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Introduction

In the present era of globalization and environmental change many infectious diseases spread worldwide leading to increased morbidity and mortality demanding greater attention for understanding of the etiology, epidemiology, prevention, and control of these diseases in order to achieve better health and well-being, especially of under privileged populations (Arden, 2008). Medical geography is an essential area of health research. It is a hybrid discipline combining geography and medicine. The main concept of medical geography is that the place and environment influence health; and this idea is as old as third century BC, put forward by Hippocrates (Meade and Emch, 2010).

Public health professionals assess health in terms of symptoms of ill-health such as morbidity and mortality, whereas medical geographers examine the spatial distribution of disease at various geographic scales and correlate it with the associated social or physical environment to determine the factors contributing to the presence or absence of the illness. In addition, geographers provide spatial perspective of the disease with an effective tool namely a map. As a consequence, it is easy to extend health care facilities in the vulnerable areas. Of late, the medical geographers are equipped with advanced techniques namely remote sensing and geographic information systems (GIS) for the implementation of effective health management in the inaccessible areas as well.
The modern technologies of remote sensing and GIS, aided by computer software for digital image processing and spatial analysis, have revolutionized understanding of earth surface features and their patterns. During the past three to four decades satellite remote sensing has developed as a tool for obtaining information on various physical, biological and cultural parameters at global, regional and local scales and at different temporal resolutions, which are not always accessible to other sampling methods (Hubert et al., 2012). GIS, on the other hand is a computer-based system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data and therefore has many applications in varied fields (Wikipedia, 2012). GIS is a hybrid of geography, cartography, spatial science and information science (Newkirk and Perkes, 2012), which enables envisioning the geographic aspects of earth surface information through querying or analysis of database and produce the results in the form of maps.

‘Nothing on the earth is more international than disease’, said Paul Russel (Gunasekharan, 2009). Health and disease have no political or geographical boundaries; disease in any part of the world is a constant threat to other regions of the world. Thus, research on the health aspects is essential both on national and international levels. The International Health Corporation was initiated in 1851. In 1907, the Office of International D’Hygiene Publique (OIHP) has started to collect information on communicable diseases and on a variety of health problems of worldwide interest. In 1923, the Health Organization of the League of Nations started analyzing the epidemiological information received and started a series of periodical epidemiological reports which are
still being maintained by the World Health Organisation (WHO), since its origin in April 1945, during the conference held at San Francisco to set up the United Nations Organisation (UNO). The main objective of the WHO is to attain highest level of health’. It collects, analyzes, tabulates and disseminates a wide variety of statistics on disease morbidity and mortality which indicates the changing patterns of the health. The United Nations International Children’s Fund (UNICEF) also established in 1946, the United Nations Development Programme (UNDP) initiated in 1966, and the Food and Agricultural Organization (FAO) formed in 1945 and International Labour Organization (ILO) instituted in 1919, are some of the international institutes which are contributing to the improvement of health and living conditions of the world populations, based on the information on health conditions received by them from various sources.

1.1 Medical Geography

Health Geography or medical geography is a scientific discipline and a subject that deals with the study of disease etiology in combination of geographical characteristics. Medical Geography considers disease as ‘maladjustment to the environment’ due to the involvement of numerous factors. Disease is an anthropological phenomenon with geographical distribution. The aim of the medical or health geography is to carry out a systematic and scientific study of the spatial patterns of the disease and of related environmental phenomena.

The clinical epidemiologic and socio-economic effects of the disease are expected to be greatest in low income countries which account for 85 percent
of world’s population (Barsoum, 2006). Human activities such as urbanization, industrialization, changing land use / land cover conditions, agricultural practices, deforestation, etc., cause imbalance in the environmental conditions and thereby responsible for certain type of diseases. Apart from these, the geochemical composition of a region also determines the human as well as animal health, agriculture potentiality and soil fertility (Chandrajit et al., 2010).

