FLUOROSIS AND SOCIO-ECONOMIC CONDITIONS OF PEOPLE IN NUAPADA DISTRICT OF ODISHA, INDIA

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ABSTRACT

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The current study was conducted to figure out the relationship between the socio-economic conditions of respondents and fluorosis in nine fluorosis-identified villages of Nuapada district in Odisha. It was observed that 100 percent of the respondents were affected with various degree of skeletal fluorosis. Fluorosis has deteriorated the respondents' health, thereby affecting their work productivity, income and quality of life. However, there are variations in the severity of fluorosis according to sex, age, weight, education and income and nutritional status of the respondents. It was observed that the number of fluorosis cases increased steeply with increase in age. The vulnerable age group of fluorosis was 41-50 years. Fluoride impact severity, however, negatively affected the body weight of the respondents. Similarly, in the lower income group and non-educated respondents, fluorosis was more vividly seen. It was interesting to note that educated and aware people were willing to pay for obtaining clean water. According to the respondents, fluorosis prevented them for performing strenuous physical activities such as farming and working as wage laborers. There is an urgency of provision of safe drinking water in the study area.

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DEDICATION

I dedicate this work to my parents and my family members.

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CHAPTER 1: INTRODUCTION

Fluorosis is a clinical disorder, generally caused by ingesting excessive amounts of fluoride (Susheela, 1984) and it affects every organ, tissue, cells in the body, and results in health complaints having overlapping manifestations with several other diseases like gouts and osteoporosis (Krishnan et al., 2006). The major clinical manifestations are severe pain in the backbone (vertebral column), joints and pelvic girdle, leading to stiffness of the vertebral column, immobile joints, terminating in a crippling condition (Susheela, 2001). Drinking water is the principal source of fluoride in India (WHO, 2006) and largest single source of daily fluoride intake (Murray, 1986).

India has 12 million of the 85 million tons of fluoride deposits on the earth's crust, accounting for 14.1 percent of total fluoride deposits on the earth's crust (Suthar et al., 2007). It is not surprising that fluorosis is endemic in 17 states of India (UNICEF, 1999; Hussain et al., 2011; Suthar et al., 2007). In 1991, 13 states of India were reported to have naturally high concentrations of fluoride in water, but in 1999, this had risen to 17 states (UNICEF, 1999; FRRDF, 1999; Yadav et al., 1999). The names of the most severely affected states in India are Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Kerela, Madhya Pradesh, Maharastra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Jammu and Kashmir and Karnataka. The highest concentrations of fluoride observed to date in some parts of India are listed in Table 1:

Table 1: Highest fluoride concentrations in states of India

State Name	Fluoride (ppm)
Rewari district, Haryana	48 ppm
Palam, New Delhi	32 ppm
Andhra Pradesh	29 ppm
Karbi Anglong, Assam	23.4 ppm
Birbaum, West Bengal	14.14 ppm
Mehsana, Gujarat	18 ppm
Amreli, Gujarat	10 ppm

(Source: UNICEF, 1999; Chaturvedi et al., 2011; WHO, 2006)

According to the Government of India, an estimated 66 million people in India are at risk of fluorosis of which 6 million are children below the age of 14 years (Shah et al., 2004). This accounts for more than 5 percent of the total population of India (Mundial, 2006). In the recent times, high fluoride in ground water has become a serious rural health problem in India, with 65% of India's villages, exposed to fluoride risk (UNICEF, 1999). At least 50 percent of the ground water sources in India are contaminated with high levels of fluoride and more than 90% of rural drinking water supply depends on ground water (Gopalakrishnan et al., 2012). If groundwater contains more than 1.0 mg/L of fluoride and is used for long time for drinking and cooking purpose then it may cause fluorosis (Shah et al., 2004). In India, high fluoride in groundwater is associated with igneous and metamorphic rocks such as granites and gneisses (WHO, 2006; Hussain et al., 2011).

The first case of fluorosis in India was reported in cattle in the early 1930s by farmers in Nellore district of Andhra Pradesh state, situated in southern part of India. Later they found similar symptoms of ache and pains in joints etc. among themselves and in the people of neighborhood villages. The first medical report on Fluorosis was

published during 1937 in the Indian Journal of Medical Research. Since then, research works have been published from Andhra Pradesh and many other fluoride-affected places of India (Krishnan et al., 2006).

In Nuapada district of Odisha (study area of this research), fluorosis was first identified in 1998 in Karlakot village of Boden block of Nuapada district, when a villager named "Prafulla Behera" developed severe pain in his joints and muscles and he was diagnosed in a hospital in Andhra Pradesh, where the doctors confirmed that he was suffering from Fluorosis. It was only then when people in Nuapada district came to know about fluorosis. Traditionally, villagers of Nuapada district used open wells, tanks, riverbeds and hilly streams for drinking water purpose. Water borne diseases were very common at that time. After the spread of tube wells, many of the water borne diseases in the area remained under control. However, this brought with it, the problem of high fluoride and gradually, fluorosis.

A survey conducted in 2006, by a voluntary organization, Sahabhagi Vikash Abhiyan (SVA), located in Nuapada district of Odisha, revealed that out of 4920 drinking water tube wells tested for fluoride in Nuapada district, 907 tube wells contained high levels of fluoride. Out of the total 661 villages, 214 villages with a population size of 22557 are diagnosed with fluorosis. According to SVA (2006), the total population at risk due to fluorosis is estimated to be 191326. This poses serious threat to the health of rural poor in Nuapada district, affecting their socio-economic conditions in several of ways. Over the entire afflicted population, fluoride contamination has a high cost on society (Indu et al., 2007).

While, there have been a plethora of scientific studies pertaining to high levels of fluoride in drinking water and its relationship with the severity of fluorosis, very few studies have investigated the relationship between fluorosis and the socio-economic status of people afflicted with fluorosis. In this regard, a field research study conducted by Indu et al. (2007) investigated the association between income and fluorosis and revealed that affordability of safe drinking water is associated with higher income level, and that the severity of fluorosis affliction is higher for lower income levels. There are other studies that reflect the importance of sex and age, loss of wages, work productivity and other factors for finding the association of fluorosis with socio-economic conditions of people. The current study was conducted to further understand the relationship of socio-economic conditions of the respondents and fluorosis in the study area of Nuapada district of Odisha, India.

1.1 Research Questions

1. Is there any relationship between socio-economic factors and fluorosis?
2. If so, how are they related and how does fluorosis affect the respondents' quality of life?

1.2 Research Paper Outline

The first section introduces the problem statement and the need to conduct the study. The second section provides the background from various literatures on similar studies. Methodology is described in the third section of the paper. The subsequent sections illustrate the findings of the study, followed by a discussion, in which the results are analyzed and substantiated with supporting details and evidence.

CHAPTER 2: BACKGROUND

2.1 Fluorosis- An Introduction

Fluorine is the lightest member of the halogen group and is one of the most reactive of all chemical elements. It is found in the form of fluorides in the environment and it represents about 0.06-0.09 percent of the earth's crust (WHO, 2006; Yasmin et al., 2011). An adult body contains an average of 2.6 grams of fluoride and more than 95-99 % of this is found in the bones and teeth (Cerklewski 1997). While it is an essential nutrient for the normal growth and development of human beings (Chaturvedi et al., 2011), it is also one of few chemicals like lead, mercury, arsenic etc. that have been shown to cause significant adverse health effects in human (Fawell et al., 2006). It damages the Pineal Gland, which secretes the melatonin hormone in the brain. Melatonin controls functions such as sleep cycles, jet lag, and hibernation in animals, immunity, and the onset of puberty. Fluoride also affects the reproductive systems and intelligence and even causes cancer. Whereas an intake of fluoride in controlled quantities is known to be beneficial for human health in preventing dental caries, an ingestion of high concentration of fluoride can cause fluorosis (Gupta et al., 1999; Beg et al., 2011; Raju et al., 2009; Yadugiri, 2011).

Fluorosis is generally caused by ingesting excessive amounts of fluoride (Susheela, 1984) and affects every organ, tissue, cells in the body, and results in health complaints having overlapping manifestations with several other diseases like gouts and osteoporosis (Krishnan, et al., 2006). There are three types of fluorosis, namely, dental fluorosis, skeletal fluorosis and non-skeletal fluorosis. Dental fluorosis is an irreversible cosmetic condition of teeth caused by intake of fluoride during the developmental

formation of teeth. In dental fluorosis, the teeth enamel is affected. In its mild forms, it appears as unnoticeable, tiny white streaks or specks in the enamel of the tooth. The severe forms of dental fluorosis are characterized by mottling of dental enamel by brown, grey or black stains; tooth appearance is marked by discoloration or brown markings/stains and the enamel becomes structurally weak or brittle and is prone to erosion (Chaturvedi et al., 2011). The discoloration is horizontally aligned and never vertical because during development, new layers of the matrix are added horizontally; the discoloration is away from the gums and is bilaterally symmetrical. The crucial period of dental fluorosis occurs between the ages of 0-14 years, but it can affect a person at any age (Susheela, 2001).

