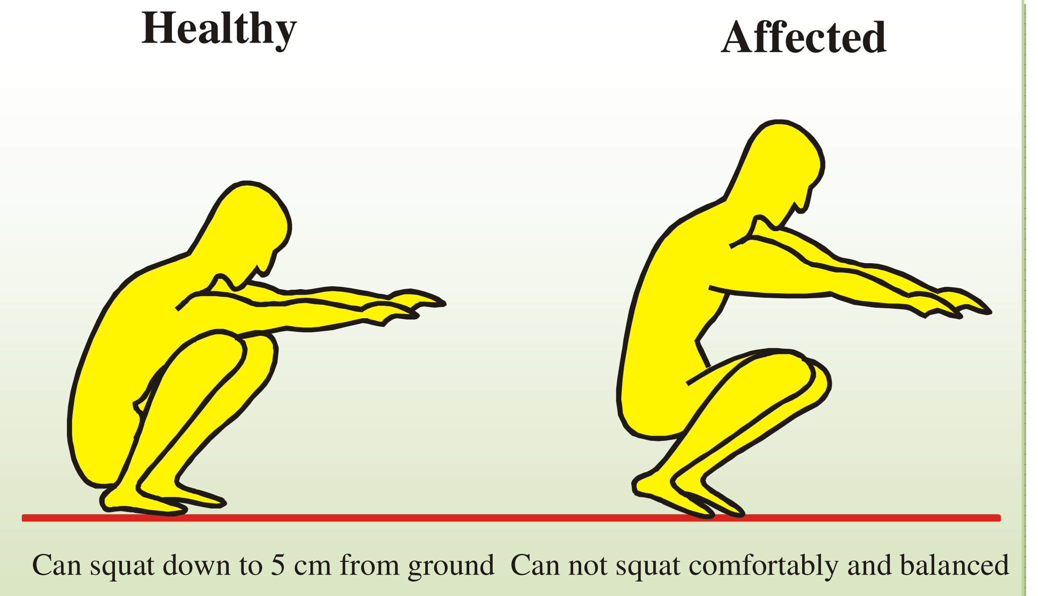


FIGURE 2. Illustration of the "squatting tests", where the fluorosis-affected patients are checked for capability to bend and squat down to 5 cm above ground level.

This has led to the present paradox situation. We have now different well-defined and widely used indexes for the dental fluorosis, the Deans Index [1] and the TF-Index [2], and these indexes are reported in uncountable studies. On the other hand there are very few studies of the skeletal and the non-skeletal fluorosis. There seems to be no well-known and widely accepted method for diagnosis of the earlier stages of these types of fluorosis. This is most unfortunate, because the manifestation of skeletal and non-skeletal is probably subject to a higher degree of biological variation and they are prevailing at a later stage in life. Because of that, it is believed that an early diagnosis of the none-dental fluorosis is crucial for any prevention and any assessment of impact of intervention.

On this background it is of major importance to adopt or to develop simple per see physical tests as indicators of initial fluoride effects on skeleton and joints. The objectives of this study is to elaborate on the usefulness of the simple physical tests recently reported by Susheela and Bhatnagar [3] as far as the reliability for use in the fluoride affected Rift Valley.

TABLE 1: Questioners used in the interviews of the study subjects.

Do you know why your teeth are affected?	□ No	□ Yes	
Do you know where the fluoride or "Madini" is coming from?	□ No	□ Water	□ Elsewhere
Do you feel any pain or "Humma" in your joints or muscles?	□ No	□ Yes	□ Sometimes
Do you know that you may get crippled if you continue dinking the same water?	□ No	□ Yes	

TABLE 2. The number of answers obtained from the study subjects in response to the questionnaire in table 1 and the physical tests.

Answer:	Females					Males				
	No	Yes	Elsewhere	Sometimes	Questionable	No	Yes	Elsewhere	Sometimes	Questionable
Know that their teeth are affected	0	18	-	-	-	0	10	-	-	-
Know where the fluoride or "Madini" coming from.	0	18	0	-	-	0	10	0	-	-
Feel pain or "Humma" in the joints or muscles.	12	4	-	2	-	8	0	-	2	-
Know that they may get crippled if they continue dinking the same water.	18	0	-	-	-	10	0	-	-	-
Can bend body and touch floor and toes.	0	18	-	-	-	0	10	-	-	-
Can bend neck to touch chest with chin	0	18	-	-	-	0	10	-	-	-
Can stretch hands and fold arms touching the back of the head	0	18	-	-	-	0	10	-	-	-
The patients could squat in a balanced and comfortable manner to 5 cm above ground level.	7	2	-	-	11	3	4	-	-	3
The patients have enlargement of the knees bending inwards (Knock knees)	1	13	-	-	4	3	5	-	-	2

MATERIALS AND METHODS

Twenty-eight subjects, 18 females and 10 males, in the age 14-25, all local residents in Ngongongare, were selected, the criteria being a clear manifestation of severe dental fluorosis. Initially their teeth were checked and it was confirmed that *all* their teeth were affected. Then they were interviewed as in table 1.

The subjects were then checked for visible enlargements in their joints and deformations in their arms and legs and requested to carry out the three physical tests proposed by Susheela & Bhatnagar as shown in Figure 1. Furthermore they were asked if they could bend and squat as low as possible and it was checked if they at the bottom could reach down to 5 cm above the ground level, Figure 3.

RESULTS

The results are summarised as shown in Table 2.

DISCUSSION

Perception of fluorosis: The response to the questionnaire shows that affected young people in Ngungongare are very well aware of having dental fluorosis. They are also very conscious about the fluoride being the reason for the fluorosis and that it stems from the water.

Pain and prognosis: In spite of the fact that subjects were clearly heavy affected with respect to dental fluorosis, only 30 % of them answered that they had pain, permanently or occasionally, in their joints or muscles. Furthermore, none of them thought they could get crippled if they continued to consume the same water.

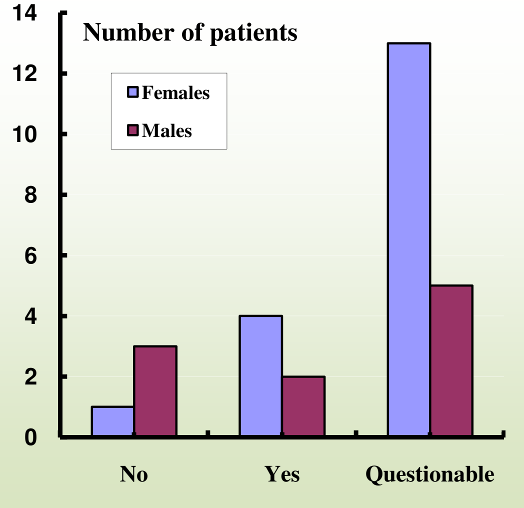


FIGURE 3. Number of tested subjects with and without knock-knees.

Physical tests: Most surprisingly however, is the uniform positive response to the physical tests as, proposed by Susheela and Bhatnagar. According to these tests all subjects should have been classified as "healthy", where none of them could possibly be. This study, though of limited volume, shows that these tests are of no use and can be directly misleading, at least for assessment of non-dental fluorosis among young subjects in rural Rift Valley. It should be added that most subjects are farmers used to do heavy work in different working positions. Thus both females and males are often doing physical work while bending with stretched legs to reach the ground with the whole of their palms. Also they are used to stretch their back and neck to carry heavy loads on their heads.

Squatting test: Only 10 of the 28 patients could do the squatting test satisfactorily, an indication of some relationship with the non-dental fluorosis. However it is well known that squatting is a habit well established in some cultures while not used in others. Thus also this test can give as well false positive as false negative results. Until further investigations can validate this test, it is concluded that it is of little use and can be misleading as an indicator of non-dental fluorosis.

Knock-knees: Only 14 % of the study subjects showed no sign of knock knees; 64 % showed this manifestation clearly and the rest, about 21 % were classified as questionable. This is suggesting that knock-knees may well be a reliable indicator of the non-dental fluorosis. Further it is the author's experience that the knock-knees phenomenon, as often observed in the Arusha Region, is closely related to the severity of dental fluorosis and it is thought of as a kind of first stage of fluorotic deformation in the legs. However, as the phenomenon is also known to prevail in non-fluorotic areas, it still has a risk for false-indication of the non-dental fluorosis.

REFERENCES

44. Dean HT. Classification of mottled enamel diagnosis. J Am Dent Assoc 1934; 37: 181 – 192.
45. Thylstrup A & Fejerskov O. Clinical appearance of dental fluorosis in permanent teeth in relation to histological changes. Community Dental and Oral Epidemiology. 6: 315-328. 1978.
46. Susheela AK & Bhatnagar M. Experiences on combating fluorosis cases in India. P.51 – 60. IN: Proceedings of the 3rd International Workshop on Fluorosis Prevention and Defluoridation of Water. (Eds. E Dahi et al.) Chiang Mai ISFR, EnDeCo & ICOH. Nov.2000.

Credibility and Limitations of Fluoride Analysis Using the Pack Test® Kit

E Dahi *, Y Matsui ** and G Mkongo ***
*Denmark, **Japan and ***Tanzania

SUMMARY: There has been an increasing need for an 1) easy, 2) rapid, 3) cheap and 4) reliable method for spot testing of fluoride concentration in drinking water and potential drinking water sources. The Pack Test® kit seems to fulfil the first three criteria. Its limitations and credibility are tested compared to the potentiometric selectrode method.

It is found that even the selectrode method has to be used with care. The calibration curve, being systematically deviating from a straight semi-logarithmic line, inquires interpolation and the detection limit in normal laboratory procedures should be stated while indicating lower concentrations as ≤ 0.2 mg/L. Furthermore, double electrode testing is recommended in order to keep deviations from average values below 5 % of average.

On a large concentration interval, the Pack Test kit does not coordinate with potentiometric testing. Further it is found that the Pack Test slightly overestimates concentrations lower than 0.5 mg/L, but underestimates concentrations above 1 mg/L. It is discussed that Pack Test could be improved by adjustment of the colour scale and standardisation of the illumination and visualisation. At the time being the relationship is found to be acceptable in the range 0.2 - 3 mg/L. Especially within the most interesting concentration interval between 0.5 and 1, the relationship seems to be quite convincing. It is thus concluded that the Pack Test kit, the mentioned serious limitations taken into consideration, provides a very handy, rapid and quite reliable tool for decision on whether a given water is fit for drinking or not or whether a defluoridator in operation should be discontinued or not.

Key words: Fluoride analysis, pack test, spot test, potentiometric method, electrode analysis, ion selective electrode, selectrode analysis, colorimetric method, qualitative method.

INTRODUCTION

One of the factors that engrave the problems facing any research and any attempts of mitigation of fluorosis is related to the properties of fluoride and the difficulties in measuring it in aquatic media. Fluoride in water is tasteless, odourless and colourless. Furthermore, being an ion, fluoride does not cause any turbidity in the water. That leaves any detection of fluoride in the water dependent on regular analysis, so far only available in the laboratory at relatively high costs.

* *Environmental Development Co-operation, EnDeCo, Denmark & Tanzania.*
Email: elidahi@hotmail.com
** *Ministry of Water Tanzania*
****Japan Techno Co.*

During the recent yours, an urgent need for simple spot testing of fluoride has been experienced. This is because water resources increasingly are suspected to be fluorotic and need to be tested at domestic level and in remote rural areas, i.e. far from laboratories and at affordable costs. Furthermore, as a consequence of such testing, a small-scale defluoridation of drinking water is increasingly introduced at domestic or institutional level. Such a defluoridation is mostly carried out in column filters that need to be monitored by the users themselves in order to be in control of the process and the filter period, before the breakthrough. In such situations the spot testing of fluoride is a must.

For the same reasons different testing kits have been developed and made commercially available for more or less unofficial use and as a first check. To the authors knowledge all of these kits are based on colorimetric comparators, making them subject to high individual variation and much error of interference. Furthermore, even these simple kits may still be too complicated and too costly for domestic use by lay people.

One of these kits is the Pack Test® launched by the Kyoritsu Chemical-Check Lab. Corporation. This kit represents a further simplification of the comparator methods, because the sample is compared, while in the disposable pillows, using a disposable colour scale-pamphlet.

The objective of this paper is to investigate the credibility and limitations of the Pack Test kit, as for analysing the fluoride concentration in drinking water when using the standard electrode potentiometric method as a reference.

BACKGROUND

Few methods of analysis of fluoride are available, the most promising of which are supposed to be included in the "Standard Methods", i.e. The Standard Methods for Examination of Water and Wastewater [1, 2]. These are the potentiometric electrode method and the colorimetric SPADNS method. Another colorimetric method is the Alizarin Visual Method, which has been included in the Standard Methods until 1989.

The potentiometric method utilises a fluoride selective electrode, selectrode, based on a crystal of Lanthanum Fluoride, LaF_6 , across which a potential is established by the presence of fluoride ions. The crystal contacts the sample solution at one face and a reference solution at the other, either internally as in the combined electrode or externally through a connected reference electrode. The potential can be measured by any modern pH-meter having an expanded millivolt scale. The electro-potential is directly related to the logarithm of the fluoride activity in the solution.

Both colorimetric methods are based on reagents of dye lake, the SPADNS and respectively the Alizarin, made translucent by means of Zirconyl ions ZrO^{2+}. Mixing the coloured reagent with fluoride sample results in dissociation of a portion of the dye lake into a colourless complex anion of ZrF_6^{2-} and the dye. The degree of discolouration or colour modification is proportional to the concentration of fluoride in the sample. Similarly, other colorimetric methods are described in the literature [3, 4].

It is characteristic for the above mentioned analysis methods that they need a high degree of standardisation and instrumentation in order to obtain a satisfactory quantitative response free of interference. Thus conducting these analyses involves relatively high cost of instrumentation and chemicals and high skills of laboratory work.

MATERIALS AND METHODS

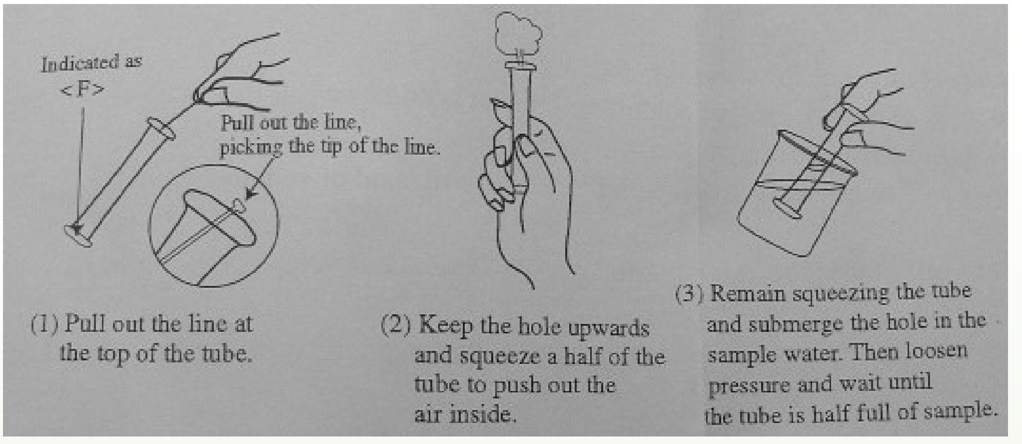
Samples and testing: Fifty-seven authentic water samples, all collected in the Arusha Region in Tanzania, were double tested for their contents of fluoride using the potentiometric F-electrode method according to the Standard Method [2]. The samples were then stored in plastic bottles for a period of 3-7 months and then analysed again according to the same method. The analyses were carried out in the Ngurdoto Defluoridation Research Station, the most experienced laboratory in Tanzania with respect to testing fluoride. Simultaneously with the renewed potentiometric testing the same samples were tested in field using the Pack Test® kit.

Pack Test measurements: The Pack Test kit is launched by the Kyoritsu Chemical-Check Laboratory Corporation [5]. The kit is a simple cartoon box containing a colour pamphlet and an instruction, beside 50 polythene pillows distributed in 10 smaller packages, cf. Figure 1. The pillows contain the reagent mix in powder form. They are sealed to contain about 4 mL of air or maybe an inert gas. On one side of each pillow a small plastic needle is pricking through in a tight manner. As the polythene pillows are opal-transparent to light and maybe not perfectly airtight, they are packed in batches of 5 pieces. The batches are sealed in aluminium foil bags that protect them from humidity, atmospheric oxygen and light.

Taking out the in-built plastic needle punctures the pillow. Then, pressing the pillow with the fingers, about half of the air content is blown out and the pillow is directly lowered in the water sample to allow for sucking up about 2 ml of it.

The sample aliquot is then mixed with the reagent chemicals and allowed to stand for 10 minutes for standardised complete colour development. The developed colour is compared with colour spots on the pamphlet. The pamphlet shows 6 colour spots corresponding to the concentrations 0, 0.4, 0.8, 1.5, 3 and equal or above 8 mg/L. The colour changes from clear reddish in the low or no fluoride level to dark blue at the higher concentration levels.

Potentiometric measurements: The fluoride concentrations were measured using a Metrohm potentiometer, 704 pH/Ion Meter, in connection with a Metrohm fluoride electrode, 6.0502.150, and a Metrohm Ag/AgCl reference electrode, 6.0726.100. An aliquot of 5.0 ml of the sample solutions was mixed with 5.0 ml CDTA-tisab and the fluoride concentration was measured using the calibration method as described in the Standard Methods [2], in agreement with the manufacturer's instructions [6].



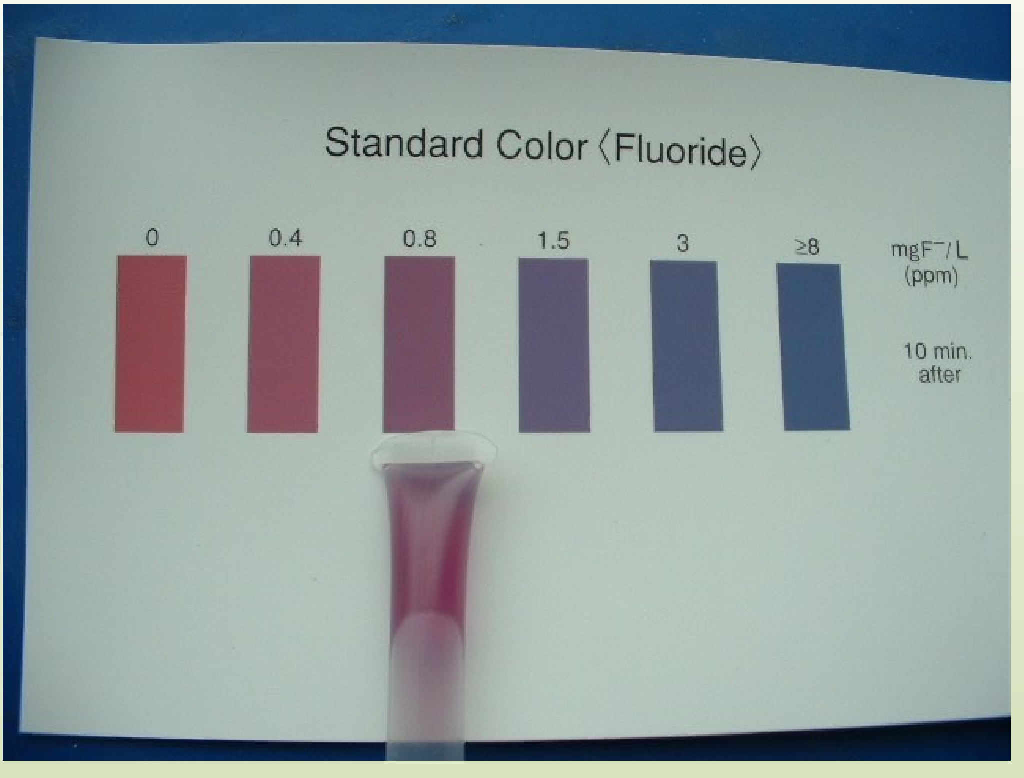


FIGURE 1. The four steps in the Pack Test measurements. Upper: 1) puncturing the pillow. 2) Blowing some of the inert gas content out. 3) Sucking a sample aliquot into the pillow. Lower: Comparison of the developed colour after 10 minutes.

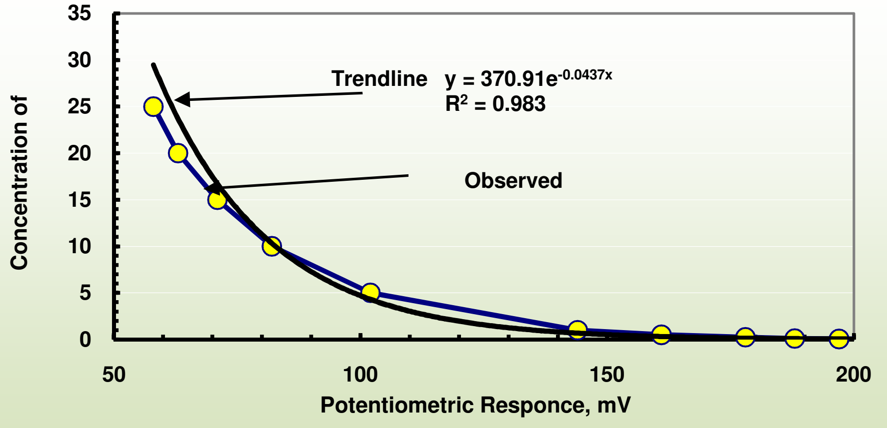


FIGURE 2. The relationship between the fluoride concentrations in prepared standards and the observed potentiometric response in the electrode method.

Standard calibration curve: An extended standard curve was prepared to cover the normal fluoride concentrations prevailing in the water of the Arusha Region. This included 0.025, 0.05, 0.10, 0.25, 0.50,1.00, 5.00, 10.00, 15.00, 20.00 and 25.00 mgF/L. The obtained calibration curve is shown in Figure 2.

Double electrode measurements: The obtained analyses data are shown in Table 1. It is indicated that the average concentration of the tested water is measured to be 4.43 and 4.55 in initial double electrode analysis, giving a grand average 4.49 mg/L for all tested water samples. The lowest concentration measured is 0.04 mg/L and the highest is 23 mg/L, cf. table 2. It is seen that even in a double measurement the absolute deviation between the two obtained figures shows a high variation, between 0 and 81 %, 11 % on an average. This individual variation among double electrode measurements is demonstrated in Figure 3.

TABLE 1. Fluoride concentrations, all in mg/L, in the tested water samples as given through one double electrode analysis, one renewed electrode analysis and the Pack Test kit indication.

Sample No	Water Source/Sample	Double electrode analysis		Renewed electrode analysis	Pack Test indication
		I	II		
1	Arusha water supply	4.83	4.95	5.03	3.0
2	Maji ya chai at the bridge	13.27	13.14	14.38	4.5
3	Themi river at the bridge	2.34	2.55	2.75	2.3
4	Canal water near Kwamangusha	3.5	3.77	4.28	2.3
5	Ngarasero river at the bridge	2.15	2.27	2.53	2.3
6	Makumira river	1.62	1.80	1.91	2.3
7	Canal near Danish bridge	1.69	1.73	1.83	1.5
8	Mbembe river at Kilala	1.76	1.80	1.99	1.5
9	Bassotughang pond	1.22	1.31	1.38	1.2
10	Nyamuri spring	11.29	11.24	12.24	1.5
11	Gigamugho S/W	9.22	9.62	10.00	2.3
12	Mara bore hole	2.98	3.22	3.23	1.5
13	Swai Dug well near NAPOCO	6.41	6.51	6.68	1.5
14	Sahila Dug well near NAPOCO	7.24	7.32	6.95	2.3
15	Lisa Peterson sample	0.05	0.03	0.10	0.1
16	Ngurdoto gate	5.46	5.79	6.41	2.3
17	Charles Shams	2.34	2.45	2.43	1.5
18	Himiti spring	2.07	2.27	2.34	1.5
19	Qutesh S/ W	5.24	5.79	5.91	2.3
20	Nyamur S/ W at Mara	7.24	7.61	8.17	2.3
21	Kangaroo S/ W at Qutesh	3.64	3.92	3.95	1.5
22	Nyamur Dug well at Hidet	6.95	7.32	7.85	1.5
23	Kiliflowers	0.97	0.82	0.87	0.8
24	Shawasa tube well	3.79	4.08	4.28	1.5
25	Olbil tube well	5.03	5.15	5.68	2.3
26	Makisoro spring	23.36	22.70	23.36	1.5
27	KIA airport	0.06	0.03	0.03	0.1
28	A to Z B/H	3.23	2.15	2.15	1.5
29	Lanadanai B/H	0.28	0.22	0.29	0.4
30	Olasiti B/H	3.23	3.50	3.64	2.3
31	Prof.Dahi Domestic Filter	0.05	0.04	0.06	0.4
32	Prof. Dahi demonstration plant	0.14	0.12	0.17	0.6
33	Prof. Dahi tower tank	2.75	3.10	3.10	1.5
34	Ngurdoto pipeline	2.86	3.10	3.23	1.0
35	Saitabick Neeri tube well	4.64	4.76	5.03	2.3
36	Olbil primary school Tube well	6.68	7.04	7.54	2.3
37	Manyara ranch B/H	3.95	4.08	3.95	2.3
38	Haries Pipe water	3.95	4.08	4.11	2.0

39	Mark Farren Well Water	10	10.40	11.29	3.0
40	Makundus B/H " B "	1.69	1.94	1.83	1.2
41	Holili B/H	1.04	1.17	1.08	0.8
42	Olbil Kwa Michael Tube well	7.24	7.32	7.85	1.5
43	Mount Meru Hospital	3.23	3.49	3.64	1.5
44	Shambarai kwa Kisaria tube well	3.5	3.92	4.11	2.3
45	Shamabarai kwa Edward tube well	0.08	0.19		
46	Ngaramtoni kwa Iddi B/H	5.91	6.26	6.16	1.5
47	Cranes B/H	0.33	0.35	0.34	0.6
48	Olasiti kwa Paul B/H	3.64	3.77	3.50	2.3
49	TAC Water tap	14.4	14.40	14.38	2.3
50	Unknown sample	2.86	3.10	3.23	1.5
51	Worthholds			2.07	1.1
52	Worthholds			1.44	0.6
53	Worthholds			4.83	1.5
54	Joe Cook, treated			0.09	0.2
55	Joe Cook, Untreated			1.69	1.5
56	Prof. Dahi Well			2.34	1.5
57	Prof. Dahi Domestic filter			0.19	0.4
All	**Mean**	**4.43**	**4.55**	**4.46**	**1.63**

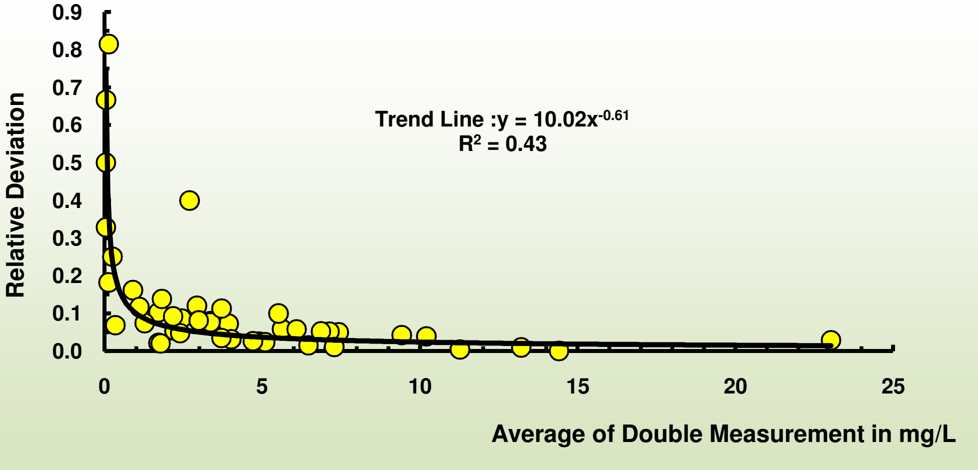


FIGURE 3. Observed deviations between double measurements of water samples, related to the average of the obtained values as a function of the average value.

