Groundwater is the major source of drinking water and dietary fluoride in human beings in rural as well as urban areas throughout the world. Fluoride ion in drinking water is known for both beneficial and detrimental effects on health. It is essential for normal mineralization of bones and formation of dental enamel with its presence in small quantity (Chouhan and Flora, 2010). When fluoride is taken up more than the permissible limit, it becomes toxic and causes clinical and metabolic disturbances in animals and human beings such as dental and skeletal fluorosis (Singh et al., 2007). The amount of fluoride present naturally in groundwater is governed principally by climate, composition of the host rock and hydrogeology (Gupta et al., 2006). Some anthropogenic activities are also contributed to cause an increase in fluoride concentration in groundwater such as use of phosphatic fertilizers, pesticides and sewage and sludges, depletion of groundwater table etc (Ramanaiah et al., 2006). Hence to monitor the groundwater quality a lot of studies carried out throughout the world now a days (Sunitha et al., 2012).

Groundwater forms a major source of drinking water in urban as well as in rural areas. Groundwater has the properties of dissolving and carrying in solution, a variety of chemical and other materials. More than 90% of the rural population uses groundwater for domestic purposes. Major problems are being faced by the country due to the presence of excess fluoride, arsenic and nitrate in groundwater in certain parts of country. At present twenty nine countries are reported to be affected with fluorosis, the fluoride related disease. Water hardness may be an ameliorating factor, that the bioavailability of F ions in water organisms is reduced with increasing water hardness (Camargo, 2003).

Fluoride contamination of groundwater is a growing problem in many parts of the world. The major sources of fluoride in groundwater are due to fluoride bearing minerals such as fluorspar, cryolite, fluorapatite and hydroxylapatite in rocks (Farooqi et al., 2007). Fluoride is one of the important factors in water quality management due to its adverse health effects. The problem of high fluoride concentration in groundwater resources has become one of the most important toxicological and geo-environmental issues in India. Excessive fluoride in drinking water causes dental and skeletal fluorosis, which is encountered in endemic proportions in several parts of the world (Fawell et al., 2006).
Organization guideline recommendation for maximum limit of fluoride in drinking water is 1.5 mg/L (WHO, 2004). About 20 out of 35 states and union territories of India were identified as endemic for fluorosis and about 66 million people in these regions are at risk of fluoride contamination. Fluorosis is known to occur due to the entry of excess fluoride into the body. It is a slow, progressive, crippling malady that affects every organ, tissue, and cells in the body, and results in health complaints that overlap with several other disorders. Most of the fluorides are readily soluble in water. Prolonged ingestion of fluoride above permissible level through water is the major cause of fluorosis.

The epidemiological evidence that concentrations above this value carry an increasing risk of dental fluorosis and progressively higher concentrations lead to increasing risks of skeletal fluorosis forms the basis of guideline derivation (WHO, 2004). The guideline value is higher than that recommended for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/L. In Andhra Pradesh, Gujarat and Rajasthan, 70–100% of the districts are affected. Fluoride levels in water in Andhra Pradesh vary from 0.4 mg/L to very high level of 29 mg/L (Fluoride and Fluorosis, 2009).

The higher concentration of fluoride may be due to the presence of fluoride-bearing minerals in groundwater as the majority of the areas in fluoride affected blocks are underlain by granitic rocks (Chofqi et al., 2004). With the increase in industrial activities water bodies with excess levels of fluoride are becoming a matter of great concern. High fluoride concentrations in groundwater, up to more than 30 mg/L occur widely, notably in the United States of America, Africa and Asia (Czarnowski et al., 1996; Azbar and Turkman, 2000; Moturi et al., 2002; Wang et al., 2002; Agarwal et al., 2003).

Physicochemical parameters such as pH, electrical conductivity, total alkalinity, total hardness as well as calcium, magnesium, sodium, potassium, chloride, nitrate, carbonate, and bicarbonates were analyzed with the determination of fluoride concentrations. In general, the ground water had no colour, odour and turbidity except few samples. The pH varies from 7 to 8.6, with a mean of 8 indicating an alkaline condition which favours the solubility of fluoride-bearing minerals (Sunitha et al., 2011).
The occurrence of fluoride in drinking water is reported from many parts of the World such as Afghanistan, Algeria, China, Egypt, Iraq etc. In India the occurrence of fluoride in drinking water is reported from different parts of the States of Haryana, Delhi, Rajasthan, Karnataka, Utter Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, and Tamil Nadu, Kerala, Jammu & Kashmir, Punjab, Orissa, Himachal Pradesh and Bihar. Except for Delhi, this regional dispersion of fluoride is mostly consistent with the major fluoride bearing minerals.

