APPENDIX - I
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Papers Published


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Geo-spatial Analysis of Fluorosis in Nalgonda District of Andhra Pradesh, India


Abstract
Nalgonda district in Andhra Pradesh is noted for both Dental and Skeletal fluorosis cases. Keeping that in view, water samples from Nalgonda revenue division were collected and fluoride analysis was carried out by using Scott-Sanchis method. The analysis revealed that the highest concentration of fluoride (>10 ppm) in the drinking water exists in the western parts of the division in Chintapalle mandal. In some parts of Chityala, Narayanapur, Munugode, Chintapalle, Kattengoor, Kathepalle and Nakrekal mandals, it ranges between 5 and 10 ppm. In the remaining parts of the division fluoride concentration is below 5 ppm. Similarly the analysis of data on fluorosis cases reported in the study area indicated that the incidence of dental fluorosis is more than skeletal fluorosis. Maximum cases of dental as well as skeletal fluorosis are reported at Marriguda 2312 and 759 respectively. Munugode and Narayanapur show maximum cases of dental fluorosis. Chandur, Gurrampode and Thipparthi recorded minimum number of Fluorosis cases. The incidence of fluorosis is directly correlated with the fluoride concentration in the drinking water. The present study indicated that the entire Nalgonda division is under the threat of fluorosis due to high concentration of fluoride in the drinking water.

Introduction
The fluorides, most active elements of halogen group were widely distributed in nature and it has been estimated that the element fluorine in the form of fluoride constituents 0.32% of the earth’s crust (WHO, 1984). Fluorine is essential for the formation of caries resistant dental enamel and for the normal mineralization of bone. On an average a person may obtain about one milligram of fluorine daily from drinking water which contains 1ppm of fluorine. In addition, humans receive 0.25 to 0.35 mg of fluorine through some foods like sea fish, cheese and tea. Fluorosis is a condition resulting from excessive ingestion of fluoride in drinking water (>1ppm). When a person drinks water with an excess of fluorine content, fluorine displace calcium in the bones leading up to twisting and weakening of bones. Even blood circulation gets affected when excess fluorine exists in the blood vessels. The chronic toxicity of these fluorides in human beings manifests significantly on dental and skeletal tissues. As a consequence, excess intake of fluorine leads to diseases namely dental and skeletal fluorosis and Genu Valgum, while its hard consumption causes dental caries. Hence, fluorine is often called as a double edged sword (Park and Park, 1972).

Muller and Gudson (1937) first reported the occurrence of Fluorosis disease in sheep, which was stated to be due to assimilation of fluorine, a disease they called as Fluorosis. Poultry is relatively resistant to fluorine intoxication (Peirce, 1940), but in Kamaguda of Nalgonda district, even poultry were also affected because of the high fluorine content of water (Siddiqui, 1955). First case of fluorosis in humans in India was reported by Short et al. (1937) from Prakasam district of Andhra Pradesh. Later several reports indicated that more and more states are under fluorosis (Chakraborti et al., 2000). Susheela and Majumdar (1992) reported that about 62 million people are suffering from various levels of Fluorosis, of which 6 million are children below the age of 14 years; they suffer from dental, skeletal and/or non-skeletal Fluorosis.

A concentration of 0.5 to 0.8 ppm of fluorine in drinking water is considered as a safe limit in India. In endemic areas, the concentration of fluorine is as much as 3 to 12 ppm and in the nonendemic areas it

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is about 0.5 ppm in the natural waters. In urban areas water quality is too low due to indiscriminate disposal of effluents into surface water bodies while in rural areas groundwater is contaminated with fluoride, arsenic, iron and other salts. Of late, Fluorosis has emerged as a major public health issue in rural India (Srikanth, 2009). Shashi and Bharadwaj (2008) in their study indicated that the incidence of the disease was found to be highest in the low economic group, followed by middle income group and lowest in the high socioeconomic group.

The symptoms of dental fluorosis include mottled enamel of the teeth (Chari and Naidu, 1998). In epidemiological surveys mottling of teeth has been used as an index of endemicity of Fluorosis in fluorosis affected persons. Teeth are characterized by chalky white patches separated by brown staining. Luster and enamel of the teeth are completely lost. Even the teeth may have a corroded appearance in severe cases. As a final stage, the teeth get dropped. Mottling is best seen on the incisors of the upper jaw. Dental Fluorosis is easily identifiable. However, identification of skeletal fluorosis at early stages is difficult. The skeletal Fluorosis is responsible for disorderly development and the twisting of skeletal bones. The symptoms of this disease include, pain in the joints, abnormal growth of bones at the joints, inactive movements, and respiratory problems. The symptoms consist of pain and rigidity of spine and later of joints or both the limbs. Some complain of paraesthesia in limbs. Radiological changes are quite characteristic. There is dense bone formation and severe spondilitis. The ligaments of the spine and tendinous insertions of other muscles may be calcified. While, in skeletal fluorosis entire bony skeleton particularly spinal column of human being will be affected (Park and Park, 1972). It is a crippling disease of the human beings. Other forms of this disease are formation of new bone in the form of exostosis, calcification of tendons and ligaments as well as interosseous membranes. In addition, recently, a new syndrome characterized by Genu valgum (Knock-knee) and osteoporosis of the lower limbs has been reported among subjects suffering from fluorosis in some parts of India (Krishnamachari and Krishnamswamy, 1973).

