

**A Study of the Fluorosis Mitigation Project in
Mundargi Taluk, Karnataka in India.**

MASTER'S PROJECT
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ABSTRACT

The report is a study of the Sachetana Drinking Water Plus project in Mundargi Taluk, Karnataka, India. Endemic fluorosis is prevalent in the area. The project aims to solve this problem based on provision of an alternate source of water and improving the quality of groundwater. This report is a mid-term appraisal for the project to determine the impacts of the project thus far and identify bottlenecks, if any, for the remaining period of project implementation. Data collected during project implementation has been analyzed and interviews had been conducted during a field visit. The provision of an alternate source of water using rainwater harvesting is a success and should be sustainable based on the nature of its implementation. The contribution of field activities could not be quantified and based on currently available information it is difficult to conclude how effective they have been so far. Some changes to the current data collection system would be helpful for future studies.

1 Introduction

Fluorosis has been a consistent problem in the State of Karnataka, India. BIRD-K (a Non-Governmental Organization (NGO)) has initiated and expanded a fluorosis mitigation project in the State, the Sachetana Drinking Water (D/W) project, with support from the State Government. The NGO has previously worked on a project on rural development and poverty alleviation (Sachetana GAA¹ project) in the same area since April, 2004 (now in its 2nd phase of implementation). The Sachetana D/W project covers clusters of villages in three districts in the State (refer Figure 1.1).

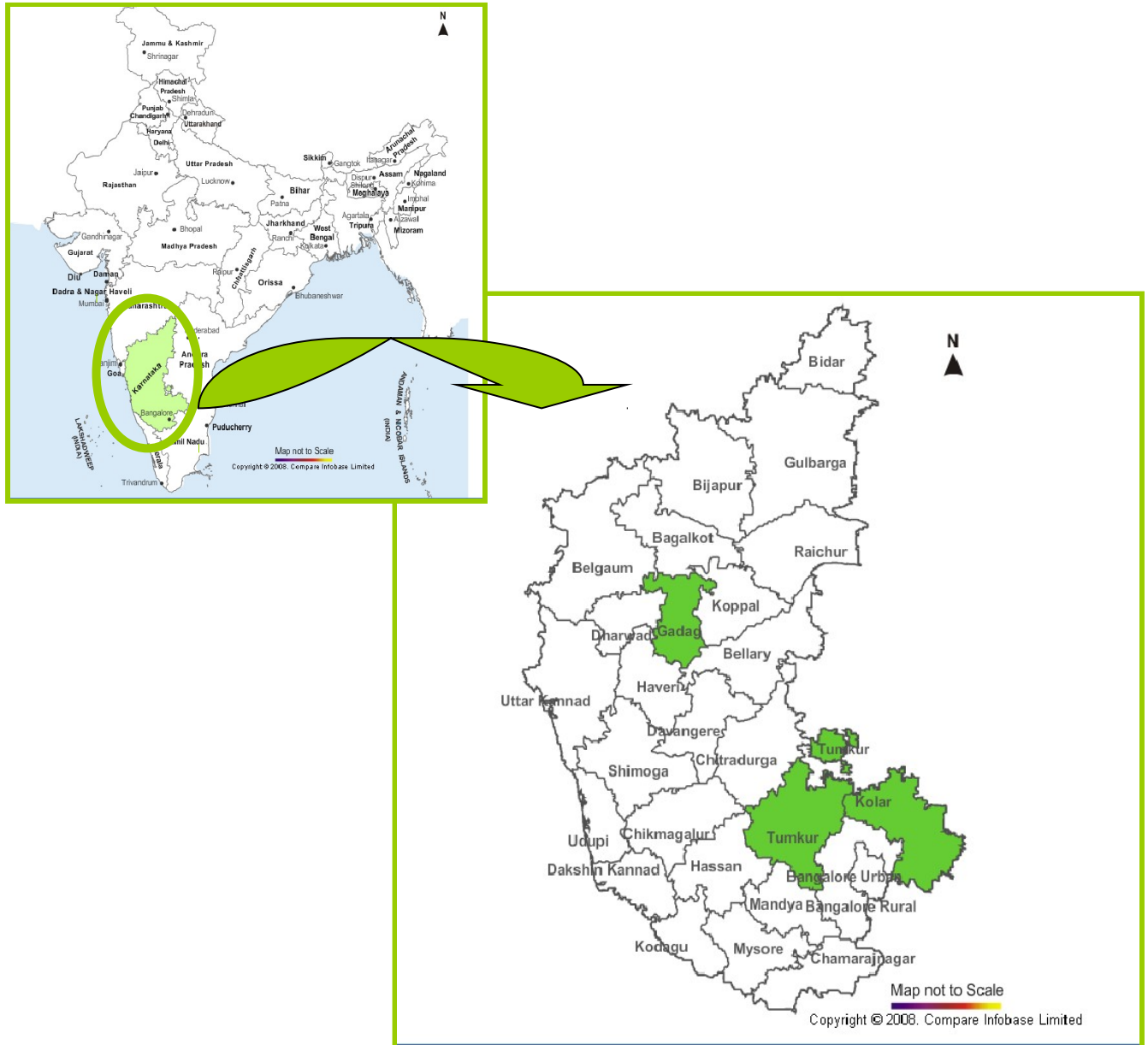


Figure 1.1. Project area (villages in the three highlighted districts) of the Sachetana D/W Plus project in Karnataka, India

¹ GAA is for German Agro Action which is funding the Sachetana GAA project.

The project has supplemental funding from Arghyam. As part of the funding requirements of Arghyam, specific project activities were added. This has resulted in the Sachetana D/W Plus² project. The aim of the project is to undertake both, household and field level activities to improve the availability of better quality water as well as mitigate the effects of high fluoride intake over a period of 5 years, starting in 2006.

The paper is a comparative study of different project activities. It is meant to be a mid-project assessment for Arghyam. The paper work is based on a field survey, the progress reports, the water quality and quantity data³ and interviews with the field officers. The key objectives of this study are⁴:

- To understand the decentralized fluoride mitigation strategy adopted in the project villages,
- To analyze the existing data on water levels and water quality of the first phase villages in relation to the project efforts,
- To analyze the equity and sustainability (environmental, technical, financial and institutional) issues in the Sachetana D/W Plus project and suggest remedial measures to overcome bottlenecks, if any, and,
- To draw a comparative study of the Sachetana D/W Plus components versus the original project.

² For the purpose of the study Sachetana D/W Plus refers to Sachetana D/W project and the additional aspects - the project being implemented currently. Only for comparison would the term Sachetana D/W be used.

³ The progress reports and the water quality and quantity data which will be studied are for both the Sachetana GAA and D/W Plus projects.

⁴ As stated in the letter of understanding with Arghyam.

2 Literature Review

Endemic fluorosis is a worldwide problem. The following section gives a brief overview of the spread, causes and symptoms of fluorosis on a global scale and in India.

2.1 Fluorine in the Surroundings

Fluorine is the most electronegative element and occurs in bound form in nature because of its high reactivity. Natural background levels in air are of the order of 0.5ng/m^3 (WHO, 2004). Anthropogenic emissions can increase the level of fluoride in the atmosphere. Fluorine in the environment is also found as fluorides in variable concentrations in soil and water. Trace levels of fluoride are found in water, with greater concentrations associated with underground water that is dependent on the mineral composition of the surrounding rock (Ayoob & Gupta, 2006, WHO, 2004, 2006).

Fluorite (CaF_2) is a common fluoride compound. It has low solubility in water. Fluorides are found as components of some major minerals such as fluorspar, rock phosphate, cryolite, apatite, hornblende, mica, etc. (WHO, 2006). Water solubility of fluoride is dependent on the concentration of calcium ions, bicarbonate ions and pH of the system⁵, such that calcium ions reduce the solubility of fluoride while higher values of the latter two increase the dissolution of fluoride (Ayoob & Gupta, 2006, WHO, 2006). The WHO, 2004 study states that fluoride levels in groundwater do not normally exceed 10 ppm, but much higher levels have been reported from some parts of the world, including India.

2.2 Fluoride and Health

Fluoride has both beneficial and detrimental effects on human health. Studies as early as the 1930s determined that the uptake of optimal amounts of fluoride in water supply helped protect teeth against caries without staining them (NIHFW, 2007). As reviewed by Ayoob & Gupta, 2006, fluoride concentration below 1 ppm in drinking water is beneficial as it helps prevent dental caries, however above 1.5 ppm it can be detrimental to health. Even though the importance of fluoride in formation of caries resistant enamel has been recognized, conclusive evidence proving that it is essential for human health has not been demonstrated unequivocally and there is no data on the minimum nutritional requirement of fluoride (NIHFW, 2007, WHO, 2004). Excess fluoride in the body results in a condition called “fluorosis” which has skeletal and non-skeletal manifestations. Chronic fluoride poisoning is more common than acute fluoride poisoning (NIHFW, 2007).

Fluoride intake in the human system can occur both from particles in air and from oral uptake. The absorption of inhaled particles is dependent of the size of the particle and their solubility. The largest single-contributor to daily intake of fluoride is drinking water, for the majority of cases however (WHO, 2006). The soluble fluoride compounds in the gastrointestinal tract are absorbed rapidly, resulting in similar levels of fluoride in the blood as the source water. The presence of high concentration of cations relative to

⁵ Refer Ayoob & Gupta, 2006 for details of the geochemistry of presence of fluoride in groundwater.

ingested fluoride, such as magnesium, calcium and aluminum, can considerably reduce the concentration of fluoride absorbed (Ayoob & Gupta, 2006, McGill, 1995, NIHF, 2007, WHO, 2004, 2006). About 99% of the fluoride in blood is deposited in teeth and bones in the hydroxyapatite matrix where it replaces the hydroxyl ions (Ayoob & Gupta, 2006, McGill, 1995). The incorporation in teeth and blood is reversible, thus when not exposed to fluoride, the fluoride in the tissues is mobilized and excreted from the system. They are removed from the system through urine, sweat and faeces (WHO, 2004, 2006).

Dose, duration of exposure, and other factors such as age⁶, health and diet are important in determining effect of fluoride on individuals. If water is the major source of fluoride, then water consumption of a population would be a good indicator of the exposure to fluoride. As noted in McGill, 1995, in temperate climates, fluoride concentrations less than 2 ppm and 4 ppm in water do not result in dental and skeletal fluorosis, respectively. Such low concentrations in tropical areas can however result in dental and skeletal symptoms of fluorosis because of greater consumption of water - attributable to the climate and nature of work (McGill, 1995, WHO, 2004). Even though water is the major source of fluoride, other sources such as air and food⁷ could be significant in some cases (Ayoob & Gupta, 2006, NIHF, 2007, WHO, 2006). It has also been found that populations in higher altitudes retain a greater part of the fluoride absorbed by the system and thus have a slightly different correlation between fluorosis and fluoride exposure of the populations (WHO, 2006).

Epidemiological studies indicate that low levels of fluoride are helpful in preventing dental caries (WHO, 2004). However, larger consumptions can also result in negative effect on tooth enamel thus resulting in dental fluorosis and in more severe cases, skeletal fluorosis. There are also non-skeletal effects of fluorosis on interaction of soft tissues and organs with fluoride. Symptoms include gastrointestinal problems, muscular weakness⁸, neurological manifestations, allergic manifestations, cardiac problems and male infertility as well as problems in pregnancy (Ayoob & Gupta, 2006, NIHF, 2007, Rao, 2003).