In medical Geography parlance, epidemiology is the study of epidemics. The word ‘epi’ means ‘upon’ and ‘demos’ means ‘people’. Thus, the study is concerned with the analysis of the health of the human population in relation to their environment. The epidemiology can be understood by descriptive as well as analytical approaches. The descriptive epidemiology indicated by questions like with whom, when, where the disease occurred which indicate the relation to the distribution of disease in human population. The assessment of underlying causes for the epidemiology is the analytical epidemiology. The data analyses based on both descriptive and analytical approaches, indicate the methods to be followed for prevention of the epidemiology.

Endemic is another familiar term used in medical sciences. The word ‘endemic’ derived from Greek language where ‘en’ means ‘in’ or ‘within’ and ‘demos’ means ‘people’ (en.wikipedia.org/wiki/Endemic (epidemiology). An endemic disease is a pathological condition entrenched and persists within a population group, a geographical unit without external influences. The
causative agents for an endemic disease may be a virus, bacteria or a parasite which are transmitted by vectors (www.Livestrong.com/article/186599-types-of-endemic diseases /#ix29SbofGAM). Endemic area is a geographically defined area, with evidence of persistent local transmission of a disease. Endemicity or disease intensity is a measure of disease prevalence in a particular region and prevalence is the proportion of people infected at a given point of time (www.map.ox.ac.uk/explore/about-malaria-endemicity). Epidemic disease becomes pandemic (derived from Greek where ‘pan’ means ‘all’ and ‘demos’ means ‘people’) when it spreads through human populations across large regions or even continents (Porta, 2008). For instance, smallpox and tuberculosis, HIV and H1N1 diseases are pandemics in the known history.

Further, endemic diseases can be recognized as holoendemic and hyperendemic. Holoendemic disease mostly prevails in the children rather than in the adult group of population. In many communities malaria is holoendemic. While hyperendemic means the disease that affects all the groups, irrespective of their age (Last, 1978).

Endemicity of a disease, often results from the transmission of disease agent from person to person. The incidence of such diseases mostly related to social mobility, migration patterns, urbanization and transportation (type of transfer mostly results by extensive contact of people due to crowding, and travelling, whereas in isolation the disease incidence may reduce (Chapman, 2012).
Hippocrates indicated that spatial patterns of ill health may be due to many causes namely climatic and altitudinal variations, distribution of disease causing microbes, vectors and hosts, differences in cultural, race and ethnicity, political and economic conditions and distribution of health resources. Since the incidence and prevalence of many diseases are related to various geographical phenomena, scientists and practitioners of medicine are increasingly seeking help of geographers (Cliff and Haggette, 2003) leading to an extraordinary growth of research activity in the field of geography of diseases. This has lead to identification of spatial patterns in the distribution of many diseases and their affinity to various physical, biological and cultural factors in different parts of the world in terms of mapping. However, mapping of disease distribution is an old tradition which can be traced back to the late 18th century. In the nineteenth century, there were several outbreaks of cholera in London. John Snow, a physician and anesthesiologist prepared spatial maps showing the location of water pumps and the houses of people who died of cholera to represent outbreak of cholera in the neighborhood of London during 1860, based on which he was able to identify the water pump which may be the contributory factor for the outbreak of disease (Michael et al., 2002; www. Healthcybermap .org/HGeo/ pg1_1.htm).

Similarly, dentists of Colorado found that dental cavities are fewer in the children in certain localities. They have prepared spatial distribution maps of existence of dental cavities and compared them with the maps of chemicals of
the groundwater. They found that localities with fewer dental cavities coincided with high level of fluoride present in the groundwater. Since then, use of fluoride gained significance in dentistry (geography.about.com). Based on the spatial maps of low-birth weight and various related parameters, it was found that the low birth weight was in New York city closely linked with the women’s declining economic status, inadequate insurance coverage and parental care as well as spread of cocaine (Sara and Barbara, 1995). Hema Malini et al. (2010) prepared geo-spatial maps showing the incidence of skeletal as well as dental Fluorosis and correlated with the areas of fluorine concentration in the groundwater’s of Nalgonda district of Andhra Pradesh State in India. The study revealed that the high concentration of fluorides is associated with high incidence of Fluorosis.