It was further observed that genu valgum was seen among people whose staple diet was sorghum than those whose staple food was rice.

Nalgonda is one of the highly drought-prone districts of Andhra Pradesh in southern India and its groundwater has 10 to 15 parts per million (ppm) of fluoride in contrast to a maximum permitted level of just 1.5 ppm. Earlier studies indicated that 48 out of 59 revenue mandals have fluoride affected villages in the district. As per 1992 survey, about 1122 habitations in the district were fluoride affected. 885 villages and 600,000 people are severely affected and 10,000 people are totally crippled (wikipedia.org/wiki/Nalgonda). People are suffering from both dental and skeletal fluorosis in the district. Keeping that in view, Nalgonda division, one of the four revenue divisions of Nalgonda district is taken as a case study to analyze the fluorosis situation.

**Study area**

Nalgonda district covers an area of about 14, 240 km² accounting for 5.18 % of the total area of Andhra Pradesh. As per the 2001 census, the population of the district is 34.5 lakhs with the density of 242 persons per km². Krishna river forms the southern border of the district for about 85 km. The soils of the district are mainly ‘red earths’ comprising loamy sands, sandy loams and sandy clay loams. The soils in some parts of Nalgonda district are sandy and consists of granite associated with fluorite (Siddique, 1955).

The district is under hot and dry climate throughout the year except during the southwest monsoon season. May is the hottest month, with mean maximum temperature of about 40°C and the mean minimum of about 28°C. December is the coldest month with the mean maximum and minimum temperatures being 35°C and 20°C, respectively. The average rainfall in the district is around 772 mm, about 71% of which is received during southwest monsoon (i.e. June to September). September is the rainiest month.

The district is divided into 4 revenue divisions and 59 mandals. The present study area, Nalgonda division comprises eighteen Revenue mandals of Kattangoor, Narekal, Tipparthy, shaligowraram,
Deverakonda, Pedda Adisherlapally, Marriguda, Chintapalle, Chandur, Narayanpur, Mungode, Nampalle, Gurrampode, Kethepalle, Kangal, Chadampet, and Gundlapally.

**Data Collection**

Data on fluorosis cases and fluorine content were collected from district medical and health office at Nalgonda for Nalgonda division and downloaded from internet (www.nalgonda.org). In areas where data on fluorine content are not available, water samples were collected and analysed to find out the fluorine content of that particular area. Data on number of cases on dental as well as skeletal fluorosis were collected.

**Fluorine Content in Groundwater**

The spatial spread of fluorine in the groundwater indicated that fluorine levels range between 0 and 15 ppm in Nalgonda division. Geospatial map of fluorine distribution in the ground water was represented in the Fig.1. Highest concentration of fluorine which ranges between 10 and 15 ppm occurs in the northwestern parts of Chintapalle mandal. There are extensive areas where fluorine content in the water ranges between 5 and 10 ppm. Those areas include southern parts of Narekal and Kethepalle mandals, northern parts of Thipparthi and Mungode mandals, western parts of Kattangoor Chityala mandals, and north western and southeastern parts of Marriguda and Northeastern parts of Nalgonda mandal. However, mandals namely Narayanpur, and Nampalle indicating small patches if fluorine in this range. In the remaining mandals fluorine content is between 0 and 5 ppm.

Munagode, Nalgonda, Marriguda, Chandur, Chityal, Nampally, Narayanpur, Narketpally, Choutuppal, Chinthapally, Peddavoor, Thipparthy are severely affected mandals in the district where fluoride content is above 8 ppm. Due to improper monitoring water quality systems in the district on a regular basis these areas are still in the clutch of fluorosis.

**Fluorosis Cases**

Analysis of data on fluorosis indicated that during 2003, a total of 8227 Fluorosis cases where reported in Nalgonda division, out of which 7076 cases were related to dental Fluorosis and 1420 cases were related to Skeletal Fluorosis.
The study reveals that maximum dental Fluorosis cases were recorded at Marriguda with 2312 followed by Munugode with 1073 and Chintapalle with 946 cases (Fig.2). Among the other mandals Narketpalle, Nampalle and Nalgonda mandals indicates reasonably maximum number cases. The remaining mandals show minimum number of cases. A survey of residents of the Tipparthi reported that most of the residents suffer from dental discoloration, early tooth decay and bone deformations. Further, it was reported that dental fluorosis was more common among female population than in males (Kishore and Hanumantha Rao, 2010).

Similarly, the Skeletal Fluorosis is at its maximum in Marriguda mandal. Data on skeletal fluorosis is not available in Chityala, Saligouraram, Kattangoor, Nakrekal, Ketepalle, Kangal mandals. The remaining mandals indicate cases below 500 (Fig.3).

**Conclusion**

The study revealed that Nalgonda Revenue Division in the Nalgonda district is endemic to fluorosis and there is a correlation between the fluorosis content and number of fluorosis sufferers.