The physical symptoms of dental fluorosis include yellowish/brownish discoloration of teeth and in more severe cases chipping of the edges of teeth (Ayoob & Gupta, 2006, McGill, 1995, Rao, 2003). Children are more susceptible to this form of fluorosis and can eventually become edentulous on chronic exposure (Ayoob & Gupta, 2006, NIHF, 2007, WHO, 2006). Skeletal fluorosis occurs on prolonged accumulation of fluoride in the skeletal system and results in fragile bones and joints. Affected people experience pain in joints such as neck, shoulder, knee and hip, thus making movement tougher and more painful (Ayoob & Gupta, 2006, NIHF, 2007, Rao, 2003, WHO, 2006). Effects on costosternal and costovertebral joints can limit chest expansion (McGill, 1995). Severe cases of skeletal fluorosis can also experience neurological problems because of mechanical compression of nerve roots and the spinal cord by osteophytes manifesting in

⁶ Children have been found to be more susceptible to fluoride intake.

⁷ Food items rich in fluoride include fish and tea (Ayoob & Gupta, 2006, NIHF, 2007, WHO, 2006)

⁸ The destruction of actin and myosin filaments in muscle tissues results in depletion of muscle energy (Ayoob & Gupta, 2006).

the form of weakness in lower limbs and difficulty in walking (McGill, 1995). Ayoob & Gupta, 2006 and McGill, 1995, note that the incidence of dental and skeletal fluorosis in endemic areas has a linear relationship with the fluoride concentration in drinking water and the exposure rate.

2.3 Fluorosis - International Scenario

Fluorosis is endemic in at least 25 countries around the world as per a 1999 survey (NIHFW, 2007, UNICEF, 1999) (refer Figure 2.1) and is particularly prevalent in the mid latitudes (Ayoob & Gupta, 2006). Groundwater with fluoride concentrations is found in all the continents and the problem of fluorosis is more acute in areas where people directly rely on groundwater as the source of drinking water. The intensity of fluorosis is particularly high in China and India (Ayoob & Gupta, 2006).

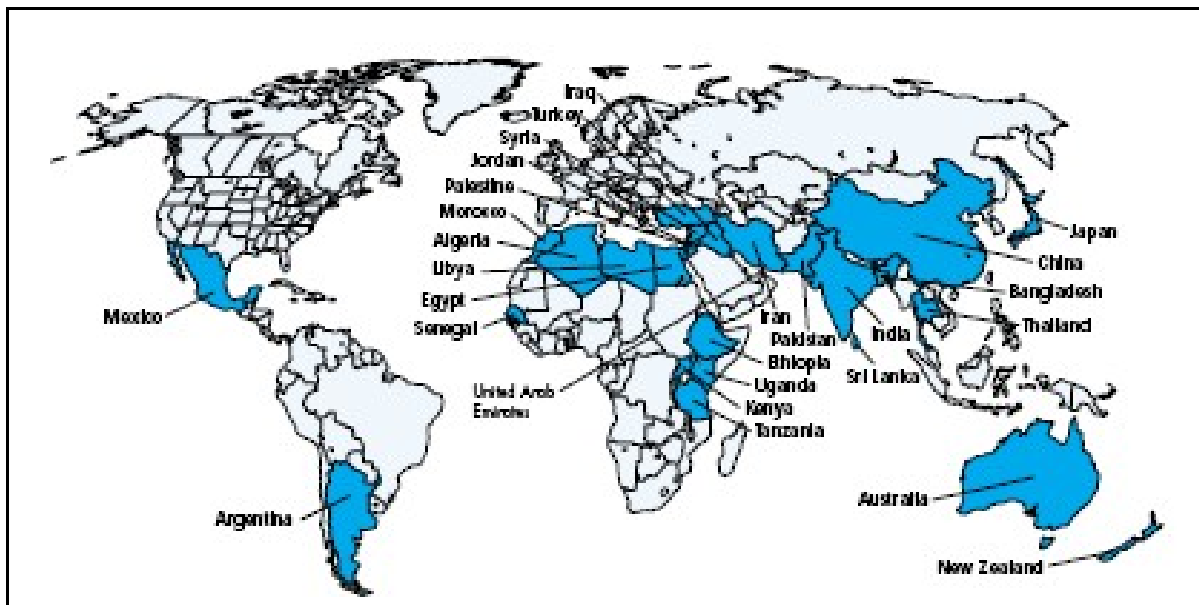


Figure 2.1 Countries with endemic fluorosis because of high fluoride in drinking water (UNICEF, 1999)

2.4 Recommended Fluoride Levels

WHO conducted a review of the problem of endemic fluorosis in 1984 and determined a guideline value of 1.5 ppm of fluoride in drinking water at which dental fluorosis would be minimal. The guideline level was re-assessed but was found to be correct. The WHO guidelines for fluoride in drinking water explicitly state that where the intakes of fluoride are about 6mg/day or more, a standard lower than 1.5mg/l should be adopted. The value is not meant to be a “fixed” value and needs to be adapted to local situations (climate, volume of water intake, fluoride uptake from other sources, and other factors) (WHO, 2006). The guidelines do not mention the minimum value of fluoride that should be present in drinking water to prevent from dental caries. The need to fluoridate water and dental hygiene products is being debated internationally in lieu of the negative effects of

excess fluoride intake as these are considered as additional sources of fluoride in endemic areas (Ayoob & Gupta, 2006, Susheela, 2007).

2.5 Prevention of Fluorosis

Fluorosis in its more severe cases (physical manifestations of dental fluorosis and skeletal fluorosis) cannot be treated and reversed (Ayoob & Gupta, 2006, Susheela, 2007). There are three main ways to mitigate fluorosis (Meenakshi & Maheshwari, 2006, Susheela, 2007, WHO, 2006):

- Using alternate sources of water,
- Improving nutritional status of population at risk, and,
- Removing excess fluoride from drinking water.

Reducing the intake of fluoride is recommended and thus identification of alternate source with low fluoride is important. Most studies recognize the need to determine alternate sources of water with lower fluoride concentrations when water is the primary source⁹. Alternate sources of water include water from another water body that has low fluoride content or rainwater harvesting where possible. Where alternative sources are not available, defluoridation of water is recommended. The nature of nutrient uptake is also important in determining the effect of ingested fluoride, thus raising awareness about balanced diet is also an important mitigation strategy (Ayoob & Gupta, 2006, Susheela, 1999, 2007, WHO, 2006).

Various methods for defluoridation have been developed including the use of bone charcoal, activated alumina, contact precipitation, Nalgonda technique, and clay for removal of fluoride in the water¹⁰. These methods rely on precipitation of fluoride ions and its adsorption/exchange. The WHO recommends the consideration of scale of implementation, technical and financial feasibility, and social setup for the choice of method of defluoridation in a given area (Rao, 2003, Susheela, 2007, WHO, 2006). The following chart presents the decision chart for fluoride mitigation as recommended by WHO.

⁹ The report of WHO on fluoride in drinking water states that many initiatives at defluoridation of water have resulted in failure and thus switching to an alternative source is recommended as the first mitigation measure.

¹⁰ For a detailed understanding of each of the techniques and feasibility of implementation refer to the WHO document on Fluoride in Drinking Water, 2006 and Meenakshi & Maheshwari, 2006,.

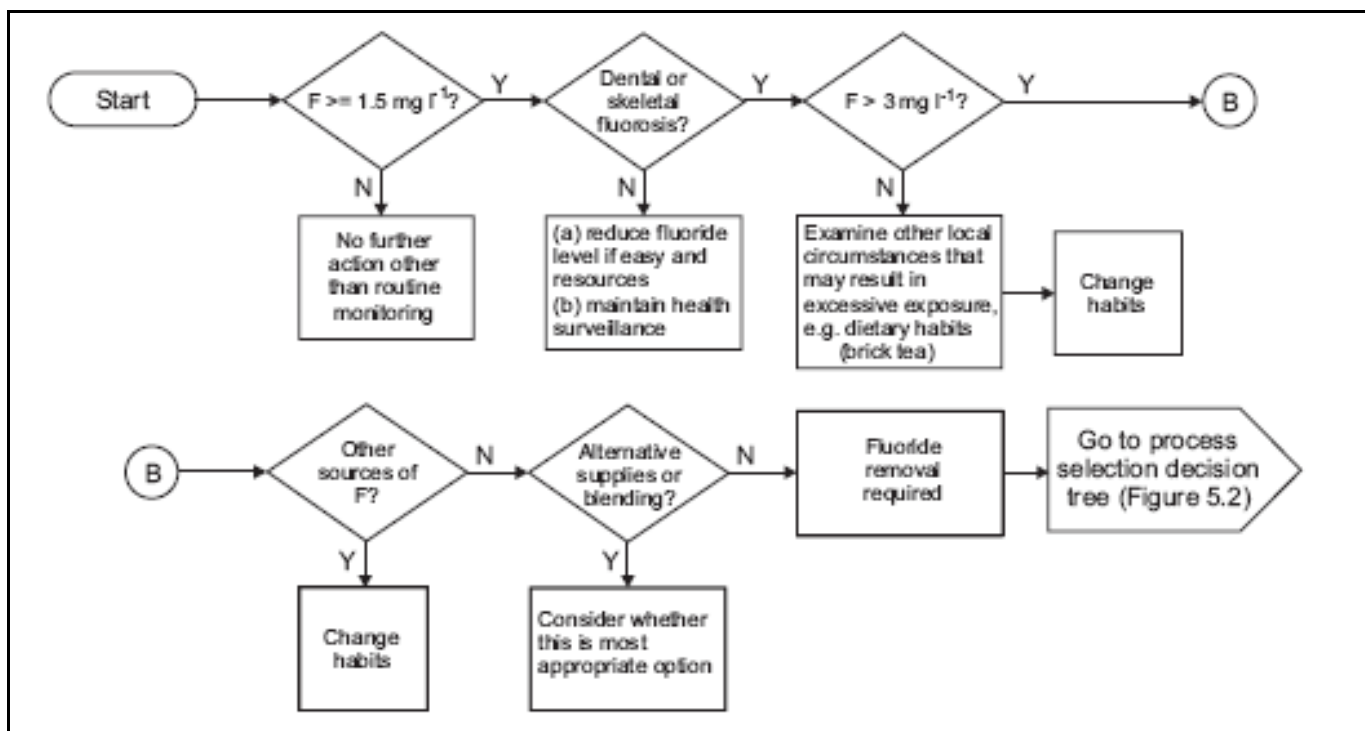


Figure 2.2 Decision tree for mitigation action where elevated fluoride concentrations occur in the water (WHO, 2006)¹¹.

2.6 Fluorosis – Indian Scenario

Fluorosis in India has been reported since the 1930s. The prevalence of fluorosis is on the rise, with about 62 million people in 19 of the 35 States and Union Territories affected with dental, skeletal and/or non-skeletal fluorosis (GoI, 2007, NIHFW, 2007)¹². This is attributable to both geologically high fluoride endemic areas and excess groundwater withdrawals (Ayoob & Gupta, 2006, GoI, 2007, NIHFW, 2007, Meenakshi & Maheshwari, 2006, Susheela, 1999). An estimation of the number of people affected or at risk in India is difficult to estimate because of lack of a comprehensive survey on dental fluorosis in all the villages and difficulty of sampling the groundwater quality in the many handpumps in the villages in the country (WHO, 2006).

