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ABSTRACT

Endemic fluorosis is a serious rural health problem in the Krishnagiri and Dharmapuri districts in the Indian state of Tamil Nadu due to excessive fluoride (F-) content of groundwater. The supply of F-free drink water that comes from surface water is an urgent matter in these regions. The Government of Japan provided official development assistance (ODA) in the amount of 22,387 million yen for a project entitled “Hogenakkal Water Supply and Fluorosis Mitigation Project.” The project was undertaken to use the Cauvery River as a stable water supply to the population, reducing their exposure to F-.

The Osaka Medical College was invited to participate in the project by Dr. A.K. Susheela, consultant for the Japan Bank for International Cooperation (JIBC) and Executive Director of Fluorosis Research and Rural Development Foundation. The present paper presents the results of a preliminary survey conducted April 1-3, 2008, the framework of the project and status of the relationship between India and Japan through the Japanese ODA.

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INTRODUCTION

In India the rapid population growth has increased the demand for drinking water in a manner that has overwhelmed the existing water treatment facilities. As a result, it has become necessary to excessive dependence on fluoride (F-) contaminated ground water, posing a serious health problem in that country [1-3]. Although F- is an ubiquitous ion normally found in the environment and diets, its ingestion above the World Health Organization (WHO) guideline of 1.5-mg per liter of drinking water can cause a condition known as fluorosis, affecting the teeth and bones. Very high levels of F- in groundwater are common in many countries such as the East Africa Rift Valley in Ethiopia, Turkey, Iraq, Iran, Afghanistan, India, northern Thailand and China [4-6]. In India the number of patients suffering from fluorosis is as high as 66 million. As a consequence, the Government of India has started the “National Fluorosis Mitigation Program,” a 5-year plan from April 2007 to March 2012 to deal with the F- issue on a national scale and to find ways to supply safe and adequate quantities of drinking water to the entire population.

The Krishnagiri and Dharmapuri districts, located in North Western Tamil Nadu were chosen for the present survey. It has the lowest annual average rainfall of India and no neighboring rivers, resulting in chronic water shortage for the entire region. In addition, the basaltic rock ground that forms the Deccan Plateau contains large amounts of F-, which are transferred to the groundwater and is the cause of endemic fluorosis in these areas [7]. Supplying F-free surface water to these districts is urgently needed to solve the problem. In 2002 the Ministry of Water Resources of India established the National Water Policy, ranking drinking water a first priority, followed by irrigation and hydropower generation. The policy is still in effect and the Indian Government continues to expand development of waterworks.

On March 10, 2008 the Government of Japan agreed to extend a package of Official Development Assistance (ODA) to India as a soft loan totaling 185,575 million yen, making India the country receiving the largest Japanese ODA for five consecutive years. The loan package covers seven large-scale projects: (a) The Haryana Transmission System Project; (b) Delhi Mass Rapid Transport System Project; (c) Kolkata East-West Metro Project; (d) Hyderabad Outer-Ring Road Project; (e) Uttar Pradesh Participatory Forest Management and Poverty Alleviation Project; (f) Hogenakkal Water Supply and Fluorosis Mitigation Project and (g) Tamil Nadu Urban Infrastructure Project.

The objective of project (f) is to provide safe drinking water to the urban and rural areas in Krishnagiri and Dharmapuri Districts through four sub-projects: construction of water supply facilities, fluorosis mitigation strategies, consulting services and capacity building of local water bodies, to be accomplished with 22,387 million yen from the Japanese aid package. [8]

The Executive Director of Fluorosis Research and Rural Development Foundation and consultant for the Japan Bank for International Cooperation (JBIC), Dr. A. K. Sushelela, asked the Osaka Medical College for assistance in the fluorosis mitigation project. In the present paper we report the authors’ preliminary survey, the framework of the project and the scope of the India-Japan relationship through ODA.

MATERIALS and METHODS

JBIC and ODA

Since 1999 the JBIC has provided ODA yen loans. The JBIC was created through merging of the Export-Import Bank of Japan (JEXIM) and the Overseas Economic Cooperation Fund of Japan (OECF). Developing countries unable to develop and maintain social infrastructure because of financial and technical limitations can apply for financial support from JBIC/ODA in the form of long-term, low-interest loans destined to support self-reliant development projects.

The Hogenakkal Water Supply and Fluorosis Mitigation Project loan was provided at a 1.2 annual percentage rate of interest, to be paid over a period of 30 years, with a 10-year grace period provision. The borrower is the president of India, the execution agency is the Tamil Nadu Water Supply and Drainage Board (TWAD) and the operation and maintenance are also the responsibility of TWAD.

Krishnagiri and Dharmapuri districts, Tamil Nadu

The state of Tamil Nadu lies on the east coast of the southern Indian peninsula. It is bordered by the Bay of Bengal in the east and by the Gulf of Mannar and Palk Strait in the southeast, dividing India and Sri Lanka (Fig. 1).