**Acknowledgements**

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[www.nalgonda.org](http://www.nalgonda.org)


[www.nalgonda.org/ aboutnalgonda](http://www.nalgonda.org/aboutnalgonda)

[telanganaonline.net/html/nalgonda.html](http://telanganaonline.net/html/nalgonda.html)
Abstract

Lymphatic Filariasis is a parasitic and infectious tropical disease, caused by thread-like parasitic filarial worms, Wuchereria bancrofti, Brugia malayi, and Brugia timori. The host for the parasite is mosquito and in India Culex fatigans Species are the main vectors. For the present study area, Vizianagaram is one of the northern coastal districts of Andhra Pradesh and identified as endemic zone of filariasis. The incidence of filaria in Vizianagaram is attributed to the existence of large water bodies and 50 other water bodies that spread all over the town. Among these water bodies, a deep and wide moat encircling the historical Fort (built in 1712-1714 A.D) and a 170-acre manmade lake, popularly known as Pedda Cheruvu are the eutrophic stagnant water bodies become major store houses and excellent breeding grounds for mosquitoes. As a result 1.95 lakhs populated town became endemic to filariasis. Analysis of filarial cases indicated that the incidence is as high as 470 during 1991 became 96 by 2005. Similarly, the micro filarial rate which was 2.18 became 0.19 by 2005. This dramatic decline in the incidence of filariasis resulted with the reclamation of moat around the Fort (which was replaced by gardens) and the commission of a waste stabilization pond system in Pedda Chruvu Tank. The study indicates that how environment management practices are helps in the improvement of health conditions of any area.

Introduction

Filariasis is the name given to a group of diseases resulted by certain nematodes belonging to the family Filariidae and transmitted by arthropods (Park and Park, 1977). The word filarial derived from filar which means threadlike. Long-term exposure and repeated infections caused by the parasite lead to severe damage to the lymph system and serious, debilitating complications.

The exact initiation of Lymphatic Filariasis is not known but it was thought to have affected since 1500-4000 years ago. It was mentioned first in ancient Greek literature. Jan Huygen Linschoten written the first documentation evidence of the symptoms appeared in the 16th century the disease has been its existence in India since the 6th century B.C. This disease was mentioned as ‘Malabar legs’ by Clarke in 1709, as it was widely prevailed in Cochin (Raghavan, 1957). The actual understanding of the disease began to develop in 1866 with the works of number of scientists. The microfilariae was identified in urine and in peripheral blood by Wucherer (1872) and Lewis (1872) respectively (Wesley W.Spink, 1978). In 1876, Joseph Bancroft discovered the adult form of the disease causing worm. And later, in 1878, Patrick Manson theorized the life cycle of the disease causing microfilaria associated with arthropod vector namely mosquito. In 1900, George Carmichael Low explained the transmission of the worm in the proboscis of the mosquito vector and Manson indicated the phenomenon of ‘periodicity’ in filaria.

Lymphatic filariasis is a permanent disability and impends to socio-economic development. At present 73 countries with one billion people are at risk and 120 million people already infected (Jamshaid Iqbal and Ali Sher, 2005). According to WHO (2005), Lymphatic filaria is a most common cause after mental illness in terms of long-term disability. Among the countries infested by this disease one-third of people are residing in India, a third live in Africa and the...
remainder live in the Americas, the Pacific Islands, Papua New Guinea and South-East Asia (Shona Wynd et al., 2007).

India contributes about 40% of the total global burden and accounts for about 50% of the people at risk. In India it is widely distributed in 17 States and six Union territories (Pani et al., 2005). World Health Organization in its report (2005) mentioned that seven States namely Andhra Pradesh, Bihar, Kerala, Orissa, Uttar Pradesh, Tamil Nadu and West Bengal contribute over 86% of carriers and 97% of cases in the country. Of all the States Bihar State indicates highest endemicity with over 17 percent, followed by Kerala with 15.7%, Uttar Pradesh (14.6%) and about 10 percent in Andhra Pradesh and Tamil Nadu. On the other hand, Goa, Assam Laksha dweep and Madhya Pradesh indicating 1 to 3 percent of disease incidence (Agarwal and Sasidharan, 2006). In Andhra Pradesh a total of 54 million people are at risk. Out of 24 districts 16 districts are identified as endemic districts, 6 districts non-endemic and 2 districts yet to be surveyed. All the coastal districts and six of the Telangana districts are endemic to filaria. Among Rayalaseema, Chittoor is more prone to the disease. Lymphatic Filariasis mostly occurs in remote rural areas and in neglected peri-urban and urban areas. The disease associates with poor people and in the areas of inadequate sanitation, stagnant waters, overcrowding and houses directly exposed to mosquito menace without any protection. In endemic areas, Lymphatic filariasis tends to develop more quickly in new migrant population than in local populations who are at risk of the infection continuously.

**Vector Mosquitoes**

Filaria is like malaria and dengue spread from person to person by infected mosquitoes. At present these Arbovirus diseases are caused by 28 varieties of viruses that are biologically transmitted by the bite of a variety of mosquitoes. Mosquito is the intermediate host in Filaria. Filariasis is the first disease proved to spread by the insects.