Much of the fluoride intake in India is attributable to drinking water, which is withdrawn from deep bore wells. Nearly 90% of the population in the country uses groundwater for drinking and domestic purposes and is thus at risk of fluorosis in areas of high fluoride concentrations in the water source (GoI, 2007). Studies also show that poverty and malnutrition are important considerations for incidence and severity of fluorosis (Ayoob & Gupta, 2006).

The prevalence of endemic fluorosis resulted in adoption of a narrower range of acceptable fluoride concentration in drinking water. The “desirable limit” of fluoride in

¹¹ For Figure 5.2 as mentioned in the figure please refer the original text.

¹² <http://cgwb.gov.in/documents/GROUND%20WATER%20QUALITY%20SCENARIO%20IN%20INDIA.pdf>

drinking water was standardized at 1.0mg/l and extends this limit to 1.5mg/l where alternate source of water is not available for the communities. The standards also mandate a minimum level of 0.6mg/l of fluoride in the drinking water (BIS, 1992, Susheela, 2007).

A national program to control fluorosis, the Fluorosis Management Program, was started in 1986-87. Its main objectives were to generate awareness, provide technology/strategy for fluoride removal and provision of safe drinking water on a sustainable basis as well as emphasizing the need to consume calcium, vitamin C and E and an anti-oxidant rich diet to minimize the effects of high fluoride consumption in rural and semi-urban areas. Ministry of Rural Development at the national level was the nodal agency for the program. The program was implemented by the State Rural Drinking Water Supply schemes implementing agency and Public Health Department. As part of the activities under this initiative epidemiological and water quality surveys¹³ were undertaken in the country and a move to teach medical practitioners about fluorosis was also initiated. The program outlines the actions to be undertaken in villages: based on the level of fluoride present in their drinking water (refer Appendix A). The actions recommend the use of alternate sources of water (from nearby villages or rainwater), and in the absence of these options to treat the water with high fluoride concentration either with activated alumina or the Nalgonda technique¹⁴ (Susheela, 1999, 2007, WHO, 2006). Check dams have been built in some parts of the country in order to increase the recharge of groundwater. The WHO report (2006) states that this mitigation measure has successfully reduced fluoride concentrations in groundwater for over 50% of the cases¹⁵.

Susheela, 2007 challenges the prior notion of drinking water being the main cause of fluorosis in the country. She states that for 40% and 20% patients of fluorosis in the country food products¹⁶ and dental products/drugs/industrial emissions respectively are the cause of fluorosis, leaving only 40% for whom it can be attributed primarily to drinking water¹⁷. She emphasizes the need to address the additive effects of different sources of fluoride for an effective fluorosis mitigation strategy. The same report also

¹³ The ion selective electrode method to determine the levels of fluoride in drinking water source is the recommended method for the program. The government has equipped laboratories around the country with the ion meter and requires of testing of water from drinking water sources in the area.

¹⁴ The activated alumina technique should be avoided in case of high alkalinity and the Nalagonda technique should be avoided where the Total Dissolved Solis (TDS) and hardness of the source water are high.

¹⁵ Bhagvan & Raghu, 2004 presents a case study where which shows that the use of check dams has been successful in reducing the groundwater concentration of fluoride which has been correlated with the health of the community in Andhra Pradesh. A similar study showing the failure of check dams as mitigation measure could not be found in my search.

¹⁶ The author has identified different food sources in the country that have high fluoride concentrations and thus should be included in the awareness camps for affected people to decrease their intake of fluoride.

¹⁷ It is important to note here that this statistic is for the reported patients of fluorosis only and may be biased by the unreported cases.

notes the importance of early detection of fluorosis¹⁸ as it is possible to reverse the symptoms in the early stages, thus making the mitigation strategy more effective.

2.7 Fluorosis - Karnataka

In the State of Karnataka, majority of the households rely on groundwater for domestic consumption. Scarcity of water and poor quality are both important concerns for the State government. Over-exploitation of groundwater has accentuated this problem (refer Appendix B for district wise assessment of water quality problems in the State) (Puttaswamaiah, 2005). The prevalence of high fluoride concentrations in Karnataka was first brought to light by the Department of Mines and Geology, Karnataka (Ziauddin, 1974). High fluoride concentration in groundwater is a major problem for 14 of its 29 districts. This has been attributed to geographical and geological characteristics as well as excess groundwater withdrawal rates in the State (Puttaswamaiah, 2005).

Further studies on prevalence of fluorosis were done in Mundargi taluk^{19,20} and other areas of Dharwad District (including the present day Gadag District). These showed that the problem was prevalent in areas beyond Mundargi as well (Ziauddin, 1974). The area in Dharwad district with endemic fluorosis has a geological base of biotite gneiss traversed by dolerite dykes with amphibolites as restites (Ziauddin, 1974). Though the same study also states that the exact source of fluoride has not been determined, but some experts state that fluoride replaces the hydroxyl in hornblende and biotite, which is then released on weathering which makes the geological connection likely (Ayoob & Gupta, 2006, Ziauddin, 1974). The study also quotes a researcher in stating that over 80% of the population in two villages in Gadag district (Kalkeri and Virupapura²¹) suffered from either dental or skeletal fluorosis or both. A recent assessment by the Rural Development and Engineering Department, Karnataka reports that about 36% of the habitations in Gadag district are affected by high fluoride concentrations.

The following section describes the extent of the problem in the project area in more details.

¹⁸ Early detection can be achieved by increased awareness in the public, medical fraternity about the symptoms of fluorosis, and, water quality monitoring.

¹⁹ The study area for this report is part of Mundargi taluk, Gadag district.

²⁰ A taluk (Block) refers to an administrative sub-division of a District in a State in India.

²¹ These villages are part of the project area for this study.

3 Project Area

This section defines and describes the study area (a sub-section of the project area) for the report. It gives a general description of the district and study area specifically (where possible) to explain the physical and socio-economic background of the project area.

3.1 Defining the Study Area

For the purpose of this study, the focus will be on the Sachetana GAA and Sachetana D/W Plus projects in Mundargi taluk in Gadag district (refer Figure 3.1).

- Sachetana GAA is a poverty reduction project based on natural resource management. It is being implemented in 9 villages in the taluk in 2 phases. The project was started in April, 2004 in Virupapura village by BIRD-K (with help from Department for International Development, UK) and has been extended to the remaining villages with funding support from German Agro Action (GAA). The second phase (April, 2007- April, 2009) is currently underway in 4 villages (refer Table 3.1 for details of the villages). The project addresses livelihood aspects and the availability of safe, reliable drinking water is also one of its components (refer Appendix C for details of project activities).
- Sachetana D/W Plus is a 5 year project that was started in April, 2006 and focuses on fluorosis mitigation in the project area. It covers 60 villages - 15 in each of the following taluks (refer Figure 1.1):
 - Gadag District – Mundargi taluk
 - Kolar District – Bagepalli taluk
 - Tumkur District – Pavagada and Sira taluks

The following study will concentrate on the overlapping area for the two projects – Mundargi taluk²² in Gadag. All 15 villages under the Sachetana D/W Plus project will be studied (refer Table 3.1).

²² The comparison between the two Sachetana projects as well as data availability over a period of time on water levels restricts the study to Mundargi taluk in Gadag district. The other two districts of the Sachetana D/W Plus project (Kolar and Tumkur) will not be considered for the study.

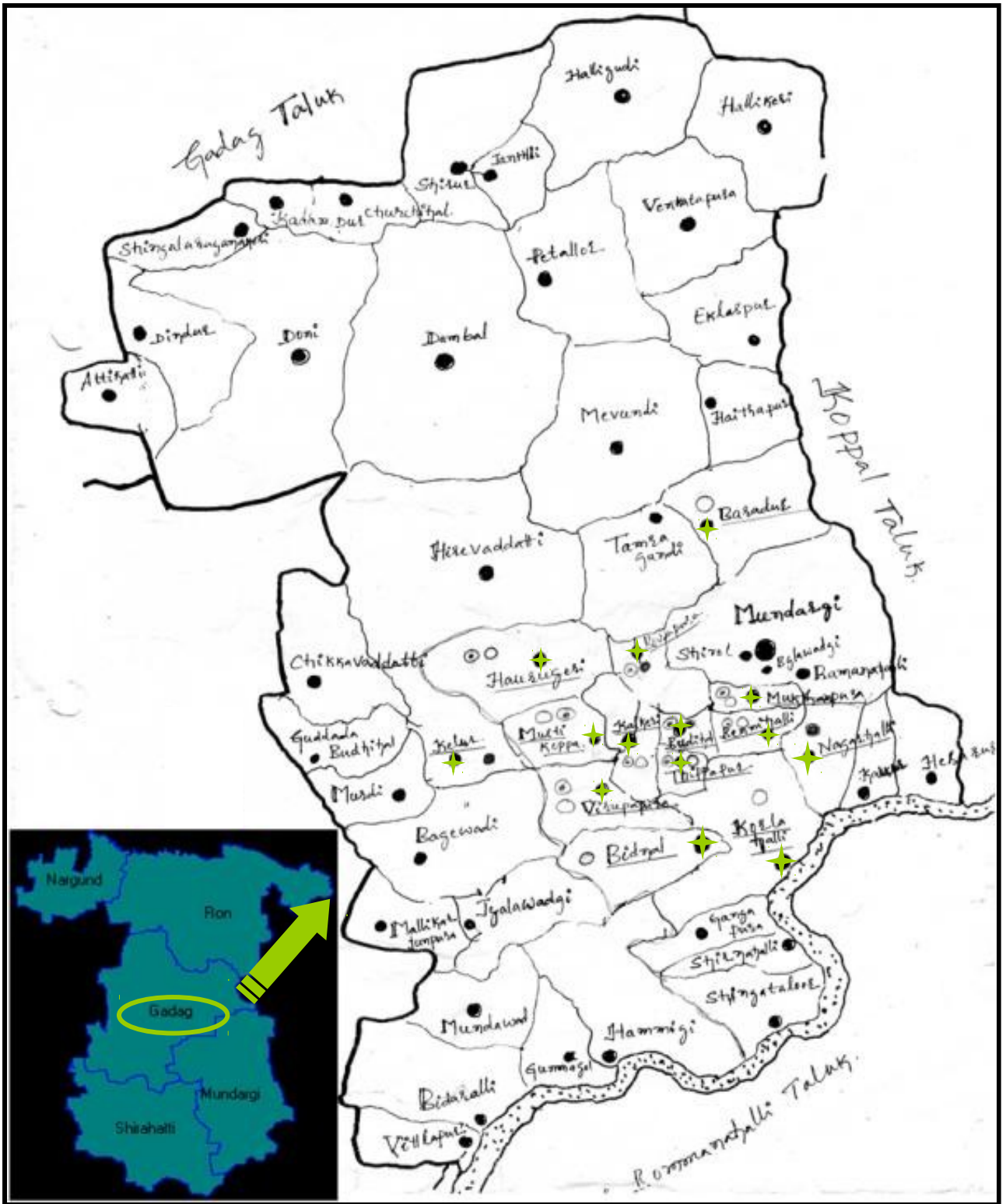


Figure 3.1 Map showing the villages in Mundargi taluk – the project villages have been marked with a green star (the inset shows the location of the five taluks of Gadag district)

Table 3.1 Project area categorization

Gram Panchayat	Village	Sachetana GAA		Sachetana D/W Plus			
		Surveyed Villages**	Phase I Apr '04-'07	Phase II Apr '07-'09	Single Phase (Apr, '06-'11)***		
					2001	2004	2006
Kalkeri	Kalkeri	x	√		√		
	Mustikoppa	x	√		√		
	Virupapura*	x	√		√		
	Virupapuratanda*	x	√		√		
	Tippapura	x	√		√		
Koralahalli	Koralahalli	x					√
	Bidnal						√
Harugeri	Haurugeri	x		√		√	
	Budihal	x	√			√	
	Basapura	x		√		√	
	Kelur	x					√
Hesarur	Nagarhalli						√
	Bennihalli	x		√		√	
	Mukthampura			√		√	
Mevundi	Baradur						√
Total No. of Villages	15	11	5*	4	5	5	5

* Virupapura and Virupapuratanda have been categorized as a single village, Virupapura, under Sachetana GAA thus making total villages in that project as 9, with 5 1st Phase villages and 4 2nd Phase villages

**Surveyed villages refers to the 11 villages that were visited during a field trip taken for the study

***Sachetana D/W Plus project has not been divided into different Phases. Instead, project implementation has followed the suit from the progress made in villages already under the Sachetana GAA project. Thus the villages have been divided based on the year in which project work was undertaken in them and since when water quality data is available for them (2001, 2004, and 2006).