Skeletal fluorosis results in deformed painful joints with restricted movements, severe pain in the back bone (vertebral column), joints and pelvic girdle, leading to stiffness of the vertebral column, stiffness and rigidity of the joints immobile joints, premature aging, terminating in a paralysis, crippling condition. (Susheela, 1984; Raju et al., 2009). Skeletal fluorosis can affect young as well as old people. In Non-Skeletal fluorosis, there is muscular pain and weakness of the body, with decreased muscle power, headache, loss of teeth in early age, neurological problems like stinging sensation in fingers and toes, nervous breakdown and depression, urine is reddish yellow with less volume, gastrointestinal problems, blood in stool and sudden pain in abdomen, and reduced mental efficiency (Susheela, 2001).

Dental Fluorosis Skeletal Fluorosis Skeletal Fluorosis

Figure 1: Dental and skeletal fluorosis in Nuapada district, Odisha, India

2.2 Sources of Fluoride

Drinking water is the principal source of fluoride in India (Hodgson et al., 1979; NRC, 1993; Cerklewski, 1997; WHO, 2006, 2004; Fawell et al., 2006) and largest single contributor of daily fluoride intake (Murray, 1986). It is estimated that an average adult may ingest 8-10 mg fluoride from drinking water. According to WHO (1997), the permissible limit for fluoride in drinking water in India is 1.5 ppm (Suthar et al., 2007). However, if groundwater contains more than 1.0 mg/L of fluoride and is used for long time for drinking and cooking purpose then it may cause fluorosis (Shah et al., 2004). Excessively high concentration (>4.0 mg/l) of fluoride in drinking water can cause Skeletal Fluorosis (Yadugiri, 2011). Crippling skeletal fluorosis occurs when the water contains more than 10mg/L of fluoride (Raju et al., 2009).

Among the secondary sources are fish such as sardines that may contribute to higher fluoride intake if bones are ingested. Turmeric used in Indian cooking is also a rich source of fluoride (Chaturvedi et al., 2011). Crops irrigated with fluoridated water may also contribute to fluoride intake (Yadugiri, 2011). High levels of fluoride have also

been found in barley and rice (about 2 mg/kg). Tea contains high levels of fluoride (up to 400 mg/kg dry weight). Fluoride exposure due to ingestion of tea has been reported to range from 0.04 mg to 2.7 mg per person per day (Murray, 1986). Brewed teas have 1-6 ppm of fluoride in them. Other food items rich in fluoride are rock salts, black tea (tea without milk), tea with lemon, food items with black salt, tobacco etc. (Susheela, 2001).

2.3 High Fluoride in Groundwater: A Geogenic Phenomenon

India is among the 23 nations wherein a large population suffers from dental and skeletal fluorosis due to high fluoride concentration in groundwater (Beg et al., 2011). At least 50 % of the ground water sources in India have been contaminated with high levels of fluoride and more than 90 % of rural drinking water supply depends on ground water (Gopalakrishnan et al., 2012). The source of fluoride in groundwater is primarily geogenic, i.e. from dissolution of fluorine bearing minerals in the rocks transmitting groundwater (Beg et al., 2011; Raju et al., 2009; Ayoob et al., 2006; Owen et al., 1995). High fluoride concentrations may therefore be expected in areas where fluoride-bearing minerals are common. Fluoride-bearing minerals include apatite, fluorite, micas, amphiboles and topaz (Goldschmidt, 1962; Koritnig, 1978). Intermediate igneous rocks contain an average of 400ppm fluoride, acidic igneous rocks about 800 ppm Fluoride (Koritni, 1978) mainly in fluorapatite (Day, 1963). Among igneous rocks, alkali rocks contain the highest fluoride, averaging 1000ppm and ultramafic rocks the lowest at 20ppm fluoride (Koritnig, 1978).

In Indian continent, high levels of fluoride in groundwater is associated with igneous and metamorphic rocks such as granites and gneisses (WHO, 2006; Hussain et al., 2011). India has 14.1 percent of total fluoride deposits in the earth's crust, which

accounts for 12 million of the reported 85 million tons of fluoride deposits on the earth's crust. Therefore, it is not surprising that fluorosis is endemic in 17 states of India (UNICEF, 1999; Hussain et al., 2011; Suthar et al., 2007). However, fluorosis was not there historically in India because people used surface water bodies for drinking water purpose that contain negligible concentrations of fluoride.

2.4 Factors Affecting the Degree of Fluorosis (Mild, Moderate or Severe)

For a given individual, fluoride exposure (mg/kg of body weight per day) via drinking water is determined by fluoride level in the water and daily water consumption (liters per day). Water consumption may increase with temperature, humidity, exercise and state of health, and is modified by other factors including nutrition and diet. Moreover, fluoride related problems are closely associated with climate; in hot tropical part of the world like India, people consume more water and consequently the risk of fluoride accumulation increases. The severity of fluorosis, therefore, depend upon several factors, such as the concentration of fluoride in the drinking water, level and duration of exposure, dietary habits, nutritional status, average water intake, chemical constituents of drinking water, and climatic conditions (Raju et al., 2009; Yasmin et al., 2011; WHO, 2006; Hussain et al., 2011) that modify the absorption of fluoride into the body (WHO, 2006).

2.5 Social Costs of Fluorosis: Health, Opportunity and Treatment costs

Pollution of environmental resources such as water imposes a high cost on society. In the case of diseases occurring due to contamination, one needs to consider the health costs directly due to the affliction such as fluorosis. These include both the treatment costs and also the opportunity costs in terms of lost wages (Krishnan et al.,

2006). There is much loss in the normal activities if one suffers from fluorosis for a long time. Fluorosis affected people may develop some physical disabilities that prevent them from performing some behavioral activities such as cycling, walking in the field, lifting loads, taking care of children, cattle, goats, etc. (Krishnan et al., 2006). This has ill effects on their work productivity and income. They cannot earn their income, and lose their ability to do their normal or regular activities. A study done by IMWI-Tata program in North Gujarat found that of the total 240 people afflicted of fluorosis, 86 persons had lost 100 percent and 69 persons had lost 75 percent of their earning capacity to earn their livelihood. Those who lost 100 percent of their earning capacity have become dependent of their relatives and neighbors for the rest of their life (Krishnan et al., 2006).

2.6 Fluorosis and Age

Fluoride exposure dose level is known to decrease with the increase in age from infants to adults (Gopalakrishnan et al., 2012). This is because a large amount of fluoride is retained in the young bones (Chaturvedi et al., 2011). However, the prevalence and severity of fluorosis in the higher age groups is almost certainly due to longer exposure to fluoride (Choubisa, 2011). A study conducted by Hussain et al. (2011) observed that at the age below 30 years, there is small difference in the number of dental fluorosis cases in males and females. However, beyond 30, the proportion of males affected by fluorosis is higher than in females. The reasons explained are due to influx of females on marriage, from other villages, where, fluorosis is not endemic. A similar study by Choubisa (2001) reasons that men drink more water than women to compensate for fluid loss during fieldwork. They also drink more wine and tea, both of which can increase fluoride intake.

2.7 Fluorosis and Income

A study conducted by Yasmin et al. (2011) found that people who lived below the poverty line are highly susceptible to fluorosis and the occurrence of fluorosis was found to be higher in the lower-income group, although both the groups were exposed to roughly the same levels of fluoride levels in ground water. A similar study conducted by IMWI-Tata programme in 25 villages of North Gujarat also found that the proportion of fluoride affected cases declined with rising income. The reasons accountable for such a difference is believed to be better nourishment from food and medical care, which has explained this decline (Krishnan et al., 2006). This study also revealed that the higher income group people could escape the ill effects of poor quality groundwater (Krishnan et al., 2006).

2.8 Fluorosis and Nutrition

Fifty percent of the total fluoride intake per day is derived from food and beverages (Gopalakrishnan et al., 2012). The toxic limit of fluoride in drinking water in India, for occurrence of skeletal fluorosis is under 2.5 ppm, owing to poor nutritional condition. Some studies have investigated that malnourishment (as a result of poverty) plays a key role in aggravating the situation of fluorosis. Studies pertaining to the relationship between the two indicate that fluorosis is aggravated due to lack of calcium, vitamins, and proteins, and antioxidants in the daily diet (Jacks et al., 1993; Li et al., 1996; Zheng et al., 1999; Hussain et al., 2010; Raghavachari et al., 2008). It is suggested that the presence of calcium, proteins and vitamin C have preventive role in fluorosis (WHO, 1984; Boyd et al., 1987; Gupta, 1999; Susheela, 2001; Krishnan et al., 2006).