Culex fatigans Species are the main vectors of bancroftian filariasis in India. It is a strong winged mosquito. They prefer to breed in dirty water collection, like stagnant drains, cess pools, septic tanks, borrow pits. In the absence of dirty water they breed in clean water. Its dispersal has been found to be 11 km. The Species is highly anthropophilic. It enters the houses in the evenings and attains maximum density in the nights. The peak bite time is around midnight. Legs, particularly below the knee are the preferred biting sites. During the day they take shelter indoors on the walls, underneath furniture and dark corners and outdoors on vegetation.

Apart from the surroundings, climate plays a key role in the epidemiology of Filariasis which influences the breeding and longevity mosquitoes and determines the development of parasite in them. Maximum prevalence of Culex fatigan and its optimum longevity was observed when temperatures are between 21°C and 41°C and relative humidity was around 70%.

**Filariasis Parasite**

Lymphatic filariasis results through thread like parasitic filarial worms *Wuchereria bancrofti* or *Brugia malayi* and *Brugia timori* that settles in the human lymphatic system (Sabasen, 2007). The adult worms are thread like measuring 4 to 6.5 cm in length and 0.1 to 2.8 mm in width which coils together in lymphatic vessels and glands. These parasites produce millions of microfilariae that circulate in the blood during their lifespan of 4 to 6 years (Nirup Sen, 2002). The young worms are called as microfilariae and they measure 280 x 7 µm. They reside 6 to 12 months in the peripheral blood of the patient after infection. In the insect vectors they pass through three stages to grow into infective larvae which are injected into the individual. The larvae settle near the lymph glands where it takes an adult form.

In India, Filariasis caused by certain nematodes namely *W.bancrofti* and *B.malayi*. *W.bancrofti* menace exists in almost all the States of India. Of which, microfilaria of *W.Bancrofti* are more
dominating and occur in larger densities during the nights in the blood especially between 10 pm and 2 am. The periodicity of microfilaria was probably linked with the blood-searching activity of the vector mosquitoes. The infected man contains one microfilaria / 40 c.m.m of blood. If the mosquitoes fed on carriers having 80 or more microfilarial per 20 c.m.m of blood, the heavily infested mosquitoes were often killed.

Like Malaria, Filaria involves with the biological transmission cycle. In which the disease agent multiplies or undergoes change in the development with or without multiplication in the anthropod host (Park and Park, 1977). The females release large number of minute larvae, which move along with the blood circulation of the infected individual. When the person is bitten by a mosquito, it ingests the larvae and later development of larvae carried out. Then the fully developed parasite re-enters into the lymph vessels by mosquito bites and develops into adults. The life span of adult worm is about 7 years. Then the cycle begins again. The symptoms of filariasis initiates when the adult worms reside in the lymph system. As the worm damages the tissue the normal flow of lymph fluid interrupted. As a result, legs and groin suffers from swelling, scarring, and infections. These symptoms can appear 5-18 months after a mosquito bite.

Though the infection attacks in the infant stage of an individual, the chronic symptoms of the disease appear only in the adulthood. In general males are more prone to filariasis than the females as mostly they engage in outdoor works. Lymphatic filariasis is rarely fatal, but it is responsible for recurring infections, fevers, severe inflammation of the lymph system and deteriorated lung condition with Tropical Pulmonary Eosinophilia (TPE). The external manifestations include enlargement of the entire leg and arm. Internally, damage can occur to the lymphatic circulation system and the kidneys. In about 5% of infected persons, a condition called elephantiasis causes the legs to become swollen. This can lead to severe disfigurement, decreased mobility, and long-term disability. The swelling of legs and other parts of the body causes physical suffering, mental trauma and carries a social stigma. Eliminating Lymphatic filariasis is a critical task as the disease carrier become physically and psychologically incapable to work (Nirupsen, 2002).

**Study area**

For the present purpose Vizianagaram town in the northern coastal parts of Andhra Pradesh which is noted as endemicity of filaria was taken to illustrate the etiological conditions of the disease. Vizianagaram town is located in the Vizianagaram district of Andhra Pradesh State and is situated in the heart of the Eastern Ghats (18°122 N latitude & 83°422 E longitude ; Fig.1 a and b). The town spread over about 38 Km² and supporting 1.95 lakhs of population (2001 census). The town is known for its Fort which was constructed in the year 1712-1714 A.D., with an elevation of 74 meters. The imposing fort formed the nucleus around which entire town developed. Administratively, the town consists of 38 municipal wards (Fig.1.c). Town experiences floating population from the adjacent agricultural villages as it is a market centre.

Data on filarial cases were collected from the existing National Filaria Unit centers for the period from 1991 to 2006 and data on weather conditions were collected from the agricultural weather station. Results were depicted in the form of tables and figures.
Table 1 and Fig.2 reveals that year 1992 records maximum cases with 580 cases followed by 2002 with 522 cases. Minimum cases recorded during 2005 with 96 cases followed by 108 cases in 2006. It can be noted that no year was free from filarial incidence. But there was a sudden decline in the cases since 2005. The temperatures are above 28ºC in Vizianagaram in all the years of study period (Table 1.). These warm temperatures are advantageous for the prolific growth of mosquito populations as they survive between 21°C and 41°C if other weather and environmental conditions are also favorable.