Malaria risk zones of Visakhapatnam city in Andhra Pradesh were identified by correlating the spatial maps of physiographic conditions, city infrastructure and slum areas (Narasimha Rao et al., 2010). The study revealed that high incidence of malaria was in the foot hill zones of the city where dense vegetation and high moisture content prevail. Vegetation provides shelter to the vectors and moist areas provide breeding zones. In addition, slum areas with poor and unhygienic housing conditions, improper drainage supports high incidence of malaria (Narasimha Rao et al., 2010). Similarly, filaria incidence zones of Vizianagaram town were identified by correlating the disease incidence with land use/land cover map from which it was inferred that filaria incidence is more in the town due to number of surface water tanks which form the mosquito breeding grounds (Hema Malini et al., 2010).
The spatial maps of rainfall, relief and iodine content of the groundwater when compared with goiter incidence in Visakhapatnam district of Andhra Pradesh revealed that high incidence of goiter was associated with low concentration of iodine, high rainfall and high elevated zones (Hema Malini, 1985). From that it was inferred that high elevation and high rainfall contribute to large-scale erosion, thereby iodine content in the soil is depleted. Low iodine content in the hilly tribal area of Visakhapatnam district is the cause for high incidence of goiter. At the same time, high concentration and low rainfall in the plain areas are almost free from goiter (Hema Malini, 1985). Further, Guinea worm prevalent zones of Anantapur district of Andhra Pradesh were identified by comparing the spatial maps of disease incidence and location of step wells. The study revealed that high incidence of guinea worm disease is associated with high number of step wells where infected persons cause spread of the worm when they get into the well to fetch water (Hema Malini, 1987).

1.2 Objective
Considering the above referred discrete studies from various parts, the present work is taken up with the main objective of investigating the geographical factors influencing the endemicity of certain diseases in different parts of Andhra Pradesh State in India, using the modern technologies of Remote Sensing and GIS.
1.3 Study Area – Andhra Pradesh State

Andhra Pradesh is one of the 28 States in India which extends from 12° 45' to 19° 50' N latitudes and 76° 45' to 84° 45' E longitudes (Fig. 1.1). The State is bounded by Maharashtra, Chhattisgarh and Odisha in the north, the Bay of Bengal in the east, Tamil Nadu State to the south and Karnataka State to the west. The State has the second-longest coastline of 972 km among all the States of India. The State covers an area of 275,045 km$^2$ and is fourth largest in terms of area and fifth in terms of population (84,655,533 as per 2011 census). The population density is about 310 per km$^2$.

1.3.1 Physiography

Andhra Pradesh can be divided into three physiographic regions namely the Coastal Plains, the Eastern Ghats and the Deccan Plateau (Fig. 1.2). The Coastal Plains extend from the northern most point in Srikakulam district bordering Odisha State to the southern most point in Nellore district bordering Tamil Nadu State. The northern coastal plain is narrow being hardly 3.65 m wide lying between the Mahendragiri hill situated in this area and the sea. The
Fig. 1.1 Map of Andhra Pradesh (AP) State with its location in India (Left). The three districts namely Visakhapatnam, Vizianagaram and Nalgonda in AP selected for the study are shown in colour.
Fig. 1.2 Physiographic divisions of Andhra Pradesh State with district boundaries overlaid (in broken polygons)