A very recent study also found that that individuals eating citrus fruits and having

good nutritional status suffer the least (Hussain et al., 2009) (Yasmin et al., 2011). Many indigenous communities in India use tamarind in their daily cooking. Apart from adding taste to the food, it is observed to be associated with reduction of adverse effects of fluorosis. The reason behind this is that, fluoride binds through hydrogen bonding to tartaric acid in tamarind, and thus the presence of fluoride ions in the body is decreased (Yadugiri, 2011). Similarly, milk and milk products diminish the fluoride availability through gastro- intestinal tract by 20–50 % in humans, due to the presence of high calcium concentrations (Gopalakrishnan et al., 2012). On the other hand, habitual consumption of excess amounts of tea and tobacco-based items contains elevated levels of fluoride, thereby increasing the body burden of fluoride in already affected people (Raghavachari et al., 2008).

2.9 Fluorosis and Education

A peculiar problem that is associated with fluorosis is that often people do not even consider it a disorder. For example, dental fluorosis is perceived by many as a question of appearance, rather than a health problem. In fact, a 1956 paper on fluorosis says, "…. in the milder forms of fluorosis the enamel of the tooth has a high luster which enhances the beauty of the tooth rather than disfiguring it" (Yadugiri, 2011). Most of the time, even though there are prevention methods available at an affordable cost, it is seen that most communities take clean water for granted and spending even a minor proportion of their income towards obtaining quality drinking water is seen as a burden (Krishnan et al., 2006). The reasons accountable are lack of awareness and poor education. Therefore, education and awareness of water quality are important factors, which influence the effort people take towards obtaining clean drinking water (Krishnan

et al., 2006; Shah et al., 2004).

2.10 Prevention of Fluorosis

There have been many attempts to develop methods to prevent fluorosis by reducing the fluoride content in drinking water. A study conducted by Gupta et al. (2005) has helped in identifying certain fluoride rich sub-aquifer zones and the geographical area where they exist, indicating thereby that if during construction of tube-wells, these zones are sealed, it should be possible to avoid high fluoride groundwater (Gupta et al., 2005).

Some of the de-fluoridated techniques used in India are Reverse Osmosis, Nalgonda technique (which involves the use of alum, lime and bleaching powder), Solar distillation, use of Activated Alumina, red mud, phyllosilicate mineral, montmorillonite, use of magnesium oxide, and using harvested rainwater for drinking (Yadugiri, 2011). Nalgonda Technique is a defluoridation method where two chemicals, alum (aluminium sulphate or kalium aluminium sulphate) and lime (calcium oxide) are added to the water (containing fluoride) and rapidly mixed. With gentle stirring, flocs (aluminium hydroxide) are developed and are allowed to settle down in the container/vessel. The flocs are then removed (Dahi et al., 1996).

In Durgapur district of Rajasthan, activated alumina and Nalgonda defluoridation techniques are practiced (Vaish et al., 2000). Defluoridation kits have been distributed at household level under the sponsorship of UNICEF and active community participation has been observed. Similarly, in Andhra Pradesh, the use of check dams have been found to be effective in reducing fluoride concentrations in ground water in over 50% cases (Bhagavan et al., 2005). The evaluation of various defluoridation methods on the basis of

social and economic structure of India reveals that the clay pot chip, activated alumina adsorption, and Nalgonda techniques are the most promising (Bhavan, 2000).

CHAPTER 3: METHODOLOGY

3.1 Study Area

Source: http://www.mapsofindia.com/maps/orissa/districts/nuapada.htm

Figure 2: Map of Study area in Nuapada district of Odisha

The study area is in Boden and Komna blocks of Nuapada district in western Odisha of India. Boden is located between 20° 30' N and 82° 54' E and Komna is located between 20° 30' N and 82° 40' E. Nuapada district is located between 20° 0' N and 21° 5' N latitudes and between 82° 20' E and 82° 40' E longitudes. The district is spread over in an area of 3407.5 km and the administrative headquarter is located at Nuapada. It has

five blocks, namely, Nuapada, Komna, Boden, Sinapali and Khariar. There are 661 villages in the district and a population of 530524 (Ministry of Panchayati Raj, 2009).

From the socio-economic point of view, Nuapada is one of the country's most poor developed districts (Ministry of Panchayati Raj, 2006). It has a long history of drought, famine and poverty. Farming is the prime occupation of the people in Nuapada district. However, ironically, drought is a regular phenomenon in Nuapada due to which, villagers suffer from abject poverty and from various degrees of malnutrition (Bhavan, 2000). The literacy rate is as low as 42.29%. The annual average rainfall received is 746.6 mm, however, the rainfall is erratic and the agriculture is mostly rain-fed.

3.2 Sampling

3.2.1 Selection of Villages

Nine villages were selected from the study area: six villages from Komna and three villages from Boden blocks. The names of the villages are, Palsipani, Jhikidungri, Karlakot, Pandrapathar, Dhumabata, Belgaon, Damjhar, Agren, and Sargiguda. One more village, named, Torbod, which has access to pipe line water supply, was studied to compare the situation of fluorosis with the problematic villages. The villages were selected randomly from a list of 214 fluorosis-affected villages as identified by a local voluntary organization, Sahabhagi Vikash Abhiyan (SVA), located in Bilenjore village of Komna block of Nuapada district.

3.2.2 Selection of Participants

For the door-to-door survey questionnaire, 10 participants were selected in small villages and 20 respondents in big villages. In total, 108 respondents (male: 53; female:

55) were identified for the door-to-door survey. The selection was done randomly from every directions of the village. The participants consisted of only adults and each participant was confined to only one household. In the Focus Group Discussion, preferably, 10-12 participants were selected. The participants consisted of adults only and they were also chosen randomly from the village.

3.3 Field Methods

Both quantitative and qualitative methods were employed in the current study as given below:

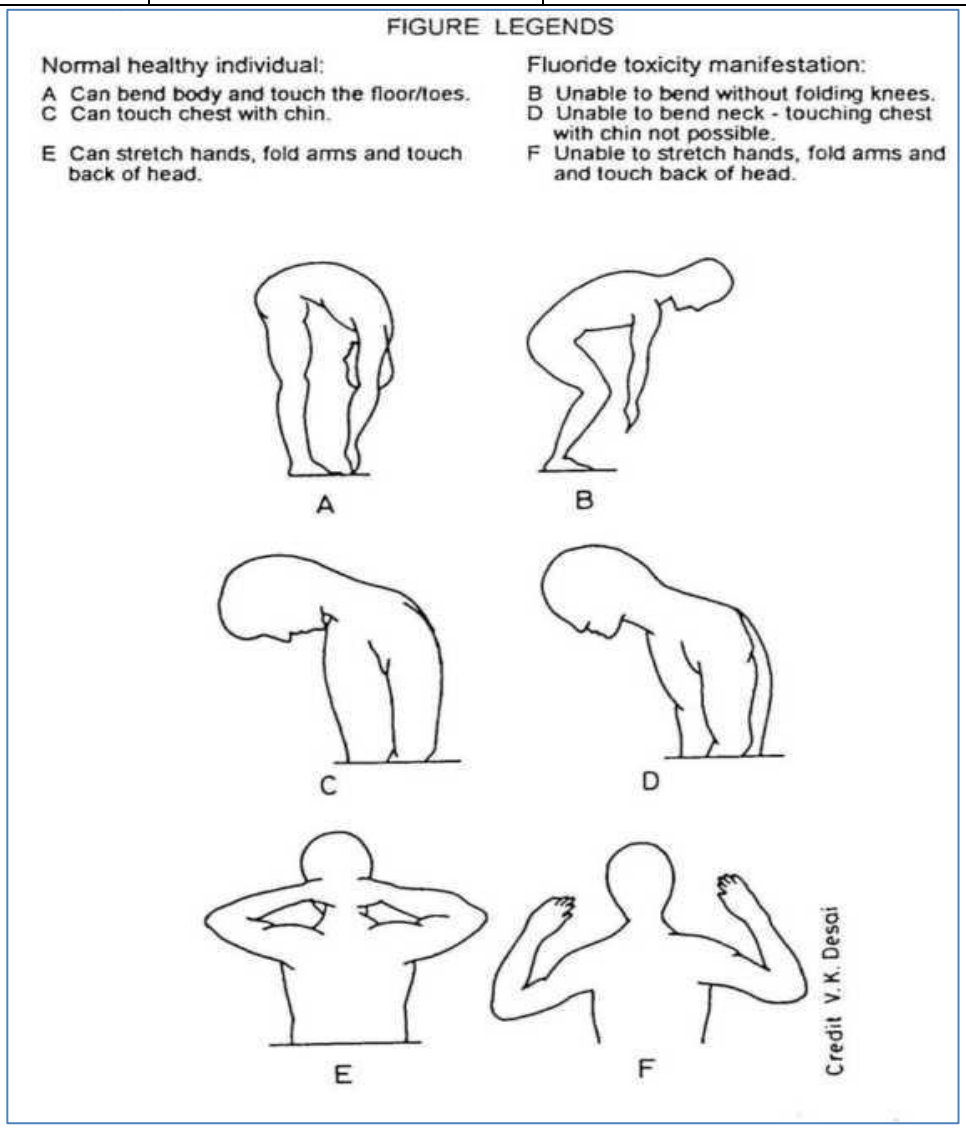
3.3.1 Quantitative Methods

3.3.1.1 Door to door survey

Two volunteers were hired for conducting the door-to-door survey and were trained prior to conducting the surveys. In the door-to-door survey, each respondent was approached at his/her doorstep and was interviewed with the help of a structured questionnaire (see Appendix-1). Each interview lasted for about 10-12 minutes. The respondent was asked questions related to three main fields viz. socio-economic details, drinking water sources and presence of fluorosis symptoms. For investigating the symptoms of fluorosis, the respondents were asked to perform certain physical exercises, which are known to detect symptoms of skeletal fluorosis (Susheela, 2001). An illustration of the various types of exercises/tests is given in Table 2:

Table 2: Physical exercises for diagnosis of skeletal fluorosis

Test name	Exercises	Indication of Fluorosis
Coin test	Subject asked to lift the coin without bending the knee	The fluorosis affected person will not be able to do so
Chin test	Subject asked to touch the anterior wall of the chest with the chin	If there is pain or stiffness in the neck, it indicates the presence of fluorosis.
Stretch test	Subject asked to stretch the arm sideways fold at elbow and touch the back of the head.	When there is pain and stiffness, it would not be possible to reach to the occiput, indicating the presence of fluorosis.



Source: Susheela et al., (1993)

Figure 3: Demonstration of physical exercises for diagnosis of skeletal fluorosis

3.3.2 Qualitative Methods

3.3.2.1 Focus Group Discussion

Focus group discussions are helpful tools that employ guided, interactional discussion as a means of generating the rich details of complex experiences and the reasoning behind actions, beliefs, perceptions, opinions, and attitudes (Richard et al., 1996). A minimum of one and a maximum of two focus group discussions were conducted by me in each village. The purpose was to understand the perceptions and opinions of participants (villagers) about the various ways in which fluorosis has affected their socio-economic conditions and vice versa. The quality of questions asked in a focus group can make a large difference in the kind of information obtained (Krueger, 1997). Hence, a semi-structured questionnaire was used in the focus group discussion (see Appendix-2). Each focus group discussion lasted for about 40-45 minutes until data saturation was reached. Data saturation occurs when no new themes are emerging from subsequent focus groups/interviews (Gussy et al., 2006). Notes were taken simultaneously in order to enhance the quality of data handling.

3.4 Data Analysis

With the objective to understand the relationship between fluorosis and the socio-economic conditions of the people, the following analyses were done using the raw data:

3.4.1 Quantitative Analysis

3.4.1.1 Estimation of Fluoride Impact Severity (FIS) or the Degree of Fluorosis

The Fluoride Impact Severity (Shah et al., 2004) was calculated using a simple scoring approach to rank the respondents into mild, moderate or severe degree of

fluorosis, depending upon the number of symptoms (number of exercises they were unable to perform), they witnessed. This is illustrated as below:

Table 3: Scoring approach for estimating FIS

Fluoride Impact Severity/Degree of Fluorosis	Scoring approach
Mild	Subject afflicted with one symptom (not able to perform only one exercise among the suggested three).
Moderate	Subject afflicted with two symptoms (not able to perform only two exercises among the suggested three).
Severe	Subject afflicted with all the three symptoms (not able to perform any of the three suggested exercises).

3.4.1.2 Simple Distribution of Respondents' Socio-economic Conditions and the Occurrence of various degree of Fluorosis

A self-report of the respondents' socio-economic conditions and the degree of fluorosis witnessed by them, and the link between the two was graphically represented through histograms, using the histogram tools of the Analysis ToolPak.

3.4.2 Qualitative Analysis

3.4.2.1 Perception of Villagers towards Fluorosis

For analyzing this section, the notes were first, transcribed. The answers were then organized and classified into different categories/themes. The themes were identified and labeled according to the themes illustrated in literature review.

3.5 IRB Approvals and Informed Consent

The current study involves human subjects. Hence, the needful consent was taken from IRB, after which the study was conducted. Prior to conducting the study, the participants were explained about what the study included, theirs' role in the study, what tools would be employed, time and duration of the survey, whether notes will be taken, discussions will be held, exercises for fluorosis will be performed etc. It was also made clear to the participants that they can deny to participate in the study if they do not want to participate. The participants were also assured that all the information gathered and the resulting data will remain confidential and anonymous. After explaining them the requirements of the study and their roles, the participants were asked for their consent (written/oral as appropriate; see appendix-3 for the written and oral consent forms) for guaranteeing present and future anonymity and confidentiality of information received and acknowledging the use of note taking, agreeing to get surveyed at the sessions. After approval of their consent, the study was conducted.

CHAPTER 4: RESULTS

4.1 Overall Socio-economic Status of the Respondents

The 108 respondents studied here have 602 family members in total with 248 earning members in the family. The average income of each household is Rs.1343 (27 USD) per month. Farming is the primary source of income, followed by agricultural labor and few persons are engaged as skilled workers such as small business, services etc. Among the 108 households, only 87 households own land amounted to 200.74 acres, with an average of 2.3 acres per household. Of the total 108 households, 99 (91.6%) houses have assets such as cycle, T.V., electric fan, radio etc., amounting to an average of Rs. 17,203(344 USD) per household.

4.2 Fluoride Impact Severity/ Degree of Fluorosis among the respondents

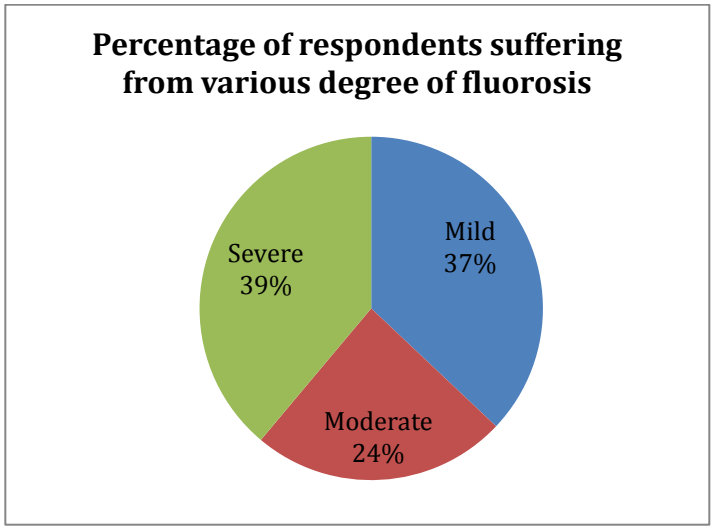


Figure 4: Prevalence of FIS in the study area

The scoring approach indicates that 40, 26 and 42 respondents are affected with mild, moderate and severe forms of fluorosis respectively.