The seasonal analysis of rainfall revealed that maximum cases were recorded during southwest monsoon season followed by cold weather and hot weather seasons. In general rainfall conditions which are always favorable for mosquito population growth and that results in the incidence of more vector borne diseases. In the present context, filarial cases during south west monsoon which is supposed to be rainiest period (572 mm) is not indicating that much high incidence of disease when compared to the hot weather and cold weather seasons. That is because the torrential rains during southwest monsoon season have a tendency of flush out the breeding grounds of mosquitoes. As a result, mosquito life cycle intermittently disrupts at egg/larval stages and the production of adult mosquitoes will be drastically reduced. The decrease in the filarial incidence during northeast monsoon (213 mm) also may be due to decrease in the mosquito population because of less mosquito population to spread the disease. On the other hand, the moderate rainfall during cold weather (28 mm) as well as hot weather (75 mm) is comparatively ideal for mosquito breeding as these two seasons giving scope for the emergence of adult mosquitoes without disruption.

**Disease indices**

The indices commonly used to understand the intensity of filariasis problem are microfilaria rate, filarial disease rate, filarial endemicity rate, microfilarial density and average mosquito infestation rate. These indices help to take appropriate measures to control the disease. For the present purpose, microfilaria rate i.e. number of persons carrying microfilarial in their peripheral blood (20 mm) out of 100 examined in the sample population and filarial disease rate i.e. number of persons showing visible manifestations of filarial disease of 100 examined in...
the sample population were analyzed and presented in the Table 2 and Fig.3.

Table 2. Disease indices of Filaria in Vizianagaram Town (91-05)

<table>
<thead>
<tr>
<th>Year</th>
<th>MF Rate</th>
<th>Disease Rate</th>
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<tbody>
<tr>
<td>1991</td>
<td>2.18</td>
<td>0.39</td>
</tr>
<tr>
<td>1992</td>
<td>2.61</td>
<td>0.64</td>
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<tr>
<td>1993</td>
<td>1.64</td>
<td>0.62</td>
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<tr>
<td>1994</td>
<td>1.56</td>
<td>0.39</td>
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<tr>
<td>1995</td>
<td>1.20</td>
<td>0.73</td>
</tr>
<tr>
<td>1996</td>
<td>0.91</td>
<td>1.14</td>
</tr>
<tr>
<td>1997</td>
<td>1.53</td>
<td>1.67</td>
</tr>
<tr>
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<td>2002</td>
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<td>2003</td>
<td>0.57</td>
<td>1.31</td>
</tr>
<tr>
<td>2004</td>
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<td>0.84</td>
</tr>
<tr>
<td>2005</td>
<td>0.19</td>
<td>0.77</td>
</tr>
</tbody>
</table>

The analysis revealed that high micro filarial rates were observed during 1991 and 1992 with 2.18 and 2.61 respectively. However, the disease rate is low during these two years. The micro filarial rates were high up to 2002 with above 0.9. From then it was declined drastically. The disease rate was at its full boom between 1996 and 2003 which ranges between 1.14 and 2.28 percent. It was also declined since 2004.

Cause and effect

The high incidence of filarial in Vizianagaram town is entirely attributed to the degraded environmental conditions. Vizianagaram Fort which was built in 1712-1714 A.D is surrounded by a deep and wide moat which was dug as a defensive measure for the enemy attacks, so that enemy couldn’t enter into the fort. This moat has become a stagnant eutrified body of water serving as an excellent breeding ground for mosquitoes. Apart from this there are more than 50 water bodies which may be potential breeding zones for mosquito population (Fig.1 c). There are three water bodies namely Pedda cheruvu, Ayya koneru, Kamudu cheruvu which spread in the central, eastern and western locations respectively in the main built-up area of the town. Apart from these, there are number of other natural water tanks with various dimensions scattered all over the town. Among these water bodies, a 170-acre manmade lake, popularly known as Pedda Cheruvu is noteworthy. It was initially designed almost one century back by a French architect and commissioned into operation by the then Maharaja of Vizianagaram as a multipurpose water body for recreational, irrigational use and for maintaining the ground water table. With progression of time and increase in population, this large man-made lake ultimately became a store house of mosquitoes and potential breeding ground with noxious and fowl odors due to continuous release of million gallons of sewage into the tank by 45,000 people living around (Prakasam Tata, 2007). Apart from the natural and manmade tanks, there are many more mosquito breeding grounds existing throughout the town in the form of stagnant water bodies, garbage dumps, improper drainage channels, etc. Because of this type of unhygienic environmental conditions Culex as well as anopheles-mosquito
swarms throughout the year in the town Culex mosquitoes which are the vectors that transmit a filariasis parasite (Wuchereria bancrofti) are solely responsible for Elephantiasis in Vizianagaram town since longtime.