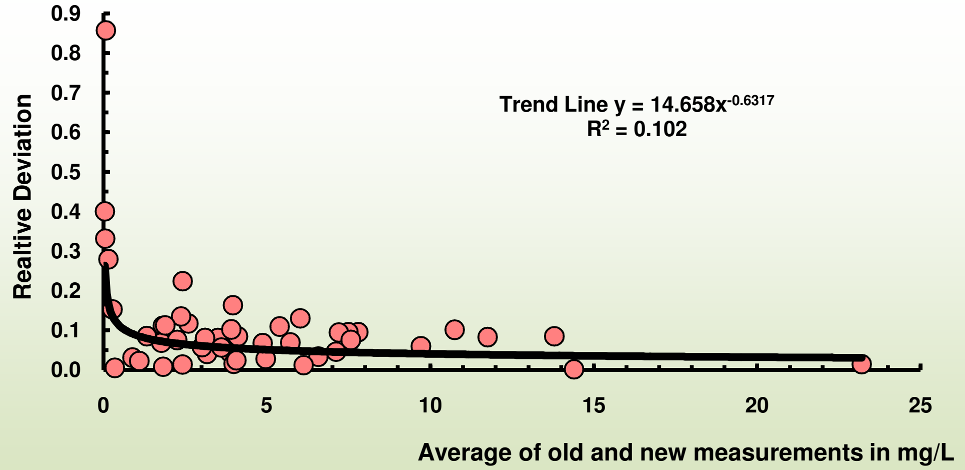


FIGURE 4. Observed deviations between previous and new electrode measurements of water samples, related to the average of the obtained values as a function of the average value.

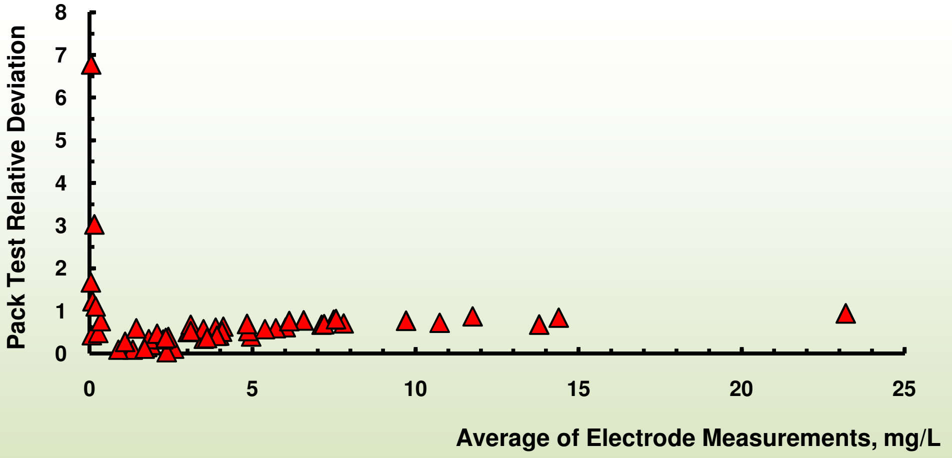


FIGURE 5. Observed deviations between previous and new electrode measurements of water samples, related to the average of the obtained values as a function of the average value.

TABLE 2. The relative variation from average within double potentiometric testing, between two different potentiometric testing and the variation of Pack Testing from the potentiometric testing.

	Parameter	Mean	Median	Range
1	Absolute deviation between double electrode measurement as related to the average	0.11	0.07	0.00 - 0.81
2	Absolute deviation between first double and second single electrode testing as related to the average	0.10	0.08	0.00 - 0.86
3	Absolute deviation between Pack Testing and two electrode measurements related to the average of the electrode measurements	0.87	0.55	0.03 – 6.77

Table 1 indicates the average values obtained by the renewed electrode testing, 4.84 mg/L for the samples 1-44 and 46-50. Compared to the first double testing, where the corresponding value is 4.58 mg/L, this is a deviation of 5.6 %. However, the individual values of the renewed electrode testing deviate up to 86 %, 10 % on an average, cf. Table 2. This individual deviation is shown in Figure 4.

Table 1 indicates that the average value obtained by the Pack Test is only 1.63 mg/L, compared to the renewed testing, where the corresponding value is 4.46 mg/L. This is a deviation of 63 %. The individual values of the pack testing deviate from the potentiometric testing up to 700 %, 87 % on an average. This individual deviation is shown in Figure 5. It was experienced that the visual impression of the developed colour was very much dependent on type of illumination, especially whether it is daylight or artificial light of white or reddish nature. Furthermore, whether the light is directed along or across the visualising line. Last but not least, whether the pillow during comparison is lifted from the pamphlet or it is directly laying on it.

DISCUSSION

Calibration curve: It is clear that the Pack Test kit has its serious limitations compared to the potentiometric electrode method. Probably there is no surprise in that. However, on the same line, this study demonstrates that even the potentiometric electrode method, which is supposed to be the most reliable fluoride testing method developed so far, does have obvious limitations, at least when used as done in the laboratory of this study.

The first limitation is related to the calibration curve. It is in most brochures illustrated to be a straight line in agreement with the Nernst equation; maybe only deviating from the straight line at concentrations lover than 2 mg/L. Looking at figure 2, this is not confirmed. The indicated trend line represents the best fitting logarithmic function and even this is seen to deviate systematically from the obtained calibration curve. Thus the calibration should remain subject to interpolation between two bordering points above and below the point of the sample.

Double electrode measurements: More serious is that deviations between two single testing supposed to make up one double testing seem to be unacceptably high. According to the "Standard Methods" the relative standard deviation between laboratories was 3.6 % with a relative error of 0.7 % in 111 laboratories testing an unknown synthetic sample of 0.85 mg/L. Thus there is a reason to conclude that the procedures used to determine the concentration of fluoride by double potentiometric testing were inadequate and in lake of quality check. For example if the laboratory in concern decided to discard results deviating more than 10 % of each others, i.e. each value is deviating more than 5 % of the average, 28 % of the measurements would have been discardable, cf. Figure 3.

Figure 3 also shows that the relative deviation in double testing increases sharply to extreme values as the fluoride concentration becomes low. A closer look at the data proves that all double measurements less than 0.2 mg/L are showing such variation. Thus 0.2 mg/L should have been used as the lower limit in the adopted procedures for double testing in the potentiometric method.

Single electrode testing: The single electrode testing and its deviation from previous double testing can not be taking as a deviation from a true value, especially when taking into consideration that the two measurements were not carried out in an inter-laboratory calibration. The average values show however that the concentration of fluoride in the containers does not change during months of storage in room temperature. Furthermore, a previous double testing of an unknown sample is after all the most likely figure of the true value. As the average deviation is of same magnitude as above, it is clear that single potentiometric measurements are loaded with unacceptable risk of error. If the laboratory in concern decided to discard results deviating more than 10 % from a previous double testing, 36 % of the measurements would have been discardable. Thus single potentiometric measurements, as carried out in the mentioned laboratory is of limited use.

Also here Figure 4 shows that the relative deviation increases sharply to extreme values as the fluoride concentration becomes low. A closer look at the data proves that all double measurements less than 0.3 mg/L are showing such variation. Thus 0.3 mg/L should have been used as the lower limit in the adopted single testing of the potentiometric method.

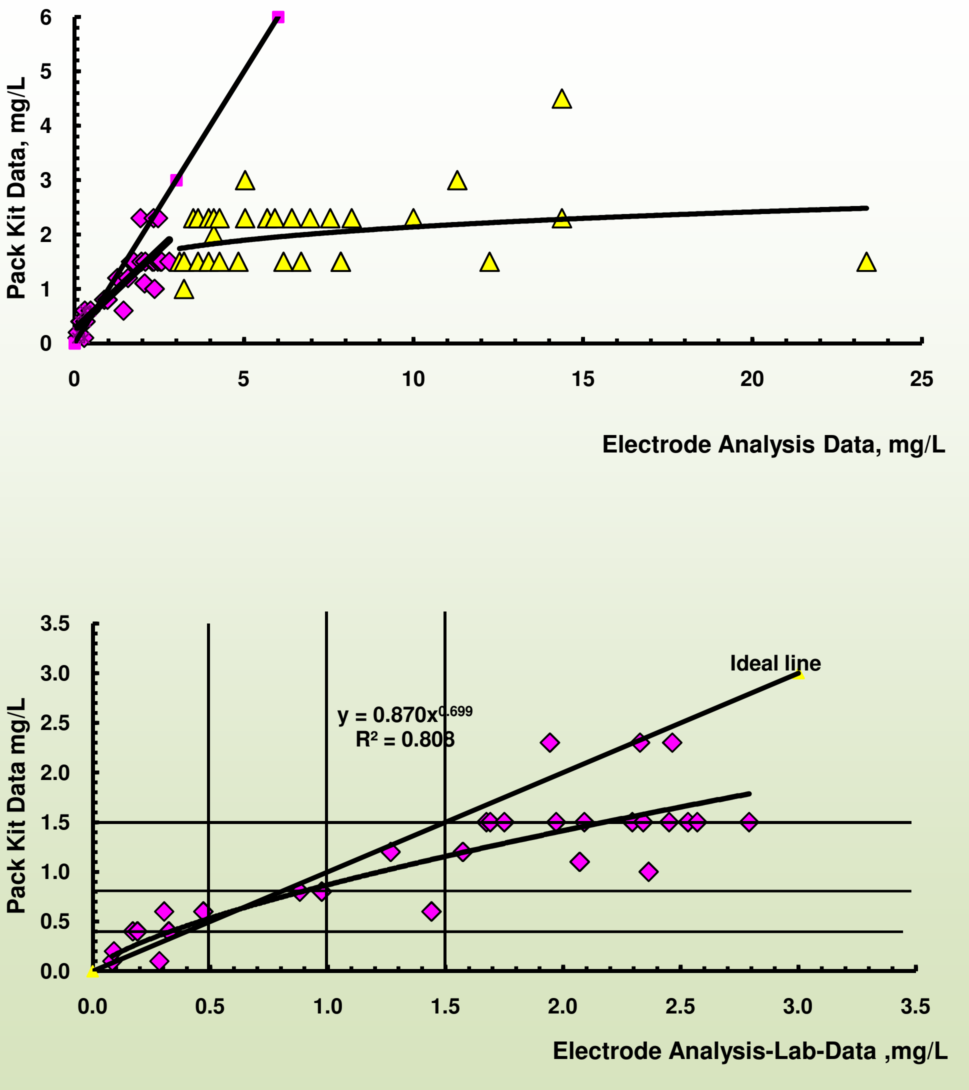


FIGURE 6. Obtained relationship between measurements of fluoride concentrations using the Pack Test kit and the potentiometric electrode method. Above: Total set of date. Below: Conc. Interval 0-3 mg/L.

Also here figure 4 shows that the relative deviation increases sharply to extreme values as the fluoride concentration becomes low. A closer look at the data proves that all double measurements less than 0.3 mg/L are showing such variation. Thus 0.3 mg/L should have been used as the lower limit in the adopted single testing of the potentiometric method.

Pack Test: Obviously the pack test could not make a reasonable estimate even on an average; 1.6 against 4.5. Also the deviation from what is most likely shows a huge deviation, up to 700 %. This could give a reason to reject the method at least as a direct quantitative tool.

Figure 5 shows that the deviation comes to such extreme values only at very low concentrations. As concluded above this could be avoided by adopting an appropriate detection limit for the method. The variation of these data suggests 0.2 mg/L, as the limit where the variation starts increasing very sharp with decreasing concentration.

Figure 6 illustrates the deviation in absolute terms. It demonstrates that Pack Kit data could in no concentration interval follow a straight relationship with the potentiometric data. Figure 6 lower shows the relationship for waters containing less than 3 mg/L. Even the relationship with this limited interval demonstrates systematic variation from the straight line, indication that the Pack Test slightly overestimates concentrations lower than 0.5 but underestimates concentrations above 1 mg/L. In this concern the Pack Test needs further development, especially concerning the adjustment of the colour scale and the standardisation of illumination conditions.

At the time being it is concluded that there is a convincing relationship between the Pack Test measurements and the potentiometric measurements between 0.2 and 3 mg/L. Actually at the concentration interval between 0.5 and 1 the relationship seems to be quite good.

It may be recalled that the most common objectives of spot testing are:

- To evaluate if a given source is safe with respect to fluoride for human consumption and
- If a filter in use should be rejuvenated or recharged.

In both situations one is interested to know if the fluoride concentration is more or less than a given optimum-maximum value. In a fluorotic area this critical value would be in the range 0.5 – 1 mg/L [5]. It is thus concluded that the Pack Test kit, in spite of serious limitations especially when testing relatively high fluoride concentrations, is a very handy, rapid and quite reliable for decision on whether the water is fit for drinking or not or whether a defluoridator in operation should be discontinued or not.

REFERENCES

1. Standard Methods for the Examination of Water and Wastewater. Greenberg et al. (Eds.). APHA, AWWA, WPCF, Washington, 1985.
2. Standard Methods for the Examination of Water and Wastewater. Eaton et al. (Eds.). APHA, AWWA, WEF, Washington, 1995.

3. Scott RD. Modification of fluoride determination. Journal of the American Water Works Association, vol. 33, p. 2018, 1941.
4. Bellack E & Schouboe PJ. Rapid Photometric Determination of Fluoride in Water. Analytical Chemistry, vol. 30 (12), p. 2032-2034, 1958.
5. Kyoritsu Chemical-Check Lab. Corporation, Instruction Manual for the Fluoride Ion Selective Pack Test. (http://kyoritsu-lab.co.jp).
6. Metrohm LTD. Ion Selective Electrodes, Instruction for use. (www.metrohm.ch).
7. Rajchagool S & Rajchagool C. On the standard setting of fluoride in water: from cookbook to bible. P.133- 145 IN: Proceedings of the 3rd International Workshop on Fluorosis Prevention and Defluoridation of Water. Chiang Mai ISFR, EnDeCo & ICOH. Nov.2000.

Field Use of the SPADNS Qualitative Technique by Beneficiaries

M Kongpun * and S Chamnanprai *
Thailand

SUMMARY: One of the constraints in fluorosis mitigation work is the testing of fluoride in the water that needs to be carried out by trained professionals using costly and complicated chemicals and instruments. This study elaborates on the usability of the SPADNS qualitative method for screening of water samples and the possibility of it being conducted by health volunteers in field. A simple procedure is developed based on addition of two drops of a ready made zirconyl-SPADNS reagent to 2 mL of the water sample and comparing the resulting colour with a 1.0 mg/L standard fluoride solution. The test would indicate whether the sample contains more or less than 1 mg/L. Twenty volunteers were instructed in using the test for half an hour. Then they exercised the test on 20 water samples containing 0.2 – 8.0 mgF/L.

The volunteers could smoothly use the test and, on an average, they delivered correct indications in 80 % of the cases. Of the 20 % erroneous the underestimation, i.e. statement that the fluoride concentration was < 1 while it was > 1, was 6.2 times the overestimation, the probabilities being 0.17 and 0.03 respectively.

There was a major variation between the volunteers, 10 % of them made error in 45 % of their testing, i.e. close to arbitrary. It is concluded that volunteers should, apart from training, be sorted and selected.

The probability of error, whether under or over estimating, as a function of the concentration of fluoride in the water is subject to larger variation, from 0.05 and up to 0.8. Within 1.0 ± 0.5 mg/L, the probability of error is estimated to be 0.08 and 0.38, respectively. Only at concentrations above 3 mg/L and lower than 0.5 mg/L, the probability of error seems to be of an acceptable level < 0.08.

It is concluded that the test is useful only in cases where concentrations of fluoride higher then 3 mg/L are needed to be identified, whereas the other samples can be taken in to a further laboratory testing for a more reliable measurement of the fluoride concentration.

Key words: Fluoride, intensity, test kit, sensitivity, specificity, accuracy

INTRODUCTION

Like many other countries Thailand has endemic fluorosis [1], and the Intercountry Center for Oral Health, being situated close to the fluorotic area, has been committed to deal with fluorosis problem for decades. One of the constraints in the mitigation

* *Intercountry Center for Oral Health, Lumphun Road, Nong Hoi, Chiang Mai, Thailand 50000. supoj@icoh.org*

work is the testing of the water for fluoride content that needs to be carried out so far only by trained professionals using costly and complicated chemicals and instruments as in the Ion Selectrode method [2].

The idea of this study is to investigate whether the standard SPDNS qualitative method could be developed for use by the beneficiaries themselves in the routine screening of water sources with respect to the fluoride concentration.

MATERIALS AND METHODS

Chemical background: The traditional method for qualitative measurement of fluoride in water utilises SPADNS, a chemical compound whose generic name is Sodium-2-(parasulfophenylazo)-dihydroxy-3,6-napthalene disulfonate, in combination with Zirconyl acid in spectrophotometric technique [3].

When the bright red solution of SPADNS is mixed with colourless zirconyl acid solution, a dark red complex of Zirconyl acid – SPADNS is formed. When zrirconyl acid–SPADNS solution is added to water containing fluoride, the fluoride ions reacts with the complex and bonds with zirconium. The concentration of the complex decreases in approximate proportion to the concentration of fluoride in the water and the colour of the reagent-mixture becomes brighter.

Zr-SPADNS	+	$6F^-$	$\Rightarrow$	ZrF_6^{2-}	+	SPADNS
Dark Red		Colourless		Colourless		**Bright Red**

In the developed technique, a standard solution of 1.0 mgF/L is prepared along with the colour reagent in dissolved form, ready for use. The sample and the standard solution are mixed with the reagent and two brighter colours are obtained. Comparing the two colours indicates whether the fluoride concentration in the sample is more or less than the standard.

Reagent solution: The SPADNS solution, $3.72 \cdot 10^{-3}$ M, is prepared by dissolving 0.4750 g of SPADNS in 250 ml of deionised water [4]. The zirconyl acid solution, $3.75 \cdot 10^{-2}$ M, is prepared by dissolving 0.0665 g of $ZrOCl_2.8H_2O$ in 25 ml of deionised water. Then 25 ml of hydrochloric acid is added and deionised water is added until the total volume of solution is 250 ml. The concentration of zirconyl acid-SPADNS reagent is prepared by mixing the two solutions at 1:1 volume ratio. The reagent is then distributed in to plastic tubes, 20.0 mL in each. The tubes are sealed in the laboratory ready for use in the field.

TABLE 1. Numbers of errors made by the 20 volunteers concerning the different sample numbers and fluoride concentrations.

	Conc.	Error numbers		Sample error	
Sample No	**mgF/L**	**Underestimate**	**Overestimate**	**Number Tot**	**Percentage**
8	0.16	0	0	0	0
16	0.28	0	1	1	5
14	0.45	0	2	2	10
19	0.66	0	2	2	10
3	0.90	0	2	2	10
13	0.97	0	4	4	20
11	1.22	-16	0	16	80
12	1.54	-11	0	11	55
7	1.67	-13	0	13	65
5	1.90	-9	0	9	45
20	2.10	-4	0	4	20
18	2.20	-4	0	4	20
1	2.49	-3	0	3	15
2	2.80	-2	0	2	10
9	3.00	-1	0	1	5
4	3.69	-1	0	1	5
15	4.78	0	0	0	0
17	4.90	-2	0	2	10
6	5.74	0	0	0	0
10	8.00	-2	0	2	10
All, No		**-68**	**11**	**79**	
All, %		**-17**	**2.8**	**19.8**	**19.8**

Screening test: The screening test is carried out by sucking an aliquot of 2.0 mL water sample in a syringe and pouring it into a 3 cm diameter Petri dish. 7 drops of the zirconyl acid-SPADNS reagent are added. The solutions are mixed by rotating 10 times to right and 10 times to the left. In parallel 7 drops of the reagent are mixed with 2.0 mL of the standard solution, and the resulting colours are compared at a white background. Fainter colour is recorded as > 1 mg/L and darker colour is recorded as < 1 mg/L.

Test volunteers: Twenty volunteers, being health workers from Ban-thi community hospital in Lamphoon, were trained for 30 minutes in how to conduct the screening test. Each volunteer was given:

TABLE 2. Numbers of errors made by the 20 volunteers concerning the different sample numbers and fluoride concentrations.

Volunteer No	Personal error Number Underestimate	Number Overestimate	Sum Number	Percentage
12	0	0	0	0
10	-1	0	1	5
17	-1	0	1	5
1	-2	0	2	10
4	-2	0	2	10
3	-3	0	3	15
6	-2	1	3	15
8	-3	0	3	15
16	-3	0	3	15
7	-3	1	4	20
13	-4	0	4	20
18	-4	0	4	20
19	-3	1	4	20
20	-4	0	4	20
15	-5	0	5	25
2	-6	0	6	30
9	-4	2	6	30
11	-5	1	6	30
5	-6	3	9	45
14	-7	2	9	45
All, No	**-68**	**11**	**79**	
All, %	**-17**	**2.8**	**19.8**	**19.8**

1. One plastic bottle containing 50 ml zirconyl acid SPADNS-reagent.
2. One plastic bottle containing 10 mL standard fluoride solution of 1.0 mg/L.
3. Twenty samples of water.
4. Twenty pieces 3 cm diameter plastic Petri dishes.
5. One plastic dropper.
6. Two 5.0 mL syringes.
7. One chart of white paper.
8. A form for notifying the screening results.

Water samples: Each of the twenty volunteers attached to the study collected a water sample from a ground water source in Lamphoon Province.

Fluoride measurements: The fluoride concentration in the 20 water samples was measured by means of the fluoride selective electrode using an Orion Digital pH and fluoride meter model 720A, Orion Fluoride Electrode 94-90 and Orion Standard

Calomel Reference Electrode 900100, in agreement with the manufacturer's instruction [5].

RESULTS

The results of the screening are shown in Table 1 & 2.

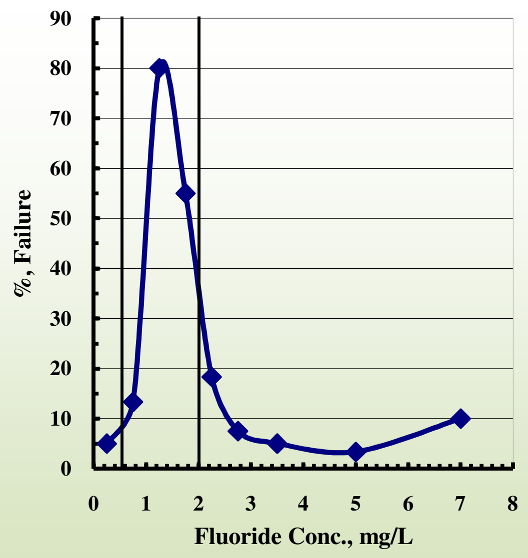


FIGURE 1. % error as a function of the concentration of fluoride.

DISCUSSIONS

Training need: Apparently the volunteers could smoothly use the test kit after the orientation and instruction of about 30 minutes and on an average finish the volunteers could do the testing of 20 samples within 1 1/2 hour. Furthermore, on an average, cf. table 1, as only 20 % of the answers were erroneous, the volunteers delivered correct answers in 80 % of the total of 400 testing.