4.3 Self Report of Participants' Primary Drinking Water Sources

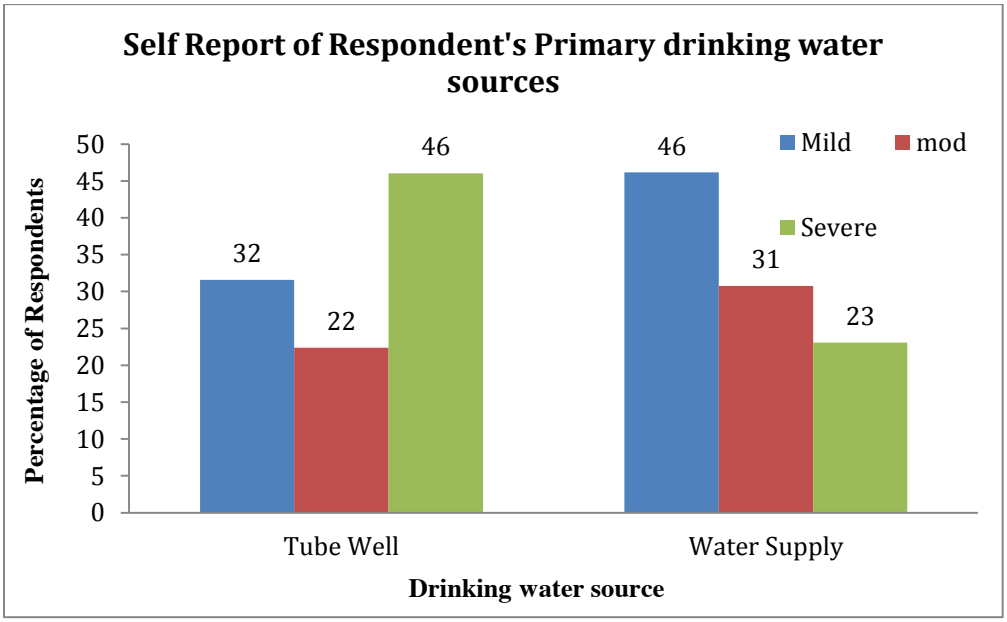


Figure 5: Self report of respondents' primary drinking water sources

70.37 % respondents (76) use tube wells for drinking water purpose followed by only 24% respondents using pipeline water supply. The remaining 5.63% of the respondents use other drinking water sources such as open wells. Of the 70.37% respondents using tube wells, 32%, 22% and 46% respondents have mild, moderate and severe fluorosis respectively. Similarly, of the 24% respondents using pipe line water supply, only 46%, 31% and 23% respondents have mild, moderate and severe fluorosis respectively.

4.4 Relationship of Fluorosis with Respondents' Age and Sex:

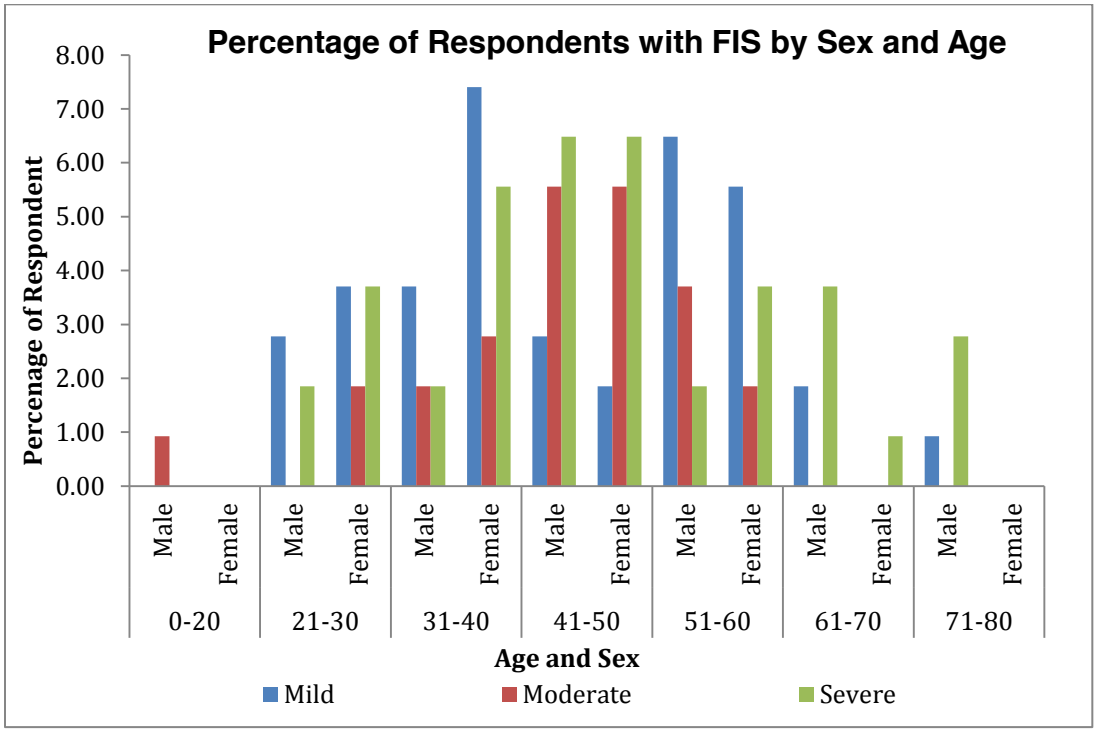


Figure 6: Percentage of respondents with FIS by sex and age

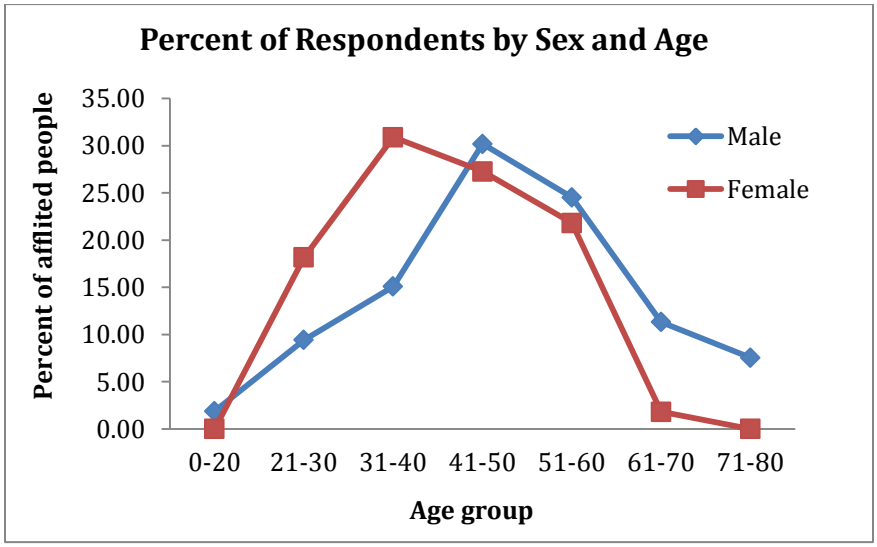


Figure 7: Percentage of respondents by sex and age

Figure 6 and 7 show that the percentage of respondents with severe fluorosis increases steeply with age, especially after the age of 30. However, it has a grim picture

after 50. The largest number of afflicted people is found in the age group of 41-50 years accounting for 51.6% of males and 48.3% of female of the total respondents in that age group. Furthermore, fluoride debility cases are higher among females with (67.5%) in the age group of 21-40 whereas after the age of 40, the cases are higher among males (63.8%), however, after the age of 60, there are negligible cases of fluorosis among females (0.9%).

4.5 Relationship of FIS with Respondents' Education

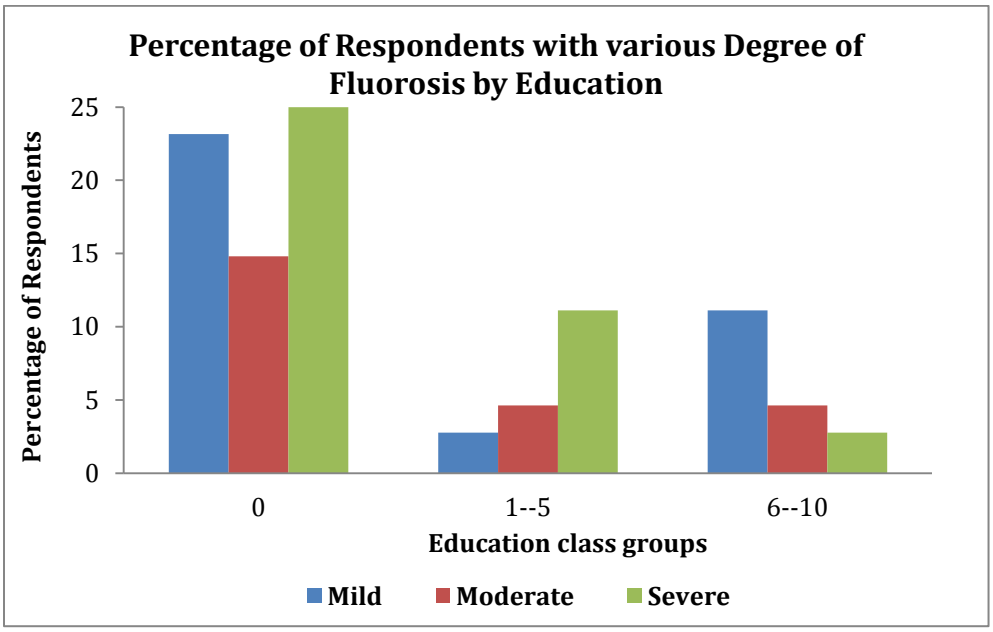


Figure 8: Percentage of respondents with FIS by education

Only 37.04% of the affected population has attended school and the rest 62.96% of fluorosis affected respondents are illiterate. At least 25% of the respondents in the illiterate class are suffering from severe degree of fluorosis, followed by 23% of moderate and 14% of mild fluorosis. It can be seen from the chart that the number of severe fluorosis cases is 11.11% in the education class group of 1-5 (primary school group) and is just 2.78% in the class group of 6-10.