Chennai, formerly known as Madras, is the capital city of Tamil Nadu. It has 6% of India’s population, which is the 9.6% of total urban popu-
Fluorosis mitigation project in India

Fig. 1 Location of the Krishnagiri and Dharmpuri Districts (★) in the state of Tamil Nadu, South-East India.

Fluorosis mitigation project in India includes the development of a system capable of bringing 1.6 x 10^7 m³ of water per day from the Cauvery River to three municipalities, 17 panchayats (Decentralized form of village Government) and eighteen town panchayats with 6,755 households in the area. The project involves the construction of a distribution network, overhead water storage tanks and pumping stations. The fluorosis mitigation sub-project includes a survey to establish a baseline human F level, studying the diet of the fluorotic individuals and a fluorosis awareness campaign with specialized training of physicians and educators in coordination with local experts. The project also includes capacity building for the members of the village water and sanitation committee, in charge of operation and maintenance, tariff control, financial management and functional extension of training facilities. Finally, the project also involves consulting services to review the details of design and construction of facilities and overall monitoring of operations by the executing agency [9].

The authors of this paper and JBIC conducted a preliminary survey during April 1-3 2008. The survey was focused on dental fluorosis and was carried out at a local bureau of waterworks, hospital, primary care centers, elementary schools and rural communities in the two districts interviewing medical doctors, community leaders, technicians and general members of the population. In addition to the survey, the F levels of groundwater were established by means of a F selective electrode (FISE, Orion 96-06 from Thermo Fisher Scientific Inc, U.S.A. The calcium, magnesium, zinc, manganese, strontium and boron concentrations were also determined by inductively-coupled plasma argon emission spectrometry (ICPAES, P-5200 Hitachi Ltd, Tokyo, Japan).

RESULTS

The analysis for F was attempted at a local waterworks facility by alizarin complexon extraction spectrophotometric method adapted from a Japanese industrial standard (JIS) method for determination of F. Limitations in the facilities and poor experimental techniques that included a hour-long sample concentration and troublesome steam distillation made it difficult to obtain reliable results (Fig. 2). Handling of the pH electrode was incorrect and affected its durability. There was a Kjeldahl system for sample digestion, but there was neither ion chromatography setup for separation of anions and/or cations nor atomic absorption apparatus for.

Hogenakkal water supply and fluorosis mitigation project

This has been a long-awaited project to solve the problem of potable water in Tamil Nadu. Since 2005 the government of India has been negotiating the pertinent details with Japan’s ODA for funding of the project. The water supply part of the project
trace metal determination. There were no dissolved oxygen (DO), biochemical oxygen demand (BOD) analyzers or bacteria in water test kit, all essential for biological analysis of water.

Although several hospitals and primary care centers provided F-free drinking water obtained via a United Nations Children’s Fund (UNICEF)-funded water purification system with ion exchange column, the system was neither effective for bacteria elimination nor capable of supplying water in sufficient quantities (Fig. 3). At a local hospital and primary care center a large number of patients with skeletal or dental fluorosis were found (Figs. 4, 5). Prevalence of fluorosis in children is strongly correlated to the F content of groundwater. The children are growth impaired suggesting the need of a nutritional survey in these districts. At these facilities, there was an extreme shortage of physicians and medical resources (Fig. 6), so the diagnosis of fluorosis was made by clinical obser-

Fig. 2 Analysis of groundwater for fluoride at a local bureau of waterworks.

Fig. 3 UNICEF-funded water purification system in primary care center.

Fig. 4 Examination of dental fluorosis symptoms at an elementary school.

Fig. 5 Child with severe dental fluorosis with pitting and brown staining

Fig. 6 The authors surrounded by elementary school students who attended dental fluorosis examination.

viation and X-ray photography, taken without adequate radiation protection. It was not possible to conduct urinary F analysis for confirmation of the
Table 1  Concentration of elements in groundwater in the Indian state of Tamil Nadu

<table>
<thead>
<tr>
<th>Source</th>
<th>Fluoride (mg/l)</th>
<th>Manganese (μg/l)</th>
<th>Calcium (mg/l)</th>
<th>Magnesium (mg/l)</th>
<th>Zinc (μg/l)</th>
<th>Strontium (mg/l)</th>
<th>Boron (μg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dharmapuri</td>
<td>5.43</td>
<td>46</td>
<td>938</td>
<td>340</td>
<td>422</td>
<td>14</td>
<td>38</td>
</tr>
<tr>
<td>Krishnagiri</td>
<td>9.82</td>
<td>5</td>
<td>525</td>
<td>200</td>
<td>330</td>
<td>2.9</td>
<td>38</td>
</tr>
<tr>
<td>Krishnagiri elementary school</td>
<td>5.69</td>
<td>250</td>
<td>1219</td>
<td>400</td>
<td>384</td>
<td>9.2</td>
<td>51</td>
</tr>
</tbody>
</table>

*The WHO guideline for fluoride is given as 1.5 mg/l
** Japanese Ministry of Health, Labour and Welfare set the level of elements in drinking water below 0.05mg/l for Manganese, 300mg/l for Calcium and Magnesium, 1.0mg/l for Zinc and 1.0mg/l for boron.

diagnostic. These are areas that also require urgent improvements. Based on these observations, equipment of laboratories and continuous training of medical doctors and laboratory technicians will be a critical issue for future operation of the water monitoring systems.