α and β errors: Defining the errors as under or over estimates, Table 1 reveals that error α, the probability of marking a sample as < 1.0 mgF/L, while it is > 1.0 mg/L is 0.17 and error β the probability of defining a sample as < 1.0 mgF/L, while it is < 1.0 mg/L is 0.03. Thus on an average, the number of under-estimates is much, 6.2 times, larger than the number of over-estimates. ´

Personal error: Table 2 reveals that the error made by the volunteers is not of same magnitude for all the volunteers. Volunteers no 12, 10, 17, 1 & 4, i.e. 25 of the volunteers could make correct hit in 90 % of their testing, while the others, 75 %, made error in more than 10 % of their testing. 50 % of the volunteers could make correct hit in 50 % of their testing, while the other 50 % made 15 % of their testing. Volunteers no 5 and 14, i.e. 10 % of the volunteers made error in 45 % of their testing, i.e. very close to arbitrary guess that is expected to give 50 % error. Thus there is huge variation between the volunteers and this study shows that it is not enough to train volunteers for testing; they should also be sorted and selected.

Concentration range: Figure 1 is extracted from table 1 and it shows that the probability of error, whether under or over estimating, as a function of the concentration of fluoride in the water. The probability of error varies very much, from

0.05 and up to 0.8, depending on the concentration of fluoride in concern. Considering the concentrations of the standard solution ± 0.5 mg/L, i.e. 0.5 and 1.5 mg/L, the probability of error is estimated to be 8 % and 38 % respectively. Thus while the underestimation may be acceptable, the overestimation is too high. Only at concentrations above or equal to 3 mg/L, the probability of error seems to be of an acceptable level.

Screening usefulness: This study shows that normal health workers can be trained to carry out the simple testing of water sources in the field. It also indicates that the usefulness of the developed procedure can be increased by an appropriate selection of the field workers. I may be concluded that the qualitative SPADNS method, as in the developed procedure, should only be used with much care, e. g. in cases where concentrations of fluoride higher then 3 mg/L needed to be identified, whereas the other samples can be taken in to a further laboratory testing for a more reliable measurement of the fluoride concentration.

REFERENCES

1. Leatherwood E.C., Burnett G.W., Chandravejjsmarn R. and Sirikaya P. Dental Caries and Dental fluorosis in Thailand. *Am. J. Pub. Helth.* 55:1792-1799, 1965.
2. 2. Clair N. Sawyer and Perry L. McCarty, Chemistry for Environmental Engineering, third edition, McGraw-Hill Book Company, 1978
3. Mary Ann. H. Franson, (eds.) Standard Methods for the Examination of Water and Wastewater, 16^{th} ed., American Public Health Association (APHA), American Water Work Association (AWWA) and Water Pollution Control Federation (WPCF), 1985.
4. Monton Kongpun, A Preliminary Study on Fluoride Determination Techniques, Intercountry Centre for Oral Health, Chiang Mai, Thailand. 1998.
5. Orion Research, Handbook of Electrode Technology, Orion Research Inc., 1982.

Means and Mode of Providing Information to People in their Fluorosis Prevention

J P Nasakolnakorn *
Thailand

SUMMARY: The nature of the fluorosis problem in Thailand differs from one locality to another. In a user-based approach to combat fluorosis, it is essential that testing of fluoride in people's drinking waters goes hand in hand with other services required for the success of the mitigation program. In order to achieve that ICOH launched the use of a mobile unit, a minibus rebuild, equipped and staffed multiple disciplinary. It covers the need for simultaneous fluoride testing, fluorosis identification and counselling, community education and mobilisation to take own decisions on measures that fit people's way of life and socio-economy. The unit's working procedure and its outcome in terms of observed fluoride levels, identified fluorosis and achieved community mobilisation are stated. The lessons learned and the success factors are discussed.

Key words: Mobile unit, fluorosis prevention, fluoride levels, fluorosis occurrence, Thailand, user-based mitigation, success factors, community mobilisation.

INTRODUCTION

During decades of work, ICOH, the Intercountry Center for Oral Health in Chiang Mai, Thailand, has experienced that sustainable prevention of fluorosis can only be accomplished through programs that fit people's way of life and allow for people's own decisions. In such a user-based approach conceptual understanding of 1) the cause and effects of fluorosis and 2) the variety of potential measures are the initial steps required for proper decision-making.

Fluorosis in Thailand only occurs in specific locations scattered from north to south. People who live in these locations have lived with the fluorosis problem for generations. The nature of this problem differs from one locality to another in terms of severity, geographic location, fluoride concentration, socio-economic and cultural dimensions. After knowing that fluoride in their drinking water is the cause of fluorosis, the communities are naturally very anxious to solve the problem. Then it is absolutely essential immediately to provide each community with more specific information about the cause of fluorosis in their community and the options in solving the problem in a timely manner.

* *The Intercountry Centre for Oral Health, 548 Chiang Mai Lumphun Rd, Muang, Chiang Mai Thailand 50000. E-Mail: jumpol@icoh.org*

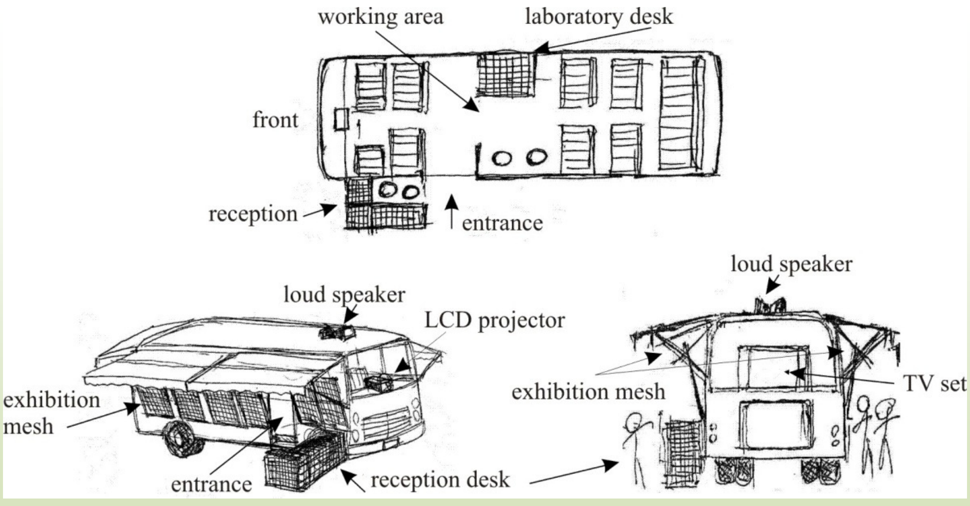


FIGURE 1. Sketch of the mobile unit.

Previously testing the water required sending samples to ICOH, doing the laboratory work at the Center and resending the results. This is took too long time and caused an unfortunate interruption in the efforts in getting the community involved in setting up their fluorosis prevention programs. To address this problem ICOH launched the idea of a mobile unit of professionals, equipment and materials all together approaching each community and working side by side with the people in the community. The objectives of the mobile unit were set as follows:

- To provide relevant information about fluorosis in each community.
- To increase awareness of the communities regarding the effect of excessive fluoride consumption on health.
- To serve the community with on-site analysis of fluoride content in the water.
- To give technical consultation concerning the possible alternatives to solve the problem in the community.

METHODS

Unit design: An old 20-seat minibus, cf. figure 1 & 2, was modified to serve as a mobile service centre. The budget for the modification of the minibus was about 10,000 Baht, equivalent to US$ 250.

FIGURE 2. Illustration of the mobile unit exhibition and out- and in-working places.

Equipment: The unit was equipped with:

- A small lab facility including in site electrode potentiometer.
- An audiovisual facility including LCD projector, cassette player, video player with screen and a microphone with an amplifier.
- An education exhibition facility including stands, posters, boards, tables, and seats, cf. figure 1 & 2.

Professional team: The unit team consists of 4 professionals, each having a task as follows:

- A public health officer, who uses the exhibition, makes video presentation and provides further information about fluorosis in Thailand.
- A lab technician, who demonstrates the fluoride testing procedure. He/she also determines the fluoride content in water samples that are collected by the people in the community and reports the results to the community and to ICOH database.
- An oral health officer, who examines and provide consultation regarding people's oral health. Specially he/she screens the children aged 11-13 for dental fluorosis and observe other deformities and symptoms regarding fluorosis in the elderly.
- A "motivator", i.e. a representative from a neighbouring community, which has been though a fluorosis prevention program. He/she would share the community's fluorosis prevention experiences.

Preparatory public relations: In 2002 a meeting was arranged with the attendance of representatives from seventy local administrative bodies all from nearby areas considered to be at risk for fluorosis. An exhibition on "Fluorosis: Etiology and Remedies" was sat up and the mobile unit and the planned activities were presented. The representatives who wanted the mobile unit to visit their community could make their request. Their name, addresses and telephone numbers were recorded and a schedule for the mobile unit was sat up.

Community preparation: The venues for the mobile unit activities were proposed by the community leader and could be a school, a temple, a health center, an office of the local administrative body or any other place that has electricity and is easy accessible to the villagers. The administrative body also informed villagers and all stakeholders i.e. health workers, community water supply workers, leaders from the league of women's group, etc. about the role and venue and time and the objective of the mobile unit visit. People are informed to bring their own water samples.

Working procedure: At arrival of the mobile unit to the selected site, the team discusses their plan with the community's leader while water samples are tested for their fluoride concentrations. The villagers have to pay 50 Baht, i.e. US$ 1.25, per sample. While waiting for the result of the test, the public health worker and the "motivator" from the experienced neighbouring community make their presentations and initiate a group discussion. The dentist would then starts activities as described above.

The result of the fluoride test would be written on a green tag if the fluoride concentration is lower than 0.7 mg/L, i.e. within the Thailand safety limit or on a red tag if the fluoride concentration is higher than this limit. The people are told that a red tag means not recommended for drinking.

The lab technician also tests the community's pipe water and school water. The results of these tests are then discussed with the community's leader. Possible alternative water sources are discussed and samples of those are tested free of charge. Based on the results of these test, alternative water sources are recommended.

RESULTS

Areas served: Of the 70 local administrative bodies who participated in the meeting preparatory meeting "Fluorosis: Aetiology and Remedies", 28 (41%) made a request for the mobile unit visit in 2002. Because of budget limitations, ICOH could only serve 18 communities. In 2003 there were 7 other requests for the mobile unit. Since all of the requests were in the northern part of Thailand, ICOH was able to serve all of them. The communities served by the mobile unit were within a 250 Km. radius of ICOH.

Involved stakeholders: The representatives from the communities could contact and motivate most of the stakeholders to join the prevention program. Apart from the community leaders the stakeholders included: sub-district chairmen, village chairmen, community water supply workers, leaders from the league of women's group and leaders of elderly groups. State agency stakeholders included a secretary of the grass root organisation, health workers and schoolteachers.

Water tests: The mobile unit determined fluoride content in 1,108 water samples from different water sources. Table 1 shows the different sources of the tested waters along with the fluoride levels found. Each community had between 5 and 10 different sources for pipe water. Of the 244 samples of deep well water used for village piped supply, 59 were tested more than once because of individual request.

Observed fluorosis: Fluorosis was clearly found in areas where the water sources had high fluoride content and where the same sources have been used for more than 10 years. 11-13 old children had moderate to severe dental fluorosis. Symptoms of joint pain, curved legs and difficulty in walking were common among the elderly. Even though some people drank rain or bottled water, dental fluorosis was still found, probably due to the use of the high fluoride water for cooking.

Observed community mobilisation: It appears that the mobile unit has succeeded in creation of concern about fluorosis and the high fluoride water. It also increased self-confidence of the members of the communities in discussion, empowered them to synthesize the alternatives in solving their problem, and to assist in transfer of knowledge and experience to other communities.

Outcome of the mobile unit: The communities visited by the mobile unit decided, according to their situation, to carry out one or more the following actions in order to solve their problem:

- Provision of rainwater tanks for safe drinking water.
- Set up of funds for later installation of rainwater tanks.
- Change of pipe water source in most cases from deep wells to shallow wells.
- Changed of the water supply.
- Set up a factory to produce bottled drinking water at low cost level.
- Preparation and use of bone char defluoridators.

TABLE 1: Water tested in different sources and supplies and their respective fluoride contents

Fluoride Conc. in mg/L	All Conc.	< 0.7		0.7-1.5		>1.5	
Public Supplies:	**No**	**No**	**%**	**No**	**%**	**No**	**%**
Deep well water used for village piped supply	244	144	59	34	14	66	27
Deep well water used for village piped supply (provided by Dept. of Rural Development)	9	6	67	3	33	0	0
Deep well water used for village piped supply (provided by Dept. of Mineral Resources)	5	1	20	1	20	3	60
Surface water used for village piped supply	37	35	94	1	3	1	3
Deep well water used for the Primary School piped supply	17	7	41	2	12	8	47
Water from river	7	7	100	0	0	0	0
Water from public reservoir	3	3	100	0	0	0	0
Private Supplies							
Deep well water with motor pumps in village households	148	104	70	16	11	28	19
Shallow wells in villager household	600	447	74	65	11	88	15
Distilled water	6	6	100	0	0	0	0
Bottled water	21	21	100	0	0	0	0
Harvested rain water	11	10	91	1	9	0	0
Total	**1,108**	**791**	**71**	**123**	**11**	**194**	**18**

DISCUSSION

The results from table 1 show that among public water supplies deep well water for village piped supply was the most likely to be tested for safety. Among private supplies, shallow wells in villager households were the most likely to be tested for safety.

The results also show that 71 % of examined water samples were safe. Surface water, rainwater and shallow well water were usually good sources of safe water. More than half of the deep wells contained fluoride within safety limit. Getting safe water by changing the source of drinking water was possible in all needy communities.

Lesson learned: The lesson learned were summarised as follows:

- Working with the community through the mobile unit at their location gives prompt information needed by the community and allows for effective facilitation of own decision making.
- A charge of 50 Baht (1.25 US$) per sample for water tested for fluoride content was acceptable to the residents of all visited communities.
- The communities themselves know their capabilities and limitation so they can make appropriate and feasible choices for themselves. State agencies can provide them with essential information, which they cannot find by themselves.
- With the decentralization policy, the local administrative body can mobilize resources to support the action promptly.
- **Success factors:** The success factors were identified as follows:
- The essential information i.e. aetiology of fluorosis, health effects of excessive intake of fluoride, the incidence of fluorosis in the community, information about water sources and experiences from other communities etc.
- The awareness of the problem by all social groups within the community and the willingness of those to work together.
- The support from state agencies to empowering people to initiate their own programs.
- The community forum, which facilitates the exchange of experiences and mutual assistance.
- The select of appropriate technology to support self-reliance of the communities.

REFERENCES

1. Rajchagool S. and Rajchagool C. Solving the Fluorosis Problem in a developing Country. In: *Proceedings of the 2nd[t] International Workshop on Fluorosis and Defluoridation of Water*. p. 170-175. (Ed. E. Dahi & J. M. Nielsen) Int. Soc. Fluoride Res. Auckland 1999.
2. The Intercountry Centre for Oral Health. *Solving the Problem of Excessive Fluoride Intake: Handbook for Health Personnel*. Intercountry Centre for Oral Health, Chiang Mai, 2002, (in Thai).
3. The Intercountry Centre for Oral Health, *Proceedings of Meeting of Representatives of Local Administrative bodies: " Fluorosis: Etiology and Remedies"*. Intercountry Centre for Oral Health, Chiang Mai, 2002, (in Thai). The Intercountry Centre for Oral Health, *Fluoride in bottled drinking water and consumer protection,* Intercountry Centre for Oral Health, Chiang Mai, 1997, (in Thai).

Session 3

Defluoridation

Domestic Defluoridation of Water Using Locally Produced Activated Alumina

N V Dzung [a], H H Phong [a], N N Long [a], N T Quang [b] and P Waldemar [c]
Vietnam

SUMMARY: A low-cost defluoridator for domestic use is developed, based on activated alumina as a sorption medium. The filter column is 11.4 cm in diameter and 1 m in height. It is designed to contain about 8 L or about 3 kg of alumina. The alumina is prepared by using aluminium sulphate and sodium hydroxide to precipitate aluminium hydroxide at 60-70 °C. The precipitate is settled, washed, granulated and calcined at 550 - 600 °C for 4 hours. A column test in the laboratory revealed that the fresh alumina could remove fluoride from 5 mg/L to < 0.7 mg/L at a capacity of 1.2 g/kg. The developed filter allows for monthly regeneration of the medium by the users themselves. A quantity of 0.4 kg of aluminium sulphate is used in the regeneration. The filter operates upwards, while the regeneration operates downwards in the filter column.

Field-testing data show that the filters could treat water containing about 2 mgF/L down to 0.15 - 0.46 mg/L, thus an average removal efficiency of 85 %. Monitoring of a filter through 5 operation periods shows that the regenerated alumina loaded with water containing 2.6 mgF/L could treat the water at an efficiency of 89 %. The medium capacity is estimated to be 0.7 gF/kg regenerated alumina.

Field experiences show that the villagers very well accept the filter; it is easy to operate and to maintain and the filter costs are affordable to the families, about 45 USD for purchase and 20 US Cents for the monthly regeneration.

Key words: Activated alumina, domestic defluoridation filter, Vietnam, regeneration, aluminium sulphate, field experiences, medium capacity.

INTRODUCTION

Various methods and techniques have been applied and used for the treatment of access fluoride in drinking water. Each of them has certain advantages and disadvantages and their individual appropriateness would always depend on the actual local conditions, the most important factor being the community's acceptance [1,5]. This article briefly presents the technique of preparation of activated alumina from Aluminium sulphate or Alum, $Al_2(SO_4)_3.18H_2O$. Furthermore it describes a device for fluoride removal on household scale using the produced activated alumina. Tests of the filter were carried out in Ninh Hoa district, Khanh Hoa province (Vietnam), an area with emerged fluorosis related to the excess fluoride in drinking water. A local area is known as "an area without smile" due to the damage and the very clear appearance of black and "dead" teeth.

a) *Institute of Materials Science – Ho Chi Minh Branch, Vietnamese Academy of Science & Technology 01 Mac Dinh Chi, Dist .1, HCMC, Vietnam; E-mail: dzunguyen@hcm.vnn.vn.*
b) *UNICEF Ho Chi Minh City, Viet Nam.*
c) *UNICEF Vientiene, Laos.*

MATERIALS AND METHODS

Preparation of activated alumina: The activated alumina commercially available in Viet Nam is imported in grades that only fit to the industrial use. Hence the activated alumina for the use by the rural family had to be specially prepared. The raw materials utilised are aluminium sulphate, $Al_2(SO_4)_3.18H_2O$, and sodium hydroxide, NaOH, chemicals that are normally used in water treatment [2]. The activated alumina is prepared as a precipitation product obtained by neutralization of 150 litres of a 15 % solution of the aluminium sulphate with about 10 litres of a 20 % solution of sodium hydroxide at 70 ^oC with an average pH value of 7.0. The solution mix is kept at 60 ^oC about 8-10 h. The collected precipitate is then washed with warm drinking water to remove the excess of sulphate ions. Hereafter, the supernatant water is removed by decanting, leaving the precipitate in suspension as a paste. The paste is then formatted as a granulate product by an extruder with screen hole diameter of 5.0 mm. The granulate product is then dried naturally and calcined at 550-600 ^0C for 4 h, the yield being about 5 kg and the bulk volume about 14 L.

Medium specifications: The granular activated alumina prepared as described above meets the following six specifications [2, 3]. 1) Main crystallite phase, γ-Al_2O_3. 2) Granular size is 3-5 mm. 3) Bulk density is 0.35 kg/L. 4) Specific surface area (BET) is 250 m^2/g. 5) Fluoride removal capacity of 1.2-1.5 gF/kg alumina and 6) Compression tolerance 50 kg/cm^2.

Capacity testing: The capacity of the freshly produced activated alumina is determined through the following column experiment: The filter bed is 50 cm in height and 2 cm in diameter thus containing 157 mL medium. Its dry weigh is 55 g. The column is fed with raw water containing 5.0 mgF/L, at a flow rate of 942 mL/h, i.e. 6 Empty-Bed-Volumes/h or flow velocity of 3 m/h. The cumulative volume of water that could be treated to an effluent concentration less than 0.7 mg/L is 16 L. Thus capacity of fresh activated alumina is 1.2 gF/kg.

Experiments showed that at the flow rates 5-7 EBV/h and the initial fluoride concentration in the raw waters of 5-10 mg/L, the capacity of the alumina is in the ranges 1.2 – 1.5 g/kg alumina.

Design of the household defluoridator: Given the above mentioned characteristics of activated alumina a special domestic filter was developed and designated as "FLOWAT". The diagram of the FLOWAT filter is presented in Figure 1.

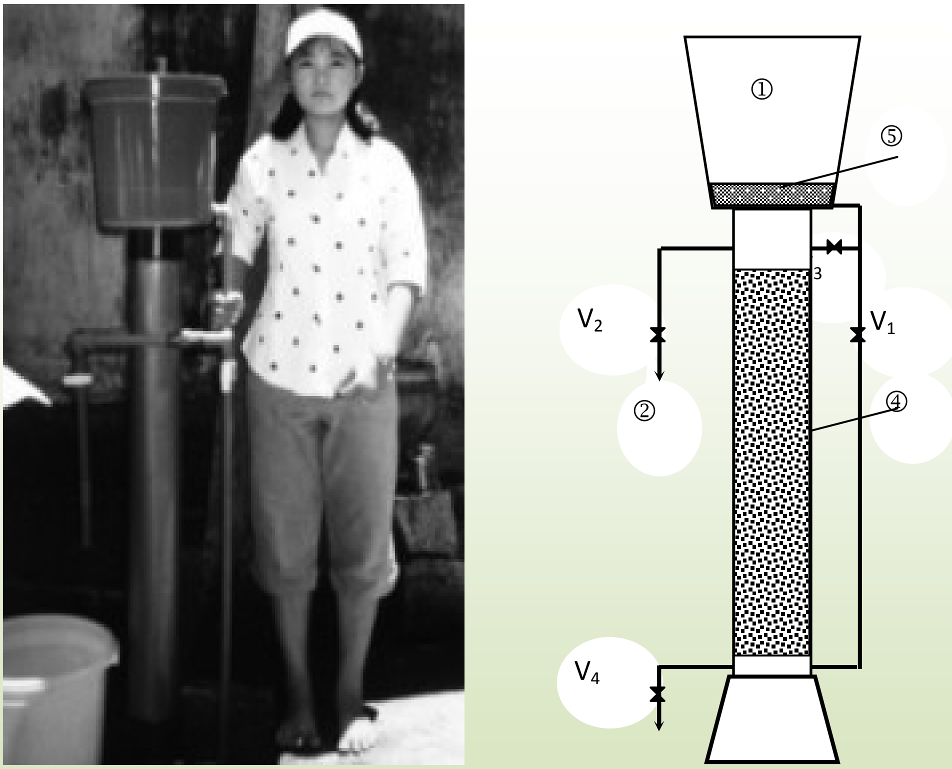


FIGURE 1. A diagram and a picture of the FLOWAT filter
① Bucket for raw water. ② Tap to collect treated water. ③ Tap for washing
④ Bed of activated alumina. ⑤ Polyethylene spongy plate for pre-filtration

The filter body is made of PVC material normally used in the water supply works. The column inner diameter is 114 mm. Its height is 1000 mm height, allowing for a filter bed height of 800 mm. A water bucket of 13 L volume is installed over the column, functioning as a raw water container. The bucket is supplied with a piece of polyethylene spongy plate in order to retain any suspended solid that might be in the raw water. The water bucket connects to the filter column through valve V_1 at the bottom below the filter medium and through valve V_3 at the top above the filter medium. All connecting pipes are made of PVC, inner diameter 21 mm. During operation the water is taped through valve V_2 above the filter medium. A fourth Valve

V_4 is fitted below the medium to allow for drain during regeneration and backwashing.

Filter operation: Under normal filter operation valves V_3 and V_4 would remain closed, while valve V_1 remains open. Raw water is poured into the bucket and the treated water is taped through V_2.

Medium regeneration: At the end of each filter period 10 L of a 4 % solution of aluminium sulphate in fluoride free water is poured to the bucket. The solution is allowed to flow through the bed of activated alumina and drained through V_4. Then 10 litres of fluoride free water is poured for wash of bed before the start of the new filter period.

Filter performance: For areas where the raw water up to 4.4 mgF/L, the filter is capable to treat about 900 litres for a month, i.e. 30 litres/family-day, before the treated water concentration reaches 0.7 mg/L and the regeneration is required. This is normally sufficient for a family's use for drinking and cooking, including final washing the food. Thus regeneration is needed once a month. For areas where the fluoride concentration is higher, usually 4 - 9 mg/L, the regeneration it would be needed to regenerate the filter 2 times per month. It takes about 2 hours to regenerate the filter.

Field-testing: Since 1999, a number of 1,200 filters have been used by villagers in Khanh Hoa province. In this study, 40 FLOWAT filters were tested in the field. Thirty filters were installed in Ninh Quang commune, Ninh Hoa district, Khanh Hoa province for treatment of well water containing 1.7 to 4.1 mgF/L. Ten filters were installed in Ninh Xuan commune, Ninh Hoa district, Khanh Hoa for treatment of well water containing 4.1 - 6.3 mgF/L. All filters were monitored continuously for 6 months.

Attention was also paid to the effect of aluminium sulphate or alumina particles on the treated water. The aluminium tests carried out shows that there is no aluminium in the treated water.[4]

RESULTS AND DISCUSSION

The obtained results are shown in Figure 2 & 3.