However, it was noted that, during 2004, 2005 and 2006 years less number of filariasis cases were reported in the study area. This decline in the incidence may be due to the initiation of waste stabilization pond system which was commissioned during 2004. The pond system was designed to be built in Pedda Cheruvu in about 15 acres of its 170-acres of area (Prakasam Tata, 2007). The system is in operation since 2004 and it is producing a clean effluent which is recycled back into the Pedda Cheruvu. As long as this system is maintained and operated properly by the municipal administration, it will improve the environmental conditions of the town and protect the residents in and around this precious water body from the endemicity of filariasis.

In addition, moat of the Vizianagaram Fort which is also identified as another potential source zone of filaria causing vectors was reclaimed and used for the development of gardens and other recreational centers. From the present study, it was concluded that by implementing environmental management practices, it is possible to get fruitful results in the eradication of diseases to a large extent. Vizianagaram town stands as an example. These types of programmes are possible only with the interest and coordination between local authorities and public.

Acknowledgements

The Project team is thankful to University Grants Commission; New Delhi for the financial support of Major Research Project entitled ‘Geospatial analysis of endemic disease in parts of Andhra Pradesh (F. No.33-74/2007 (SR). This paper is part of the Project work.

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Malaria Risk Zone Assessment -
a Case Study of Visakhapatnam City, India


Abstract
Data on malarial incidence were collected for the existing 50 wards of Visakhapatnam city (1990-2003). The yearly analysis of the data revealed that maximum cases of malaria were during 1993 and 1994. High malaria risk is associated with slum areas of the city. With the aid of spatial maps generated in GIS environment high malarial prone areas were identified which is beneficial to implement health care facilities in time and space.

Introduction
Human is, by and large, influenced by environmental elements such as soil, water and air, which play a deterministic role in the occurrence of certain diseases. The spread of diseases and threat of epidemics is more likely with overcrowding of population and increased transport facilities, which indirectly spread the disease (Susan and Paul, 2000).

The over growth of population leads to congestion and poor maintenance of the environment, which ultimately becomes store houses of disease causing vectors. One such vector borne disease, mostly associated with environmental degradation, is malaria which is one of the oldest chronic diseases that have plagued the mankind for centuries and was also mentioned by Hippocrates as early as the 5th century B.C. The term ‘malaria’ derived from the Latin ‘mala means ‘bad’ and ‘aria’, means ‘air’. The term first used by Dr. Francisco of Italy denoting the disease’s association with foul air in the marshy areas during 18th century. Later in 1880 the scientists discovered that malaria was a parasitic diseases transmitted by the anopheles mosquito (Christian Nordqvist, 2009). And it was once considered as a predominant disease in rural areas, has become a serious threat to urban life as well. Urban malaria in India is mostly caused by Anopheles stephensi, which breeds in permanent clean water and also can withstand in quite polluted water, any stagnant water from lakes down to temporary pools, cattle hoof-prints and discarded containers (Awash et al., 1991). There are about 400 species of anopheles mosquitoes, but about 70 species are responsible for transmitting malaria (Cleveland, 1977).

Among the anopheles the female anophilne mosquito which feeds on human blood, plays the role of a vector in transmitting the parasite and incidence of malaria. Climatic elements namely temperature, relative humidity and rainfall have direct relation in the growth and dispersal of vector mosquito as well as development of parasites. Direct sunlight is detrimental for the growth of vector mosquito and temperatures between 20°C and 30°C are ideal for the malaria parasite. The parasite ceases to develop at temperatures below 16°C and above 30°C (Park and Park, 1977).

The relative humidity should always be above 60 percent for the normal life span of the host mosquitoes. In the low humidities mosquitoes die soon, whereas in high humidities they become active and feed more voraciously. As a result, more and more parasites are released into the human blood. Hence, the high incidence of malaria is always more in high humid conditions (Park and Park, 1977).

Moderate and frequent rainfall leads to prolific breeding of mosquitoes. Hence, mosquito population increases enormously and provides breeding grounds in the form of pits, garbage bins, left out containers, open tanks, unlined drains, cattle shelters, etc., where water gets stagnated. On the other hand, torrential and continuous rains cause a temporary flushing out of breeding places and reduction in mosquito population. Thus, heavy rainfall is detrimental to mosquitoes as the washout

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of breeding places destroys the larvae. Hence, it was observed heavy rainfall and cyclonic storms were always associated with low incidence of malaria (Hema Malini, 1996).

**Study area**

Visakhapatnam, a million plus city is located on the east coast of India, in Andhra Pradesh State, bordering the Bay of Bengal. The built up area of the city occupies about 76 km$^2$ (Fig.1). The city is situated in a low-lying basin rimmed by the Kailasa hill range (478 m) in the north and the Yarada hill range in the south (352 m). Apart from these a few isolated hillocks of less than 50 m elevation, dot the city area. As a consequence, a number of streams descend these hills and flow in all directions in the city before directly reaching the Bay of Bengal to the east or into the tidal swamp, in the western fringes of the city.