Endemic fluorosis is an important public health problem in India. Prevalence of dental and skeletal fluorosis among the population assesses the relation between drinking water fluoride level and prevalence of fluorosis. A report published by Rajiv Gandhi National Drinking Water Mission (RGNDWM, 1994) identified 20 states of India facing the problem of excessive fluoride in the ground water and about 62 million people including 6 million children suffer from fluorosis because of consumption of water with high fluoride concentrations (UNICEF, 1999). Where water intake is low, fluoride level upto 1.5 mg/L is acceptable. The Ministry of Health, Government of India, has prescribed 1.0 and 2.0 mg/L as permissive and excessive limits for fluoride in drinking water, respectively. Excess intake of fluoride beyond permissible limit brings out dental and skeletal fluorosis along with neurological disorders. Fluorosis in human beings was reported by (Chandra Shekar and Anuradha, 2004; Raghavachari Srikanth et al., 2008; Sunitha et al., 2011; Ramesh and Vennila Soorya, 2012; Lakshmi, 2013; Khadar Basha and Jayantha Rao, 2014; Sandeep, 2014).

Several studies on F toxicosis in domestic animals have been conducted on buffaloes (Bubalus bubalis), camels (Camelus dromedarius), cattle (Bostaurus), donkeys (Equus asinus), goats (Capra hircus), horses (Equus caballus) and sheep (Ovis aries) living in areas with high F (>3.0 ppm) in the drinking water (Choubisa, 2013).

Study Area

The investigation was carried out in two affected villages of Kurnool district (A.P.), of Tuggali mandal. The first village is Tuggali, located about 62 km from Kurnool city. The second village is Sabhashpuram, which is about 58 km from Kurnool city and 15 km from Tuggali town. Tuggali has a population of 750 approximately in various age groups and Sabhashpuram has about 400 approximately.
Kurnool district, in the south western part of Andhra Pradesh, covering an area of 17,658 sq. Km consists of 54 mandals and lies between latitudes 14° 55’ and 16° 07’ N latitudes and 76° 59’ 50” and 78° 50’ E longitudes. The district is bounded on the North by Mahaboobnagar district, on the East by Prakasam district, on the West by Bellary district of Karnataka State and on the South by Anantapur and Cuddapah districts of Andhra Pradesh. The district consists of two distinct physiographic provinces viz., the undulatory gneissic terrain with low denudation hills in the west and a sedimentary terrain with structural plateaus and homo clinical ridges and valleys in the east. The climate of this district may be described as semiarid with annual rainfall ranging from 40 to 60 cm and the daily temperature varying from 18° to 43° C. The Krishna River and its tributary Tungabhadra flow through the area in the north.

The major part of the district in western part is occupied by the granite gneisses, while the eastern part is underlain by the quartzites, shales and lime stones of cuddapah and Kurnool group. The recent alluvium is confined to the major stream and river courses like Krishna, Tungabhadra, Gundlakamma and Kuderu. Out of the 918 villages of the district 72 villages are facing poor and quality in problem.

The main source of drinking water in two villages is coming from bore wells and dug wells. The present survey is conducted to know the concentration of fluoride level in water in dug well and bore well and total incidence of skeletal and dental fluorosis in both males and females of the two villages, such as Tuggali and Sabhashpuram.

**Estimation of Fluoride Concentration:**

Water samples were collected in good quality glass bottles of one litre capacity and brought to the laboratory without adding any preservatives. To avoid contamination, the samples were collected directly in rinsed bottles. Fluoride concentration of the samples were determined with fluoride ion electrode (IRION) and IROIN 407A ion meter. A 25 ml of aliquot was taken in polythene beaker and 25 ml of TISAB - iii (Total ionic strength adjuster buffer IRION - Application solution) was added (Barnard and Nordstorm, 1982). Ion meter was standardized against solution of known fluoride concentration in the standard sample and read directly on
the meter scale. The scale was calibrated in ppm of fluoride concentration in water. The affected persons were photographed both for dental and skeletal fluorosis.