Figure 2 shows that the 10 filters have been loaded with water containing 1.7 – 2.3 mgF/L, 2 mg/L on an average. On average the filters could remove the fluoride down to 0.15 mg/L at the start of the filter periods. The removal efficiency decreased to 77 % at the end of the filter periods where the treated water had an average concentration of 0.46 mg/L.

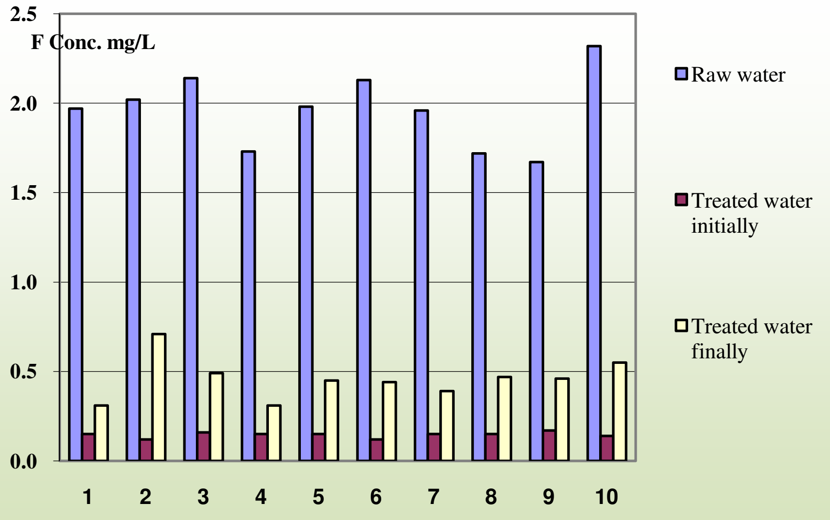


FIGURE 2. Monitoring data from 10 FLOWAT filters during 5th operation period.

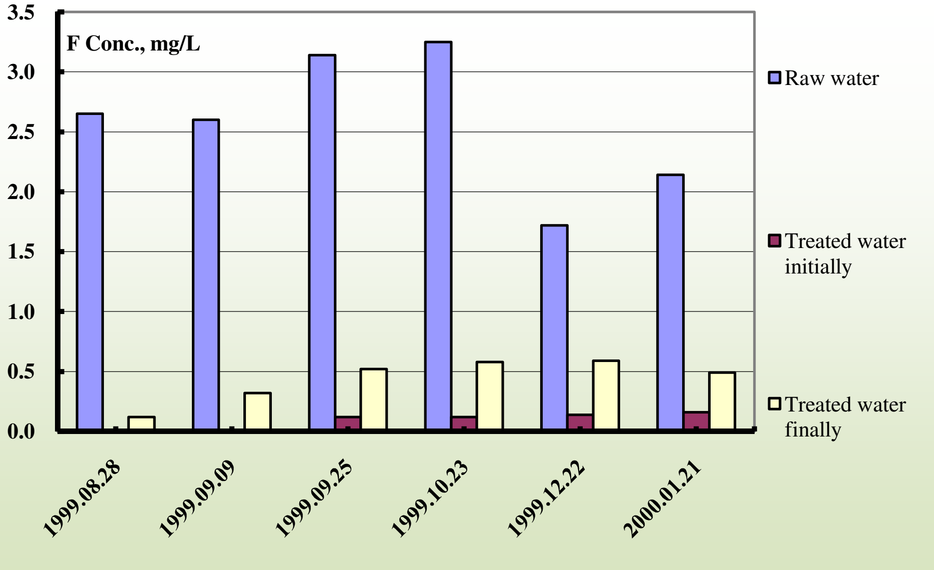


FIGURE 3. Monitoring data of a FLOWAT filter during 5 operation periods including 5 regenerations (no data available for November, 2000).

Figure 3 shows that one filter was operated for 147 days, during which the filter was regenerated five times. On an average, the raw water had a fluoride content of 2.6 mg/L and the treated water was between 0.1 and 0.4 mg/L, indicating an average removal efficiency of 89 %. Assuming a daily consumption of 30 L of water per family per day, the fluoride removal capacity of activated alumina in this filter is calculated to be 0.7 g/kg. This figure is very close to what is recommended by Dahi 2000 as a design parameter for activated alumina [5].

The field experiences have shown that FLOWAT is easy to operate and to maintain. The cost of the filter is 650,000 VND, equivalent to about 45 USD. The monthly regeneration requires only 0.4 kg of aluminium sulphate, which is considered affordable to the beneficiaries, as 1 kg of alum is 3,000 VND, equivalent to 20 US Cents. Furthermore, the filters seem to be highly accepted by the communities in the tested communes. The villagers there considered the filters as a necessary facility in their households and were ready to pay for them.

ACKNOWLEDGMENTS

The present research was supported by UNICEF and the Project of Technology & Science of the National Target Programme for Rural Water Supply and Environmental Sanitation, Vietnamese Academy of Science and Technology.

REFERENCES

1. A.K. Susheela. Defluoridation Of Drinking Water – Merits Of Alternative Technologies. Available from URL: http://www.nutrionfoundationofindia.org/ARCHIVES/JUL92C.HTM.
2. N.V.Dzung *et al.* Treatment of Excess Fluoride in Drinking Water by Activated Alumina. Selected Scientific Works - Institute of Materials Science, Ho Chi Minh City Branch, 2000.
3. N.V.Dzung *et al.* Appropriate Technology for Defluoridation of Drinking Water In Khanh Hoa Province. Selected Scientific Works - Institute of Materials Science, Ho Chi Minh City Branch, 2001.
4. N.V.Dzung, N.T.Quang. Field Test of Fluoride Removal Filters. Final Scientific Report to UNICEF, 1999.
5. E Dahi 2000. The State of Art of Small Community Defluoridation of Drinking Water. P. 143-173. In P.51 – 60. IN: Proceedings of the 3rd International Workshop on Fluorosis Prevention and Defluoridation of Water. (Eds. E Dahi et al.) Chiang Mai ISFR, EnDeCo & ICOH. Nov.2000.

Domestic Defluoridation Using Brick Chips in Sri Lanka

J P Padmasiri *
Sri Lanka

SUMMARY: Dental surveys carried out in the fluoride rich, dry zone areas in Sri Lanka have shown a prevalence of 55 - 71 percent fluorosis. Excessive fluoride in drinking water is found to be the principal causative factor in the development of the fluorosis. Nearly 40 percent of the wells in these areas have fluoride content of more than 1.0 mg/L. Several cases of skeletal fluorosis have been reported from these areas and it has been found that they have been drinking water from wells with a fluoride content of around 6- 8mg/L.

The National Water Supply and Drainage Board in collaboration with several other organisations and community leaders, carried out a fluorosis awareness and defluoridation programme. As an initial step the consumers of wells with fluoride content about 3 mg/L were informed not to use this water for drinking and cooking. They were helped in finding alternative sources.

Since 1994, domestic defluoridators based on brick chips as a medium were introduced to consumers using wells with fluoride content of 1- 3 mg/L. Presently there are about 3000 domestic defluoridators in operation.

There is a marked reduction in the incidence of dental fluorosis of children living in the programme areas.

Key words: Fluorosis, Sri Lanka, defluoridation programme, defluoridator, awareness, sustainability, brick chips, fluoride occurrence.

INTRODUCTION

Recent studies carried out by several groups in Sri Lanka, show that seven out of 24 districts have the fluoride problem, cf. Figure1. In these studies it is revealed that more than 50 percent of drinking water wells in the 7 districts have fluoride levels exceeding 1.0 mg/L. In some of villages more than 70 percent of the wells have exceeded fluoride levels. Some of the village wells have fluoride content of 6-8 mg F/L [1].

A dental survey conducted in 1986 [2] revealed that in five communities in Embilipitiya the community fluorosis index, CFI, ranged from 1.30 in Katalgara to 2.35 in Galvanguwa. Other communities in Anuradhapura where the CFI has been determined are Hidogama 1.89, Galkulama 2.29 and Thalawa 1.85, Chandanapokuna in Polonnaruwa had a CFI of 2.17. Table 1 gives the dental fluorosis data carried out in schools more recently (1996) [2]. The dental fluorosis survey carried out in Trincomale district in 2001, showed 22.5 percent in Gomaramkadawalla 7.5 percent in Kantale [3].

* *National Water Supply and Drainage Board, Peradeniya, Sri Lanka.*
Email: midwater@slt.lk

So far about 3000 defluoridation units based on brick chips as a medium [4 5] have been introduced to rural families in these areas, subject to easy operation and maintenance in order to reduce fluoride contents in the drinking water down to acceptable levels.

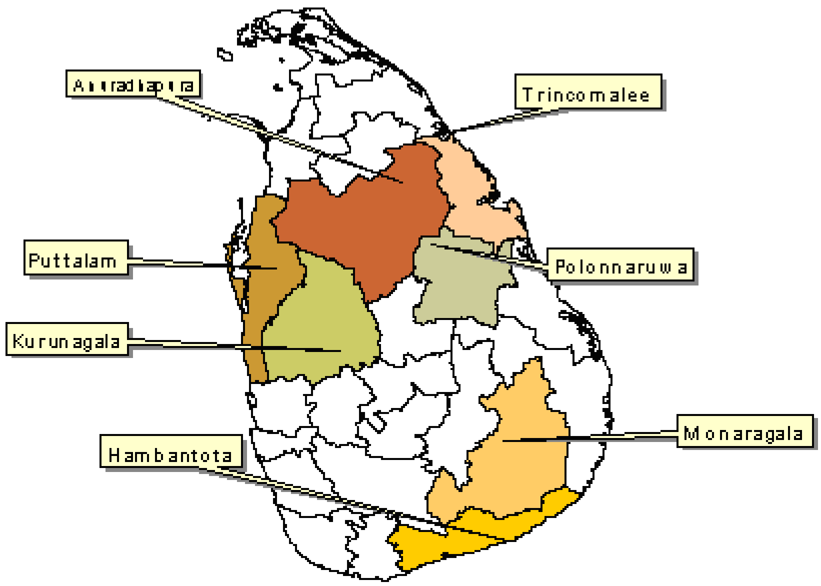


FIGURE 1. Fluorosis affected districts.

TABLE 1: Dental fluorosis surveys. From Ratnayake, 1996 [2].

Location	Number examined	Number of dental fluorosis cases	Percentage affected
Sooriyawewa	2158	546	25.3
Kiri-Ibbanwela	4387	1068	24.3
Mahaweli B,C,H&L	49280	12320	25.0

MATERIALS AND METHODS

Institutional arrangement: A strategy to carry out awareness programmes explaining the gravity of the fluoride problem was adopted at various levels. The institutional arrangements utilised are illustrated in Figure 2.

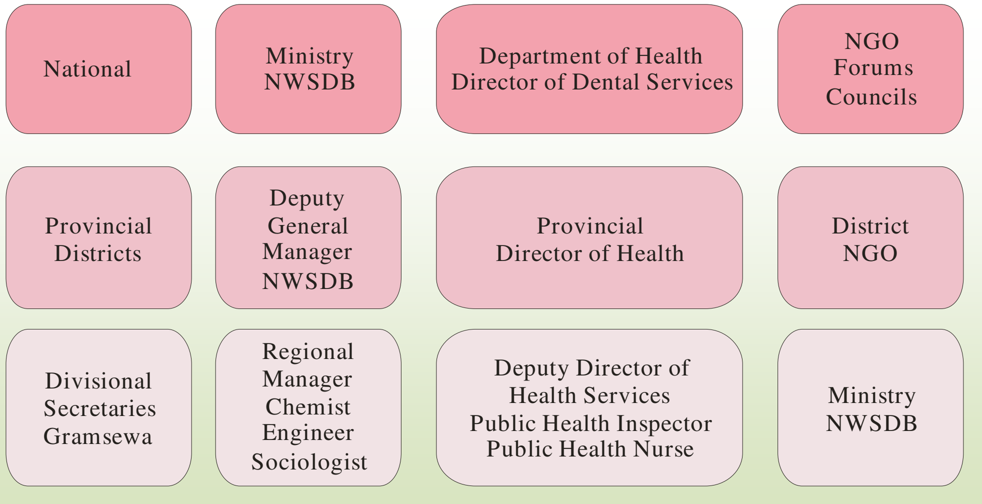


FIGURE 2. Institutional Arrangements.

Awareness programmes: At the divisional/village level school awareness programmes were carried out to educate the students on fluoride in drinking water. Students were requested to bring samples of their drinking water. The fluoride levels of the water samples were measured and the results were discussed.

Further, the primary health care workers carried out similar awareness programmes in the villages. In this programme, once the fluoride levels of the wells are measured, the householders are divided in to three categories according to the fluoride content of their wells. The householders using water with fluoride levels less than 1 mg/L were advised to continue using their wells for drinking purposes. Where the fluoride content of the wells was found to be more than 4 mg/L the householders were notified not to use their wells for drinking or cooking purposes. Alternative water sources in the villages were recommended for this category.

Domestic defluoridators: Then the householders using wells with fluoride content of 1 - 4 mg/L, and who have children of the age group less than 4 years, were provided with domestic defluoridators, Table 4.

Fluoride mapping: The obtained fluoride data were further used in the fluoride mapping and future reference, Table 2 and 3.

TABLE 2 Fluoride content of examined wells in Anuradhapura District, 1998/2003.

Divisional Secretary Division	Examined wells No	% of wells with indicated fluoride levels		
		< 1.0 mg/L	1.0 - 2.0 mg/L	> 2.0 mg/L
Padaviya	142	90.9	9.1	0
Medawachchiya	64	60.9	39.1	0
Galenbidunawewa	311	63.7	32.5	3.8
Mihintale	210	53.8	36.2	10.0
Ipalogama	350	52.6	33.1	14.3
Rajangane	473	52.0	38.1	9.9
Kekirawa	1052	47.4	34.7	17.9
Thalawa	276	45.6	43.5	10.9
Nuwaragam P.Central	255	41.9	47.5	10.6
Nachchaduwa	225	41.4	40.4	18.2
Kebitigollewa	210	40.0	46.7	13.3
Thirappane	141	39.7	36.9	23.4
Nuwaragama. P East	164	33.5	53.0	13.4
Thambuttegama	569	32.9	32.0	35.1
Nochchiyagama	138	30.5	23.2	46.3
Palagala	471	28.9	38.6	32.5
Maha Villachchiya	46	28.3	47.8	23.9
Kahatagasdigiliya	209	27.7	49.3	23.0
Galnewa	265	18.5	41.5	40.0
Rambewa Horowpathana Palugaswewa		Samples were not analysed		

TABLE 3: Fluoride content of wells in Pollonnaruwa District 1998/2003.

Divisional Secretary / Division	**Examined Wells No**	**% of wells with indicated fluoride levels**		
		< 1.0 mg/L	**1.0 -2.0 mg/L**	**> 2.0 mg/L**
Elahera	16	75.0	25.0	-
Hingurakkgoda	127	44.0	46.0	10.0
Medirigiriya	327	41.9	48.9	9.2
Thamankaduwa	490	37.4	42.2	20.4
Lankapura	194	26.3	44.3	29.4
Dimbulagala Welikanda	Samples were not analysed			

RESULTS AND DISCUSSIONS

Fluoride occurrence: Table 2 shows the fluoride content of wells in 19 divisional secretary divisions in Anuradhappura district. Column 3 in the table shows the percentage of wells with fluoride content less than 1.0 mg/L, considered suitable for human consumption. In Padeviya and Medawachchiya fluoride contents of all the wells were less than 2.0 mg/L. Ninety percent of the wells in Padaviya contained acceptable amount of fluoride i.e. less than 1.0 mg/L. On the other hand 46.3 percent of wells in Nochchiyagama were found to have fluoride content of more than 2.0 mg/L. The maximum fluoride content in Nochchiyagama was 8.0 mg/L. In Galnewa, Thambuttegama and Palagala, respectively 40.0, 35.1 and 32.5 percent of wells were found to have fluoride content of more than 2.0 mg/L. The maximum fluoride content in these areas was found to be 6.5 mg/L. More than 50 percent of wells in 13 divisional secretary divisions contain fluoride levels higher than the acceptable level of 1.0 mg/L. In Keekirawa, considering the fact that several skeletal fluorosis cases have been reported, more than 1000 water samples were analysed. Several wells with fluoride content of 6-8 mg/L were thus identified and rejected for drinking and cooking use.

Table 3 shows the fluoride content of wells in 5 divisional secretary divisions in Pollonnaruwa district. 75 percent of wells in Elaherea contained acceptable amount of fluoride less than 1.0 mg/L. In Lankapura and Thamankaduwa, respectively 29.4 and 20.4 percent of the wells were found to be more than 2.0 mg/L.

TABLE 4: Number of distributed domestic defluoridators in 1994-2003.

District	Divisional Secretary division	No
Anuradhapura	Palagala, Galnewa. Kekirawa, Thalawa. Kebitigollawa. Gallenbidunuwewa. Thambuttegama. Nochchiyagama	1500
Pollonnaruwa	Athumlapitiya. Parakrama Samudraya. Kalahagala. Dakunuela. Patanagama	500
Kurunegala	Giribawa. Girillea. Nikarawetiya	500
Puttalam	Karuwalagaswewa	50
Moneragala	Hambegamuwa. Thanamalvila. Balahuruva	350

Achieved benefits: Since 1994 about 3000 domestic defluoridators have been distributed in the affected areas, cf. Table 4. Already in some areas the benefits of the defluoridation programme has been achieved. Thus in villages with defluoridation programmes, there is a low incidence of dental fluorosis in the new generation who reached the age of 7-8 years.

Gained experiences: The salient features observed in this programme are as follows:

- Alternative sources were identified for the wells with high fluoride content of 4-8 mg/L in these areas.
- Musalpitiya in Thambuttegama was identified as fluoride rich area. The water supply in Thambuttegama was extended to this area thus providing low fluoride water.
- At Galewela while the housewife was in Middle East, the husband carried out the defluoridation work in the house.
- Housewife returned from Middle East completely discarded the unit because bricks were used as the filter medium.
- When the husband was in the war front the housewife in Olukarade did the defluoridation and both her children had milky white teeth.
- The low-income groups, who live in daub and wattle houses, carried out the defluoridation.
- Drama and poetry contest was held in Palagala organized by Rajarata Praja Kendaraya to motivate the beneficiaries to use the defluoridators.
- NGOs, such as Rajarata Praja Kendraya in Kekirawa, Janodaya in Thambuttegama, Manava Prabode Padanama in Kahatagasdegiliy, World Vision in Galenbidunuwewa and Sri Lanka Environmental Journalist Forum, helped in this programme.
- Education department helped in carrying out awareness programme in schools.
- Health department helped in all possible ways to initiate and follow up defluoridation programme in villages.
- Though the mother is seriously affected with dental fluorosis, she was not motivated to feed her children with defluoridated water.
- A Teacher by profession, who obtained a defluoridator, used the filter as a step in a partly constructed house.

CONCLUSION

This study shows that the awareness of the fluorosis problem in Sri Lanka can be enhanced thorough proper publicity. It is essential to carry out awareness programmes and further follow up services in order to achieve sustainability. The joint efforts of the National Water Supply and Drainage Board, the Department of Health, Non Government Organizations, the Department of Education and the community leaders are essentially needed in order to eradicate fluorosis from Sri Lanka.

REFERENCES

6. Padmasiri JP. Low cost domestic defluoridation to prevent dental fluorosis in Sri Lanka. Journal of the Geological Society of Sri Lanka 1998:7:59-70
7. Ratnayake I. Fluorosis in the settlement schemes. A cause for concern. 52nd Annual sessions- Sri Lanka Association for the advancement of Science p.27-47 – Nov 1996.
8. Lappague J: Evaluation of the risk of dental fluorosis in Trincomale district. Action contre la Faim, Trincomalee 2001. Project Report.
9. Padmasiri JP. Effectiveness of domestic defluoridator in preventing fluorosis in Kekirawa, Sri Lanka. In: Proceedings of the 3rd International workshop on fluorosis and defluoridators water, P. 91-96. Eds. E Dahi, S Rajchagool S & N Osiriphan, 2000 November 20-24, Chiang Mai, Thailand. ISFR, EnDeCo & ICOH, Chiang Mai.
10. Padmasiri, JP. Low cost domestic defluoridation. In: Proceedings of the 2nd workshop on fluorosis and defluoridation of water, P. 146-155. 1997 Nov. 19-22. Nazreth Ethiopia. Eds. E Dahi & H Bregnhøj. Intern. Soc. Fluoride Res. Dunedin.

Session 4

Mitigation

Southern Thailand Experience on Combating Fluorosis

B Sirisakulveroj [1] and S Mongkolnchai-arunya [2]
Thailand

SUMMARY: In 2001 dental fluorosis was unexpectedly reported in school children in a southern district of Thailand, where fluorosis otherwise was unknown. A regional survey was carried out and a mitigation project was initiated in one of the affected villages. It was found that, within the past 10 years, the villagers had shifted from using harvested rainwater and shallow well water into using municipal piped water and private well water, both based on high fluoride deep ground water.
A baseline survey showed that the prevalence of dental fluorosis was 28 % among the children, some of who were found with severe Dean's index scores. The fluoride concentrations in the village's water supply ranged from 4 to 7 mg/L.
The project adopted a strategy of creating awareness and leaving it to the villagers themselves to decide about the preventive measures that fit with their daily habits and economy.
Due to the initiated project, a year later, comprehensive awareness of the fluorosis problem was achieved and the use of low fluoride water for drinking was significantly increased. In particular the school- and the day center changed from using the deep well high fluoride water, to water of low fluoride contents, i.e. 0.05-0.4 mg/L. It is concluded that the project has made a successful start that can be duplicated in neighbouring villages.
It is discussed that good coordination, easy understandable communication to beneficiaries and simplicity and appropriateness of the presented measures are some of the key factors of the encountered success.

Key words: Community approach, success criteria, fluoride occurrence, dental fluorosis, water supply, shallow wells, rainwater harvesting, deep wells, water use, bottled water, Thailand.

INTRODUCTION

Songkhla is a province located in the South of Thailand. Its population is 1.28 million [1]. In 1996 the Songkhla provincial health office carried out a water fluoride survey covering all its 16 districts. A fluoride map of Songkhla [2] was made for the first time. However, dental fluorosis was yet not reported, even though it became known that some villages had high fluoride in their water sources. This was probably because those sources have not been used for drinking.

1 *Songkhla Provincial Health Office, MOPH Thailand.*
dbanyen@hotmail.com
2 *Dental Health Division, Department of Health, MOPH Thailand.*

In 2001 the dentist of the district of community hospital reported suspected cases of dental fluorosis among school children in a certain village, Tha Meanglak. An expert dentist carried out an investigation and it proved that the suspected cases actually were dental fluorosis with up to severe Dean's scores. Water samples from the village were analysed and it was found that the forty percents of the village was consuming water with fluoride concentration of 4.95 mg/L [3].

A mitigation project was set up. Its objective was to find out alternatives to the high fluoride water supplies in order to prevent dental fluorosis in new generation.

This paper illustrates the strategy and efforts carried out so far in order to combat the fluorosis problem in the village.

METHODS

Strategy: The strategy was selected as one baseline survey followed by two informative stakeholder meetings and then two monitoring and evaluation activities.

Baseline survey: Baseline community data of Tha Meanglak Village were collected. This included oral examination for dental fluorosis among students in the community's primary school. The Dean's Fluorosis Index was used, modified in one respect, i.e. score 1 indicating primarily fluorosis instead of questionable.

Furthermore drinking water samples were collected from households and the school and analysed for fluoride concentrations.

Also household members were interviewed in order to establish knowledge about the types of drinking water consumed.

Stakeholder meetings: The dentists and health personnel facilitated a meeting between stakeholders and related government organizations to gather their proficiency and resources. Altogether these are dental and sanitation team from Provincial Health Office, financial and technical support from the Dental Health Division and the most important group is the local team including personnel from the district hospital, health centres, teachers and Local Administrative Organization and representatives from village households.

Two meetings were arranged in the village, both of about 4 hours duration. The first one was among key persons and Local Administrative Organization members and the second among villagers and key persons. In the meetings selected knowledge was presented. This included:

- General information about dental fluorosis and its aetiology.
- General information about fluoride and its environmental occurrence.
- Survey data about the prevalence of dental fluorosis in the village.
- Survey data about the fluoride concentrations in the village's drinking water.
- Information about fluorosis mitigation methods.

This was followed by a discussion of what actually can be done in order to combat the problem. The second meeting is held with all villagers in attempt to get full participation and to ensure co-ordination. In this meeting, in addition to the above given issues, more technical information was given on how to collect hygienic rainwater, how to treatment fluoride water and how to improve shallow wells.

Monitoring and evaluation: The follow up is set up as two activities of monitoring and evaluation. These took place 6 and 12 months after the initial baseline study and the educational meetings. Health workers and village health volunteers collected data of community water sources and the water consumption behaviours of the villagers.

RESULTS

Fluorosis prevalence: Out of 126 children in the primary school, belonging to 4 different villages and all of age 6-12 years, 35 children, approximately 28 %, had dental fluorosis of primarily or above, cf. figure 1. The affected children belonged mostly to the Tha-Maenglak Village.