The city can be divided into two broad sectors namely, the western industrial sector and the eastern residential and commercial sector. These two differ from each other in terms of population, built-up area; vehicular traffic and land use/land cover conditions. The southern part of the eastern sector is congested with narrow roads and overlapping buildings, whereas the northern part of it is relatively spacious with well-planned and wide roads and dwelling units. For the administrative purpose, the city is divided into 50 municipal wards. The old town (i.e. the southern part of the eastern sector) consists of a maximum number of wards with a congested space, while the wards of the northern and eastern parts are relatively extensive. The city experienced influx of migrants since the 1950’s due to industrialization and consequent urbanization. As a result, density of population is very high in certain locations of the city. Due to increased pressure on land, a number of slums have emerged which has increased from 70 in the 1968 to 251 by the 2003 and are scattered unevenly within the 50 municipal wards of the city. The ditches left all over the city during constructions, ornamental tanks and cisterns of the multi-storied buildings are ultimately becoming the storehouses of larvae of malaria vector *A. stephensi* (Samar and Subhadra, 1997). As a result, malaria is frequently occurring in the city with variation in the incidence in space and time in the recent times (Hema Malini and Pampa Choudhury, 1997).

Data on monthly malarial cases (1990-2003) in all the 50 wards of the city have been collected from the existing records of the office of the National Malaria Eradication Program, Visakhapatnam. Data on the nature of physiographic, vegetal cover and surface water bodies of the city have been obtained from the topographical maps and satellite imagery of the study area. For the correlation, the data on weather elements namely temperature, rainfall and relative humidity pertaining to the corresponding period were obtained from two weather stations existing in the city. Data on malaria incidence in the city as averaged for both the stations namely Airport and Waltair are computed. The mean monthly data for these weather elements are also computed. Data on the social conditions such as ward-wise population and densities and slums have been collected from the records of the Municipal Corporation for the same period.

Analysis of the temperatures revealed that the city experiences high temperatures throughout the year with the annual average temperature ranging between 23.8$^0$C and 30.9$^0$C. The average annual rainfall of the city is about 1024 mm out of which 560 mm occurs in the southwest monsoon (June-September) and 324 mm during the retreating monsoon (October-November). The remaining part of the annual rainfall occurs in winter (32 mm) and the summer (108 mm). Further, the analysis of relative humidity reveals that the city experiences high relative humidity throughout the year with 78%
during the southwest monsoon season, 75% during the summer, 73% during the retreating monsoon season and 70% during the winter. Thus the analysis indicated that the climatic parameters are suitable for mosquito proliferation in the city. Climate-wise, the city is providing ideal conditions for both malaria parasite and vector to spread the disease vigorously.

Data on the incidence of malaria during a 14-year period between the 1990 and 2003 showed that Visakhapatnam has recorded highest number of malaria cases during first half of the 1990s. Since then, however, there was a progressive decline in the number of malarial cases. From figure 2, it can be assessed that the maximum incidence of malaria occurred during 1993 followed by the 1994. The rate of incidence decreased since then up to 2003 except during 1999 where there was a slight increase in the incidence. The decline in the malaria incidence may be due to the improvement in the sanitation in the city during recent years. However, the analysis clearly emphasized the fact that the disease was not completely eradicated from Visakhapatnam city.

**Rainfall Vs malaria incidence**

Incidence of annual malaria cases correlated with the annual rainfall revealed that the years with the maximum malarial incidence (i.e., the 1993 and 1994) experienced low annual rainfall of about 844 mm and 888 mm, respectively. On the other hand, the minimum of 1606 cases occurred in the 2003, which recorded about 1102 mm of rainfall. This is due to the fact that moderately high rainfall is favorable for the growth of mosquitoes without interruption of the life cycle of mosquitoes. On the other hand, heavy rainfall causes flushing of breeding grounds of the mosquitoes leading to a decrease in the incidence. However, since 1998 there was decrease in the incidence of disease, may be due to improved sanitary and drainage conditions as well as maintenance of the city areas especially slums with frequent fogging to control mosquito menace.

**Spatial Patterns of Malaria**

The basic theme of geographic analysis of disease is to assess the spatial patterns of the disease. For the present purpose, GIS technique together with statistical and spatial analytical methods have been applied for spatial analysis of malaria incidence in Visakhapatnam city to find out the zones of maximum malarial incidence across the various municipal wards.

The population distribution is variable in its density levels in different wards of the city (Fig.3). The ward-wise population densities are worked out based on the number of persons per km$^2$ residing in each ward. Depending upon the values obtained the density levels are classified into four categories, namely ‘Very High’ with more than 600 persons / km$^2$, ‘High’ with population density between 400 –600 persons/ km$^2$, ‘Medium’ with 200–400/ km$^2$ density and ‘Low’ with a density of less than 200 persons/ km$^2$. Accordingly, all the 50 municipal wards are assigned with category levels. The density levels of ‘very high’ to ‘high’ are associated with the wards in the southern parts of the city, which is known as the old town. The central and northern parts of the city show medium density of population. Most of the wards along the coast and also in the western side of the city have low density of population.

An attempt is also made to analyze the slums in the city. The percentage of the slum population to the total population for all the 50 municipal wards in the city was computed (Fig.4). Ward 8 (Paindorapeta) has a maximum of 78 percent of its population living in the slums. This ward along with the wards 5 and 35 are classified under the ‘high’ category of slums as more than 60 percent of slum population living in these areas. The wards 1, 2, 3, 13, 18, 21, 22, 26, 32, 38, 39, 43, 46 and 48 with slum population ranging from 40 to 50 percent are classified under the ‘medium’ category.