(Source: Oxford Student Atlas, 2007)
central coastal plain is the broadest. It comprises the extensive low-lying plains of the Krishna and Godavari deltas. The south coastal plain is characterized by a narrow belt of sand ridge, lagoons, and smaller deltas. Andhra Pradesh State is referred as a ‘River State’. Of the 34 major and minor rivers that flow through the State, five are major viz., the Godavari, the Krishna, the Penner, the Vamsadhara and the Nagavali (Fig. 1.3). In Visakhapatnam district, the coastal plain area gets greatly distributed by several outliers of the Eastern Ghats. The Eastern Ghats are a series of detached hill ranges, bordering the peneplained plateau in the interior. These hills reach an elevation of 900 to 1500 m above the mean sea level. The Eastern Ghats in Kurnool district are known as Nallamalai. These hills are with thin forest cover due to porous soils and deficient rainfall. Valleys are mostly under cultivation. The western peneplain comprises parts of the Deccan Plateau.

1.3.2 Administrative units

Administratively Andhra Pradesh is divided into three regions namely Coastal Andhra, Telangana and Rayalaseema with twenty three districts (Fig. 1.4). The Coastal Andhra region is mostly the coastal plain, which runs along the entire length of the state in a NE-SW direction, between the Eastern Ghat ranges and the Bay of Bengal. It consists of nine districts of Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore, from north to south. The Telangana region lies to the west of the Eastern Ghats on the Deccan Plateau. The Godavari and
Fig. 1.3 Major River system in Andhra Pradesh State

(Source: Oxford Student Atlas, 2007)
Fig. 1.4 The three major Administrative regions and the corresponding districts in AP
Krishna rivers that rise in the Western Ghats, almost close to the west coast of India flow eastward across Karnataka and Maharashtra States and the Telangana region in Andhra Pradesh to empty into the Bay of Bengal where they built a 12,700 km\(^2\) twin delta complex. The Telangana region comprises nine districts namely Adilabad, Nizamabad, Karimnagar, Khammam, Nalgonda, Rangareddy, Hyderabad, Mahaboobnagar and Warangal. The Rayalaseema lies in the southwestern part of the State in the Deccan Plateau. It is separated from Telangana by the low Erramala hills, and from the Coastal Andhra by the Eastern Ghats. It consists of four districts namely Anantapur, Kurnool, Cuddapah and Chittoor. The Krishna and Godavari rivers together irrigate thousands of square kilometers of land in Andhra Pradesh, and create the largest perennial cultivable area in the country. Andhra Pradesh leads in the production of rice (paddy) and hence is called India's Rice Bowl.

1.3.3 General climate

The climate of any region is determined by its latitudinal location, elevation and the physiographical conditions. Summers are cooler and winters are warmer in the coastal zones. The orographic features of the State have their own influence on the climate. The plateau regions experiences more temperate climate than other plains and coastal areas. Of all the weather elements, temperature and rainfall play a key role in social and economic aspects.
The mean annual temperature distribution in Andhra Pradesh indicates that temperatures are high in the central parts of the State and decrease both towards south and north. The mean annual temperature of the State varies between 25ºC to 30ºC (Fig. 1.5a). May is the hottest month with an average temperature of 33.2ºC (Fig. 1.5b) while January is the coolest month (Fig. 1.5c) with 23.0 ºC of average temperature (Hema Malini et al., 2010). The Telangana and Rayalaseema regions experience high mean temperatures than the Coastal Andhra during the hottest month. The mean annual range of temperature is between 8ºC and 11ºC in the entire State except in the extreme northern portions of the State which record 12ºC (Fig. 1.5d). This indicates the continentality effect of the area.