**Results**

The main source of drinking water in Tuggali and Sabhashpuram villages are bore wells and dug wells. The fluoride content in Tuggali village is 4.35 (mean) and Sabhashpuram village 3.93 (Mean) is observed in the present study. In these two villages Tuggali has more amount of fluoride content in water when compared to Sabhashpuram. In these two villages, dug wells have more amount of fluoride content when compared to bore wells.

The epidemiological survey conducted reveals that in Tuggali village 68% of the people affected with dental fluorosis and 59.5% of the people are affected with skeletal fluorosis. In Sabhashpuram village 62.5% of the people are affected with dental fluorosis and 54% are affected with skeletal fluorosis.

The skeletal fluorosis is evidenced with crippled limbs and bending of stature in adults and people have experienced difficulty in walking because of stiffness and limitations of various joints (Plate 1.1; Figs. A&B). Some skeletal fluorosis persons are suffering from compression of spinal cord, vertebral crippling, osteophytosis. Some skeletal fluorosis patients are suffering from restricted movement of neck, trunk and rigidity of bones (Plates 1.2 – 1.4; Figs. C – H). In some cases weight loss, brittleness of bones, muscular wasting, anaemia and weakness is observed. In children crippling of limbs and stunted growth is observed in both the villages. (Plate 1.5; Figs. I&J).

Dental fluorosis patients showed brownish colour stains, white flecks, abnormal patchy mottled teeth, dental carries, dental erosion, loss of enamel, damage of molar teeth, spongy gums etc (Plates 1.6 - 1.8; Figs. A - I).

**Discussion**

In the present study total incidence of fluorosis is more in Tuggali village than Sabhashpuram village due to high fluoride content in drinking water (Table 1). Endemic genu valgum associated with fluorosis was reported from the state of Andhra pradesh in 1973 (Krishnamachari and Krishnaswami, 1973). Sporadic cases of genu valgum associated with excess fluoride have been reported from a few more
states in India (Gupta et al., 1994). High fluoride content in drinking water is the main reason for dental and skeletal fluorosis in Kurnool district.

In the present investigation it is noted that dug wells contain higher concentration of fluoride than the deep bore wells (Table 1). This is due to the fact that the recharge source for the deep zone is different from the shallow zone (Subba Rao et al., 1997). Investigations conducted in the crystalline terrains of Prakasam, districts of Andhra Pradesh, India have revealed that deep well water contain less fluoride than the dug well water (Khadar Basha and Jayantha Rao, 2014). Chachra et al. (2010) observed that municipal water can reduce the incidence of dental caries as compared to ground water. However in the present study, fluorosis occurred due to consumption of water from deep borewells, eventhough such wells were proposed as a method to protect individuals from endemic fluorosis (Teotia et al., 1987).

Fluoride concentration in natural waters depends on various factors such as temperature, pH, solubility of fluorine-bearing minerals, anion exchange capacity of aquifer materials (OH- for F-) and the nature of geologic formations drained by water and contact time of water with a particular formation (Sunitha et al., 2011). The main source of fluoride in ground water is fluoride-bearing rocks such as fluorspar, fluorite, cryolite, fluorapatite and hydroxylapatite (Meenakshi et al., 2004). Ground water is the only source of potable water for majority of people in the study area. However, the inhabitants here are adverse to drink bore well water or water from public water system. For drinking suitability, the selected eight important water quality parameters such as pH, Chlorides, Fluorides, TDS, Total Hardness, Calcium, Magnesium and Nitrates are compared with standards laid by Bureau of Indian Standards (BIS).

Na$^+$ content is more than that Ca$^{2+}$, Mg$^{2+}$ in water that may be due to Caco$_3$ and Mgco$_3$ deposited, and NaF is easily formed in the water solution (Payal and Bhatt, 2008). The positive correlation of pH with fluoride indicates that alkaline groundwater is likely to have a higher amount of fluoride, suggesting that the pH of the groundwater is more important in determining the concentration of fluoride (Sujatha, 2003). Alteration of mud and clay layers in the subsurface lithology and which have very low hydrologic conductivity all these factors together constitute a favourable condition for the maximum absorption of F$^-$ by the clay minerals in the
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soil. Moreover, the weathering of alkaline sedimentary rocks releases F into soil and groundwater.