3.2 Geography

Gadag District was established in 1997 with 5 taluks from Dharwad District²³. The study area of the 15 villages in Mundargi taluk covers about 216 km² (24% of the taluk area).

The landscape in these villages is classified by rolling topography with gentle slope. It is classified under the Northern dry zone based on agro-climatic classification and has an average annual rainfall of 490 mm. It has three different seasons: summer (March-May), rainy (May-October) and winter (November-February). Rains might also be experienced in April. Peak rain is experienced in the months of May, June, September and October. The average number of rainy days is 35-40 (BIRD-K (GAA), BIRD-K, 2005).

There is little vegetative cover and the soils are highly degraded. The soil depth ranges from 2-3 feet. Most of the area has red sandy soil with gravel. There are small patches of black sandy soil too. It is drought prone with scarcity of drinking water and irrigation water. Lesser than average rainfall resulted in drought in 2001-2003 (refer Appendix D for rainfall data for the area). The soil has high concentrations of fluoride, resulting in high fluoride concentrations in the groundwater. The project proposal for Sachetana D/W Plus states that the fluoride concentration during the rainy season is about half of the fluoride concentration in the summers.

²³ Official site of Gadag district (<http://gadag.nic.in/>)

3.3 Livelihoods

Agriculture is the main occupation of the people in the area and is largely rainfed. The River Tungabhadra flows through part of the cluster of villages but is hardly used for irrigation or drinking water purpose²⁴. The months of May to December are agriculture intensive and a large number of landless people area employed as agricultural labourers during this period. Major crops grown in the area are:

- Food crops: Jowar, Cow pea, Green gram, Horse gram, Wheat, Bajra, and Maize.
- Cash crops: Sunflower, Cotton, Groundnut, and Bengal gram.
- Plantations: Neem, and Eucalyptus.

Most of the farmers have been practicing mono-cropping on their land. The Sachetana GAA project has introduced the concept of mixed faming in the area. The new practice has been adopted by many farmers along with different soil conservation measures, introduced as part of the Sachetana GAA project.

Other modes of employment in the study area include trading, construction, and small business activities (carpentry, bangles making, hotel, etc.). Agricultural productivity is low and people have to migrate to nearby towns in search of work during the off-season. Animal husbandry is also a source of income generation. Rearing of buffaloes, cattle, goats, sheep and poultry are common. Recently, construction work for wind power establishments in the area as well as construction work for project activities has also been a source of income for many households.

3.4 Economic Status

Marginal and small farmers form the major percentage of the population in the area. Most of the people have small land holdings ranging between 1 and 3 hectare of land area (BIRD-K, 2005, BIRD-K (GAA)). Many farmers rely on money lenders for purchase of seeds and fertilizers in seasons following a drought or poor yield period. With the recent drought in 2001-2003, a number of farmers were in debt of these money lenders when the Sachetana GAA project was started (BIRD-K (GAA)). The crop yield in these areas has also been low, attributable to both high erosion rates and lack of awareness of farming practices in the farming communities, resulting in greater dependence on the money lenders. Small land owners and the landless have been reported to have a lower social standing in the villages (BIRD-K, 2005).

The literacy rate for the area is also low. The average literacy rate for Mundargi taluk is only 38.5% - this is much lower than the State average of 67%. The female literacy rate (25%) is about half of the male literacy rate (51%) in the taluk (BIRD-K, 2005).

²⁴ The Government did take the initiative of using the river water as an alternate source of low fluoride water to the population. However it was not successful and of the 11 villages surveyed for this study, only Bennihalli still has considerable use of the River water supplied by the government.

3.5 Health

All of the fifteen villages in the study area have population suffering from fluorosis, though the extent of fluorosis differs in different villages. As per a 1973 study 85% of the male population and 76% of the female population were found to be affected by fluorosis in Mundargi taluk. According to Ziauddin, 1974, the fluoride content in the taluk was found to range between 3.5-7.0 ppm.

As the awareness about the problem of fluorosis and its genesis increased, the Government came up with a scheme to determine alternative and better sources of potable water in and around the area. This included construction of bore wells; however it did not yield any positive results. Hence a new plan was developed which relied on treated water from River Tungabhadra. The implementation of the project however resulted in poor quality (pathogen, silt, etc.) water reaching households, as the water treatment plant near Korlahalli was not operationalized because of stated dispute between the villagers and the officials. Hence, neither mitigation measure helped solve the problem of high fluoride in drinking water (Rajashekhar, 1983).

Since then, the Sachetana GAA project is the first project in the area that has tried to find a solution to the problem of high endemic fluoride concentrations in the groundwater and provision of alternate source of drinking water for the population. This has been followed by the Sachetana D/W Plus project which tries to address the problem on a larger scale and in a more exclusive way.

4 Sachetana D/W Plus Project

The following section describes the action plan and goal of the Sachetana D/W Plus project.

4.1 Background

The Sachetana D/W project was initiated by the State government on the lines of work done by BIRD-K in the Sachetana GAA project villages. BIRD-K is the sole implementing agency for the project. In 2006, Arghyam was also approached for additional source of funding for the project (refer Appendix E for the roles of the different organizations in the project). This resulted in incorporation of and emphasis on some project activities with the additional funds. Based on the baseline survey and the project proposal for the Sachetana D/W Plus project, some key issues that have been considered during project design and implementation by BIRD-K are listed here.

- Low productivity of land,
- Low and unreliable rainfall,
- Rainfed agriculture and dependency on groundwater as a source of temporary irrigation in summers,
- High fluoride concentrations in the groundwater resulting in endemic fluorosis,
- High incidence of fluorosis in most villages, with skeletal manifestations in the older generation,
- Low groundwater level with scarcity of water, particularly in summers,
- Rolling topography,
- Lack of technical know-how about improved agriculture,
- Lack of year round employment,
- Diminished work capacity of the work force, and,
- Low level of nutrition.

4.2 Target Population

For the project purpose, the target population has been identified as all the people suffering from fluorosis. The project action plan makes special economic available only for the economically weaker sections of the population (BIRD-K, 2005). The target group had been involved in a series of dialogues and discussions to determine their priorities for required changes in the area. The immediate priorities were all related to the problems associated with water in the area – improving groundwater situation, availability of safe drinking water and curing the fluorosis already prevalent in the population.

4.3 The Project – Goals and Action Plan

Based on the problems in the area, there are two main objectives of the Sachetana D/W Plus project:

1. Ensuring the availability of safe drinking water for the population in the project area through rainwater harvesting and improved availability of groundwater, and,
2. Improving quality of life for 1,400²⁵ families in the 15 project villages in Mundargi taluk, within the project period.

The project is being implemented in a single phase, from June, 2006 to May, 2010, for the target population. It is being funded by the State Government, Arghyam and the participants. The participants contribute about 23% of the total project costs (excluding the funding provided by Arghyam). The activities aim at improving the availability of low fluoride concentration water, increasing awareness as well as documenting the work being undertaken and its impacts. The key activities are:

1. Construction of Water Harvesting Structures for
 - o Roof top rainwater harvesting (for domestic consumption)
 - o Artificial rainwater harvesting (to increase recharge to dilute groundwater)
 - o Recharge of borewells (to dilute groundwater)
 - o Direct aquifer recharge (to dilute groundwater)
 - o Farm ponds (to increase recharge to dilute groundwater)
2. Water Purification (Defluoridation)
 - o Slow sand filters
 - o Chemical disinfection of water sources
3. Institution and Capacity Building
 - o Water quality monitoring training and awareness activities
 - o Formation of Self Help Groups (SHGs)

Arghyam included additional activities, as well as laid emphasis on certain others:

1. Fluorosis awareness camps for school children,
2. Awareness camps and exposure visits for the SHG women and production of posters and publicity material to raise awareness,
3. Monitoring fluoride content in drinking water and studying the impacts of measures taken under the project,
4. Clinical trials for treating the fluorosis affected population with alternate systems of medicine including homeopathy, and,
5. Geo-hydrological studies for understanding the cause of fluorosis and to assist in effective recharge process for diluting the fluoride in the aquifers.

The project is being implemented by a group of project officers who stay in the field. The team is required to undertake a systematic micro-planning for construction of their RWH structure in each of the selected households. The family members are required to actively participate in this planning process. The project envisages to be environmentally, financially, technically, and institutionally sustainable in its design. The decentralized approach with involvement of the participants in the planning and implementing phase as well as institutionalization of village development committees is aimed at ensuring the post-project period survival and sustainability of the project works.

²⁵ The number of families was chosen at the time of drafting the project proposal and was stated to be amenable to change based on the results of the baseline survey during the course of the project.

5 Methodology

The following section describes the different sources of information and methodology adopted for analyzing it in order to achieve the objectives of this study.

5.1 Project Documents

Baseline project documents as well as the monthly progress reports (for Sachetana GAA and Sachetana D/W Plus) have been used to study the progress of the two projects as well as to assess the emphasis on different activities and the sustainability (financial, institutional, environmental and technical) aspects. The progress reports for the Sachetana GAA project were available on a semi-annual basis. The progress reports for the Sachetana D/W Plus project on the other hand were available on a monthly basis, containing the project status in the three taluks.

5.2 Field Visit and Interviews with Field Officers

A field visit (28th June-4th July, 2007) was undertaken to understand the project site for the Sachetana D/W Plus project in Mundargi taluk. 11 of the 15 project villages were selected for site visits (refer Table 3.1). The selection process was an informed process, based on discussions with the project implementation team at Kalkeri. The villages cover the diversity of the region with respect to the project activities undertaken (awareness campaigns, self help group formations, model school project, etc), physical attributes (soil type, topography, etc.), and socio-economic parameters (communities in the village, food habits, etc.). Similarly, during the site visits care was taken to interview people and groups so that income variation, social status, house type, livelihood practice differences, gender, etc. were captured. It was however not possible to capture all the mentioned variations at each site. The details of the field interviews have been given in Appendix F.

Discussions with field officers during and after the field visit have been used to get their perspective of the two projects, the difficulties in implementation in field and suggestions for improving the sustainability of the project works, as applicable.



Figure 5.1 A photograph of the project officers at the Kalkeri office of BIRD-K (From left to right, starting at the top row: Rajendra Prasad, Rafik Sab, Venkan Goudar, Manjunath, Mr. Veerana, Mr. Patil and Mr. Gudugunti (Project Incharge))

5.3 Water Quality Data

Water quality data for the project villages has been examined to determine the levels of fluoride in different water sources and examine changes in the levels that may have occurred in view of the project activities. Various sampling points, including bore wells, open wells, farm ponds, filtered water, and harvested rainwater, have been considered for fluoride concentration determination. The stated frequency of measurement was once every 3 months. The sampling frequency however varied over time, with more regular assessment in 2007. The samples collected were sent to laboratories (Bangalore, Bagalkot and Davanageri) for fluoride concentration measurements.