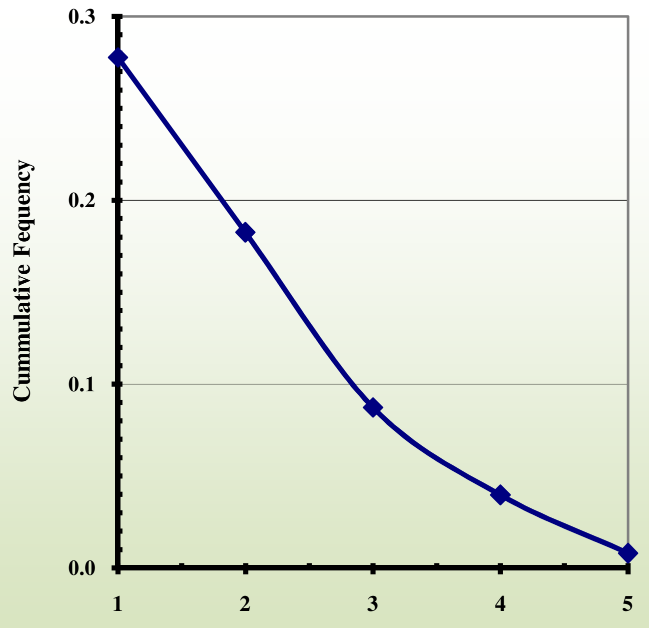


FIGURE 1. Cumulative frequency of Dean's fluorosis scores among the examined school children.

Fluoride water use: The results of the fluoride testing in the village water sources and supplies are given in table 1. Fluoride concentration in the village's water supply ranged from 4.45 to 6.85 mg/L, however, many households had private deep wells of 30 meters or more, installed with electric pumps. The water of these wells contained fluoride of 4.6 mg /L. The public water well contained fluoride of 4.45 mg /L.

Shallow wells were common as a drinking water source in the past. At present some still exist in or nearby the houses. Some wells that are still in use and contained fluoride of 0.11 to 0.57 mg/L. Some villagers improved their seasonally drying shallow wells by drilling boreholes through the existing dug wells. In this way the reliability of the well was ensured but the well water became a mixture of low fluoride surface- and high fluoride ground water.

Table 1 shows that also bottled water and rainwater, both having low fluoride contents, were used in the village. The baseline study showed that out of 161 households about 30 % of the villagers consumed high fluoride water supply.

TABLE 1: Baseline data on fluoride in water sources and supplies of the studied village.

Supply & Source	mgF/L
Public Supplies:	
Deep well water used for village piped supply	3.45 - 4.75
Artesian borehole well with hand pump	4.45
Deep well water used for the Primary School piped supply	6.85
Deep well water in Day Care Centre for 3-5 years Children	4.95
Private Supplies	
Deep well water with motor pumps in village households	1.18 - 5.47
Shallow wells with household motor pumps	0.11 - 0.57
Shallow well water used earlier in village households	0.08 - 0.41
Bottled water	0.06 - 0.40
Harvested rain water	0.05 - 0.32

The survey revealed that the primary school, with its 6-12 years old children, consumed the piped water supply containing 6.85 mgF/L. Furthermore, that the school has been using this water supply for the last 5 years. The supply is based on ground water from a deep well. The school had rainwater-harvesting containers, but these were used for storage of ground water instead.

Also the village's day-care center, with 3-5 years old children, had large concrete rainwater containers. Even though the center is supported by and attached to the village temple, it also had containers that were used for storage of water from the deep well and this fault has been going on for some years. The water contained fluoride at level of 4.95 mg/L.

Meeting resolutions: The first meeting resulted in a decision that dental fluorosis is an issue of priority for the community and that the villagers should be informed about facts and data of dental fluorosis in the village. Hereafter, in the second meeting, the health workers and community leaders should persuade the villagers to change their drinking water sources, from deep ground water to rain water or shallow wells.

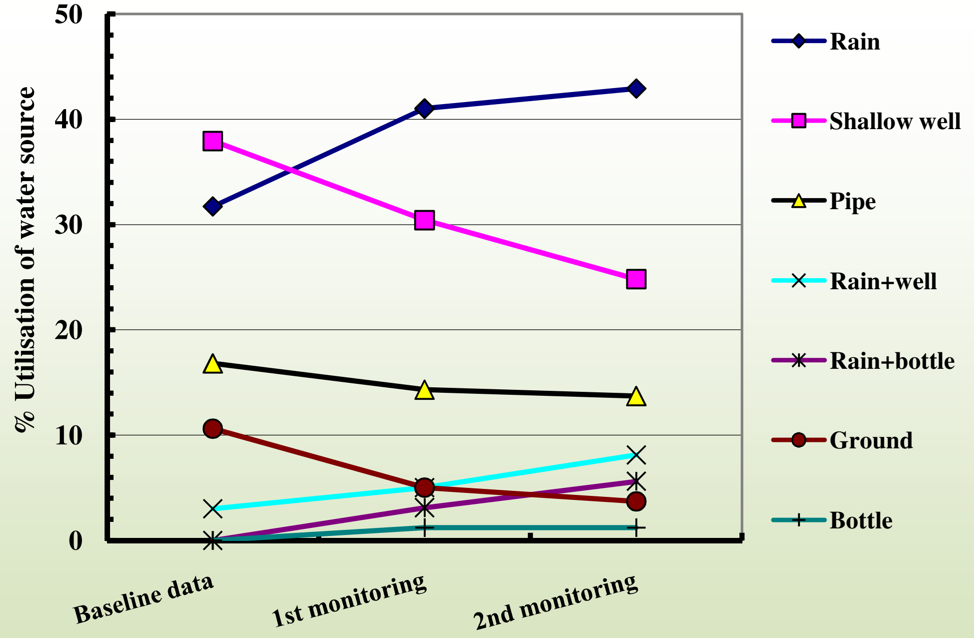


FIGURE 2. The first year development of utilisation of water sources in the study village.

One of the main outputs of the second meeting was the community's decision about the change of the water source for the primary school and day care center. Rainwater should be harvested and used as a first choice. Then more rainwater containers should be provided. The villagers, especially those who have children less than 8 years old, would change their drinking water to rainwater or bottled water or improving shallow well in their houses.

Another conclusion was for the village health volunteers to distribute the information to the other villagers who could not come to the meeting. At the same time the local administrative organization would search for new source for the village pipe scheme.

Monitoring and evaluation: The monitoring, 6 and 12 months after the meetings, could reveal the changes and the improvements achieved as follows:

- In the primary school rainwater containers were cleaned and taken in to use for storage of rainwater. The rainwater was then used by the school children for drinking. Due to the schoolteachers' encouragement the children abandoned the pipe water and were now consuming harvested rainwater instead of deep well water.
- At the village day care center, children brought their water from their homes.
- The household survey revealed that many people were more concerned of dental fluorosis and has changed their water sources. The number of families drinking rainwater was increasing, cf. figure 2.
- The village pipe scheme was still utilising high fluoride water but village administrative committee continued to search for alternative water source.
- Plans were made for future yearly combined surveillance of the dental fluorosis and fluoride contents in the village drinking waters.
- Utilising the gained experiences, plans were adopted to propagate the same strategy to neighbouring villages.

DISCUSSION

Obviously the sudden prevailing of dental fluorosis in Southern Thailand is to be attributed to the shift in use of water sources that has been taking place during the recent decade or so. As a part of what was believed to be a good development, the villager, who used harvest rainwater and utilise shallow well water for drinking, have changed their habits into using municipal piped water and private deep well water. Until recently it was unnoticed that both these waters contained high fluoride concentrations, 5 - 7 mg/L. Thus dental fluorosis appeared as a new calamity, total not-understood by the local people.

A year after the initiation of the Tha Meanglak village project, comprehensive awareness of the fluorosis problem was achieved among the village people. This was also expressed through the general increased use of low fluoride water for drinking. In particular the school- and the day center changed from using relatively high fluoride water, to water of negligible fluoride contents, i.e. 0.05-0.4 mg/L. Thus it may be concluded that, though the fluorosis problem was not yet solved in the village within this short period, the project in total constituted a successful start.

It is believed that this immediate success is attributed to some main factors, observed as follows:

- A strategy that relies on the dental and local health personnel only as facilitators and the beneficiaries taking their own decisions in agreement with their own way of life and economy.
- An educational and easy understandable information and presentation of knowledge to the given community.

- The simplicity and technical appropriateness of the presented measures.
- A good coordination between the related sectors.
- A full mobilisation and active participation of key persons and villagers.
- A commitment among the dental and local health personnel.
- In spite of the immediate success, it is believed that an appropriate follow up of motivation and monitoring would be needed if the prevailing fluorosis is to be eradicated.

ACKNOWLEDGEMENT

The authors acknowledge the support from the Dental Health Division, Department of Health, the Chief Medical Officer of Songkhla, the Tha Maenglak Local Administrative Organization, the village health personnel and volunteer, the teachers of the Wat Kongkasawad primary school and last but not least the villagers in Tha Maenglak.

REFERENCES

1. Department of Local Administration, Ministry of Interior. Population data of Songkhla province 1999 (in Thai) from website of the Ministry of Interior (WWW.songkhla.go.th/newweb45/data/401htm)
2. Songkhla Provincial Health Office. 1996. Mapping of fluoride concentration in water of Songkhla Province.
3. World Health Organization. Oral Health Surveys Basic methods 4th Edition Geneva: World Health Organization 1997 p. 35-36.
4. Laboratory Report of fluoride concentration in water samples, July 2001,
5. Dental Health Division, Department of Health.
6. 5. World Health Organization. Fluorine and fluorides. Environmental Health Criteria 36. Geneva; 1984
7. Rasamee-leungon J. Case study 2: Dental fluorosis prevention project in the poor village of Mae Tod District, Lampang Province. In Ungchusak C, Rachagoon S, Wongkongkathep S (eds) 2000 Decentralization and local participation in order to resolve dental public health problems.(in Thai) Nonthaburi: Health Care Reform Office p. 18-22.

Mitigation of Fluorosis in Nalgonda District Villages

A S Narayana **, A L Khandare* and M V R S Krishnamurthi ***

SUMMARY: Previous attempts to solve the fluorosis problem in Nalgonda by using the alum precipitation technique have been of little success. In stead the Sai Oral Health Foundation assisted by the Government of Andhra Pradesh, has adopted a strategy of providing low fluoride water in affected villages through the use of bone char based domestic defluoridators and rainwater harvesting systems. Besides children, age 8-13 years, are given vitamin A and D.

The intervention was introduced to two villages previously having 3.7 and 3.8 mgF/L in their drinking water. The base line study showed that the two villages had prevalence of dental fluorosis, 96-97 %, skeletal fluorosis 45-60 %, genu valgum, 0.56-2.2 %, genu varum, 1.8-2.0 % and paraplegia 0.3-0.7 %. Joint pain, neck rigidity, gastric problems and burning sensation during urination were reported in 50-70 % of the people.

Twelve 8-13 years school children and eight 27- 60 years adults were recruited for testing of intervention effects. The results show, on an average: 38 % of decrease of urinary fluoride, 6 % increase of serum calcium, 5 % increase of serum phosphorus and 8 % increase in serum alkaline phosphatase. Furthermore a significant decrease in joint pain, an improvement in body movements and a relief in the gastric problems and in the burning sensation during urination were observed.

The villagers expressed high acceptability of the used bone char defluoridators and rainwater harvested system.

Key wards: Skeletal fluorosis, dental fluorosis, fluorosis effects, intervention, bone char, rainwater harvesting, India, Nalgonda, Nalgonda technique, serum fluoride, serum calcium, serum phosphorus, serum phosphatase, acceptability.

INTRODUCTION

Fluorosis occurrence: Fluorosis is a major public health problem spot wise all over the world, including India. Endemic fluorosis has been recognized as a major public health problem in 18 States out of 33 constituent States and Union Territories in India [1], around 62 million people including 6 million children suffer from fluorosis due to excessive consumption of fluoride through water[1]

Fluorosis effects: Excessive fluoride intake causes fluorosis, paraplegia, arthritis and other diseases [2-6]. It also affects human intelligence, especially in children, who are most susceptible to early fluoride toxicity [3, 6]. Contamination of water with fluoride beyond acceptable limits occurs because of the earth's crust in those regions has

* *NIN (ICMR) Hyderabad FDTRC, NIN (ICMR) Hyderabad 500007 India. alkhandare@yahoo.com*
** *Sai Oral Health Foundation.*
****Panchayat Raj Dept. Govt. of A.P. Hyderabad.*

relatively soluble fluoride-bearing minerals [8]. In some regions of India, water contains fluoride up to 38 mg/L, which is extremely high compared to the maximum permissible limit of 1.0 mg/L [1, 9].

Andhra Pradesh situation: Nalgonda district is highly affected by fluorosis in Andhra Pradesh State in India: 17 out of 21 districts in Andhra Pradesh are affected. The fluoride levels in these districts range from 2 to 7 mg/L. People suffer from various skeletal deformities like genu varum, genu valgum, antero posterior bowing of tibia, kyphosis, exostosis etc, and muscular tenderness, neck rigidity, stiffness of joints and mental retardation.

There are 15 huge defluoridation plants based on the use of alum, the so-called Nalgonda technique, were constructed by Rajiv Gandhi Water Mission. However, all of them are not working, except one at Choutuppal, in this regard Government of Andhra Pradesh is taking steps to improve the status of the defluoridator. The severally affected subjects were physically handicapped and psychologically upset, which added burden to their families. The social stigma attached to this village made it difficult to get spouses for their youth and can lead to unrest and become a social problem.

Study background: The Sai Oral Health Foundation has been working since 15 years in the affected villages of the district. The foundation, with help from the Government of Andhra Pradesh, has taken actions towards sustainable supply of safe low fluoride drinking water to the villages. This is done either by giving the families bone char based domestic defluoridators and by constructing rainwater harvesting systems.

The present study was undertaken in two affected villages to investigate the effects of the intervention on biological fluids of the beneficiaries and their reaction to the introduced systems.

MATERIAL AND METHODS

Villages and subjects: Two villages, Anthampet, village A, and Batlapally, village B, were selected. Both villages lie in the Nalgonda district, 25 and 40 km respectively, away towards south of the National Highway No. 9. Village A had 2691 inhabitants, while village B had only 395. In both cases villagers were engaged mostly as small farmers and agricultural labourers. The only source of drinking water in both villages was bore wells, 4 wells in village A and 2 in village B. The mean fluoride level in the village's drinking water was 3.7 and 3.8 mg/L respectively.

Twelve children, age 8 - 13 years, from Village A and 8 adults, age 27 - 60 years, from Village B were recruited for the evaluations of the study.

Intervention:
Village A was given 90 bone char defluoridators and in village B constructed 11 rainwater harvesting units. The domestic defluoridator was used containing 1 kg of bone char [10].

A typical roof top rainwater harvesting system, cf. Figure 1, comprises: 1) Roof catchment. 2) Gutters. 3) Down pipe and first flush pipe. 4) Filter unit. 5) Storage tank.

FIGURE 1. The utilised bone char filter.

Beside the low fluoride water, 9 children in Village A were given, daily, 6000 I.U. vitamin A, 400 I.U. vitamin D and 500 mg of calcium.

Sampling and analyses: Six month after the start of the intervention program, urine of 24 hours for three consecutive days and blood samples were collected from the study subjects both before and after six month use of the defluoridated/rain harvested water. Fluoride was analysed in urine using ion selective electrode, EA940, Boston, MA. Serum calcium, phosphorous and alkaline phosphatase were analysed using a kit, supplied by Roche Diagnostic, Germany. Before and after 6 month of the intervention, the water was analysed for some chemical parameters, conductivity, pH, alkalinity, hardness, chloride and fluoride, using the Standard Methods.

FIGURE 2. Illustration of on of rainwater harvesting system installed.

Statistical analysis: Statistical analysis was carried out with SPSS 11.5 for windows. The unpaired 't' test was used to check the parameters differences between groups. The statistical significance was set at $P<0.05$ and $P<0.01$.

RESULTS

In both villages people were motivated to use the low fluoride water from the provided units for drinking and cooking. Table 1 shows the results of chemical analysis of the well water, the rain-harvested water and the defluoridated water from both the villages.

Clinical manifestation: The prevalence of different clinical manifestations observed in the population is presented in table 2. Among the school children age 6 – 13 years of village A and B respectively, dental fluorosis of various degrees prevails in 97 % and 96 %, skeletal fluorosis in 60 % and 45 %, genu valgum in 0.56 % and 2.2 %, genu varum in 1.8 % and 2 % and paraplegia in 0.3 % and 0.7 %. Joint pain, neck rigidity, gastric problems and burning sensation during urination were reported in 50 – 70 % of the people in both the villages.

After the intervention there was a significant decrease in joint pain, an improvement in body movements and a relief in the gastric problems and in the burning sensation during urination.

TABLE 1: Chemical analysis of drinking water before and after the provision of low fluoride water.

Parameter,	& Unit	Village A		Village B		Supplied A&B
Water Sources:		**Well**	**Defluoridated**	**Well**	**Harvested**	**Lake**
Conductivity,	µS/cm	885	833	868	295	344
pH	-	7.51	7.51	7.4	9.74	7.8
Total Dissolved Solids,	mg/L	566.4	541	559	188	223
Alkalinity:						
a) Carbonate,	mg $CaCO_3$/L	0	0	0	80	0
b) Bicarbonate,	mg $CaCO_3$/L	476	468	352	0	140
c) Hydroxide,	mg $CaCO_3$/L	0	0	0	2	0
Hardness,	mg $CaCO_3$/L	344	324	332	98	116
Calcium,	mg $CaCO_3$/L	92	124	196	56	62
Magnesium,	mg $CaCO_3$/L	252	120	136	36	54
Chloride,	mg/L	68	68	72	40	40
Fluoride,	mg/L	3.8	0.2	3.7	0.08	0.45

Biochemical findings: Mean fluoride content in drinking water sources was 3.7 and 3.8 in village A and B respectively. Due to supply of low fluoride water to the village A (0.18) and village B (0.04) were relieved from joint pain and joint stiffness particularly in village B, there was significant decrease in urinary fluoride in both the villages. Serum calcium status was improved in village B but not in village A. Serum alkaline phosphatase KA units/L was increased in village A as well as in village B subjects, cf. Table 3.

DISCUSSION

In the earlier studies [1, 11-13], it was reported that the deformities like genu varum have been associated persistently with high fluoride in drinking water in both adolescent and adult population as well as in the younger age group children, in the fluorotic areas of the country. No abnormal skeletal deformities were reported in villages where fluoride content of drinking was within acceptable limits [11-14]. In the present study, it was found that the crippling bone deformities were associated with poor socio-economical status of the community. This is in agreement with findings earlier studies [11, 12].

TABLE 2: Village base line data and analysis data of fluoride calcium and phosphorus before and after the intervention.

Base line data:		Village A		Village B	
Total Population		2681		395	
Number of households		950		84	
Drinking water Fluoride, mg/L		3.7		3.8	
Prevalence of dental fluorosis, %		97		96	
Prevalence of skeletal fluorosis,%		60		45	
Cases of genu valgum, No (%)		15 (0.56)		9 (2.2)	
Cases of genu varum, No (%)		50 (1.8)		8 (2.0)	
Cases of paraplegia, No (%)		8 (0.3)		3 (0.7)	
Before and after intervention:		Before	After	Before	After
Drinking water Fluoride,	mg/L	3.7	0.18	3.81	0.04
Urinary F,	mg/L	6.7 ±2.18	4.0 ±1.83**	7.13 ±2.0	4.6 ±2.8*
Serum Ca,	mg/L	1.00 ±0.06	1.01 ±0.03	0.88 ±0.02	0.98 ±0.021*
Serum P,	mg/L	0.54 ±0.04	0.53 ±0.03	0.28 ±0.05	0.33 ±0.03
Alkaline P,	KA units/L	684 ±204	735 ±247	275 ±154	297 ±183

* Significance for $P < 0.05$. ** Significance for $P < 0.01$

In the present study, the people are equally affected in village A and village B. It is known that malnutrition modifying the clinical profile of fluorosis in developing countries had been suggested by the high rate of crippling deformities among poor individuals residing in fluorotic areas [11, 12, 13]. Thus poor nutrition, including calcium deficiency and hard manual labour seem to play in additional role [12, 14]. Calcium deficiency may result in a secondary hyperparathyrodism[14]. The occurrence of such deformities only in fluorotic areas but not in similar socio-economic communities of non-fluorotic areas directly involves fluoride toxicity in modifying the formation of bone matrix [6].

Neurological sequelae, usually in the form of cervical radiculomyelopathy, results from the mechanical compression of the spinal cord and nerve roots due to ossification of soft tissue ligaments like posterior longitudinal ligament and ligamentaum flavum. Stiffness and weakness in lower and upper limbs, paraesthesia and numbness of whole body, inability in gripping of articles and they were unable to move and get up. These complications occur at a later stage of the disease. In the present study there are 8 cases of cervical radiculomyelopathy were found (age between 40 to 55 years) which clearly shows that 3 to 4 mg/L fluoride exposure for 40 to 55 years can develops cervical radiculomyelopathy.

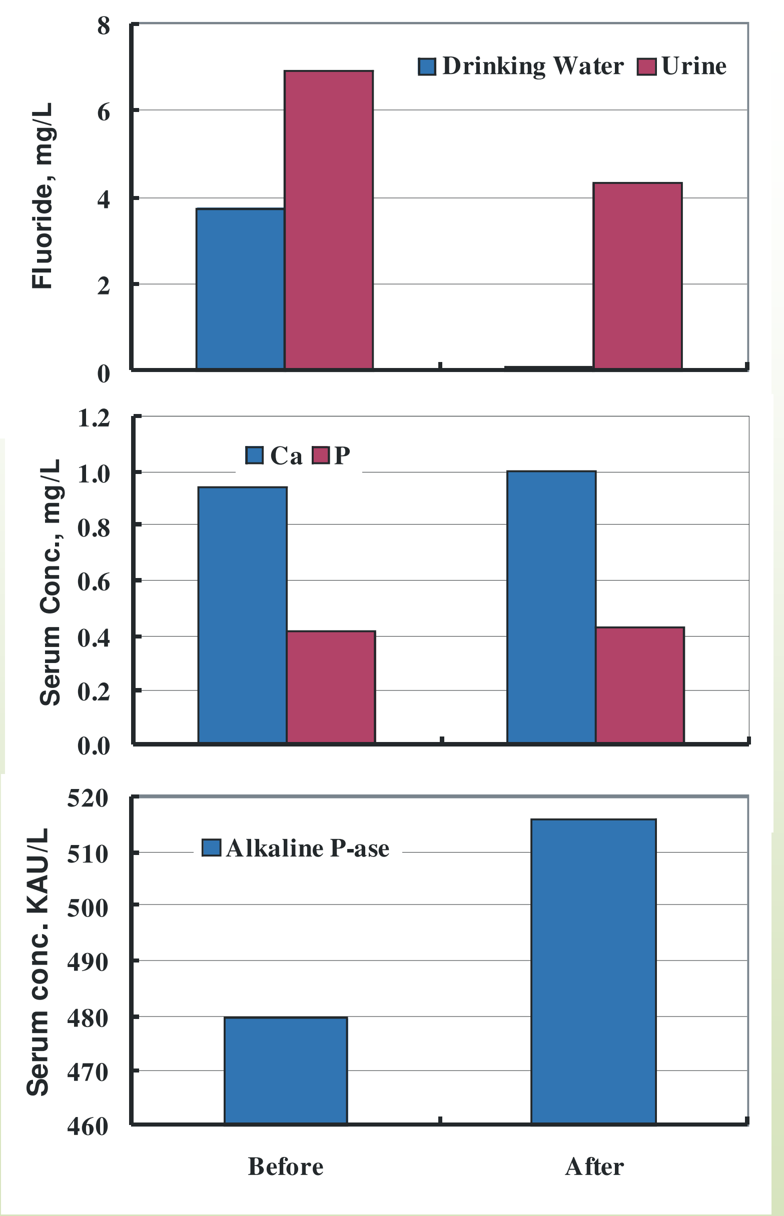


FIGURE 2. Concentrations of fluoride calcium, phosphorus in water and serum before and after the intervention.

Supply of bone char defluoridator to the village made significant change in the users health status and technology is being adopted in neighbouring villages too. The rainwater harvesting tanks are constructed in village B and people's acceptability is very high, though the rain is seasonal. The difficulty with this technique is that it required rooftop home. Experimental trials are on to harvest rainwater even from thatched house roofs.

Decrease in urinary fluoride, increase in serum calcium in children and increase in alkaline phosphatase in children and adults is observed after consumption of the low fluoride water obtained from the bone char defluoridators and the rain harvesting systems introduced in village A and B. Thus the results show clearly, both clinically and from the biochemical indicators that the health status was improved along with the intervention.

ACKNOWLEDGEMENTS

The Authors acknowledge Telugu Association of North America (TANA) for financial assistance and A. Krishna Reddy, Shanker Rao and T. Malati, Nizam's Institute of Medical Sciences, Hyderabad for surgery and biochemical analysis.

REFERENCES

1. Susheela AK, Fluorosis management programme in India,1999. Curr. Sci 77,1250-1255.
2. Yiamouyiannis J. Fluoride the ageing factor. 3rd ed. Delaware, Ohio, USA: Health Action Press: 1993
3. Waldbott GL. The preskeletal phase of chronic fluoride intoxication. Fluoride 1998; 31 (1): 13-20.
4. Maurer JK, Cheng MC, Boysen BG and Anderson RI. Two year carcinogen city study of sodium fluoride in rats. J Nat Cancer Inst 1990; 82: 1118-26.
5. Cohn PD. N Epidemiological report on drinking water fluoridation and Osteosarcoma in young males. New Jersey Department of Health. Environmental Health Service . Tenton, NJ. Nov. 8, 1992.
6. Li XL, Zhi JL, Gao RO. Effect of fluoride exposure on intelligence in children. Fluoride 1995; 28(4): 189-92.
7. Susheela AK. Epidemiology and Control of fluorosis in India. Fluoride 1985; 18 (2): 120-121.
8. Karthikeyan G, Anitha P and Apparao BV. Contribution of fluoride in water and food to the prevalence of fluorosis in areas of Tamil Nadu in south India. Fluoride 1996; 29(3) 151-155.
9. Krishnamachari K.A.V.R. Further Observation on the Syndrome of Endemic Genu Valgum of South India, Indian Journal of Medical Research 2 Feb 1976; 64, 5.
10. Bregnhoj H. Process and kinetics of defluoridation of drinking water using bone char. Thesis. Technical niversity of Denmark.1995
11. Chakma TP, Vinay R, Singh SB, and Tiway RS. Endemic genu valgum and other bone deformities in two villages of Mandla district in central India. Fluoride 2000; 33:187-195.