**Rajesh et al. (2012)** reported Children are the most prone to dental fluorosis as Fluorides and oral their body tissues are in growth stage high fluorosis incidence above 6 years of age may be due to growing age and fluoride consumption increases with increase in quantity of drinking water. **Agrawal and Purva (1998)** conducted a survey on prevalence of dental fluorosis among children and adolescents residing in Banasthali and Rajasthan and reported that symptoms of dental fluorosis like discoloration and distinct brown staining are found more in boys than village girls and hostel girls. This may be attributed to high physical activity by males thus resulting in more consumption of water and in turn more intake of fluorides.

If the enamel organ is exposed to the excessive amount of fluoride during formative period, the normal mineralization pattern of tooth will be disturbed in various degrees of prolonged period characterized by mottled enamel called “Dental Fluorosis” (**Nazneen et al., 2005**). This condition is marked by visible mottling and / or discoloring of tooth enamel, pitting of the enamel and disturbed tooth surface. Teeth with moderate dental fluorosis typically may have yellow and brown stains, pitted, brittle and susceptible to fracture. Severe dental fluorosis not only produces unattractive teeth but also may increase the risk of tooth loss because it destroys path of the protective enamel.

**Shanthi et al. (2014)** reported that the mutilated morphology of fluorotic teeth facilitates plaque accumulation and food lodgement that leads to initiation of dental caries. There was a positive correlation between fluorosis and dental caries. **Chandra Shekhar and Anuradha (2004)** reported increase in the prevalence of dental fluorosis with the corresponding increase in water fluoride content. **Baruah et al. (2011); Bhosle and Peepliwal (2010)** observed prolonged use of fluoride containing water, low calcium food habit and sanitation to be the reasons for dental fluorosis. **Choubisa (2013)** reported mild to severe intermittent lameness or restricted movements in their hind legs, stiffness of tendons in the legs, wasting of main mass of hind quarter and shoulder muscles, snapping sounds and lowering of neck during walking in one-month-old cattle calf.
Raghavachari Srikanth et al. (2008) reported that the hot climate with a mean annual temperature as high as 38°C, water consumption is very high. The occupation of the majority of people living in the rural areas of farming, where many of the working adults consume an average of 7 liters of water per day including water used for cooking. The native diet is semisolid and starchy, containing substantial amounts water. High levels of F intake have long been associated with various forms of debilitating fluorosis.

Poor nutrition and low Ca intake enhance the deleterious effect of fluoride. With high level in their drinking water it is also known that bone formed in response to large doses of F has increased crystallinity may have decreased elasticity and greater susceptibility to stress fractures. Higher Bone Mass Density in the lumbar spine and femur neck in fluorotic subjects as compared to non fluorotic subjects may be due to prolonged intake of high F (Khandare et al., 2007). Choubisa et al. (2011) conducted a survey in domestic ruminants reported that differences in the sensitivity of camels, goats, and sheep to fluorosis may also be due to inherent differences in susceptibility to fluorotoxicosis and frequency of F intake. In this connection, it should be noted that many breeds of sheep and camels in general are better adapted to desert ecosystems and require less water for their survival than most other ruminants.

Intake of essential nutrients like Calcium, Iron, Folic acid, Vitamin-C, D, E and other antioxidants (Jackson and Masler, 2002), role of diet on fluorosis has a double sword action. Intake of high fluoride diet increases the toxic manifestations of fluorosis, whereas intake of diet rich in calcium and vitamin-C helps in overcoming the toxicity of fluorosis (Susheela and Bhatnagar, 2002). Presence of calcium, protein and vitamin-C in food has preventive role in fluorosis. A study conducted in fluoride endemic villages of Dharward district by Pushpa Bharati and Meera Rao (2003) showed that the intake of protein and calcium adequacy are the important factors in determining the severity of disease.

The present water availability situation in Tuggali, Sabhashpuram, Kurnool district, Andhra Pradesh, is under great threat. Most of the chemical concentrations collected from the study area do not comply with the water quality standards. Geological formation is found to be a basic cause for the higher concentration of fluoride in most of the sampling points. Alkaline environment is the dominant
controlling factor for leaching of fluoride from the source material in the groundwater. The high fluoride content in the groundwater of this area has affected villagers in the form of primary level of fluorosis resulted in stained and darkened tooth enamel and Neurological disorders also observed. Several reports on dental and skeletal manifestations of fluorosis are also reported in the study area, which shows that the population of the study area is at higher risk due to excessive fluoride intake.