![Fig.2 Year-wise Malaria incidence in Visakhapatnam city (1990-2003)](image-url)
between 20 and 40 percent are considered as ‘medium’ category, while the rest of the wards with less than 20 percent fall under the category of ‘low’ slum population.

Data on ward-wise malarial cases that have been collected for the period 1990-2003 were analyzed through Location Quotient method for a comparison of disease spread through wards. The quotient is the derived ratio between the local observed data (by ward) and the observed data of the reference unit (entire city). This ratio is calculated for all the wards to determine whether or not the local observed data have a greater share of that reference unit.

The Location quotient (LQ) is an index for comparing area’s share of a particular parameter with the area’s share of some basic or aggregate phenomenon.

\[
LQ = \frac{\frac{N_{\text{ward}}}{P_{\text{ward}}}}{\frac{N_{\text{city}}}{P_{\text{city}}}}
\]

Where:

- \(N_{\text{ward}}\) and \(N_{\text{city}}\) represent number of incident cases in the ward and the city, respectively.
- \(P_{\text{ward}}\) and \(P_{\text{city}}\) represent the number of population of the ward and the city, respectively.

The intensity levels of malaria in different wards in the Visakhapatnam city have been computed based on the LQ distribution. Table 1 illustrates the categorization of disease intensity based on the LQ values.

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<tr>
<th>S#</th>
<th>LQ Values</th>
<th>Disease Intensity</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Less than 0.5</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>0.5 to 1</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>1 to 2</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>2 to 3</td>
<td>Very High</td>
</tr>
<tr>
<td>5</td>
<td>Above 3</td>
<td>Extreme</td>
</tr>
</tbody>
</table>

Table 1: Categorization of malaria intensity levels in Visakhapatnam

The analysis of disease distribution through statistical analysis provides only quantitative information, while combinations of statistics and GIS methods enable visualization of the spatial distribution of diseases.

The spatial distribution maps of malaria (Fig.5) clearly reveals that, ward number 23 experienced high to...
This ward experienced extreme type of malaria incidence in 1996, and very high level of incidence in 1994, 1995 and 1997. During the remaining years, the ward experienced high incidence of malaria. From the analysis, it was observed that the eastern parts of the city experienced all levels of malaria intensity during the study period, whereas the western parts recorded only low level of malaria.

Further, based on the yearly intensity levels, the ward-wise malaria risk factor was computed in order to derive the malaria risk zones in the city. For that purpose, the year-wise LQ rank values (shown in Table 2) of each ward are assigned weightages and their respective weighted values are computed by multiplying the rank frequency value with its weightages number. For instance, low LQ value is
given a Rank value of 1 and its weightage value is one, and for moderate LQ value the rank value is two and its weightage value is two.

Therefore, the frequency number of a given LQ value during the entire period (i.e., during how many years that LQ value repeated itself) is multiplied by the weightage value assigned to it to obtain its weighted value. Considering the LQ values of each ward for each year, frequency number of all the LQ values is noted against their respective ranks. For instance, the malaria incidence in Ward # 1 (Kothaveedhi), as per the LQ values, was at low level in six times (i.e., during six of the 14 years), four times at moderate level and during the remaining four years the malaria incidence was in high level.

The average weighted values are then classified into four groups each indicating a certain level of malaria risk as shown in Table 3.

The malaria risk levels thus computed are categorized for all the 50 municipal wards. The spatial distribution of these four levels of malaria risk zones are illustrated in Fig. 6, which indicates that high malaria risk zones are located in the eastern residential part of the city, whereas the entire western industrial part is under low level of malaria risk.

A comparison of Fig. 6 and Fig. 4, Shows that the high malaria risk areas coinciding with the higher slum population zones of the city. As the field observations revealed, the slum dwellers dump all sorts of solid wastes into the adjacent drains and streams creating very ideal breeding grounds for mosquitoes. The slum dwellers are mostly under nourished and are more prone to diseases. In addition to the areas with slum population, the malaria proneness along the foothill locations is also significant due to stagnation of rain water in the left out ditches of quarrying activity which forms in to mosquito breeding grounds. Moreover, some of the hill streams that descend the hills are converted into sewage drains around these residential areas in the eastern foothill zones. In addition to these wet conditions, the eastern areas are characterized by the dense growth of vegetation, which also acts as good shelter for mosquitoes during daytime.

On the other hand, in the western industrial sector, the low incidence of malaria (in spite of the existence of large number of slum population and unhygienic environment) is due to the fact that these areas are always under the influence of noxious gases released from the industries, which are detrimental to the growth and spread of mosquitoes.

As a whole, it can be inferred that most part of the city is under malaria threat although there has been some decline in the incidence due to the efforts of the local authorities. The persistence of the disease is mainly due to the rapid growth of the city. The industrialization and urbanization attracted migrations. The influx of population has given rise to slums and slum population. The study revealed that the slums, which were 70 during 1968, increased to 251 by 2001. Population, which was 3, 63,467 during 1971, has risen to 10, 60,000 by 2001. This multifold increase caused deterioration of the living environment and as a consequence, diseases like malaria persist in the city.

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