In the northern coastal districts, the unbroken range of the Eastern Ghats lying to the west about 40 km inland and rising steeply exert significant influence on rainfall and its distribution as it acts as barrier to the rain bearing easterly winds blowing in association with depressions from the Bay of Bengal during the southwest monsoon. The annual rainfall in the coastal areas is about 900 mm (Fig. 1.6a). On the other hand, the Rayalaseema has certain limitations in attracting the monsoons due to its location. The Western Ghats on the west and the Eastern Ghats on the east are blocking the normal course of southeast and northeast monsoons, respectively. As a result, the Rayalaseema region receives only 660 mm of annual average rainfall (Raju, 2003). Hence, the frequent failure of the either or both the monsoons is a common feature of the Rayalaseema in the southwestern part of the State.
Fig. 1.5 Isotherms (in °C) showing the temperature distribution in AP
Fig. 1.6 Annual and seasonal rainfall patterns in Andhra Pradesh
On the whole, the State receives about two-thirds of its annual rainfall during the southwest monsoon season, (i.e., during June-September (Fig. 1.6b) and a fourth is received during the northeast (or retreating) monsoon i.e. during October and November (Fig. 1.6c). The onset of monsoon over Andhra Pradesh takes place by the middle of June. It increases progressively as monsoon advances over the peninsula. The increase is very well marked in the northern portion of the State and is less pronounced in the south. During the peak period of the monsoon the north coastal Andhra Pradesh and Telangana receive heavy to very heavy rain in association with the amount of synoptic features. Towards the end of the monsoon, the entire State gets extensive rainfall with active to vigorous conditions. The rains in cold weather season (Dec-Feb) are too scanty and unreliable to have much effect on agricultural practices (Fig. 1.6d). During hot weather season (March-May) the rainfall ranges between zero and 150 mm (Fig. 1.6e). Climatically, the entire Andhra Pradesh State is under the influence of semi arid climate except the southwestern parts (portions of Rayalaseema) which is under the influence of arid climate and susceptible to frequent droughts, as a result of which crop failure is a common phenomena (Hema Malini, 1981).

1.3.4 Endemic Diseases
As any disease is a result of combination of climate and geographical conditions, it is essential to understand such combinations in order to take preventive measures to control the causative factors. Medical geographical studies enable understanding the disease patterns of a given area in terms of
morbidity and mortality indices. Andhra Pradesh which possesses varied geographical, environmental and climatic conditions as described above is endemic to certain diseases. However, it is a fact that only some parts of the State are endemic to certain diseases. For example, the entire Andhra Pradesh is endemic to malaria except the districts of Medak, Nalgonda, Mahaboobnagar, Chittoor and Nellore which are more or less free from malaria. The most malarious districts of the state are Visakhapatnam, Adilabad, Khammam, Srikakulam, Vizianagaram, East Godavari and Krishna, which contribute 88 percent of the cases as well as deaths in the State due to malaria. Among all the malarious districts of the State, the incidence of malaria is very high in Visakhapatnam district which is higher than state’s average as it is evident by the Annual Parasite Index (API) of 8.46 during 1991-95 and 8.35 during 1996-2000 as against the States averages of 1.28 and 1.75 respectively during the corresponding periods. In addition, malaria has been widely prevalent in the agency area of Visakhapatnam since long time. A survey in 1976 indicated 21737 cases in the western hilly area of Visakhapatnam which is a tribal belt. Among those cases Plasmodium Falciparum cases are more than those caused by Plasmodium Vivax (Rani, 1996). Hence, for the present study, Visakhapatnam has been taken as it records highest number of cases in the State and also represents urban, rural and tribal malaria. Similarly, the neighbouring Vizianagaram district, which although indicates overall low malaria incidence, but recorded high mortality rate has also been taken into consideration for the study of malaria.
Further, Andhra Pradesh is one of the 22 endemic States of Filariasis in India, which contribute 95 percent of total burden along with other eight States namely Bihar, Gujarat, Kerala, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal (Pani et al., 2005). Out of 23 districts of Andhra Pradesh, Filariasis is endemic to 16 districts (Mukhopadyay et al., 2008), such as Srikakulam, Visakhapatnam, Vizianagaram, East Godavari, West Godavari, Krishna, Guntur, Nellore, Karimnagar, Mahaboobnagar, Medak, Nalgonda, Nizamabad, Chittoor, Prakasam and Rangareddy (Annual Report of National Programme to eliminate Filariasis, 2002). Out of these 16 districts, nine districts namely Srikakulam, Visakhapatnam, Vizianagaram, East Godavari, Nellore, Adilabad, Nizamabad, Medak and Ranga Reddy are highly endemic with above 10 percent of endemicity (Das et al., 2002). Among these highly endemic districts, Nellore and Vizianagaram indicate high microfilaria rates of 1.73 and 1.39 respectively which are more than the State’s average of 1 percent (pipnrhm-mohfw.nic.in/.../Andhara%20Pradesh/AP_NRHM_PIP_201). Microfilaria rate (MF) is the percentage of population showing disease causing microfilaria in their peripheral blood in sampled population based on which endemicity of the region will be determined. Based on the MF rate, Vizianagaram has been taken into consideration for the disease analysis for the present study.