The measurement of fluoride concentrations did not start simultaneously in all the project villages, but follows the pattern in which work was started in them. Thus, the 5 villages of Kalkeri Gram Panchayat (Virupapura, Virupapuratanda, Kalkeri, Mustikoppa and Tippapura), all part of the start of both the projects have measurements starting in 2001 and 2002. Budihal, Basapura, Bennihalli, Harugeri and Mukthapura have observations starting in 2004. The remaining 5 villages, Kelur, Koralahalli, Bidnal, Nagarhalli and Baradur, have been monitored only starting in 2006. These three clusters of villages have been referred to as Group 1, 2 and 3 for the purpose of water quality data analysis, where required.

Field replicates were collected for some of the samples to determine the precision of concentration measurement. In the data set, though a large number of sampling locations had been selected for the first 5 villages, not all of them were continuously sampled. Some of the sampling points have been discontinued over the period of time, while most other points have irregular collection periods.

The data has been studied for variations over timescale and difference in the before and after concentrations of fluoride relative to implementation of project activities.

5.4 Water Quantity Data

The water level data in the project villages has been assessed to understand the effects of the project activities to increase recharge. There is fewer number of sampling points for the water level data in the project area. Three villages, namely, Kalkeri, Virupapura and Mustikoppa, were monitored for water level in 2002, 2003 and 2007. Monitoring has been undertaken in four villages in 2007 – Budihal, Mukthampura, Bennihalli and Basapura. Where there is water level data, the sampling has been done on a monthly basis. However, the period of coverage is small with 3 months in 2003. Sampling has however been regular at the same sampling points in 2007 with consecutive data points starting in March, 2007.

The data set has been analyzed to determine if there has been a significant increase in the water level in the project area from 2002 to 2007. Analysis to determine the relation between water level and fluoride concentrations was not possible because of the limited number of sample points with both values for fluoride and water level available in the same time period.

6 Observations and Analysis

The following section looks at the different aspects of the project as outlined in the previous section. The key observations for each source of information have been listed and analyzed to understand the project implementation.

6.1 Project Documents and Field Visit

The observations and analysis for the project documents and field visit have been combined as they supplement each other. The following section looks at the outputs of the project based on the results of implementation of the Sachetana GAA project since 2004 and the Sachetana D/W Plus project since 2006. The information in the baseline survey has been analyzed to bring out some key points of the project area. The understandings from the study of progress reports and field visit have been compiled into three categories - awareness raising, household rainwater harvesting and field activities²⁶ based on targeted activities of the project. Some of the unintended outputs of these activities have also been mentioned.

Baseline Survey

The baseline survey for the project area covered the social, economic, and health data for the households in villages in great detail. As only some of the surveys had been catalogued at the time of the field visit, survey data only for Group 1²⁷ villages could be analyzed. Here, the economic status of the household villages and the relative prevalence of different types of fluorosis manifestations have been presented.

Economic Profile - The relative presence of landless households and categorization based on income in terms of “Above” and “Below Poverty Line”²⁸ (APL and BPL) is shown in the following table for Group1 villages:

Table 6.1 Economic profile of five villages in the project area

Village	Landless Households		Economic Status
	Total	Percentage	BPL (%)
Kalkeri	238	39	68
Mustikoppa	47	28	83
Tippapura	17	24	88
Virupapura	45	9	98
Virupapuratanda	97	43	78

²⁶ There are no fine distinctions between the three categories as far as observations are concerned. The division has been made to roughly classify the project outputs of the project activities.

²⁷ Only Virupapura, Virupapuratanda, Kalkeri, Mustikoppa and Tippapura have been considered based on availability of the baseline survey data.

²⁸ Rs. 11000/annum is the reference line for categorizing households as Above Poverty Line or Below Poverty Line.

The economic profiling shows that in all of the villages, majority of the people belong to BPL category. The percentage of landless people is relatively much lower, thus there is a fairly large number of poor farmers in the study area.

Prevalence of Fluorosis - The following table shows the prevalence of fluoride in the project villages (except Kelur and Nagarhalli) for the years of 1988 and 2001. The 1988 data set is from an epidemiological study of Mundargi along with two other taluks, and the 2001 data is based on the baseline survey conducted at the start of the Sachetana projects. The data for the remaining villages is being catalogued and hence was not available for this comparison.

Table 6.2 Epidemiological data on prevalence of fluorosis in the villages (percent of population in parentheses)

S.No.	Village	Population Surveyed							
		Total		Non-Skeletal Fluorosis		Dental Fluorosis		Skeletal Fluorosis	
		1988	2001	1988	2001	1988	2001	1988	2001
1	Baradur	1748		109 (6)		1023 (58)		166 (10)	
2	Basapura	477		20 (4)		140 (39)		12 (3)	
3	Bennihalli	909		87 (10)		438 (48)		73 (8)	
4	Bidnal*	1900		37 (2)		169 (9)		92 (5)	
5	Budihal	1348		130 (10)		332 (25)		119 (8)	
6	Haurugeri	1935		70 (4)		72 (4)		105 (5)	
7	Kalkeri	3251	1538	1750 (54)	291 (19)	1772 (55)	330 (21)	943 (29)	267 (17)
8	Koralahalli	3349		140 (6)		629 (27)		87 (3)	
9	Mukthampura	594		87 (5)		184 (31)		7 (1)	
10	Mustikoppa	350	310	62 (18)	2 (1)	168 (48)	56 (18)	79 (13)	35 (11)
11	Tippapura	146	123	52 (36)	1 (1)	87 (60)	0 (0)	20 (14)	23 (19)
12	Virupapura		302		24 (8)		69 (23)		27 (9)
13	Virupapuratanda	794	655	2 (0)	3 (0)	261 (32)	10 (2)	165 (21)	76 (12)

*The data for Bidnal for 1988 includes the data for Bidnal and Bidnaltanda. It thus covers a larger area than present day Bidnal

There were some discrepancies in the survey data for the number of population surveyed²⁹. This could in part be attributable to double counting for the number of household members suffering from particular manifestations of fluorosis (same member suffering from non-skeletal and dental/skeletal fluorosis). Based on the comparison between 1988 and 2001, the incidence of fluorosis in the project villages has actually gone down for majority of the cases. The incidence of skeletal fluorosis has increased for Tippapura. Similarly on-skeletal fluorosis has increased for Virupapura since 1988.

Project Documents and Field Visit³⁰

The various understanding from this analysis have been clubbed under the impact of awareness raising activities, household rainwater harvesting and field activities.

²⁹ The total members of households differed for majority of the households in all the Group1 villages between health and social survey datasheets.

³⁰ As the number of households visited is fairly small the conclusions based on it may not be representative of the study area. In this report, I have tried to supplement it with information from the progress reports and the field officers. It would be helpful to cover these details by another questionnaire survey.

Awareness Raising Activities – Under the plan of action for the Sachetana D/W Plus project numerous awareness raising activities have been mandated to increase the public understanding of the causes of fluorosis and mitigation measures that should be adopted. The following are some of the salient impacts of these activities.

- **Rapport building:** The issue of fluorosis in the area has attracted many researchers in the past resulting in scientific studies which did not bring any relief to the people suffering from fluorosis - project officers cited this as one of the major reasons for difficulty in gaining the confidence of the local population. People were also reluctant in sharing the details of their land holdings and economic status. Interactions with villagers from other villages, where BIRD-K had already done similar work, individual house-to-house interaction during the project activities, coupled with village meetings and exposure visits to previous villages where work had been done, helped in developing the rapport with the communities. (BIRD-K (GAA), Progress Reports)
- **Confidence in success of project work:** “People strongly believe that the area is receiving good rainfall this year only due to the series of farm ponds excavated and the water collected in them. Awareness and desire to excavate field ponds in their fields is increasing”. This quote from the April – June, 2004 progress report for Sachetana GAA project shows the changing attitude of the people from skepticism to enthusiasm towards the project works - farm ponds in particular³¹. The subsequent report also mentions the growing interest of the people in project activities. The project officers have been approached by people from nearby villages to undertake similar project works in their villages - same people who were earlier skeptical of letting any work be undertaken on their lands for fear of losing cultivable area. (Progress Reports)
- **Awareness:** Awareness has been increasing continuously with people demanding farm ponds and rainwater harvesting structures. The multiple uses of farm ponds and immediately visible results made them very popular. People from neighbouring villages, where even awareness activities had not been undertaken were beginning to demand construction in their areas. The campaigning in school has resulted in increased awareness in school children as observed in the 2006 progress report for the Sachetana GAA project. The children interviewed during the field visit were also well informed about fluorosis. (Progress Reports, Field Visit)
- **Balanced diet:** As part of the awareness raising activities, people were taught about the importance of a balanced nutrient intake. Consumption of vegetables was specifically meager at the start of the project. Many farmers have started growing vegetables close to the farm ponds (because of higher soil moisture) for self-consumption and even as an agricultural produce. Many households have consciously included vegetables in their diet. (Progress Reports, Field Visit)

³¹ The understanding of the impacts of project works though seems to be not very clear based on the quote from the progress report.

- Self Help Groups (SHGs): By mid-2005, over 90% of the people, in the project villages where work had begun, were organized in SHGs. Three Gram Vikas Samiti's had also been formed by then. The interviews supported the success and utility of SHGs. (Progress Reports, Field Visit)
- Women's participation: Women have started coming forward and interacting and participating in project activities. This was noticed as early as the end of 2004.
- Homeopathy: A homeopath from another NGO undertook the task of treating 30 villagers suffering from skeletal fluorosis in the project area, in a training camp at Tiptur with a month's supply of free medicine in order to ensure follow-up (2005). However, introduction of homeopathy on a larger scale is just beginning in the project area. Only one of the interviewed households (has a rainwater harvesting structure) had a member using homeopathy. The old woman has been suffering from skeletal fluorosis and has reported considerable benefit since the interventions. (Progress Reports, Field Visit)
- Informing others: Families with the rainwater harvesting structures or field works implemented in their land were enthusiastic about informing others. Most of them were willing to participate in awareness raising activities with BIRD-K officials and share their experiences with villagers from new project villages. (Field Visit)

Household Rainwater Harvesting (RWH) Structures – The construction of rainwater harvesting structures on a household basis has been considered as an immediate relief measure for the fluorosis affected families.

- Health: Houses with rainwater harvesting structures noted a considerable improvement in their health. They were willing to share this water with neighbors, but only during the rainy season. (Field Visit)
- Costs: The interviewed families were agreeable to the idea of paying part of the rain water harvesting structures cost. However, across the board, most felt that the relative contribution needs to be lower for affordability. (Field Visit)
- Maintenance know-how: All the members of households with rainwater harvesting structures were well informed about the maintenance requirements. Both male and female members of the family were well versed in the procedure. If asked whether they would allow us to open the cover of the storage tanks, they promptly refused, explaining that it would contaminate the water. The children in the household were also aware of the hygiene issues. (Field Visit)
- Participation: The families had been involved in the design selection of the RWH structure. They were consulted for the nature (roof top, underground storage, above ground storage, etc.) and location (inside or outside the house) of the RWH structures. Most of the RWH structures that were visited differed from each other. (Progress Reports, Field Visit)
- Government RWH structure: There were cases where the government had also installed rain water harvesting structures (without any input from the owner) in the same village. The structures were in need of repair and not reliable for drinking water purpose. As noted by one of the villagers during the field visit,

these structures were not completed as per plan and information about maintenance was not conveyed properly. (Field Visit)

- Outlook: Most families were enthusiastic about installing the structures in their houses. It was either due to financial constraint, house type or qualification criteria (of the project for selecting a house to build a rainwater harvesting structure) that they had not installed the structure so far. (Field Visit)

Field Works - Field activities such as farm ponds, bore well recharging and trench cum bunds have been undertaken as long term relief measures. They work on the principle of increased groundwater recharge resulting in dilution of fluoride.