4.6 Relationship of Fluorosis with Respondents' Body Weight

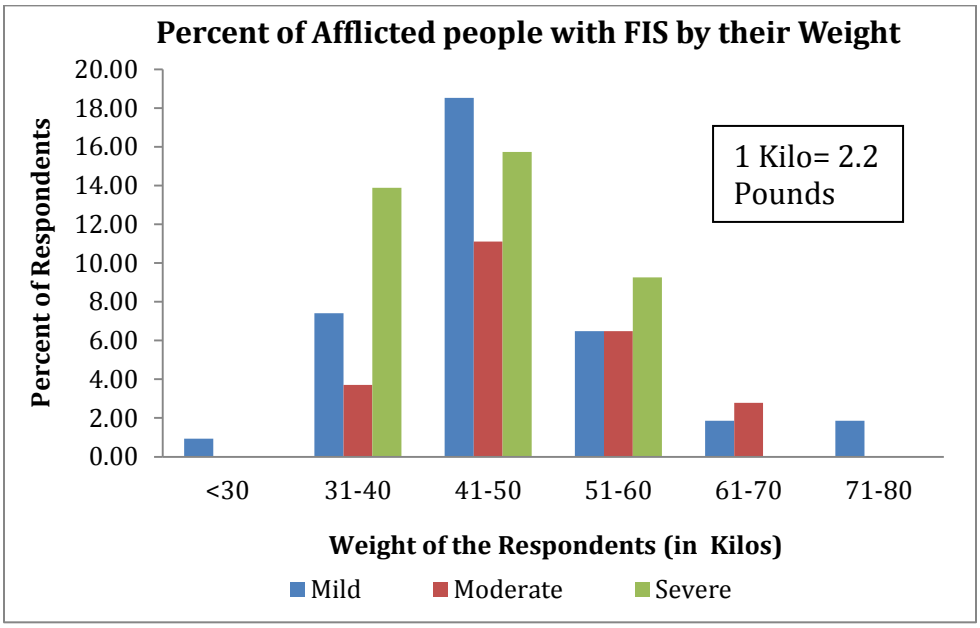


Figure 9: Percentage of respondents with FIS by weight

71.3% of the respondents suffering from fluorosis weigh less than 50 kilos (110 pounds) and only 28.7% respondents weigh between 51-80 kilos.

4.7 Self Report of Respondents' Occupation before Fluorosis and now

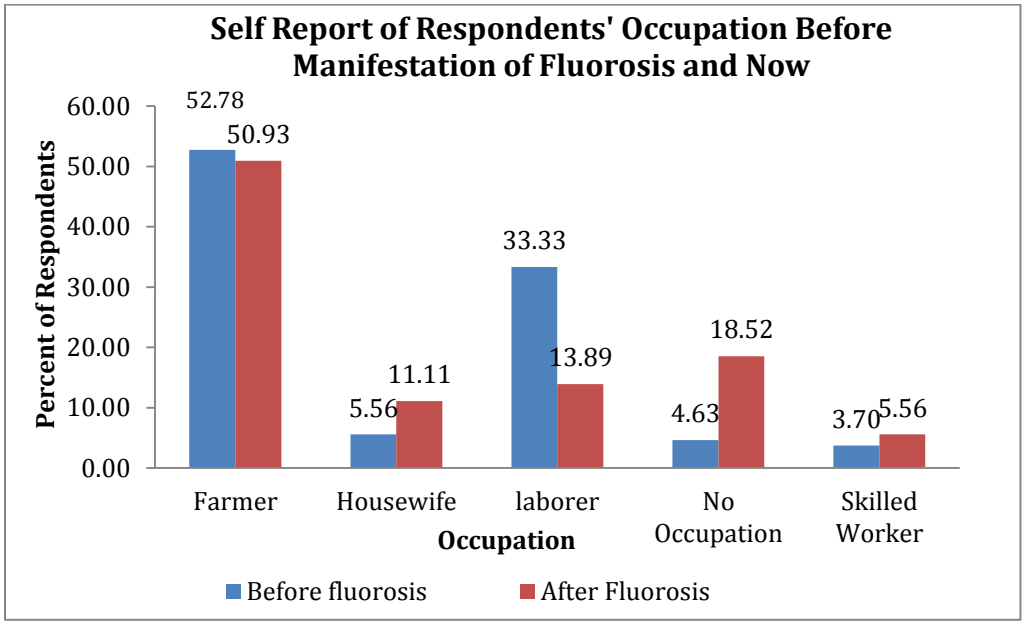


Figure 10: Self report of respondents' occupation before and now

There has been decline in occupation involving strenuous physical activity such as agricultural labor by 19.44%. However, this is only 1.85% decrease in respondents previously working as farmers. There has been loss of employment of 13.89% respondents, who are now, completely dependent on their family members for the rest of their life. Moreover, housewives have increased by 5.55%. The percentage of skilled workers such as teachers, small business etc. has increased by 1.85%, however, this is negligible.

4.8 Self-Reported Income of Respondents before Fluorosis and now

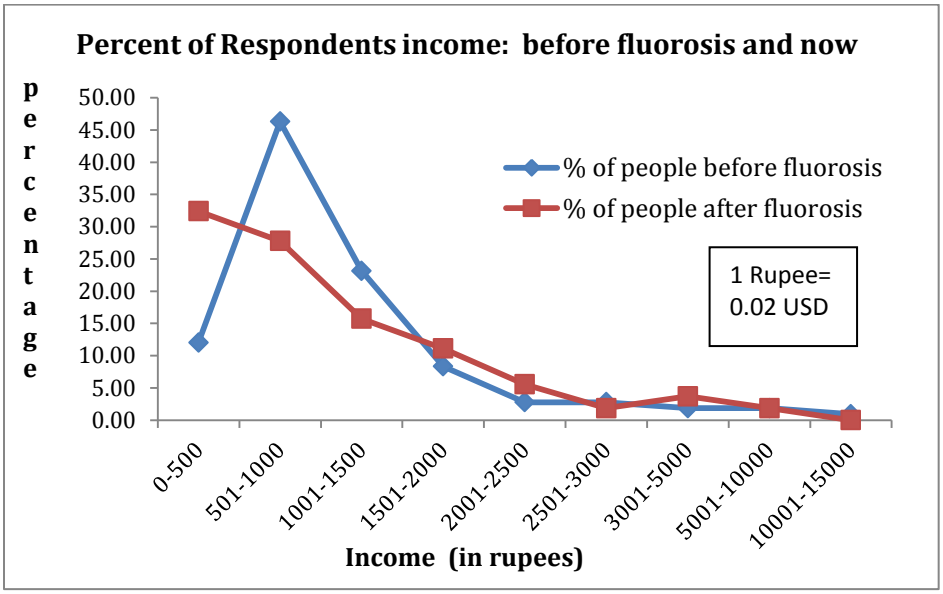


Figure 11:Self-reported income of respondents before and now

46.3% of the respondents (before affected with fluorosis) were in the income range of 501-1000 rupees, however, after fluorosis, only 27.78% are now in this income group. Similarly, the income group of 0-500 rupees had only 12% of the respondents before fluorosis, which has increased to 32.4% after fluorosis. The income group of 1501-2000 rupees has only 15.7% of the respondents after fluorosis as compared to 23% of the respondents before fluorosis. There has been an average change in income of Rs. 191 per person per month due to fluorosis.