12. Srivastava RN, Gill DS, Maudgil A, Menon RK, Thomas M and Andona PD, Normal ionized calcium, parathyroid hyper secretion and elevated osteocalcin and family with fluorosis, metabolism 1989;38: 120-124.
13. Moudgil A, Srivastava RN, Vasudev A, Bagga A Gupta A. Fluorosis with crippling skeletal deformities. Indian pediatrics 1986;23,769-773.
14. Teota M, Teotia SPS and Singh KP. Endemic fluoride toxicity and dietary calcium deficiency interaction syndromes of metabolic bone disease and deformities in India. Indian J Pediatrics 2000; 371-381.

Highlights of Forty Years of Research on Endemic Skeletal Fluorosis in India

S P S Teotia *, M Teotia and K P Singh
India

SUMMARY: This paper highlights the Authors' studies and their personal experiences on skeletal fluorosis in the period 1963-2003, based on surveying 337,690,000 population residing in 390,000 villages in 22 of the 32 states of India. The safe level of fluoride is standardised to 0.5 mg/L and 1.0 mg/L, respectively as the desirable and maximum allowable concentrations in drinking water. The fluoride water concentrations found varied from 0.1 to 25 mg/L. 45 % of the drinking water sources surveyed had fluoride content exceeding 1.0 mg/L.

Among the surveyed population 411,744 patients had disorders of calcium and bone metabolism. Of those 52 % had nutritional bone diseases, 43 % had endemic skeletal fluorosis and 5 % had metabolic bone diseases. Thus endemic skeletal fluorosis in India continues to be a national health problem and the drinking water remains the major source of intake of excess of fluoride. The most seriously affected states are Andhra Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Uttar Pradesh, Bihar, Tamil Nadu, Kerala, Karnataka and Maharashtra. It is estimated that the fluoride skeletally affects about 100 million people, while furthermore not less than 200 million are at risk in India.

The main mechanism of fluorosis is the fluoride incorporation into the bone hydroxyapatite, altering the size and structure of its crystals. The fluoroapatite formed decreases the mechanical competence of the bone, resulting in abnormal structure and poor quality of bone, with increased risks for fractures. Rickets, osteomalacia, secondary hyperparathyrodism and regional osteoporosis are often associated with skeletal fluorosis. The bone diseases and deformities are more severe and complex in patients with dietary calcium and vitamin-D deficiencies. It was found that goitre and renal stone diseases, which are major environmental health problems in India, are inversely related to the occurrence of skeletal fluorosis. The mineral composition of water is the main factor behind these relationships.

A combined approach through urbanized rural drinking water sources (deep bore wells, rivers) and correction of nutritional deficiencies of calcium and vitamin-D provides practically full recovery of the affected and the protection of people at risk of fluorosis. This is especially valid in case of early discovery of the fluorosis. Further, the pregnant mothers should use drinking water with fluoride less than 0.1 mg/L in order to avoid foetal/neonatal fluoride intoxication

Key words: Fluorosis, India, calcium and vitamin-D nutrition, bone quality v/s bone quantity, bone diseases, secondary hyperparathyroidism, fracture risk, foetal intoxication, goitre, renal stone, radio-clinical reversibility, recovery, deep-bore water technology, urbanized rural water supply, defluoridation, safe and adequate water supply, treatment.

* *Sri Sathya Sai Charan, 14-15, Hanuman Road, Sai Colony, Belthur, Kadugudi, Bangalore 560 067. India*
Email: teotia9@yahoo.com

INTRODUCTION

Endemic skeletal fluorosis is the state of chronic fluoride intoxication caused by high intakes of natural fluoride through drinking water. Intake through beverage is also harmful, depending on its contents of high fluoride water. Intake through foods is not of practical nor clinical importance, even in the endemic areas where the fluoride concentration in crops is relatively high.

More than 90 % of the ingested fluoride is absorbed from the gut. Approximately 50 % of the fluoride absorbed is deposited in the bones and teeth. The remaining is excreted in urine. About 99 % of the fluoride retained in the body is stored in the mineralised bones and teeth on account of its affinity for calcium phosphate. Its effects on bones and teeth only are of clinical importance influencing their mineralisation, structure, functions and development. Fluoride ions are taken up rapidly by bone by replacing hydroxyl ion in bone.

Fluoride is a bone seeker and its incorporation into hydroxyapatite, i.e. the spot wise production of fluoroapatite, alters the size and the structure of the bone crystals. The fluoroapatite crystals are larger in size; offer less surface exchange, less soluble, more stable and less reactive to the actions of parathyroid hormone. The biological response and severity of fluoride toxicity mainly depends on the concentration of fluoride in drinking water, the daily intake of fluoride, the continuity and the duration of exposure and calcium and vitamin D nutrition status. The composition of foods in respect to Ca, Mg, P and Al, age, sex, occupation, growth and remodelling of bone are other factors, which influence the toxic effects of fluoride.

The toxic effects are more severe in children with growing bones, women with children with their depleted bone and mineral reserves and in labourers with excessive drinking of water that can be up to 6 to 8 litres in summer. There is no conclusive evidence proving that fluoride is an essential nutrient for human health [1]. We have yet to know the biochemical indicators of deficiency of fluoride and the clinical fluoride-specific deficiency syndrome which could be reversed, prevented or cured by addition to diet of fluoride alone.

The widely propagated dental caries protection effect of fluoride is erroneous and has not been supported by long-term control double blind scientific investigations on a large cross-section of population [2]. The decline in the incidence of dental caries in fluoridated areas, in fact has resulted due to simultaneously increased dental health facilities, increasing number of dental clinics and hospitals, besides education and rising community awareness on 1) oral health and hygiene, 2) calcium and vitamin D nutrition, and 3) the deleterious effects of excess consumption of the sugary and starchy foods on dental health.

The chronic toxicity of fluoride in man was first reported by Eager 1901 [3]. Endemic skeletal fluorosis was first described in India by Shortt et al. 1937 [4] among the residents of Nellore district in Tamil Nadu. Chronic fluoride intoxication due to residence in an endemic area was reported to develop during 30-40 years by Shortt et al. 1937 [5], 10-15 years by Pandit et al. 1940 [6], 10-20 years by Roholm 1937 [7] and Singh and Jolly 1970 [8] and 1-4 years by Siddique 1955 [9]. Teotia and Teotia 1971 [10] reported that skeletal fluorosis is not confined only to adults but also afflicts the newborns, infants and children and may develop only within six months of exposure to high intakes of fluoride. Teotia and Teotia [11] further reported that the young and growing bones are metabolically active, highly vascular and accumulate fluoride faster and greater than the older bones. Krishnamachari and Krishna Swamy 1973 [12] and Krishnamachari 1976 [13] demonstrated the occurrence of endemic genu valgum in children of less than 14 years of age living in endemic fluorosis areas.

EPIDEMIOLOGY

Surveyed population: The authors of this paper have been studying fluorosis in India in the period 1963-2003. The continuous work during 40 years allowed for surveying of a 337,690,000 population residing in 390,000 villages in 22 of the 32 states of India.

Fluoride in water: Our surveys revealed that the fluoride concentration varied from 0.1 to 25 mg/L depending on the rocks it flows through. 45 % of the drinking water sources had fluoride content exceeding 1.0 mg/L. We have placed safe level of fluoride in the potable drinking water up to 0.5 mg/L and up to 1.0 mg/L respectively as the desirable and maximum allowable concentrations.

Fluorosis in India: Endemic skeletal fluorosis continues to be a challenging national health problem in India, largely because of its persistence in the older areas, new areas are being found and defunct defluoridation plants with inadequate safe water supply. Among the surveyed population the total number of patients identified with disorders of calcium and bone metabolism was 411,744. Of those 52 % had nutritional bone diseases, 43 % had endemic skeletal fluorosis and 5 % were of metabolic bone diseases. Drinking water remains the only and the major source of high intake of fluoride in India. The most seriously affected states were Andhra Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Uttar Pradesh, Bihar, Tamil Nadu, Kerala, Karnataka and Maharashtra, Figure 1.

Our studies [16, 17] showed that the continuous daily intake of 2.5 mg of fluoride for more than 6 months deposits 4000-6000 mg/kg of fluoride and causes detectable radiological changes of fluorosis. About 100 million people in India are affected and more than 200 million are exposed to the risk of developing endemic fluorosis.

FIGURE 1. Occurrence of Fluorosis in various stats (underlined) and districts (circles) in India, based on national surveys performed by the Authors during 1963-2003.

SKELETAL FLUOROSIS

Clinical features: In general any person with features of stiffness, rigidity, restricted movements at the spine and joints, bone and joint pains and has been residing continuously for more than 6 months in a fluorotic area is a case of skeletal fluorosis unless proved otherwise. Dental fluorosis occurs in children who are exposed to high intakes of fluoride before completion of dental mineralisation, i.e. 12-14 years of age.

Dental fluorosis is the clinical index of the epidemiology of fluorosis. Estimation of fluoride in drinking water and skeletal radiographs alone are enough to confirm the diagnosis of skeletal fluorosis.

TABLE 1: Author's classification of skeletal fluorosis.

Severity	Clinical	Radiological
Mild:	Generalised bone and joint pains	Only osteosclerosis.
Moderate:	As above + Stiffness, rigidity and restricted movements at spine and joints.	As above + Periosteal bone formation, dense cortex, loss of trabecular pattern, calcifications of interosseous membrane and ligaments.
Severe:	As above + Flexion deformities at spine and joints (hips, knees, elbows, hands), features of metabolic bone disease.	As above + Osteophytosis, exostoses, Calcification of muscular attachments, tenons and capsules.
Very Severe:	As above + Crippling deformities, neurological complications (radicular pains, muscle wasting, compression rediculo-myelopathy at cervical and lumbar regions, paraplegia, quadriplegia) and bed-ridden state.	As above + Metabolic bone disease (osteomalacia, pseudofractures, osteoporosis, hyperparathyroid bone disease), Calcification of neural arch and narrowing of spinal canal and intervertebral foramina.

FIGURE 2. Skeletal fluorosis of the types genu valgum, genu varum, flexion and rotational.
Water F^- = 4 mg/L.

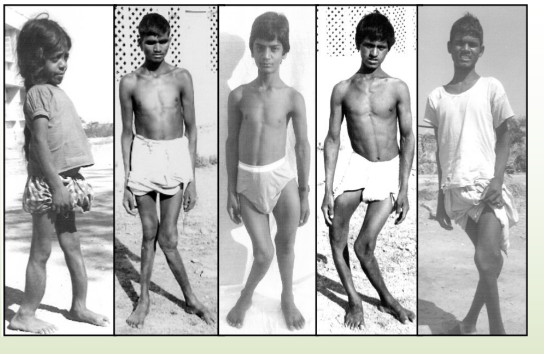


FIGURE 3: Skeletal fluorosis of the types genu valgum, rotational and wind swept in patients during their critical growth; age 4-18 years. Water F- = 3.6 mg/L.

Progressive evolution of clinical features, Figures 2 & 3, correlate with the duration of stay in the endemic fluorosis villages and high intakes of fluoride from the drinking water, Table 1. The bone disease and deformities are more severe and complex in patients with dietary calcium deficiency (intake < 300 mg/d) as compared to those with adequate calcium nutrition (Ca intake > 800 mg/d) [18, 19].

Radiological features: The earliest radiological findings appear within six mouths of continuous exposure to high intakes of fluoride and include periosteal and endosteal reactions, coarse axial trabcculations and osteopenia in the metaphyseal regions, sclerosis, and modelling abnormalities of the epiphyses, carpal and other bones of the hand, more particularly observed in growing children, cf. Table 1. The incidence of spinal osteoporosis is significantly low and of osteomalacia and secondary hyperparathyroid bone disease significantly higher in women residing in endemic fluorosis villages [18-24].

FIGURE 4: Generalised osteosclerosis, of the spine (A), pelvis with exostosis (B), hand (C) and calcification of the interosseous membrane in the forearm (D) in a patient with ESF. Age 33 years.

FIGURE 5: Radiograph of the hand of a 6 weeks old child born by a mother with ESF showing osteoscleorosis and modelling defects in the phalanges and metacarpals.

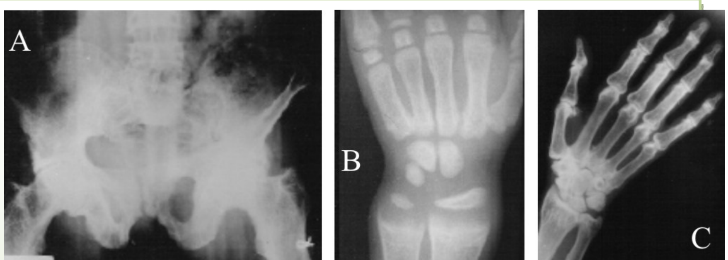


FIGURE 6: Radiographs of patients with ESF, Showing generalised osteosclerosis, deformed pelvicavity with coa cystic resorptions, B widened, irregular and dense metaphy and C thin cortices, cortical erosions and submetaphysical cy resorption.

Diagonistic of fluoride induced osteomalacia, rickets associated secondary hyperparathyroidism.

The dietary calcium deficiency further exaggerates the severity of radiological features [18, 19, 25, 26], cf. Table 1. Radiological findings, correlate with the fluoride content of water, daily intake of fluoride, continuity and the duration of stay in the fluorosis area, calcium and vitamin D nutrition status and the clinical course of fluorosis, Figures 3-6.

Biochemical Markers: Plasma calcium, magnesium and phosphorus remain normal, alkaline phosphatase and fluoride levels are elevated. Serum parathyroid hormone levels are always raised as a compensatory mechanism to maintain extracellular ionised calcium equilibrium consequent to decreased solubility and reactivity of fluoroapatite crystals, fluoride induced osteomalacia and dietary calcium deficiency. Osteocalcin, calcitonin and (1,25 $(OH)_2D_3$) concentrations are increased or high normal. In clinical relevance pituitary, thyroid, adrenal and gonadal functions remain essentially unaltered and serum growth hormone levels are variably increased. Twenty-four hour urinary excretions of fluoride and of hydroxyproline are increased and of calcium and magnesium are decreased or low normal. Renal functions remain unaltered [18-27], cf. Table 2.

TABLE 2: Early radiological manifestations of endemic skeletal fluorosis

A: Secondary Hyperparathyroidism (Increased bone remodeling)	**B.: New Bone Deposition**	**C: Impaired Mineralisation**	**D. Modeling Defects**
Coarse trabeculations. Microcystic expansion of bones - hands and feet. Sub periosteal phalangeal erosions. Thinning of cortices and osteoporosis. Periosteal, cortical, endosteal reactions. Osteopenia in metaphyseal regions. Neo-osseousporosis. Erosions of lamina dura. Resorption of alveolar bone.	Dense epiphyses and metaphyses. Periosteal bone formation. Osteosclerosis.	Irregular rickety metaphyses Neo-osseousmalacia (spine, pelvis, hands)	Epiphyses Carpal bones

TABLE 3: Biochemical markers of skeletal fluorosis.

Marker	Serum			Urine		
	Decreased	Normal	Increased	Decreased	Normal	Increased
Fluoride			✓			✓*
Calcium	✓	✓		✓	✓	
Magnesium		✓		✓	✓	
Phosphorus	✓	✓			✓	✓
Alkaline phosphatase BSP			✓			
IPTH			✓			
Calcidiol		✓				
Calcitriol		✓	✓			
Calcitonin		✓	✓			
Osteocalcin		✓	✓			
Hydroxyproline						✓

* Further increase after exposure to fluoride is ceased.

Bone scanning and densitometry: 99^{m}TC dl-phosphonate bone scanning revealed non-specific appearance of generalised increased tracer uptake throughout the skeleton. Greater uptake is observed in axial skeleton with tie sternum sign, patella sign and faint kidney images, diagnostic of compensatory secondary hyperparathyrodism with high bone turnover. The DXA bone densitometric measurements of lumber spine (L_1-L_4) showed increased BMD 1.12 ± 0.04 g/cm^2 in patients of endemic skeletal fluorosis[25] as compared to matched normal controls 0.78 ± 0.03 g/cm^2.

Bone histopathology and histomorphometry: Histopathological studies of undecalcified iliac crest biopsies revealed poorly formed haversian systems, disordered lamellar orientation of the bone and the new bone formed is immature, woven, amorphous and hypomineralized. There is an increase in bone surfaces lined with wide osteoid seams associated with increased bone re-sorption.

These findings [26, 28, 30, 31] suggest occurrence of osteomalacia with secondary hyperparathyroidism in patients with endemic skeletal fluorosis. Fluoride is incorporated into hydroxyapatite, altering the size and structure of the crystals and the fluoroapatite formed decreases the mechanical competence of the bone. Thus the bone formed in patients with endemic skeletal fluorosis is abnormal in structure and of poor quality, thereby compromising the bone strength and increasing the risk of fractures, cf. Figures 7, 8 & 9.

Bone quantity in skeletal fluorosis is increased at the cost of bone quality, which increases the risk for fracture. However in our experience the true fractures in skeletal fluorosis are extremely rare and occurred in less 1.5 percent of our cases and the pseudofractures appeared in more than 35 percent of the patients with endemic skeletal fluorosis, more particularly in women of child bearing age. The rare occurrence of true fractures and of spinal osteoporosis in our patients with skeletal fluorosis may be due to increase in their bone mass or due to associated osteomalacia consequent to chronic exposure to fluoride [28-31].

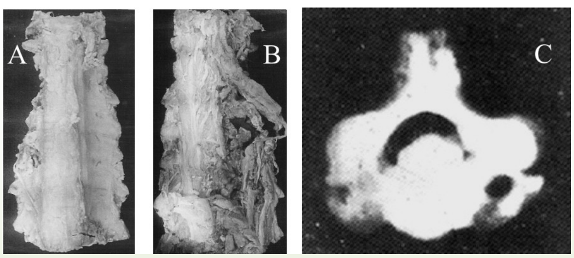


FIGURE 7: Autopsy findings from the patient with ESF, aged 29 years, showing fluorosed spine with extensive calcifications of the ligaments, intervertebral discs, facets and total block of intervertebral foramen 'A, B' and exostosis projecting into the vertebral canal 'C'. Water fluoride 25 mg/L.

FIGURE 8: Electron micrograph of fluorotic iliac crest showing dense Irregular pattern and disordered lamellar orientation of the bone x 50. Water fluoride 6.5 mg/L.

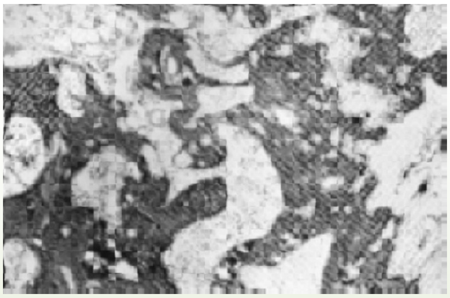


FIGURE 9: Undecalcified solochrome cyanine section of illiac crest biapsy from the patient of ESF showing filligree pattern of trabecular bone, loops and bridges of excess osteoid and internal tunnelling resorption x 50, diagnostic of fluoride induced osteomalacia and secondary hyperparathyroidism. Water fluoride 6.0 mg/L.

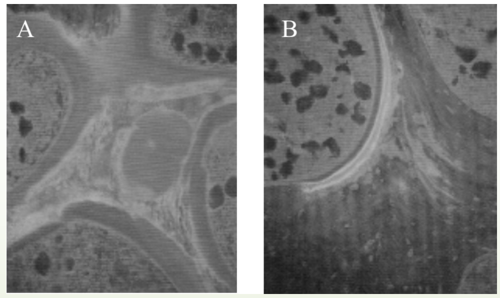


FIGURE 10: Photo micrographs (x100) of undecalcified villanueva osteochrome sections from the patient of ESF before (A) shwoing diffuse tetracycline uptake and 18 months after (B) exposure to fluoride is ceased and treated with vit-D and calcium, showing clear double tertracyline labels indicating normal mineralised bone formation.

ASSOCIATED DISORDERS

Foetal and neonatal intoxications: Pregnant mothers residing in endemic fluorosis villages, where the mean fluoride intake was 21 mg/d, revealed declining concentrations of fluoride in their plasma and the urine during the course of pregnancy, they were at their lowest at 36 weeks of gestation. The fall in the maternal plasma and urine fluoride concentrations during pregnancy occurred due to increasing deposition of fluoride in the rapidly mineralising and the growing foetal bones. The transplacental transport of fluoride to the growing foetus may thus cause foetal/neonatal skeletal fluorosis. The message thus emerged strongly suggests that the pregnant mothers should receive safe drinking water with fluoride less than 0.5 mg/L to avoid foetal/neonatal fluoride intoxication, cf. Figure11 [33].

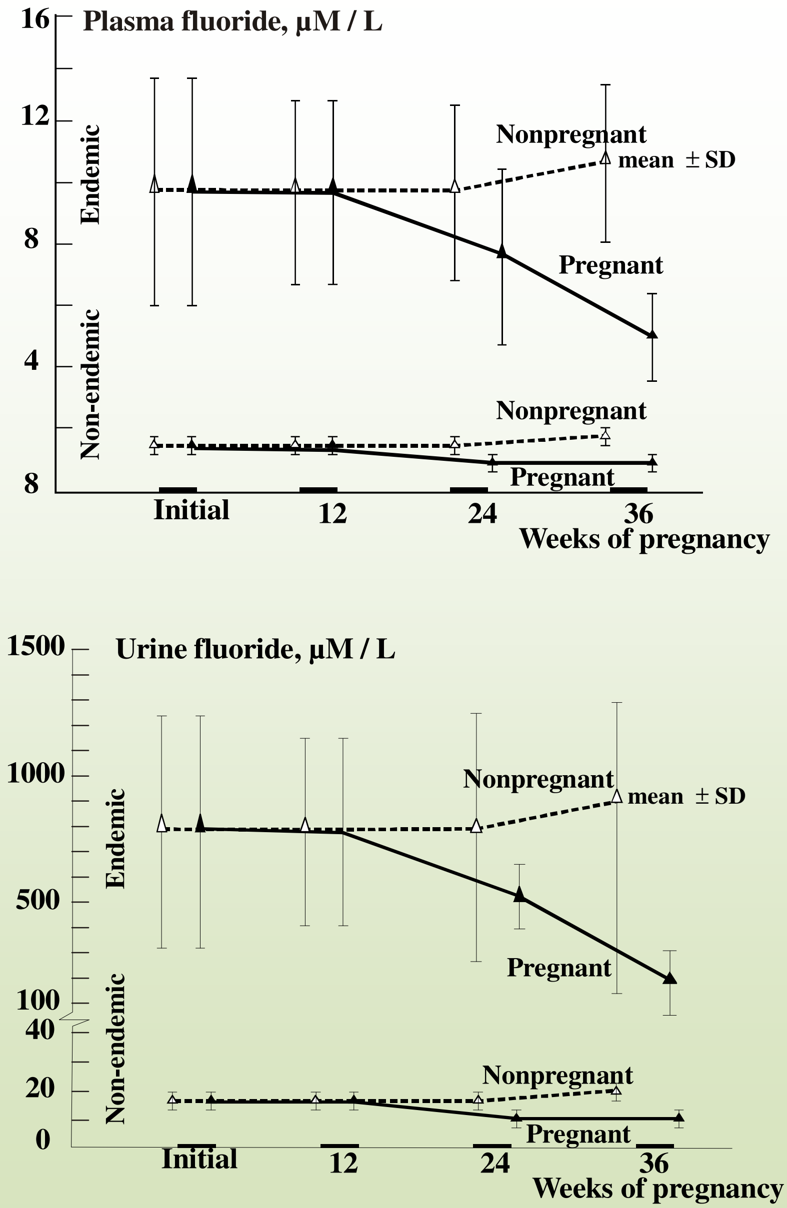


FIGURE 11. Plasma (upper) and Urinary (lower) F- in pregnant women and in their age-matched non-pregnant controls residing in endemic and non-endemic fluorosis areas.

Histomorphometric analysis [32] of the double tetracycline labeled undecalcified sections of the iliac crest biopsies revealed the profiles of Osteomalacia and secondary hyperparathyroidism in varying combinations, cf. Figures 9 & 10.