- Rise in groundwater table: People had been reluctant to undertake increased borewell recharging methods at the start of the project phase as they were afraid of damaging the borewells. However, observing the benefits (higher land productivity, higher groundwater levels as well as better soil moisture) on farm lands where such measures had been implemented, many farmers have come forward now. As early as the end of 2004, the dried up wells (open and borewells) which were close to the farm pond networks started getting water. Farmers have also reported an increase in the water output of the wells.
- Farm ponds:. They fill up at least twice during a normal rain. This water is being used for both human and animal consumption. Vegetables are being cultivated around the farm ponds. Some families have planned to rear fishes in them. The easy availability of water in farm ponds has also reduced the drudgery of pumping water manually from hand pumps (Progress Reports, Field Visit).
- Farm ponds for drinking water: As early as 2004, people had started using the water in farm ponds for drinking after filtering it. Field ponds were specifically reserved to serve as drinking water source for the people (Progress Reports, Field Visit).
- People's participation in design: In the start of 2005, people had expressed concerns about the intended design of the borewell recharge areas. They were afraid that the boulders, jelly, etc. designed for filtering the water may collapse under the weight of the silt. This point was duly considered and it was decided to incorporate the minor changes in the design of the structure and observe the difference in effectiveness. The flexibility available to households for locating the storage tank allows easier integration of different types of houses, and provides another basis for input from household members (Progress Reports).
- Employment generation: As noted in early 2005, the rate of migration had dropped considerably due to increasing employment of people in the project activities. However, these are not long-term but just an immediate output of the project (Progress Reports).
- Importance of field activities: The villagers recognized both the short term and the long term measures as importance of the filed activities in increasing land productivity and water table. When asked if these activities also contributed to decreased fluoride in groundwater, some of them quoted the change in fluoride from the monitoring study. Most of them recognized that both short and long-

term measures are important aspects of the solution to the fluorosis problem (Field Visit).

Apart from the observations listed above, there were certain unintended outputs of project implementation. These are:

- Government attention and acceptance: The project activities have drawn the attention of the Government agencies locally and at the State level. This recognition has resulted in the project officers participating in the meetings being held by the Panchayats³² to give inputs on similar work that the Government wants to begin in other areas (such as borewell recharge, location of field ponds, and contour bunds). The Zilla Panchayat³³ has also started undertaking similar work in other villages in the taluk in 2006, thus providing means for safer drinking water to the people in areas not covered under the project (Progress Reports).

Box 6.1 Following are some of the quotes from the 2006 Progress Report, which explain the success of the project.

“Project becomes the resource centre for rainwater harvesting and groundwater recharge for development agencies within and outside the State.”

“District authority has adopted farm pond model in their watershed under food work program.”

“Project leader has become the resource person to the Department of Science and Technology, Government of Karnataka for rain water harvesting. He has attended the state level workshop for engineers and the district level workshop for departmental heads as a resource person ”

- Media coverage: The attention by the Government bodies at different hierarchical levels and the visits by their representatives have helped highlight the work being done. The visits have been covered by the press. In the later half of 2004, the State level newspapers covered the problem of water scarcity and quality in Kalkeri as well as the work being undertaken there. As a consequence, people from Basapura were seen coming to Kalkeri to collect water from the farm ponds to supplement their drinking water (Progress Reports).
- People empowerment: The 2006 Progress Report mentions that people have started coming out of the clutches of money lenders. Women are becoming less reluctant in interacting with the project officers about the project works and other related issues.

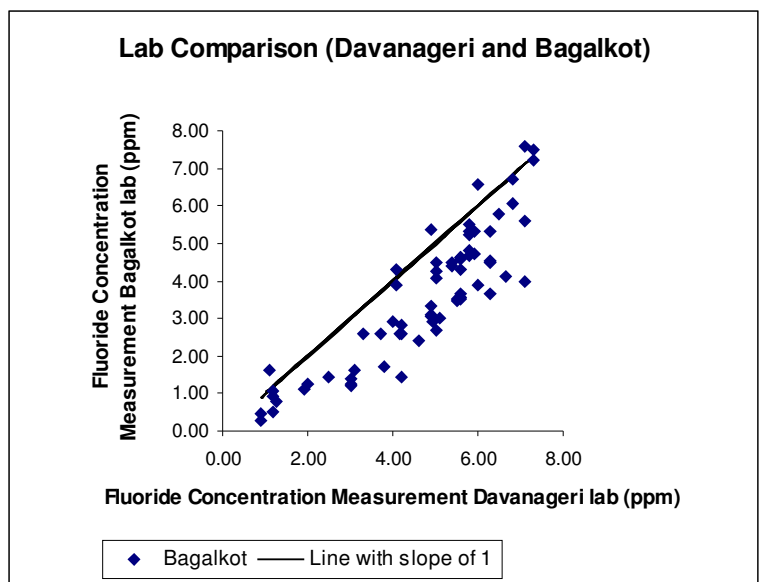
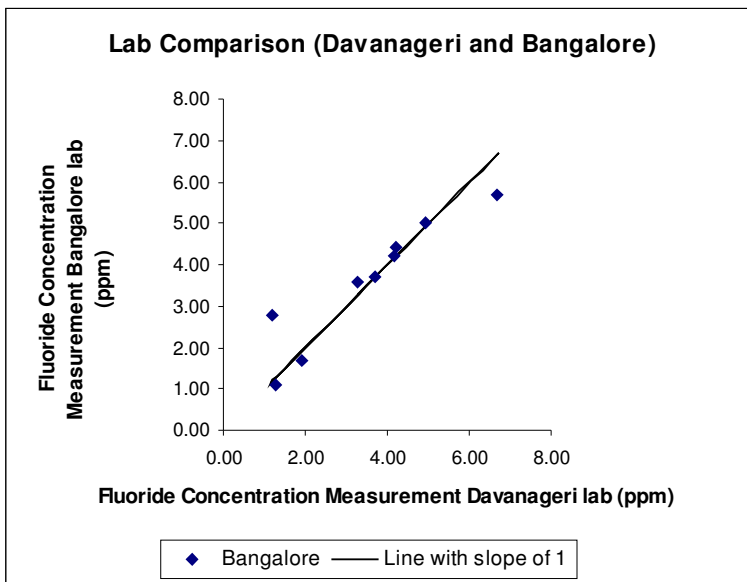
³² Panchayat refers to the local governing body of a cluster of villages in a taluk (administrative block)

³³ The Zilla Panchayat is the governing body at the taluk level.

6.2 Water Quality Data

The water quality data for the villages has been analyzed to study the difference in fluoride concentrations in different sources of water, and changes in these fluoride concentrations since the start of the projects. The maximum permissible fluoride concentration in drinking water of 1.5 ppm³⁴ has been considered as the reference level for the purpose of this study based on the standards set by the Bureau of Indian Standards (BIS 1992) and the World Health Organization (WHO 2006), as noted in the earlier part of the report³⁵.

The fluoride concentration measurements from 2001 to 2007 have been presented in Appendix G. The water samples were sent to 3 different laboratories, on different dates, for fluoride concentration measurement. However, in the dataset, the measurements of Bagalkot are consistently different from the other two laboratories. For December, 2004, the samples were sent to all the three laboratories. There were 9 sample points for which the fluoride concentrations were measured by all the three laboratories. For May, 2005, there were 59 sample points for which field replicates were sent to both Davanageri and Bagalkot for analysis. These datasets were used to draw a comparison of the value reported for field replicates by the three laboratories. The following charts show the results. A reference line with a slope of 1 has been plotted. Ideally, most of the points should lie along this reference line if there is precision in fluoride concentration measurement across the laboratories.



The comparative study shows that while most of the data points fall on the reference line for Bangalore and Davanageri, most of the points lie below the reference line for Bagalkot. Thus, for the remaining analysis of the water quality data, the dates with