4.9 Respondents' Monthly Expenditure on Treatment of Fluorosis

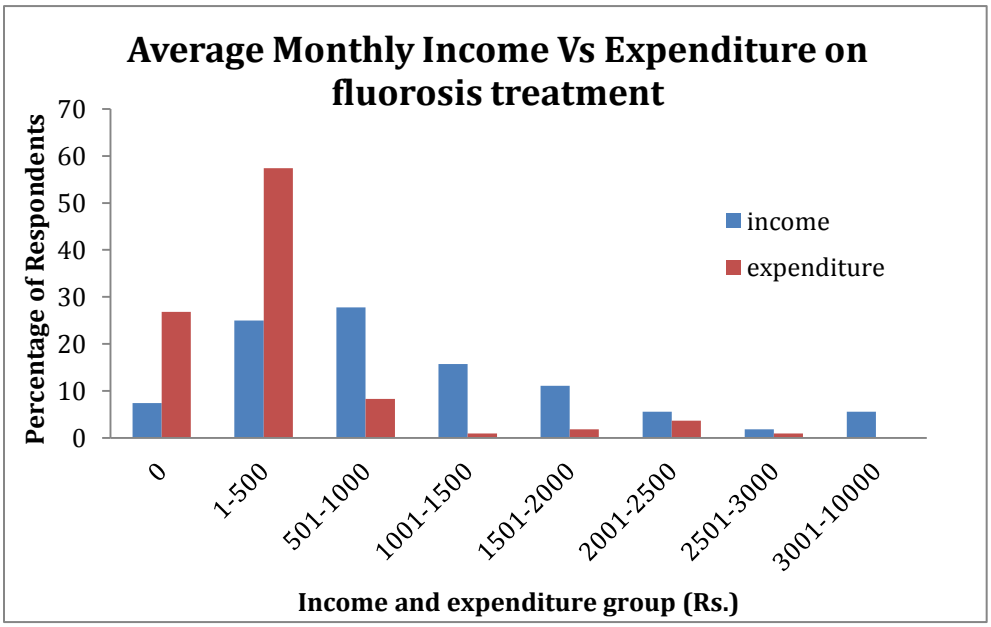


Figure 12: Respondents' monthly expenditure on fluorosis

Of the total 108 respondents, 79 respondents (73.15%) took medical treatment for fluorosis, while the remaining 29 respondents (26.85%) did not take any treatment for fluorosis. While the average monthly income per person (who took treatment) is Rs.1322, the average monthly expenditure per person(who took treatment) is Rs.421. As many as 57.4% respondents spent in between Rs.1-500 for treatment and so far, the total average monthly amount incurred due to medical treatment (for fluorosis only) for 79 afflicted persons is Rs.33308. At least 32.4% of the respondents have taken 1-3 years of treatment followed by 26% of respondents with 4-6 years of treatment. The average years of suffering are 5.3 years. Only two cases have reported temporary improvement due to treatment and in the rest of 77 respondents, there is no improvement.

4.10 Qualitative Results

Focus group discussions were held in each identified fluorosis affected village to understand the perceptions and opinions of participants (villagers) about the various ways in which fluorosis has affected their socio-economic conditions and vice versa. A number of themes emerged as a result of the discussion such as respondents' health effects due to fluorosis, other consequences, results of treatment, belief in treatment, protective effects of income and education etc. Each theme is discussed as under:

4.10.1 Health Effects due to Fluorosis

According to the participants, the common fluorosis symptoms experienced by the villagers in the study area are pain and stiffness in the body joints, gastro-intestinal problems, inability to do sit ups, and difficulty in stretching arms. In some severe cases, respondents were unable to walk without stick or any other support and few villagers also used wheel chair. In the village, Karlakot, teenagers at very young age of 16-17 years are also developing skeletal fluorosis. It is an irony that people of every age group are affected with various forms of dental and skeletal fluorosis A woman, aged, 50 years of Dhumabata village, said that:

> *"I got afflicted with fluorosis long back in 2000, after which, I got bed ridden. Suddenly, after 4 years, I was able to walk, but with the support of a stick on one hand and some other tool on another hand. I have severe pain in my body joints. I cannot raise my left arm anymore. The doctors said that I am suffering from crippling skeletal fluorosis."*

The health effects of fluorosis have led to various consequences. For example, due to skeletal fluorosis, young girls of 16-17 years old, in Karlakot village, are facing

the social stigma of not able to get married. An old man, aged, 70 years, sadly pointed out that:

> *"We have 10-12 girls in our village, who have not been able to marry because they are afflicted with fluorosis."*

4.10.2 Treatment Costs due to Fluorosis

Fluorosis has added financial burden to the poor families by adding huge treatment costs. Most of the villagers have taken treatment for fluorosis and have spent hefty amounts on it. Few have experienced temporary relief due to treatment and the rest are silently suffering in pain. People of higher income groups have also paid visits to hospitals outside the state. A villager of Dhumabata, male, aged 40 years said that:

> *"During 2009, I suddenly experienced stiffness in my whole body and gradually, my spinal cord started bending. I went to the hospital in Waltier and got my spinal cord operated. The pain has not completely disappeared after the operation. However, I get temporary relief from the medicines. Hence, I visit the hospital in Waltier every year with a hope to recover soon. I also suffer from severe gastric problems and I take medicines regularly. I have spent a huge amount of money on the treatment."*

4.10.3 Loss of Productivity and Wages/Income

The villagers mentioned that there has been loss of working hours and work productivity due to pain in their body while doing farming and labor activities; especially while bending forward, lifting loads, riding cycle, and walking in the fields, taking care of cattle at home, etc. Many villagers opined that they used to work for at least 7-8 hours before developing fluorosis and now they are only able to work for 2-3 hours and with

difficulty. There are also a number of villagers, who have lost their jobs, due to fluorosis. A woman, aged, 40 years of Phalsipani village, stated that:

> *"I used to work in the agricultural fields for at least 8 hours and today, I cannot work anymore". She sighs with pain that, "I am no more independent."*

4.10.4 Awareness on Fluorosis

The majority of the villagers in the study area are aware of the fact that their health is being affected by drinking water from the fluoride contaminated tube wells. Moreover, many of them are aware that the drinking water sources in their villages have been tested for fluoride in the recent past.

However, it is interesting to learn that very few villagers are aware that there is no cure for fluorosis. Hence, due to lack of awareness on this ground, they continue to spend hefty amounts on medical treatments rather than paying for clean water.

Some participants opined that they are not willing to pay for clean water and reasoned that provision of safe drinking water is the sole responsibility of the state government.

It was also learnt that few educated villagers who are quite aware of the health effects of fluorosis are using mitigation measures such as Reverse Osmosis filters for fluoride removal.

4.10.5 Income and Fluorosis

There are also a large number of people who cannot pay for clean water due to their poor economic conditions and they continue to use the contaminated tube wells for

drinking water, because of the absence of any other alternative and affordable drinking water sources.

A farmer, aged 45 years, stated that:

> *"In my village, almost every single children has black stains on their milk tooth. Many young girls and boys have difficulty doing sit-ups. We are aware that this is because of the water that we are drinking from the tube wells in our village. However, we have no choice."*

For many families who are below the poverty line and having very low income, water is seen as a burden for them. Apart from clean water, due to poor income, these villagers have low nutritional diet, lack adequate proteins, vitamins, calcium and other essential nutrients in the food. Most of them consume black tea (tea without milk), and only few families are able to afford a nutritional diet with essential nutrients to prevent fluorosis. While many of the villagers consume tobacco on a daily basis, there are people, who do not have any such habits but still face symptoms of fluorosis.

Most of the villagers held the opinion that the rich people do not face an equal amount of risk because they can afford to use filters for de-fluoridation of water. A poor farmer, 40 years old, sadly pointed out that:

> *"Do you see you that big house there? The rich people live there. They have a filter, which purifies water, and none of the members in their family have fluorosis."*

4.10.6 De-fluoridation of Water and its Effects

Some educated and aware families have taken mitigation measures at household level. One of such beneficiary of Agrain village, a woman, 60 years, who has been using Reverse Osmosis filter for past five years, stated that:

> *"I am no more a fluorosis-afflicted person. I am free from the trap of mild fluorosis, which I was suffering five years ago. After that, my sons (both educated, BA and B.Ed.) installed a filter (Reverse Osmosis for fluoride removal) at home. All my family members use the filter for drinking water purpose and everyone in the family is free from any kinds of fluorosis symptoms."*

There are very few villages in Nuapada that have access to pipe line drinking water supply. One of such village is Torbod, which has minimal cases of both dental and skeletal fluorosis. The majority of the participants in this village were happy to state that:

> *"We have access to pipe line water supply in our village for the past 8 years. Our village does not have any cases of severe fluorosis. There are only few cases of mild fluorosis."*

CHAPTER 5: DISCUSSION

In this study, 100 percent of the respondents are affected with various degree of fluorosis. Fluorosis has deteriorated the respondents' health, thereby affecting their work productivity, income and quality of life. However, there are variations in the severity of fluorosis according to sex, age, weight, education and income of the respondents.

There is a significant role of groundwater in aggravating fluorosis. This was evident from the number of fluorosis-affected respondents using tube wells (ground water source). In fact, highest number of fluorosis afflicted cases (mild: 24, moderate: 17, severe: 35) use tube wells with contrast to 32 respondents who use other drinking water sources. Several studies have indicated that fluoride level in ground water is the primary reason of fluorosis in rural India (Gopalakrishnan et al., 2012) and the study by SVA (2006) revealed that tube wells in Nuapada have been found to contain higher amounts of fluoride.