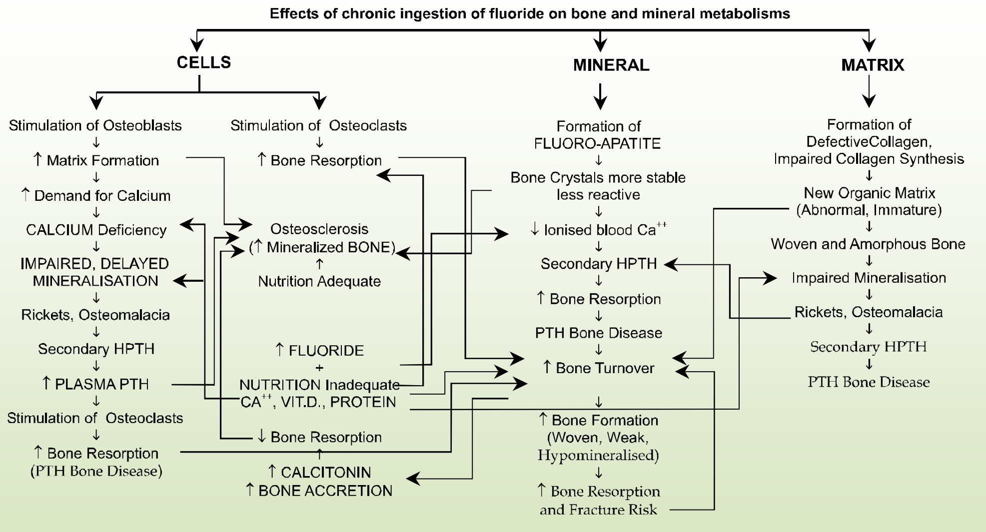


FIGURE 12. Interactions of calcium-PTH-calcitonin and fluoride in the evaluation of disorders of calcium and bone metabolism in patients with endemic skeletal fluorosis as a primary disorder.

Metabolic bone disorders: Metabolic bone diseases commonly associated in patients, in whom endemic skeletal fluorosis is a primary disorder were rickets, osteomalacia, secondary hyperparathyrodism and regional osteoporosis. The lack of spinal osteoporosis in women with skeletal fluorosis has been our unique observation. Hyperparathyrodism, which develops as a compensatory mechanism to maintain extracellular ionised calcium equilibrium consequent to decreased solubility and reactivity of fluoroapatite crystals to parathyroid hormone, occurred in all the patients with endemic

TABLE 4: Observed prevalence of different bone disorders among patients with skeletal fluorosis.

Disorder	**%**
Secondary hyperparathyroidism (20HPT)	100
Bony leg deformities (genu valgum, genu varum, bowing, rotations, wind-swept)	78
Osteomalacia	42
Regional Osteoporosis	38
Refactory secondary hyperparathyroidism	32
Rickets	28
Tertiary hyperparathyroidism (30HPT)	0.9

skeletal fluorosis and was more severe and complex in calcium and vitamin D deficiency states. The incidence of the various disorders of calcium and bone metabolism associated in patients with endemic skeletal fluorosis is shown in Table 4. The mechanisms for the production of metabolic bone diseases in patients with skeletal fluorosis, based on calcium-vitamin D-parathyroidhormone axis and fluoride interactions are summarized in Figure 12. Hyperparathyrodism in endemic skeletal fluorosis was first reported by Teotia and Teotia [10, 17-20, 26].

Bone quantity vs. quality: Although bone mass (bone quantity) in patients with endemic skeletal fluorosis is increased and is highly correlated and can explain about 70 percent of the bone strength, but the quality of the bone, which can be defined as the ability of the skeleton to withstand force and not the fracture, formed during exposure to fluoride is immature, woven, hypomineralised, compromised in mechanical strength and at risk for fracture, Figure 7-10.

INVERSELY RELATED DISORDERS

Goitre and renal stones: Endemic fluorosis, goitre and renal stone disease constitute major environmental health problems in India. An epidemiological study was undertaken to study the etiological relationship of these endemic diseases to the chemical composition of drinking water and the nutritional status of the community. The patients studied and examined in detail included 9,200 of endemic renal stone disease, 18,500 of fluorosis and 17,100 of goitre. In the community with endemic fluorosis, goitre and stone disease were practically non-existent. In the community with endemic goitre, fluorosis was non-existent and the stone disease was sporadic. In the community with endemic renal stone disease, the prevalence of goitre was sporadic and fluorosis was practically non-existent. A positive correlation existed between the occurrence of stone disease, water hardness and its calcium content. In endemic fluorosis villages water analysis showed higher the fluoride, higher the iodine, higher the alkalinity and softer the water. In the areas endemic for goitre lower the iodine and lower was the fluoride in the drinking water. The study confirmed that the composition of drinking water is an important environmental factor in the aetiology and epidemiology of these endemic disorders. This is a major breakthrough in the environmental interrelationship of fluorosis, goitre and stone and has important implications for national health programmes aimed at their control and eradication.

CLINICAL RECOVERY

Radio-Clinical Reversibility: During the period 1963-2003 we had and opportunity to follow 2,885 patients of endemic skeletal fluorosis for a long term period of 9 months to 21 years and continuing. At the end of 5 years we were left with only 2,664 patients in the regular follow up for skeletal radiographs and the estimation of fluoride in the urine. Clinical recovery occurred in more than 85 percent of the patients with mild to moderate severity within 1-5 years after the exposure to fluoride is ceased and treated with calcium and vitamin D, cf. Figures13 & 14.

In severe cases clinical recovery was slow and took 5-15 years for satisfactory clinical and occupational recovery after the exposure to fluoride is ceased and treated with calcium, vitamin D and appropriate physiotherapy. The radiological reversibility in radiographs of the pelvis, spine, chest and hands showed that the trabecular sclerosis in all the films was slowly reduced. The urine showed persistent increase in the excretion of calcium. The cortical thickness and sclerosis, calcifications of ligaments, muscular attachments, tendons, capsules and of interosseous membrane essentially remained unchanged, cf. Figure 15 [11, 17, 24].

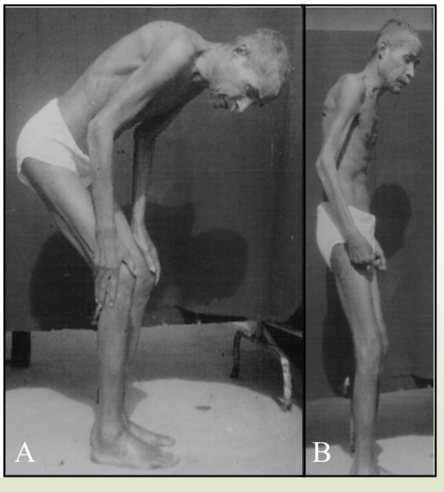


FIGURE 13: Clinical Reversibility of ESF in a patient aged 65 years 24 months after exposure to fluoride is ceased.

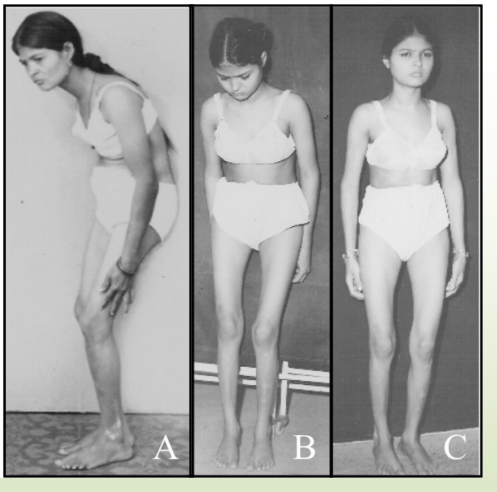


FIGURE 14: Reversibility of ESF in 15 years old girl 9 months after exposure to fluoride is ceased and treated with vit-D and calcium.

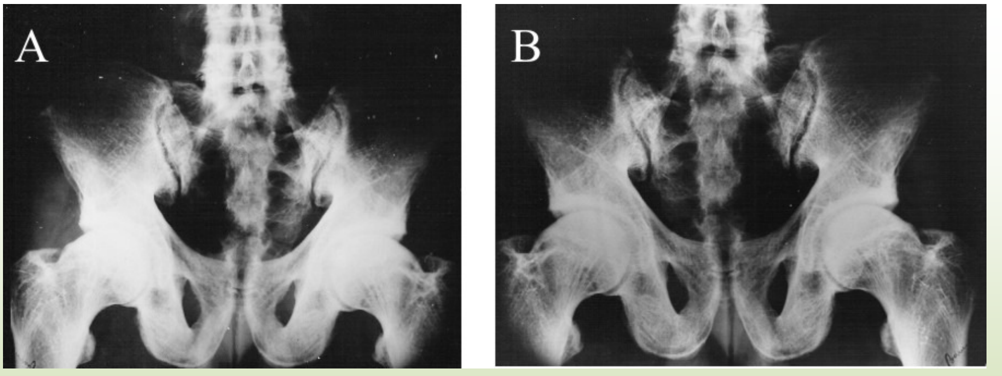


FIGURE 15: Reversibility of ESF in 18 years old boy 8 years after exposure to fluoride is ceased and treated with vit-D and calcium. (A) Before Treatment, (B) After Treatment

PREVENTION AND TREATMENT

Combined measures strategy: A combined approach of safe water supply, improvement of the calcium and vitamin-D nutrition and correction of nutritional deficiencies of the affected and at the risk community provides practically full protection against fluorosis [21]. Clinical improvement occurs in all the patients within 12-20 weeks and more than 85 % are able to resume their occupational works within 1-5 years after the exposure to excess of fluoride is ceased and vitamin-D and calcium nutrition is balanced [21]. Even the Cattle served with the safe water recover from lameness, stiffness and improve in their appetite, physical performance and milk output. Also with continuous remodelling of bone the trabecular sclerosis slowly reverses. Naturally the implementation such integrated strategy would need proper education and motivation of the community [22, 27, 28].

Water supply: Prevention is the key to treatment. Endemic fluorosis practically exists only in the villages and not in the cities. The people residing in the villages is not different from those in the cities and must be equated with potable drinking water with fluoride < 1.0 mg/L or preferably < 0.5 mg/L. Therefore the only practical, community acceptable, economically viable and permanent measure to control fluorosis is the provision of safe and 24 hours-reliable water supply to the rural areas as made available in well urbanised areas (river, deep bore wells). The proof of evidence is that 13,000 villages which were endemic for fluorosis and over the past 11 years have been included in the municipality limits of the neighbouring cities and received municipality drinking water supply, got control of their fluorosis soon after their exposure to excess of fluoride is ceased [17, 21].

Author's 25 years follow-up of water analysis from 15, 250 deep bore hand pumps and 2,600 deep bore tube wells installed in villages endemic for fluorosis, revealed that the fluoride content was being maintained within normal limits practically in all the sources. The most illustrious and practical example is of Sri Sathya Sai Project for the safe drinking water supply, which has controlled fluorosis from more than 1,000 villages in district Ananthpur of the state of Andhra Pradesh, using deep bore water technology.

Thus the experience of the authors of this paper shows that the use of more than 100 m deep bore water supply [21, 29, 30] is able to provide water with fluoride less than 1 mg/L, low alkalinity and normal or high normal calcium contents and this could play a master role in the control of endemic fluorosis.

Calcium and vitamin D supplements: Calcium is the strongest antagonist of fluoride toxicity. The toxic effects of fluoride on bones and teeth are more severe and complex in dietary calcium deficiency states. Calcium deficiency and fluoride interaction syndrome of bone disease and deformities are more severe and complex in growing children, adolescents, pregnant and lactating mothers, because of the greater demands for calcium in these groups [14, 17, 19, 20]. Adequate intakes of calcium to maintain the positive calcium balance to counteract the toxic effects of fluoride is therefore essential for the population residing in endemic fluorosis villages.

TABLE 5: The Authors' recommended total daily intake of absorbable calcium. Most individuals only require 0.5-1.0 g of calcium in dietary supplement.

Group	mg/d	Group	g/d
0 to 6 months	300	Adult males & females	1.0
6 to 12 months	500	Pregnancy 1st and 2nd trimesters	1.2
1 through 3yr	600	Pregnancy 3rd trimesters	1.5
4 through 8yr	800	Lactating women	1.5-2.0
9 through 12yr	1200	Post menopausal women	1.2-1.5
13 through 20yr	1500	Elderly male above 60yr	1.5

The daily requirement of vitamin D (400-1000 iu) can be obtained by 30-60 minutes of exposure to sunlight (UV-B of wavelength 290-315 nm) in the morning. Endogenous skin synthesis of vitamin-D constitutes more than 90 percent of the circulating serum 25 OHD concentration and the dietary source for vitamin-D is insignificant or negligible. The recommended daily optimal intakes of calcium based on our long-term metabolic balance studies in each age group are summarized in Table 5. The associated nutritional imbalances and deficiencies should also be corrected. The improvement of nutritional status of the community should be adopted as a national priority public health policy for all in India.

Defluoridation of Drinking Water: The authors of this paper do not support the installations of defluoridation systems. The reasons being: 1) A potential health risk particularly to growing children and child bearing mothers, due to possible pollution of the water with unknown trace elements. 2) remains a temporary measure with high recurring costs. 3) inadequate defluoridated water supply to steadily increasing population 4) operation and maintenance problems head for failure [14, 21, 22, 27].

The defluoridation of drinking water, however, may be undertaken as only an interim measure, until the rural water supply has been urbanized.

Early detection and recovery: Early detection of fluorosis is the crux of the problem. Once skeletal fluorosis has developed and the patient has symptoms, treatment largely remains symptomatic, using analgesics and physiotherapy. Recovery, however, is quick if the patient is kept off the fluoride intake, nutritional inadequacies are corrected and the calcium nutrition is improved. Surgical intervention like spinal decompression and laminectomy may be undertaken in selected cases with neurological complications, particularly advanced compressive rediculomyelopathies.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial supports during the years 1963-2003 of the Indian Council of Medical Research, Department of Science and Technology, Council of Scientific and Industrial Research, Department of Environment, Ministry of Environment and Forests, New Delhi, Government of India and the International Development Research Center Canada.

REFERENCES

1. Fluorides and human health. WHO monograph series No.59, World Health Organization, Geneva, 1970.
2. Teotia SPS, Teotia M. Dental caries: A disorder of high fluoride and low dietary calcium interactions (30 years of personal research) Fluoride 1994; 27:59-66.
3. Eager JM Denti di chaise.Pub.Health Rep. 1901; 16:2576-77.
4. Shortt HE, Pandit CG and Raghavachari TNS. Endemic fluorosis in the Nellore District of South India. Indian med. Gaz., 1937; 72:396-98.
5. Shortt HE, Mcrobert GR, Barnald T.W, Nayar ASM. Endemic Fluorosis in the Madras presidency Ind. Jour Med.Res. 1937; 25:553-61.

6. Pandit GG, Raghavachari TNS, Rao DS and Krishnamurthi V. Endemic fluorosis in South India. A study of the factors involved in the production of mottled enamel in children and severe bone manifestations in adults. Indian J. Med. Res., 1940; 28:533-58.
7. Roholm K. Fluorine intoxication: A Clinical hygienic study with a review of literature and some experimental investigations. HK Lewis and Co., London 1937 p.364-75.
8. Singh A and Jolly SS. Chronic toxic effects on the skeletal system. In:Fluorides and human health. WHO monograph series No.59, World Health Organization, Geneva, 1970:238-49.
9. Siddiqui AH. Fluorosis in Nalgonda District, Hyderabad Deccan. Brit.Med.J. 1955; 2:1408-13.
10. Teotia M, Teotia SPS and Kunwar KB. Endemic skeletal fluorosis. Arch. Dis.Child. 1971; 46:686-91.
11. Teotia SPS, Teotia M. Endemic skeletal fluorosis in children: Evidence of secondary hyperparathyroidism. In: Clinical Aspects of Metabolic Bone Disease (Eds. Boy Frame, Parfitt and Howard Duncan), Excerpta Medica, Amsterdam, 1973, pp. 232-238.
12. Teotia M and Teotia SPS. Skeletal fluoride toxicity in children. Indian J. Pediat.,1979;46:389-96.
13. Teotia M, Teotia SPS, Singh RK. Metabolism of fluoride in pregnant women residing in endemic fluorosis areas. Fluoride, 1979; 12:58-63.
14. Teotia SPS and Teotia M. Fluorosis-India. Technical report on metabolism of fluoride in the newborns, infants and children living in endemic fluorosis areas. Sponsored Project, Department of Environment, Government of India. 1987; p1-56.
15. Krishnamachari K.A.V.R, Further observations on the syndrome of endemic genuvalgum of South India. Indian J Med Res, 1976; 64:284-91.
16. Teotia SPS and Teotia M. Endemic fluorosis: A challenging national health problem. JAPI 1984; 32:347-52.
17. Teotia SPS Teotia M. Endemic fluoride: Bones and teeth. Ind, J. Environ. Toxicol: 1991; 1:1-16.
18. Teotia SPS and Teotia M. Endemic skeletal fluorosis Clinical and radiological variants (Review of 25 years of personal research). Fluoride, 1988; 21:39-44.
19. Teotia M, Teotia SPS, Singh K.P.: Endemic Chronic fluoride toxicity and dietary calcium deficiency interaction syndromes of Bone disease and Deformities in India. Year 2000, Indian j pediatr 1998; 65:371-81.
20. Teotia SPS, Teotia M. Fluoride and calcium interactions: Syndromes of bone disease and deformities(Human studies) In: Frame B, Potts JT Jr (Eds). Clinical Disorders of Bone and Mineral Metabolism. Excerpta medica, Amsterdam 1983; P 520-21.
21. Teotia SPS, Teotia M, Singh K.P. A current perspective on endemic skeletal fluorosis In: Thakur BB(Ed) Medicine update Association of physicians of India, APICON: 2000;10:597-603.
22. Teotia SPS and Teotia M. Environmental studies of endemic fluorosis, goitre and stone and their epidemiological interrelationships- Major breakthrough in environmental research and its technical impact on safe drinking water supplies to

villages. Technical report Government of India, Ministry of environment and forests. 1990; p1-91.
23. Teotia SPS, Teotia M, Singh K.P. Non-invasive measurement of Bone Mass: Indian experience In: manoria P.C(Ed) Postgraduate Medicine. APICON-98; 12:185-91.
24. Faccini JM and Teotia SPS. Histopathological assessment of endemic skeletal fluorosis. Calc. Tiss. Res., 1974; 16:45-67.
25. Teotia SPS, Teotia M, Singh DP. Bone static and dynamic histomorphometry in endemic skeletal fluorosis. In: Tusnoda H, Yu MG (Eds). Fluoride Research 1985. Studies in Environmental Science, Elsevier, Amsterdam 1985; 27: 347-55.
26. Teotia SPS and Teotia M. Secondary hyperparathyroidism in patients with endemic skeletal fluorosis. Brit. Med.J., 1973; 1:637-40.
27. Teotia SPS, Teotia M. Fluorosis in India. Endemic fluorosis: A challenging national health problem. Technical Report, International Development Research Center Canada (IDRC). 1984; 1-58.
28. Teotia SPS. Dental Fluorosis: The National Medical J. of India 1999; 12:96-98.
29. Teotia SPS, Teotia M, Singh DP and Singh NP. Endemic fluorosis: Change to deeper bore well as a practical community acceptable approach for its eradication. Fluoride, 1984; 17:48-52.
30. Teotia SPS and Teotia M. Deep bore drinking water as a practical approach in the eradication of endemic skeletal fluorosis in India. Indian J. Med. Res., 1987; 85:699-705.

Session 5

Strategies

Strategy for Fluorosis Mitigation Program in India

A K Susheela*
India

SUMMARY: An innovative approach for fluorosis mitigation in endemic areas of fluorosis in India is developed, due to the previous major failures met with, and due to the subsequent corrections made which led to reasonable success. The strategy involves networking between health, education and public health engineering department personnel besides the NGOs (Non-Governmental Organisations). The implementation is framed in three stages. Stage I implies preparation in terms of multi-disciplinary human resource development. In stage II three surveys are carried out: first one on dental fluorosis in schools leading to short listing of affected villages, second one house to house health survey and third one on water sources and water quality. The data emerged are summarized and reviewed. Decisions are then taken, how, in the third stage, to provide safe water and nutritional counselling. 'Village' is the operating unit. Priority is laid on existing safe sources for provision of adequate water for cooking and drinking purposes. If all sources are contaminated, the community is informed of the technologies for removal of fluoride, using either the activated alumina or the Nalgonda techniques either in domestic units or in hand-pump attached plants. The community is made aware of the experience that recovery from fluoride poisoning is achieved in 10-15 days, if the victims practise a diet with adequate calcium, iron, Vitamin C, E and other anti-oxidants through dairy and agro products (vegetables and fruits).

The impact of the interventions is demonstrable in a matter of a few days and recovery from non-skeletal fluorosis is assured.

Key words: Fluorosis mitigation, India strategy, implementation, interventions, recovery, impact assessment.

INTRODUCTION

A survey carried out in 1992, has shown that among the 29 fluorosis mitigation projects implemented in 29 districts in 10 endemic states of India only 34 % met with reasonable success, while 66 % failed miserably [1]. The main reason for the failure that led to the collapse of promoting fluorosis control and prevention activities could be summarised in three points [2].

- Lack of initiative on the part of the Health & Public Health Engineering Departments to follow-up the activities.

* *Fluorosis Research & Rural Development Foundation.*
C – 103 , Saransh , 34 I.P. Extension, Delhi – 110092, India.
Email: susheela@ndf.vsnl.net.in

- The surveys were done but summarizing of the field data was never taken-up.
- Those who understood the pros and cons and was taking the responsibility of implementing the project, were transferred as usually happens in Government Departments and the successor never understood the project implementation strategy and therefore could not devote time by himself / herself to get the programme going.

This paper presents our present project implementation strategy, developed due to the major failures met with, and due to the subsequent corrections made which led to reasonable success. As an example we are highlighting the events and the data generated from projects under implementation in Nagoan and Karbianglong, two highly endemic districts in Assam, India.

STRATEGY COMPONENTS & STAGES

Strategy components:

- Identification of endemic villages.
- Diagnosis of fluorosis at early stages.
- Conduct of house-to-house health survey with focus on fluoride poisoning effects / health complaints.
- Analysis of 100 % of ground water sources for fluoride.
- Record of dietary habits of the families.
- Interventions in terms of:
- Promotion of consumption of fluoride safe water, either defluoridated water or water from alternative low fluoride sources.
- Provision of nutritional counselling.
- Assessment of the impact of the interventions.
- Record of recovery among the family, the duration taken for recovery being considered.

Implementation stages: The project implementation goes through 3 stages as indicated in Figure 1:

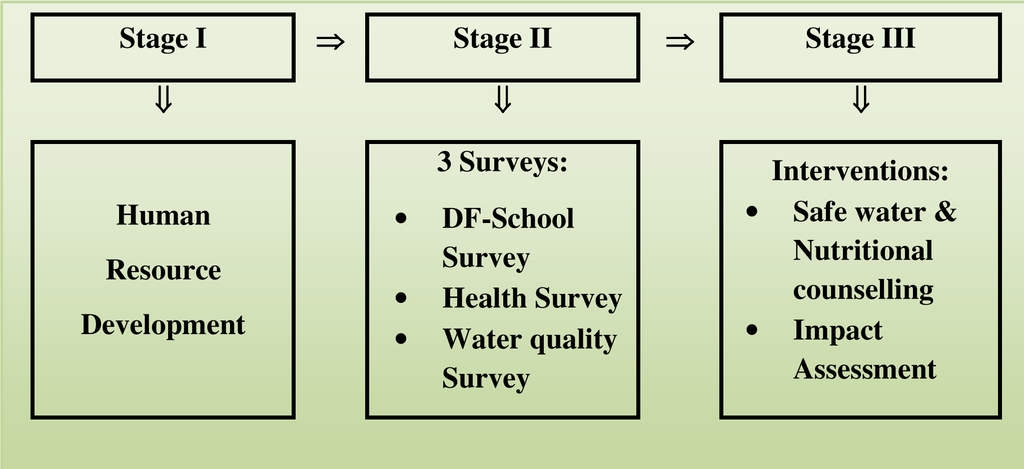


FIGURE 1. Framework of the project implementation strategy [3]

HUMAN RESOURCE DEVELOPMENT

Stage I: Stage I concerns human resource development and comprise of four trainings, each of one-day duration, of following groups:

- Doctor's training on all aspects on fluorosis mitigation.
- Training of the Public Health Engineers from Water Supply Agency on water quality testing and provision of safe water.
- Training of schoolteachers on identification of dental fluorosis and differentiation from caries and other dental disorders.
- Training of village level workers / NGOs on how to conduct house to house health surveys, how to collect water samples and how to fill-up the pre-coded survey formats.

For the human resources development, the training team comprises of resource persons from the following four departments / disciplines.

- Community Medicine.
- Dental Surgeon (Paediatric).
- Water Quality & Water Defluoridation.
- Health Sciences Expert & Coordinator.

However, presently, the Foundation is also involved in up-dating the faculty and clinicians of medical colleges in the endemic states / districts, so that every batch of Medical / Dental students graduating from the respective university are taught on all aspects of Fluorosis, so that in the years ahead, training of Doctors may not be necessary. The training team for the Medical/Dental Faculty comprises of:

- An orthopaedic surgeon
- A dental surgeon
- An endocrinologist
- A gastro-enterologist
- A paediatrician
- A community medicine specialist
- A health science specialist and coordinator

These specialists are chosen from those who have many years of research experience and who have dealt with patients of fluorosis during their clinical practise.

DF, HEALTH & WATER SURVEYS

Stage II: This stage focus on 3 surveys: one on school dental fluorosis, one on health and one on water quality.

Dental fluorosis survey: The survey on dental fluorosis among school children is carried out for short-listing the villages endemic for fluorosis and to identify the percentage of children who are victims of fluoride poisoning. For reliability of results, children of 8 years and above are screened. The trained schoolteachers do the survey. The teachers are often provided with colour charts revealing the various types of derangements and characteristics of dental fluorosis.