³⁴ Ppm equals milligram per liter

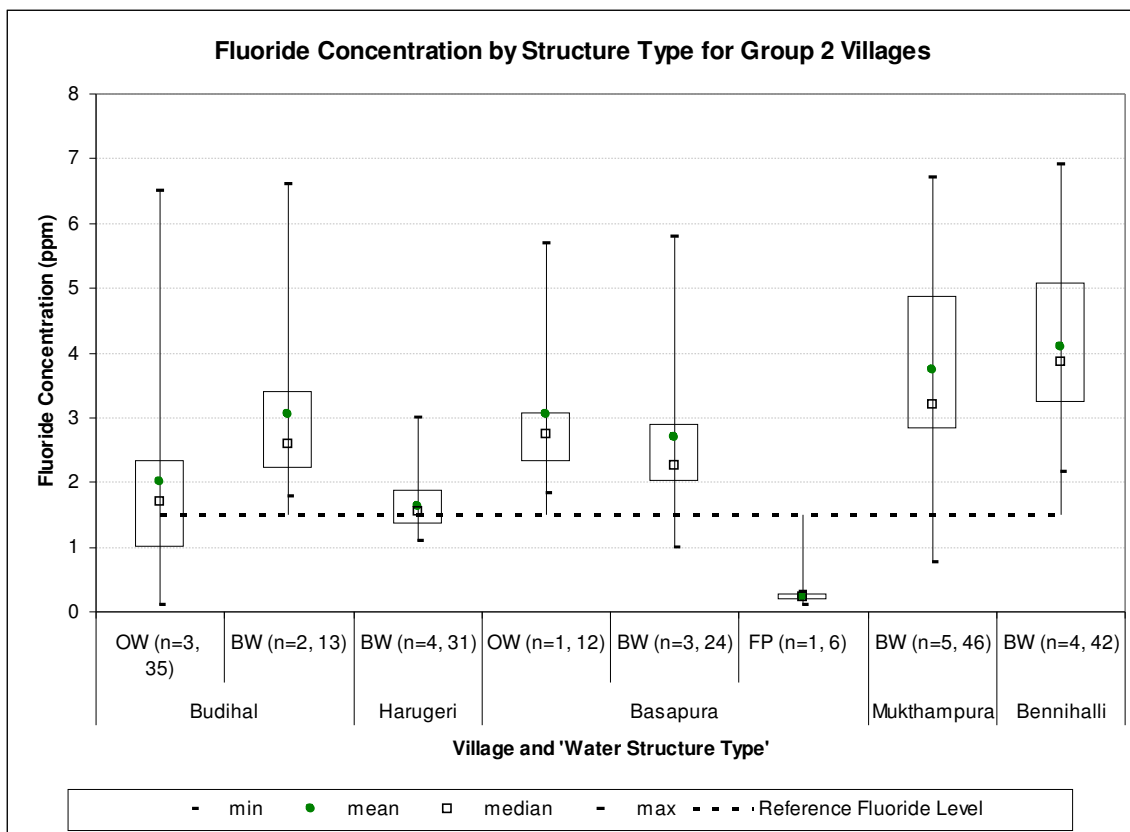
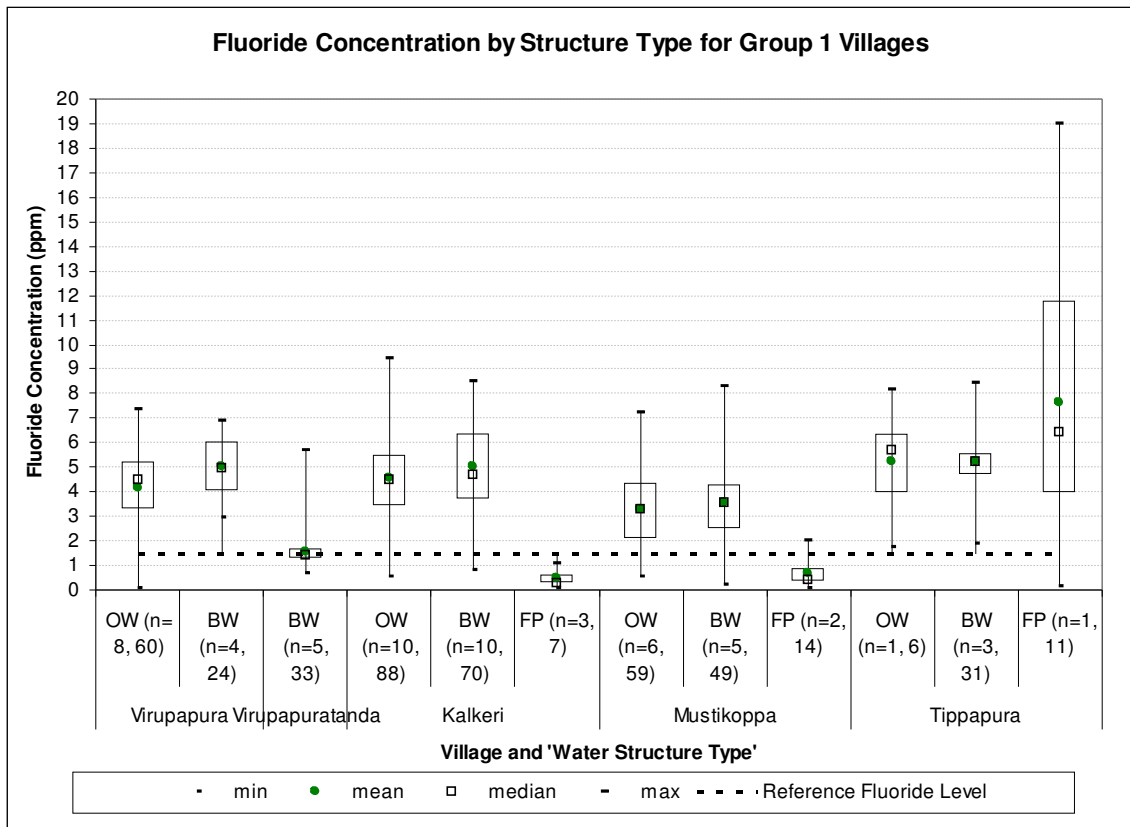
³⁵ Even though the “desirable” maximum fluoride concentration as per Bureau of Indian Standards is 1.0 mg/l, they allow 1.5 mg/l in areas where an alternate source of water is not available.

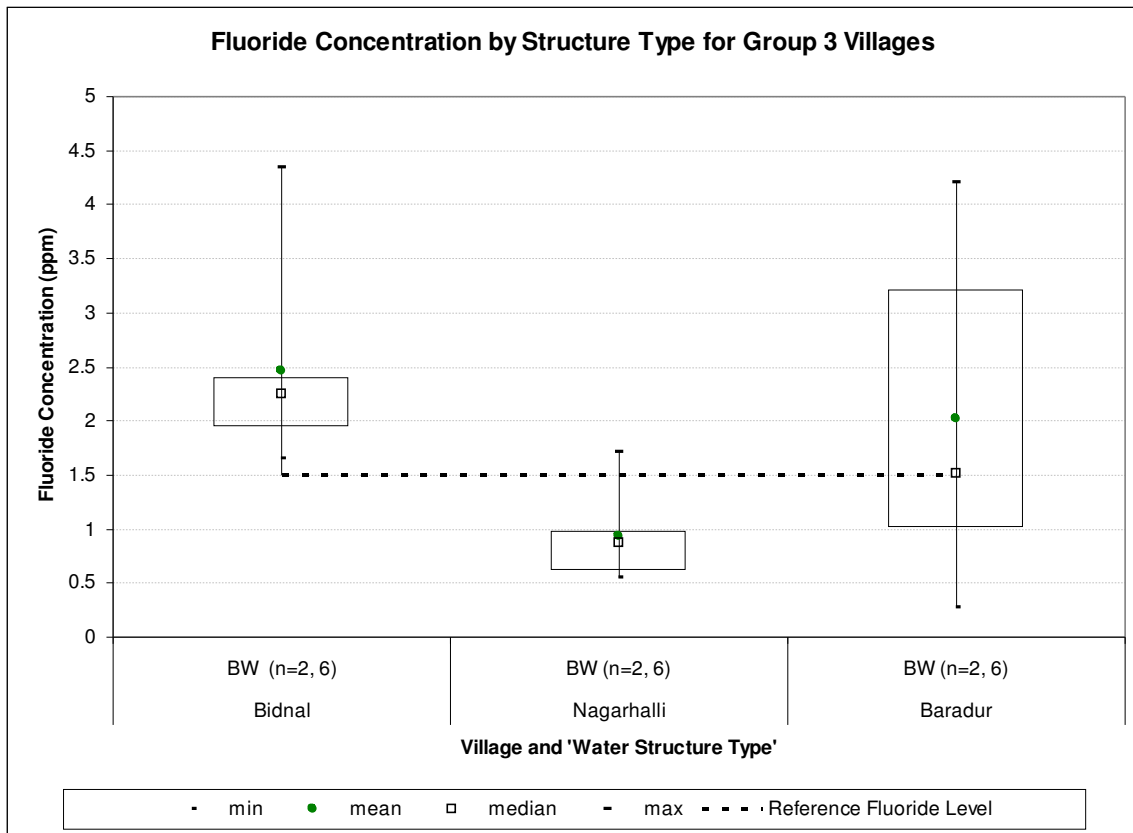
samples tested in Bagalkot laboratory have been excluded. For December, 2004, the values for both the other laboratories have been averaged and for May, 2005, the fluoride concentrations report of Davanageri has been considered for this study.

Values of fluoride for field replicates were compared to check the precision for samples tested by Davanageri (8 field replicates³⁶) and Bangalore (6 field replicates) laboratories. The average coefficient of variation for the two labs as calculated was 14% and 22% respectively. The results show that there is good precision in the measurements for these laboratories.

A boxplot analysis was done for each of the villages to understand the relative fluoride concentrations in the groundwater. The sample points in each village were further grouped based on the nature of the sample point: bore well (BW), open well (OW) and farm pond (FP). A minimum of 5 data points were required for each water structure type in each village to make the boxplot. Thus, Kelur and Koralahalli, two of the new villages do not have boxplots. The following charts show the boxplots. The numbers for 'n' represent the total number of sampling points for a structure type in that village (spatial coverage), and the total number of samples assessed from all the sample points for a give structure type in that village (spatial and temporal). The reference line shows the reference fluoride concentration of 1.5 ppm.

³⁶ Field replicates had been collected for some of the sample points in the villages for the laboratory comparison.





The boxplots show that the Group 1 villages, except Virupapuratanda, have fluoride concentrations largely in the range of 3.5 - 6.0 ppm. These values are well above the maximum acceptable level of fluoride in drinking water as per established standards in the country. For the Group 2 villages of Mukthampura and Bennihalli, the range is similar, but the other 3 villages have a relatively smaller and lower range. For Group 3 only 3 villages had sufficient data points for a boxplot and they also show a considerably smaller and lower range bordering the reference limit of 1.5 ppm. The plots indicate that there is considerable difference in the fluoride concentrations of the villages in the three groups. The study also shows that the farm ponds for a village show consistently lower range of fluoride concentrations than their respective open wells and bore wells, except in the case of Tippapura³⁷.

An ANOVA was done to assess whether there is a significant difference between the fluoride levels in each of the 'water structure type' as was shown in the boxplot analysis. In order to account for spatial variations, the data points for different villages were considered individually. The test was performed using 2 datasets:

- Average value for each sampling point in a village, and,
- Average value for each structure type in each village.

³⁷ This could be because of an error in data entry as farm ponds show consistently lower fluoride concentrations across all villages (maximum 2ppm).

The ANOVA results for both the datasets shows that there is a difference in the fluoride values for farm ponds, bore wells and open wells. The difference in the values was found to be significant (95% confidence interval in Tukey's test) when farm ponds were compared to open wells and bore wells. A possible explanation for this could be that water in the farm ponds is largely accumulated rain water, and hence, does not have as much fluoride content as groundwater, which has concentrated fluoride over a period of time. The study also showed that there was no significant difference in the values between bore wells and open wells. On the basis of these findings, farm pond data is excluded from all further analysis.

As noted earlier, different measures have been adopted for reduction of fluoride intake through drinking water – field measures to dilute the fluoride in groundwater and rainwater harvesting to provide immediate low fluoride containing water. The stored water from the rainwater harvesting structures was tested for fluoride content. It was found to be between 0.10 and 0.18 ppm, which is below the recommended minimum requirement of 0.6 ppm (BIS, 1992).

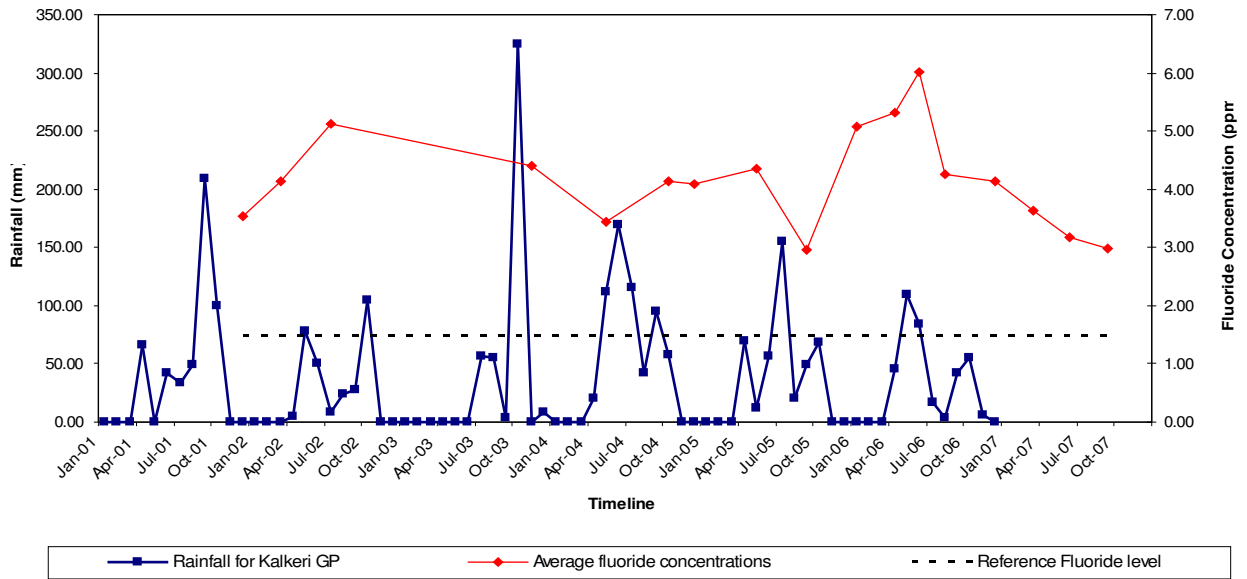
Some households also had Government provided filters for treating the water before consumption. Twenty such data sets of before treatment and after treatment values of fluoride in the water samples from the same water source were compared using paired t-test (average value before and after filtration is 3.67 ppm and 1.87 ppm). The p-value being less than 0.05 tells us that there is a significant difference in the fluoride content in the treated water sample, such that the concentration drops significantly post filtering.