Table 1.1: Fluoride content in drinking water of two villages (in ppm)

<table>
<thead>
<tr>
<th>Name of the Village</th>
<th>Source of Water</th>
<th>Fluoride content (ppm)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borewell – I</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borewell – II</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borewell – III</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dugwell – I</td>
<td>4.7</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td>Dugwell – II</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dugwell – III</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Tuggali</td>
<td>Borewell – I</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borewell – II</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borewell – III</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dugwell – I</td>
<td>4.0</td>
<td>3.93</td>
</tr>
<tr>
<td></td>
<td>Dugwell – II</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dugwell – III</td>
<td>4.4</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.2: Total incidence of fluorosis including gender distribution in the Tuggali village

<table>
<thead>
<tr>
<th>Gender</th>
<th>Total No. Surveyed</th>
<th>Affected with dental fluorosis</th>
<th>Affected with skeletal fluorosis</th>
<th>Total incidence of fluorosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>100</td>
<td>73</td>
<td>65</td>
<td>69%</td>
</tr>
<tr>
<td>Female</td>
<td>100</td>
<td>64</td>
<td>52</td>
<td>60%</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>68%(137)</td>
<td>58.5%(117)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.3: Total incidence of fluorosis including gender distribution in the Sabhashpuram village

<table>
<thead>
<tr>
<th>Gender</th>
<th>Total No. Surveyed</th>
<th>Affected with dental fluorosis</th>
<th>Affected with skeletal fluorosis</th>
<th>Total incidence of fluorosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>100</td>
<td>65</td>
<td>58</td>
<td>61.5%</td>
</tr>
<tr>
<td>Female</td>
<td>100</td>
<td>60</td>
<td>50</td>
<td>55%</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>62.5%(125)</td>
<td>54%(108)</td>
<td></td>
</tr>
</tbody>
</table>
LEGEND FOR FIGURES

PLATE – 1.1

Fig. A: Skeletal fluorosis patient experienced difficulty in walking because of stiffness and limitations of various joints.

Fig. B: Bowed legs & bent neck.
PLATE – 1.1
LEGEND FOR FIGURES

PLATE – 1.2

Fig. C: Skeletal fluorosis person suffering from crippling of legs

Fig. D: Skeletal fluorosis patient suffering from restricted movement of spine, rigidity of the spine, osteoarthritis of spine and backbone bending
PLATE – 1.2
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LEGEND FOR FIGURES

PLATE – 1.3

Fig. E: 30 years women suffering with bent knees

Fig. F: 10 years child having weak & bent left leg
PLATE – 1.3
LEGEND FOR FIGURES

PLATE – 1.4

Fig. G: Skeletal fluorosis person having restricted movement of neck, trunk and rigidity of bones.

Fig. H: Woman suffering from compression of spinal cord, vertebral crippling and osteophytosis
PLATE – 1.4
LEGEND FOR FIGURES

PLATE – 1.5

Fig. I: 6 years baby having weight loss, brittleness of bones, muscular wasting, anemia and weakness

Fig. J: 5 years child suffering from crippling of legs and with nervous disorder
Chapter – I

PLATE – 1.5
LEGEND FOR FIGURES

PLATE – 1.6

Fig. A: Dental fluorosis with gold colour and metallic shiny teeth

Fig. B: Whitish colour teeth with slight brown stainings

Fig. C: Teeth showing hypoplasia, attrition, brown staining and spongy gums
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PLATE – 1.6

Fig. A

Fig. B

Fig. C
LEGEND FOR FIGURES

PLATE – 1.7

Fig. D: Dental fluorosis with gold colour and metallic shiny teeth

Fig. E: White flecks on lower incisors and brown stains in upper incisors

Fig. F: Effected enamel surface, brown staining on incisors
Chapter – I

PLATE – 1.7

Fig. D

Fig. E

Fig. F
LEGEND FOR FIGURES

PLATE – 1.8

Fig. G: Brown patches on Molars and pitting of Molars

Fig. H: Teeth showing hypoplasia, attrition, brown staining and spongy gums

Fig. I: White spots and metallic shiny teeth
PLATE – 1.8

Fig. G

Fig. H

Fig. I