Table 1 shows the levels of fluoride, magnesium (Mg), calcium (Ca), manganese (Mn), Zinc (Zn), strontium (Sr) and boron (B) in groundwater samples obtained in the districts under study (Fig. 7). The F⁻ concentrations were 3-7 times higher than the WHO guideline value of 1.5 mg/L. The Ca and Mg concentrations were 2-5 times that of the Japanese standard of 300 mg/L. The Sr, Mn and B levels were also high, indicating that the groundwater presently in use is hard and unsuitable for human consumption.

The people of these regions showed keen interest in the demonstration of a conventional colori-

Fig. 7  Water well in India.

Fig. 8  Determination of fluoride in groundwater with a commercial colorimetric kit.

Fig. 9  Result of the colorimetric assay for fluoride. The comparison chart shows a concentration that exceeded the upper limit of 5 mg/L by this method.
metric kit for determination of F⁻ in water. The change in color was easily detected and understood, making this an effective tool for training of teachers and of the general public (Figs. 8, 9).

**DISCUSSION**

For forty years the UNICEF has supported water supply and sanitation projects in India. Water was provided in rural areas from deeply bored wells. As fluorosis evolved as an endemic health problem, the UNICEF shifted focus to strengthening methods for improving water quality, facilitating in-house water treatment, education and finding alternative sources of water both for households and communities.

Without proper training and education, people living in a rural community will not realize how adequate personal and domestic hygiene practices have a positive impact on their health and, unless the authorities do not provide safe and abundant water for human needs people will not be able to reach a better health status. Education of the water chemists is important because F⁻-contaminated water does not have any particular color, odor or flavor. Education of health providers will allow them to detect and prevent fluorosis before irreversible skeletal and dental damages of F⁻ are present.

The fluorosis mitigation project aims to establish a baseline survey, training for physician and health providers, nutritional advice and awareness campaigns [10]. A balanced approach that considers all these factors is essential for the success of the project. This project would be carried out in tree initial stages: (1) Human resource development; (2) Survey; (3) Intervention for control and treatment of fluorosis. These would be followed by two additional stages: (4) First impact assessment and (5) Second and third impact assessment. During stage (1) a total of 547 health care providers need to be trained at several clinics and hospitals for proper methodology to use FISE, which is a sensitive and reliable method for F⁻ analysis in liquid samples. These electrodes can be obtained from Thermo Fisher Scientific, Inc., U.S.A. and have become the universal standard for research and routine determination of F⁻.

Our research group has ample expertise on the FISE method [11] and will be able to transfer skills and knowledge as soon as laboratories are operational in the selected districts. We are also willing to invite personnel from India through JICA as has been the case in the past with foreign researchers [12] to receive training in our facilities in Osaka, where they would be made aware of the danger of F⁻ toxicity due to environmental or occupational exposure.

With over 1.1 billion inhabitants, India is the second most populated country in the world, with potential for sustained market growth in the 21st Century. At present India is growing at a fast rate, attracting foreign investment and becoming one of Asia’s emerging economies. Its education system is well recognized and produces a vast pool of skilled laborers, making it an attractive market for foreign investors. On the contrary, in spite of its overall economic success, India is home to the largest number of people that earns less than one US dollar a day, with about 30% of its population living under the poverty line. The domestic problem of human rights and gender and social inequalities derived from the caste system persists even after the economic liberalization in 1990.

Together, these advancements and historical problems make India a most unique country in which international cooperation will play a crucial role. In a recent trend of ODA, recognition of the importance of combating extreme poverty in India is key to attain the Millennium Development Goals (MDGs), so India has become the biggest recipient of ODA from Japan in the last five years. It should be stated that India does not accept international interference in domestic issues of poverty and the gap among different strata of the population as part of ODA programs or activities. In divergence to most other developing countries, India’s approach to international assistance embraces the concept of self-help or autonomous ownership that Japan needs to respect and explore forms of assistance that take full advantage of the strengths of this policy concerning acceptance of ODA [13].

As dental and skeletal fluorosis in the Krishnagiri and Dharmapuri districts is essentially a rural problem of the poorest people, the caste system structured around graded inequality in education, opportunities and access to healthcare programs needs to be overcome if the vicious cycle is to be broken to reduce the economic and social issues that are underscore the public health problem.

Although the Hogenakkal water supply and fluorosis mitigation project includes important issues of the millennium’s development goals such as Target 7c: “Reduce by half the proportion of people without sustainable access to safe drinking water,” the employment and income will never improve and the issue of poverty will never be settled without mitigation of endemic health problems such as fluorosis in the Krishnagiri and Dharmapuri Dis-
tricts. It is necessary for us to offer the best aid package that we can within the concept of self-help or ownerships valued by the Indian government in cooperation with the local inhabitants, non-governmental organizations and the United Nations’ offices in the region.

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REFERENCES


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