The following analyses try and establish whether there has been a quantifiable effect of the project activities on the fluoride concentration in the groundwater.

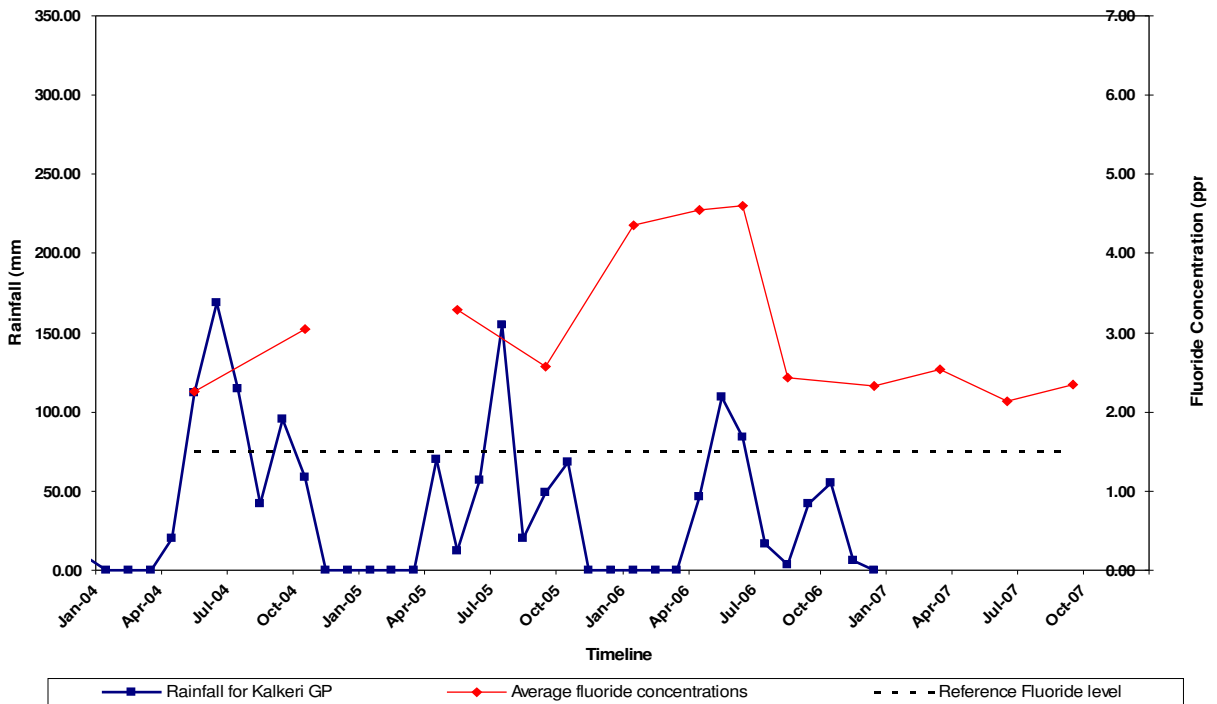
To see if there is a correlation between the rainfall trend and the fluoride concentration a trend analysis was done, however a correlation study could not be done to support the results as there were not sufficient data points. Creation of greater recharge potential should increase the recharge of aquifers and dilution of fluoride. For the same reason it would be reasonable to assume that greater rainfall would result in greater dilution of the fluoride, the relationship being dependent on a number of other factors (soil characteristics, vegetation, water withdrawal rates, recharge areas, etc.). To test this assumption also, the trend analysis of fluoride concentrations and average rainfall for the taluk (refer Appendix D) was done³⁸. Average values for each date of data collection, across all the sampled points, have been considered for the charts, thus giving an average value at each point in the timeline. There were large variations in the trends for individual sample points; hence using the average values have been used, though it compromises on the variability in the data set. Group 3 has not been plotted - as sampling began only in June, 2006 and there are only three data points for each of the sampling sites.

³⁸ Monthly average rainfall data for Mundargi taluk was available from 2001 to 2006. However, no data was available for 2007.

Trend Analysis for Rainfall and Fluoride Concentrations in Group 1 Villages



Trend Analysis for Rainfall and Fluoride Concentrations in Group 2 Villages



The fluoride concentrations are highly variable for the region for each of the cluster groups³⁹. Similar plots for individual sampling points also showed considerable fluctuations of fluoride levels so that a trend was not evident either for individual sampling point or between multiple sampling points for a village. For both the groupings, the fluoride concentrations are markedly above the reference fluoride concentration of 1.5 ppm. A trend between rainfall and fluoride is not evident in this analysis. This could be because of other factors that play a significant role in the correlation, small time period for analysis, or because of loss of variability on averaging values spatially. On more data collection, it may be useful to do a correlation study to support the current conclusions.

Based on the above analyses it is difficult to conclude that there has been a significant reduction in the fluoride concentrations because of field activities. The use of rainwater for drinking however is a good source of low fluoride water. Changes in dietary composition of affected households could also have a significant impact on severity of fluorosis. This however could be quantified in this study. Studying these relative impacts would be helpful in determining the effective strategies for this project or future projects.

6.3 Water Level Data

Water level in the region is dependent on recharge potential and withdrawal rates. The major purpose of the field activities in the project is to increase the percolation of water in the aquifer in order to dilute the fluoride content of the groundwater. It would be interesting to conduct a study to assess this relationship. As the data for water quality and quantity were not taken at corresponding time periods, a regression study of the relation between the changing water levels and fluoride concentrations could not be undertaken.

A simple paired t-test was done for the water levels for May 2002 and May 2007. The results show that there has been a significant increase in water level during this period for a confidence interval of 95%. Considerable fluctuations have been noted for water quality over a period of time and it is likely that there maybe variation in water level changes also if a trend analysis were possible. As the test was done for only two years, t is

³⁹ In order to evaluate if there has been a significant drop in fluoride levels in groundwater paired t-tests were carried out for the modified data set. Water quality data was available at different time periods, for different years – thus averages were taken in order to have a dataset where the fluoride concentrations in a pre-project period/year could be compared with a post-project period/year. For the Group 1 villages, average of the values for 2001-2002 and 2002 were considered as the pre-project scenario. This has been compared with averages for 2006 dataset and 2007 dataset. For Group 2 villages, average for 2004 has been compared with averages for 2006 and 2007 for a similar comparison. The paired t-test results show that for all sets of comparison for Group1 villages there is a significant difference in fluoride concentrations after the interventions, except for the dataset where the average of 2002 was compared with 2006. Similarly, for Group2 villages there is a significant difference for 2007 but not for 2006 as the post-period. As the project activities have begun recently in 2004, the discrepancy between 2006 and 2007 could be attributable to this. The low rainfall in 2006 (362 mm) could also have resulted in the higher concentration of fluoride. It would be insightful to carry out a similar study for a seasonal variation for different years.

difficult to conclude that there has been significant increase in groundwater table because of field activities. Therefore, it is important to determine the trend in water level change.

7 Discussion and Recommendations

The following section discusses the main findings of the study and makes some recommendations based on these.

7.1 Discussion

The project work has been implemented by BIRD-K with participation from the village communities. A detailed baseline survey had been done before the start of the project and data on water quality and quantity has been collected over a period of time. Analyzing the available data on water quality shows that there are considerable data gaps and inconsistencies. Despite these gaps, the analysis resulted in some useful findings which have been discussed in Section 6.2 and 6.3. Use of an alternate source of water has been recommended as the primary mitigation strategy followed by defluoridation of the existing source, in the Fluorosis Mitigation Program in India and the World Bank report on fluorosis (WHO, 2006). Rainwater harvesting is the alternate source in the project area. The study shows that this is a good source of low fluoride water. Field works have been implemented to increase groundwater recharge to dilute the fluoride content. Though there is a change in the fluoride concentrations, the fluctuations over a year are very high. The paired t-test results show differences and hence it is difficult to say that there has been significant drop in the fluoride in groundwater. However, analysis of the water table, based on measurements in May, 2002 and 2007, there has been a significant increase in the water table. It seems like there is no correlation between the rainfall trend and fluctuations in fluoride in the study area. However, as the project has started in 2004, it may take a study of a longer period to ascertain the impacts on groundwater quality.

Various aspects of project implementation foster sustainability of its measures. Rainwater harvesting structures have been installed in households in the area. The people who were interviewed during the field visit were informed about the maintenance aspects of these structures and its functioning. The children were also aware of the hygiene issues. Project works (field measures and rainwater harvesting structures) were constructed with the help of the local people, this involvement as well as the realization of benefits accruing from these works, foster the technical sustainability of the project beyond the project period. People paid financially and in kind for the project works⁴⁰. The medical expenditures for households has also been reducing (the relative difference differs for households based on mitigation measures adopted). The maintenance costs of most of the works are very low too, thus contributing to the financial sustainability of the project. The increase in land productivity, reduced surface runoff, changes in water quality, and water table rise are all aspects can be used as possible indicators of environmental sustainability of the project. Establishment of SHGs has contributed to empowerment of people, especially women and awareness activities have contributed immensely in informing the communities about the cause of the problem and mitigation measures. The program at school has further

⁴⁰ Financial participation from the participants (Total: Rs 143, 433, 088, Government: Rs. 116, 553, 088, Participants: Rs. 26, 880, 000) = 23% of the contribution (BIRD-K, 2005)

helped inform children. People have been a part of the project activities and understand the functioning of the project works. These have helped strengthen the institutional framework for the project villages. There is Government support for the project and the officials are working in tandem with the project officers. However, the support has to continue beyond the project period. Most of these contribute to institutional sustainability of the project.

The Sachetana D/W Plus has laid a lot of emphasis on awareness raising activities. This need was echoed during the field visit by the people as well as the project officers. Increased funding for awareness raising activities and school works was deemed very important. It is indeed integral to sustaining the outputs of the project activities beyond the implementation period. The effects of homeopathy could not be analyzed as the scheme has still not been extended to the larger community.

7.2 Recommendations

Based on the work done so far, following are some recommendations for the remaining period of the project.

1. The water sampling for fluoride concentrations has been done at irregular intervals in the past for different sample points. It is important to ensure that the water is tested regularly for each of the sample points. The sampling should be done so that the different seasons in the region are captured. Thus, at least four sampling times for the year.
2. It is equally important to sample the points at the same time each year.
3. The same sample points should be monitored consistently.
4. The water samples should not be sent to Bagalkot for analysis as the results for the field replicates from here and the other two laboratories showed considerable variation.
5. There is more consistency in the sampling for water levels. However, lesser number of points have been covered and for smaller periods. The samples need to be monitored more consistently through the years.
6. There is need to conduct a similar survey as the baseline survey for health effects in the area, in order to assess the difference in health in the area.
7. It might also help to monitor the water quality and water levels beyond the project period as it seems that to assess the impact of the works we would need longer time intervals.

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