Health survey: Fluorotic individuals are mostly confined to their homes. They are seldom entertained in hospitals except for research. Therefore, to conduct a health survey of fluorosis victims, hospital records are not helpful. The only alternative to get reliable information on the prevalence of fluorosis (all 3 types) is to visit the houses in the endemic villages and record the disease prevalence. A house-to-house health survey with focus on health complaints, suggesting fluoride poisoning effects are recorded in the pre-coded formats.

Water quality survey: The water quality survey with focus on fluoride is done from the water samples collected by the health workers who visit the homes, cf. Table 1. Water samples are not to be collected by the water supply agencies. The health workers would communicate to the family the reason for collecting the samples of the ground water and the family would then be informed of the test report for fluoride during the subsequent visit of the health worker. This is also a method of sensitising the family; the dangers of fluoride and the family would anxiously await the test report.

However, the testing of the water samples is done by the water analysist who is under the administrative jurisdiction of the water supply agency. Fluoride estimation needs to be carried out by the ion selective electrode method, as it is the best method for getting reliable and precision data.

TABLE 1: Results of school dental fluorosis survey and water quality of samples brought by the students in Rongkhang block in Karbianglong district of Assam.

Number of villages where schools are located	100
Dental fluorosis prevalence (DF)	1.16 - 39.20 %
The number of villages where the DF children come from	245
Water sources brought and tested for Fluoride	72
Existing safe sources (F < 1mg/L)	59 (0.06– 0.94 mg/L)
Contaminated water sources (F > 1mg/L)	13 (1.1 – 2.3 mg/L)

While the health survey is carried out, the information on the food habits of the family is recorded. This includes the consumption of high fluoride containing food products, viz. drinking black tea (i.e. tea without milk); use of black rock salt; use of fluoridated dental products, fluoride containing drugs for treatment of any ailment, preserved and canned / bottled, food products viz. fruit juice, fish (tuna) and others where fluoride may have been added as a preservative. It is important that the field workers are trained and use pre-coded, field-tested, proforma.

Some results from health and diet survey is summarised in Table 2.

Review of the data: The water testing data would reveal the linkage to the user family and would also be linked to the health complaints recorded through the house-to-house survey. The data of the 3 surveys, with linkage established, would be summarized by an agency not involved in conducting the survey and reviewed, village by village by all the agencies involved in programme implementation.

It is of considerable importance for all the agencies responsible for the project implementation i.e. the funding agency and the departments of the health, education, water supply and others, who are responsible for the project implementation to meet for review of the data emerged from all the 3 surveys. This includes the linkages established between the water sources and the consumer families. The information on the extend of contamination of the ground water sources with fluoride besides the safe sources existing are taken into consideration when a decision is taken for provision of safe water to the village / community / families.

TABLE 2: Information on health complains and diet habits, as gained from Binnakandi Village, Nagoan District.

I: General Information:	
• Total number of members / population surveyed in a village	758
• Total number of families surveyed in the village	120
• Number of adults in the village	413
• Number of Children in the village	325
• Number of pregnant women at the time of survey	8
• Breast feeding women at the time of survey	39
II: Health complaints of the community in % [4]	
• Knock- knee in children	0.31
• Pain in the joints	0.13
• Non-Skeletal changes / early warning signs [5]	40.76
• Still birth / abortion	0
III: Food and other habits of using items with high fluoride content %	
• Chewing of Supari (Aracnut)	44.2
• Chewing of Tobacco	18.9
• Consuming Black tea (without milk)	71.5
• Consuming canned food	16.5
• Using Black rock salt in cooking	28.9

The review meeting would provide an opportunity to the agencies involved, to assess the gravity of the problem / the prevalence of the disease, the number of villages / habitations that are endemic for fluoride and the safe sources existing in the same village and fluoride contaminated sources. The information is used to decide upon the course of action for provision of safe water to the community in a village. It is highlighted that in a district project implementation process, the village is the unit, the family and the members are the focus and the community is the beneficiary.

DOUBLE INTERVENTION & IMPACT ASSESSMENT

Stage III: In stage III the events are mainly focusing and promoting interventions i.e. 1) Safe drinking water and 2) Nutritional / diet counselling. The community has 3 options to choose from for pursuing interventions i.e. collecting safe water for cooking and drinking purposes.

1st Intervention: The 1st intervention is the provision of safe drinking water, which is done in one of three options:

- Option 1 is establishment of new stand-posts to provide water from an existing safe water source that might be available at a central location in the village. These stand-posts should operate at certain time intervals during the day, e.g. 2 hours in the morning or the evening in order to meet the requirements for collecting safe water for drinking and cooking only.

- Option 2 is the establishment of a new safe water source, be it a hand pump, a tube well or a dug well. It is necessary for the community to ensure, that the wells never dry up in the summer months. This is achieved by putting-up bunds and getting the rainwater during the rainy season to stagnate and percolate to the underground thus recharging the aquifer. The community leaders need to be adequately sensitised and they undertake the work on a voluntary basis.

- Option 3 isselected when no safe water sources are available. It implies introduction of defluoridation to existing high fluoride water sources. The community may choose between activated alumina (AA) domestic filter, AA based treatment plant attached to hand pump and the Nalgonda bucket system using lime and alum.

The community also need to be informed about the cost involved, how to re-use the same activated alumina, by regenerating / washing of the AA using dilute acid and alkali followed by washing with water. The community should be aware that they have to choose from AA technology, domestic filter made of food grade plastic, stainless steel and/or terracotta. This exercise need to be undertaken with village women involved in the exercise, so that they understand and should have the right to opt for, from the available options.

2nd Intervention: The diet/nutrient counselling is based on five principles, i.e. 1) avoidance of fluoride contaminated food and beverage from the daily diet, 2) adequate consumption of health promoters, 3) easy to practise, 4) affordable and 5) consideration of family's likes and dislikes [6, 7].

The focus of diet counselling is primarily to drive home the essential message that for combating fluoride toxicity/poisoning, it is of prime importance to consume through diet adequate Calcium, Iron, Vitamin C, E and other antioxidants. If the daily diet is rich in vegetables and fruits for obtaining the vitamins and other antioxidants, in a matter of 10 – 15 days the poisonous effect of fluoride can be nullified. Recovery would be remarkable.

Impact Assessment: Prevention and Control of Fluorosis is easily achievable in an endemic area. The acceptance of safe water and practise of better nutrition on a sustainable manner in a household/community need to be evolved. Depending upon the awareness status of the community, if considered necessary, a KAP study (Knowledge, Aptitude and Practise) workshop should be held for sensitising the community.

In the final stage of the project Implementation, the impact of the 2 interventions practised need to be assessed at certain intervals. The first interval should be between 15 – 20 days after practise of interventions. The second may be commenced between 3 – 4 months and the third, during 10 – 12 months. It is our observation that, those afflicted with fluoride poisoning and detected very early would have regained health in a relatively short time frame of 3 to 4 months.

The impact assessment is essentially focusing on the repeat of the health survey with focus on non-skeletal fluorosis only in 50 %, 75 % or 100 % of the families. If it is an urban sector, besides non-skeletal fluorosis manifestations, the blood and urine fluoride levels could also be assessed which shall drop to normal limits i.e. serum = 0.02 mg/L; urine = 0.10 mg/L within the period of recovery.

The communication should enable investigators to implement a successful fluoride mitigation program within a shortest span of time, through lessons learned from India from our failures and successes extended over a decade. Necessary checks have been introduced at various stages. Eventually the out come of the project success shall be a great satisfaction to those involved in project implementation whichever part of the world, they may belong to.

REFERENCES

1. Prevention and Control of Fluorosis in India: Health Aspects (Volume 1). Ed. A. K. Susheela, Government of India Publication 1993.
2. Evaluation of the activities of the Sub-mission "Control of Fluorosis" and Fluorosis Control Cell; Harcharan Singh Committee Report. 1995 Government of India Report (Restricted Document).
3. A K Susheela and K. Majumdar: Fluorosis Control programme in India. Proceedings of the 18th WEDC (Water and Environment Management) Conference Katmandu, Nepal. 229-331, 1992.
4. A K Susheela : "Treatise on Fluorosis". 2nd Revised Edition. Published by Fluorosis Research & Rural Development Foundation, New Delhi, India, 2003
5. A K Susheela: Studies of health risks from drinking water naturally contaminated with fluoride in: Proceedings of the Rome Symposium. Assessing and managing health risks from drinking water contamination. Approaches and applications. 123-134, IAHS. Publication No. 233. Edited by: Eric G. Reichard and Giovanni, A. Zapponi. Published by the International Association of Hydrological Sciences, 1995.

6. A K Susheela: Fluorosis: Early detection and management. Importance of practising interventions with focus on consuming safe water and essential nutrients In: Touch , Heinz Nutrition Foundation of India. 3, 3, 2001.
7. A K Susheela and Madhu Bhatnagar: Reversal of fluoride induced cell injury through elimination of fluoride and consumption of diet rich in essential nutrients and antioxidants. Molecular and Cellular Biochemistry 234/235, 335-340, 2002.

Towards an Integrative Approach to Fluorosis Mitigation

S Rajchagool * and C Rajchagool
Thailand

Summary: The paper proposed a 'roadmap' for fluorosis mitigation at national level. It was synthesized from the experiences of ICOH in the last two decades. The road map is composed of three tasks. Task I: to equip one's organization with well-rounded knowledge about fluorosis. Task II: to create, on the basis of the knowledge from Task I, awareness of the community about the cause and effects of fluorosis and some viable ways to reduce or even eradicate it. And Task III: to bring the problem to the attention of people capable of making policy at the top level together with implementing personnel. These tasks perhaps could be understood as an 'integrative approach' to fluorosis reduction, which as development strategy could hopefully be extended to other areas of work.

Key words: Fluorosis mitigation, knowledge-base organization, community mobilization, integrative approach, development concept.

INTRODUCTION

> ***The first undertakers in all great attempts commonly miscarry, and leave the advantages of their losses to those that come after them.***
>
> ***Samuel Butler***
>
> ***Vision is the art of seeing things invisible.***
>
> ***Swift***

Prominent among a large lexicon of concepts from development studies are the questions of ***who*** and ***how***, namely, who is to carry out the work of development, and how to bring it about. As to 'the who-question', there is a dichotomy to the answer.

Which entity between the state or the people should be the prime actor in the work of development? The argument has been at the core of the debate, and as in a debate there are weaknesses and strengths in each position. Hence the middle position, being the well-known concept of 'people's participation' and some other variations on the theme, has been proposed. Regarding 'the how-question', the issue revolves around the question of 'technical-know how' as distinct from the socio-administrative aspect of 'the who-question'.

This paper is an attempt to draw a 'road map' of fluorosis reduction. Encouraged by some success at the village level in North Thailand, it is ambitiously aimed at the nationwide scale. The paper has three parts, namely; a) a brief description of the history of fluorosis reduction efforts made by ICOH , b) a proposed 'road map' and c) some thoughts on the question of development strategy.

ICOH FLUOROSIS REDUCTION HISTORY

Often our work does not strictly follow a pre-designed definite policy. Rather they are in response to the demands and needs arising in a particular circumstance. More importantly the significance of actions and the direction they take become clearer after being seen in the general context and with a certain perspective. The organization of events into four phases is current and conceptually formulated with the wisdom of hindsight. For the sake of brevity, the experiment and field experience can be compressed into table 1.

A PROPOSED 'THE ROADMAP'

The drawing of the following road map is based on the experience of ICOH, a medium-size organization. Hence the roadmap would bear special characteristics that it is neither a very broad scheme like the national five-year plan from the state bureaucracy, nor it is a specifically limited grass-roots community programme. Basically it is to draw attention of the high-level policy makers and the policy implementers in the field as well as to sustain active interest of the villagers. The road map comprises of substantively three areas of tasks, and temporally three stages.

Task/Stage I:	Building up a knowledge-based organisation.
Task/Stage II:	Mobilising and supporting the affected community,
Task/Stage III:	Gaining attention of policy-making / implementing state agencies.

Task I: The diagram in figure 1 shows that at the core factor is knowledge which here means the scientific as well as practical aspects of the fluorosis problem. It also includes experience, skills and experience that the office has acquired. The knowledge may be generated through one's own research or gained through experience of other organisations. The knowledge is to be made known to all concerned, both along the organisational and individual basis, as well as from those working in the field of public health to the public and the community at large. The spread of knowledge on fluorosis will lead at least to four desired results:

TABLE1: Delineation of activity orientation at ICOH over the last two decades.

Phase 1: 'The office in command' phase, 1990 – 1992 [1]

Events: ICOH as the sole actor in the planning and the implementation of defluoridation.
- Designed the domestic ICOH defluoridator using bone char;
- Provided ready-made filter columns to villagers;
- Monitored and evaluated of the use of the ICOH defluoridator;

Result:
- ICOH obtained good responses from villagers;
- Highly satisfactory scientific success on technical-know-how.

Phase 2: 'The people in command' phase, 1992 – 1994*

ICOH acknowledged certain areas of failures:
- Not being able to continue supply of the filter medium to the users;
- Not being able to extend the project to other communities in need;

The community showed willingness and initiative to work out its own ways:
- Some villagers turned to use alternative low-fluoride sources;
- Others took precaution in their water consumption.

Results :
- The ICOH project objective was realized by the people's initiative;
- Transferability of the project and dissemination of information were limited;
- Radical change of the project was considered necessary.

Phase 3: 'The technology in command' phase, 1995 – 1998.

ICOH became uncertain about its roles in the field, turned to focus on scientific research:
- Experimented with the incinerator for bone char production;
- ICOH engaged in the problem of the standard setting of fluoride intake;
- Acknowledged the importance of technical know-how, but was also aware of its limitation and implementation in the field.

Phase 4: 'The Reach-Out' Phase, 1999 – present

ICOH attempted to:
- Reach larger numbers of affected villages;
- Unify positive experience of people's attempts with ICOH's scientific contributions;
- Support the community to work out its own way to reduce fluoride content;
- Engage communities with longer experience in consultative discussions with those in need.

By means of:
- Identification of affected communities;
- Identification of key actors;
- Mobilization of key actors for the purposes of:
  - Bringing greater awareness of the nature of the problem of fluorosis;
  - Initiating possible and practical ways to people-based solutions;
  - Exchanging ideas and experience among the community leaders;
  - Learning about successful cases
- Organizing a mobile unit for the purposes of:
  - Helping the pioneers (the training attendants) in their mission,
  - Deepening the learning and the working-out solutions on community basis.

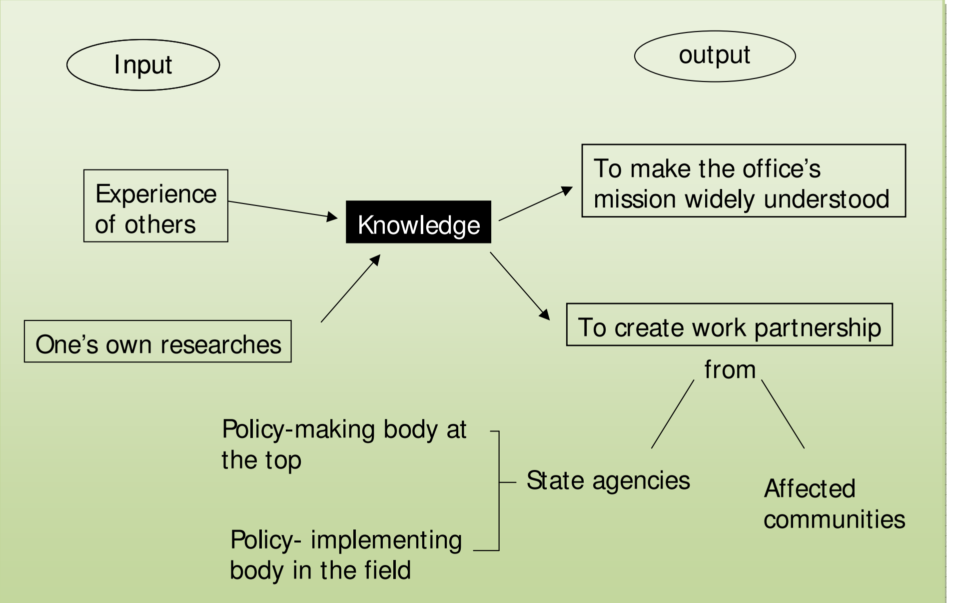


FIGURE 1: Illustration of Task I.

- Creating awareness of the magnitude of the problem.
- Making the office's mission widely understood.
- Opening the office's door wider to offer services and to welcome potential work partners.
- Rallying further actions.

Task II: Having realized that once the communities became aware of the nature of the problem and acquired a conceptual understanding of the situation, their potentials would be put into effective efforts. The aims of Task II are to create awareness of affected communities about the cause and effects of fluorosis and some viable ways to reduce or even eradicate it.

The task began by identifying the affected communities all over the regions of the country from the available database. Then key actors were to be identified, since some members of the community are more active than others. It is important to first recruit those promising ones to carry out a jointly planned project. Subsequently these active members could facilitate the dissemination of the information to targeted communities.

The meeting, organized on a national scale, naturally had a limited number of attendants. Only three community representatives were selected from each community. After the meeting and having gone back to their respective community, they were theoretically to become the pioneers of the community, paving the path of fluorosis prevention/reduction.

The point then is to reach out to the communities at large with the information and knowledge they need. The principle of self-reliance is to be adhered to as far as possible, both in the technical as well as the practical aspect. The means of accomplishing this task was to organize meetings of and training sessions for representatives from local administrative organizations of the affected areas. Additionally a certain group of active representatives formed a network for mutual assistance.

The process of reaching the villagers has been reinforced by another supplementary action programme. That is to form a mobile unit travelling to meet the communities. The idea is to deepen the learning and the working out of solutions on an individual community and even on a household basis. It is also to reach more people with the information. On top of offering the services of water and dental examination, it is to strengthen the action process following the meeting. The mobile unit is to facilitate the representatives and their network in their mission.

Task III: Fluorosis has never been a hot issue. It does not claim people's lives, nor is it an alarming kind of illness. It affects mostly the poor in rural areas. It has never been on the priority list of the country's health problems, and it has never received sufficient attention by any government.

Being motivated by some uplifting works carried out by the community in cooperation with the concerned health work unit, ICOH entertains the idea of how the work on fluorosis prevention/reduction at the community level could be magnified to the regional and even the national level.

To achieve this grand objective, the involved state agency at the macro planning level, and the work unit at the field level, have to be unified. A very effective way to attract attention of policy makers is to put them in touch with the affected communities. Some promising and successful cases from Task II could function as a demonstration example. The visit to the demonstration site is tantamount to seeing the knowledge and the idea in action. The visit has to be followed by a series of discussion afterwards. This is to reach a common understanding among various units at different levels.

The dissemination of information, Task I, is an important initial step for the community and the state agency. Necessary action might not be promptly taken, but at least both are scientifically equipped. Task I will lead to Task II, and if accomplished, will give impetus to Task III. The coordination of all the tasks could certainly undermine the danger of fluorosis from the local to the national scale.

However, as a saying goes, there is a universal ironic gap between plans and actualities. Two foreseeable accounts could make the road map rough, they are:

- **The misalliance between the community and the work unit.** Co-operation between the community and the official work unit is a new terrain of management for both. The former may have the idea that the latter is responsible for most, if not all, of the works. While the official work unit, on the other hand, could fall into the danger of going to the extreme, i.e., doing too much or too little. In either case it tends to impair the working relationship. Ideally the official work unit must see its role, for active communities, as a technical advisor offering assistance, when requested, and, for less active ones, as catalysts.

- **The conflicting practices of fluoridation and defluoridation.** The concept of the harmful effects of fluoride was not disturbed until the practice of fluoridation (water, milk and fluoride supplement) came to the scene. These two opposite practices are very much at odds, as much for the lay people as for the scientist. The conflicting practices are confusing and the adversely the most victimized in this cloudy issue are the affected community. This paper cannot enter into the argument which demands much longer discussion. Here it is to point out that Task I needs also to be prepared to take up the challenge from a different school of thought.

SOME THOUGHTS ON DEVELOPMENT STRATEGY

Generally one's field of expertise determines one's own outlook. Officials from a state agency see the role of the state as the prime-working unit. Hence comes the concept of people's participation, and not officials' participation. Similarly, the concept of community-based development resonates well with the community and their supporters. In so far as this outlook is observed, the development work is likely to be tilted to the aspect of emphasis. To distance one's self from one's own field of specialization, perhaps one can also see one's own limitation clearer. The parable of the description of an elephant is aptly applicable here. We have seen the shortcomings of the working principles privileging one determinant in the different phases of ICOH experience. They are also indicative of the false dichotomy between the state and non-state entities as the principal actor. For the developmental strategies, we need to synthesize all the components in an integrative fashion. One may come sooner than others, but eventually all need to come together. This is what can be termed "the concept of integrative approach" which is the answer to the question of *who* in development context.

The question of *how* requires further consideration, i.e. two crucial propositions:

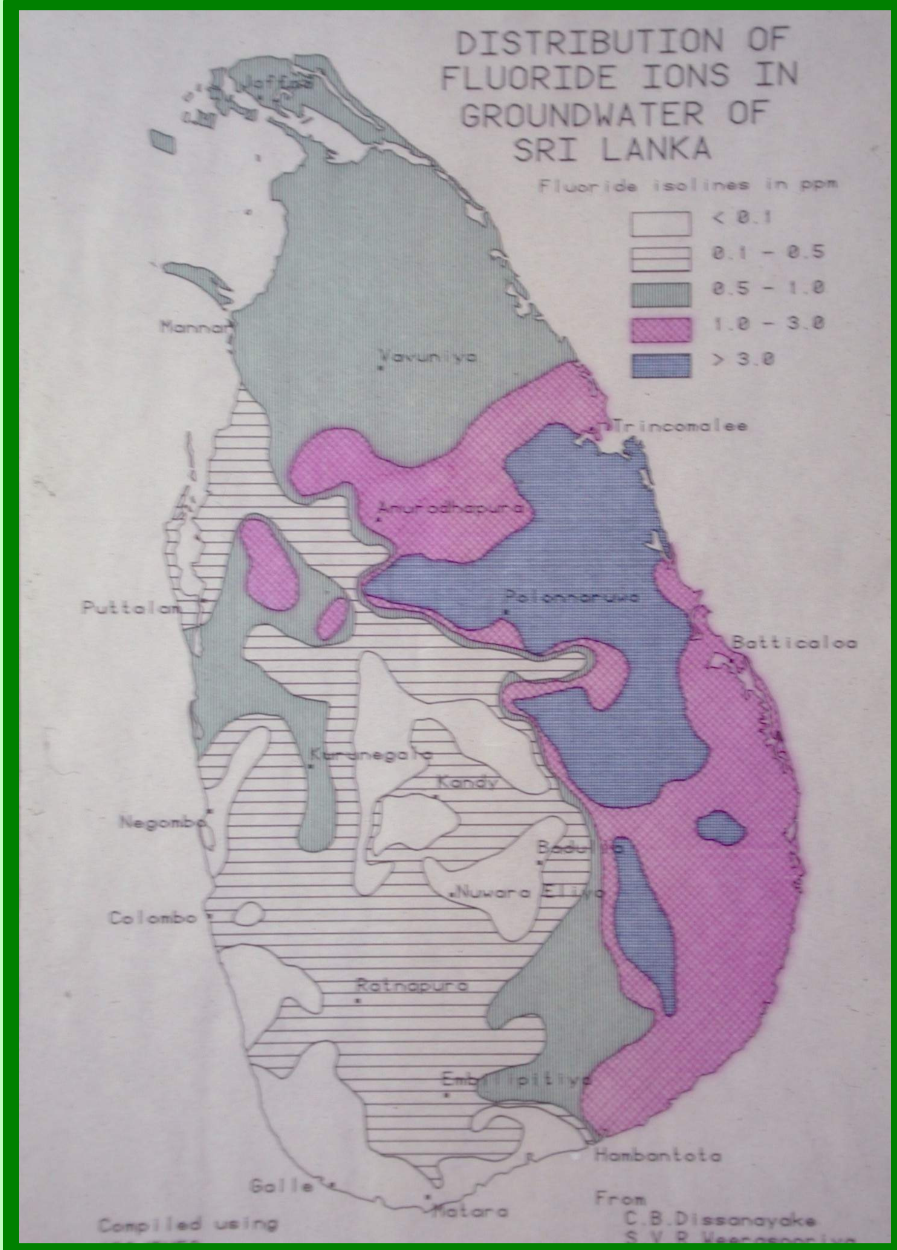
- Technical know-how is supremely important.
- Appropriate technology is a matter of dispute.

The technology does not work in a vacuum but in a social context for it is an extension of human hands. In other words the success of technology does not depend exclusively on its work mechanism alone. It is its application that is more decisive. This requires an insight of how people work and live. Social and technological aspects have to go hand in hand.

It can be concluded that developmental strategies need to be carefully designed for each matter and each context depending on the availability of technology in order to reach an integrative approach.

REFERENCE

1. Rajchagool S. and Rajchagool C. Solving the Fluorosis Problem in a developing Country. In: *Proceedings of the 2nd[t] International Workshop on Fluorosis and Defluoridation of Water.* p. 170-175. (Ed. E. Dahi & J. M. Nielsen) Int. Soc. Fluoride Res. Auckland 1999.


DISTRIBUTION OF FLUORIDE IONS IN GROUNDWATER OF SRI LANKA
Fluoride isolines in ppm
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 3.0
> 3.0
Jaffna
Mannar
Vavuniya
Trincomalee
Anuradhapura
Polonnaruwa
Puttalam
Batticaloa
Kurunegala
Kandy
Negombo
Badulla
Nuwara Eliya
Colombo
Ratnapura
Embilipitiya
Hambantota
Galle
Matara
From
C.B.Dissanayake
Compiled using