Andhra Pradesh is also noted for Fluorosis disease incidence. Out of 23 districts of the State, 17 districts are prone to Fluorosis. The districts namely Nellore, Nalgonda, Vizianagaram, Warangal, Medak, Chittoor, Cuddapah,

Nalgonda district has high fluoride in the granitic rocks which contain fluoride from 325 to 3200 mg per kg. This content of fluoride is much higher than the world average concentration of 810 mg/kg (Wedephol, 1969). Ram Mohan Rao et al., (1993) in their studies mentioned that in fluoride rich granitic rocks of Nalgonda district, the fluoride concentration in the ground waters is 0.4 to 20 mg/litre. Ingestion of such quantities of fluoride above the permissible limit of 1.5 mg/litre leads to the incidence of dental as well as skeletal fluorosis (Dissanayake, 1991). As many as 600 villages and 300,000 persons in Nalgonda district are suffering from various skeletal deformities like dental fluorosis, skeletal fluorosis, genu valgum, genu varum, antero posterior bowing of tibia, kyphosis, exostosis etc and muscular tenderness, neck rigidity, stiffness of joints and mental retardation, of which 10,000 people are totally crippled due to the excess consumption of fluoride from the groundwater (Narayana et al., 2004; Farooq, 2003). Keeping the severity of fluorosis in view, Nalgonda district has been taken for fluorosis analysis in this study. The study has been carried out for Nalgonda district in general and Nalgonda division in particular.
Thus, the incidence of endemic diseases namely Malaria, Filaria and Fluorosis diseases that are associated with various parts of Andhra Pradesh State were taken up in this study to analyze the geographical patterns in disease incidence and their intensities in terms of morbidity and mortality.

1.4 Materials and Methods

Data on the incidence of malaria reported in the Primary Health Centres of Visakhapatnam and Vizianagaram districts were collected from the records of District Malaria Offices of Visakhapatnam and Vizianagaram. Similarly, data on Filariasis have been collected from the records of National Filaria control units of Vizianagaram district. Population data were collected from census records of 2001. To carry out landscape epidemiology, data on topographic maps and satellite imagery of Visakhapatnam and Vizianagaram districts were analyzed.

Data on dental as well as skeletal Fluorosis cases and Fluorine concentration in the drinking water of Nalgonda Division were collected from District Medical and Health Office and from relevant websites (www.nalgonda.org). Fluorine content was estimated by analyzing the water samples collected for selected locations. Data is represented graphically as well as in the form of maps. Geospatial maps were generated using GIS software.

Incidence of vector borne diseases namely malaria and filaria were analyzed both on annual and seasonal basis. Statistical techniques were used in the...
analysis. Incidence of fluorosis was analyzed. Land use/land cover conditions of the districts under study were assessed from toposheets and satellite imagery by visual as well as digital interpretation. Satellite imagery were processed by using ERDAS Imagine software. Spatial patterns of the diseases were generated in GIS environment using ArcGIS software. By using statistical analyses, malaria as well as filaria risk areas were assessed for both Visakhapatnam and Vizianagaram districts. The spatial analysis coupled with the study of annual trends of mosquito borne diseases were found beneficial for understanding the trends of these vector borne diseases.

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