Education plays an equally important role towards affliction of fluorosis among the individuals. The concurrent study found that the cases of fluorosis were fewer in the educated group as compared to higher cases of FIS in the illiterate group. This is in concurrent with the study conducted by Shah et al. (2004) and Krishnan et al. (2006), which finds out the importance of education in prevention of fluorosis by stating the reasons that educated and aware people are more conscious of their health and are willing to pay for clean water and eat nutritious food in order to remain healthy.

Age, sex and weight were found to be correspondingly important in governing the fluoride impact severity (FIS) or the degree of fluorosis among the respondents. The percentage of respondents with severe fluorosis increases steeply with age and gradually

decreases after the age of 50 and is very few after 60 years. Similar findings have been revealed in the study conducted by Shah et al. (2004) where, the fluoride debility cases increases steeply with age. The reasons for this have been explained in a study by Chaturvedi et al. (2011) as, the amount of fluoride taken up by bone and retained in the body is inversely related to age with more fluoride being retained in the young bones.

While the study by Shah et al. (2004) found the vulnerable age to be in between 31-40 years, where fluorosis was most vividly seen; the current study found it to be 41-50 years, with highest cases of fluorosis in both males and females. This variation depends upon several other factors such as dietary habits, nutritional status, average water intake, chemical constituents of drinking water, and climatic conditions, as described by Hussan et al. (2011).

Fluoride impact severity was, however, negatively associated with the body weight of the respondent, which means that the body weight plays a vital role in reducing the severity of fluorosis. Very few fluorosis affected cases and low FIS was seen in the respondents with body weight above 60 kilos. The reason might be that respondents with proper body weight have been eating a healthy and nutritious diet enriched with the essential nutrients, needed for ameliorating fluorosis.

A number of studies have investigated the importance of nutrition in alleviating the harmful effect of fluorosis (Susheela, 2001). Researchers have pointed out that sufficient intake of calcium, vitamin C, E and antioxidants in daily diet can reduce the negative impact of fluoride on human body (Susheela, 2001, 99). These are the possible explanations for the results obtained in the current study where, greater number of

fluoride affected cases (71.3% cases) are found in adults with a low body weight (<50 kilos) and fewer cases (28.7%) in case of a maintained body weight (>50 kilos).

Similarly, results varied by sex. In the study, males and females reported different reactions to fluoride exposure, with more female respondents afflicted in the younger age group and a greater number of male respondents, in the older age group. This has also been observed by studies conducted by Choubisa (2001) and Hussain et al. (2011), who explain the reasons behind such a difference is due to the influx of females on marriage from other villages, where fluorosis is not endemic. Moreover, men drink more water than women to compensate fluid loss during fieldwork and other strenuous activities. They also drink more wine and tea, both of which can increase fluoride intake.

Fluorosis has also resulted in huge opportunity costs in terms of participants' ability to work. Loss of productivity (in terms of not being able to perform strenuous physical activities) has negatively impacted the nature of occupation of the respondents and their wages. The respondents who continue farming, are not able to perform long hours of strenuous physical activities in the fields and this has dwindled their income. It is worth mentioning that eight respondents out of 108 have lost their jobs or they are no longer able to work because of the adverse effects of fluorosis on their physical fitness and health. These findings comply with the study conducted by Shah et al. (2004), where fluorosis prevented the respondents from performing certain physical activities, due to which, there is much loss in the normal activities.

Adverse health effects have added a hefty amount of treatment costs to the already poor families. Fluorosis is known to have no cure (Susheela, 1984); however in order to get instant relief from the unending pain, respondents continue to take treatment

for fluorosis. On the other hand, there were 26.8% of the respondents who did not take any treatment measures for fluorosis. The reasons are that some had financial constraints to avail any treatment methods and secondly, few respondents did not believe in any treatment measures. As expected and obvious, the respondents who have taken treatment have seen negligible improvements in themselves.

CHAPER 6: CONCLUSION

All the respondents in the study area are affected with various degree of skeletal fluorosis. The factors responsible for various degree of Fluoride Impact Severity among the respondents are low income, poor education, lack of awareness, poor nutrition, low body weights, drinking water sources such as tube wells and age and sex of the respondent. According to peoples' perception, fluorosis has deteriorated their health, thereby affecting their work productivity, income and quality of life and on another hand, the fluoride impact severity varied according to sex, age, weight, education and income of the respondents.

Out of the 108 respondents, there were 40 mild cases, 26 moderate, and 42 severe cases of fluorosis. It is an irony that these respondents still continue to use tube well water for drinking water purpose; they have few options because of their extremely poor economic conditions. While it was seen that the village having access to pipeline water supplies had minimal fluorosis cases, the villagers using tube wells suffered from dangerous symptoms of fluorosis. This calls for an urgent need of provision of safe and fluoride-free drinking water through pipeline water supply and other feasible alternatives. While it is important for villagers to be aware of the situation and be willing to take mitigation measures, it is equally important for the state and authorities to take this issue seriously.

APPENDICES

Appendix-1: Door to door Survey Questionnaire

Survey Questionnaire- (Relationship between Socio-economic conditions of Respondents and Fluorosis

Name of the Block: ..... **Name of the surveyor:.....**

Name of the Village: ..... **Date:.....**

Sl. No.	Name of the individual (Code)	Sex	Age	Wt. (in Kg)	Education	Occupation At present	Household size					No. of Members Working	Current Average Monthly Income (Rs.)	Land Holding	Approx. value of other assets (Rs.)
							Adult		Children		Total				
							M	F	M	F					

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Fluorosis								Other health problems	Drinking water source + Location			
									Before Fluorosis		Now	
Physical exercises Symptoms	Year of Manifes -tation	Occupation before Fluorosis	Avergage Monthly income before (Rs.)	Treatment Taken + medica ion	Period of treatment	Total amount Spent (Rs.)	Any Impro vement seen		Source	Location	Source	Location

Appendix-2: Focus Group Discussion Questionnaire

1. What are your daily food habits during different seasons?
2. Do often do you eat meat/fish/eggs?
3. Do you drink black tea/ milk tea and how many times a day?
4. Do your children drink milk every day? If yes, how many times a day?
5. Do you consume tobacco regularly? How many times a day?
6. What kind of salt and toothpaste do you use?
7. What are the sources of drinking water available in your village?
8. Is there any provision of pipe line water supply? If yes, since when and how many families use them?
9. What are the different types of jobs being done by people?
10. What are the diseases prevailing in your village?
11. What is the monthly expenditure on health medication/doctor visit/ treatments?
12. Do you know anything about Fluorosis? If yes, what?
13. Have you ever complaint about Fluorosis to any doctor? If yes, what have they said? Have they prescribed any medicine and has it helped?
14. Are there incidences of migration from your village? If yes, why? Is it related to Fluorosis?
15. Are there incidences of marriage failure in your village due to Fluorosis?
16. What are other problems you face in your day-to-day life due to Fluorosis?

Appendix - 3

INFORMED CONSENT FOR STUDY PARTICIPANT

Statement of person agreeing to take part in this research study

STUDY TITLE: Fluorosis and Socio-economic Conditions of People in Nuapada district of Odisha, India

RESEARCHER: Subhashree Pradhan

The process, aims, affiliation, risks and benefits of this study were explained clearly to me, and I freely give my consent to participate. I understand that I might be interviewed once or twice for 20-35 minute, that there are no potential risks to me or my family, and that my information and what I share will remain confidential, and cannot be traced back to me.

I was given a copy of this consent form for my records. I understand that if I have any questions, I can call Subhashree Pradhan at +1 774 329 5911, spradhan@clarku.edu her supervisor, Professor Barbara Goldoftas at (508) 421-3824 or by email at bgoldoftas@clarku.edu or her university directly at: Chair of the Institutional Review Board (IRB), Dr. James Elliott, Clark University, 950 Main Street, Worcester, MA 01610-1477; phone: (508) 793-7152.

_____	_____	_____
Name	**Signature or thumbprint**	**Date**

I agree to be audiotaped (circle one): YES NO _____
Initial

_____ _____
Signature of person obtaining consent Date

ORAL CONSENT:

Statement: The study participant, (ID/name) _____ has refused to sign the form for reasons of confidentiality, anonymity literacy and or linguistic reasons. I have instead read her/his the consent statement above, and she/he has given consent to participate in this study.

_____ _____

Signature of person obtaining oral consent Date

The person has orally agreed to be audiotaped (circle one): YES NO

_____

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