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Spatial mapping of cholera using GIS tools in Chennai, India

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ABSTRACT

Cholera is an acute intestinal infection caused by ingestion of food or water contaminated by comma-shaped bacteria, Vibrio cholerae. Geographical Information System (GIS) was used to map cholera-epidemic prone areas and determine the predisposing factors in Chennai district, Tamil Nadu. A database was developed to store spatial and non-spatial data showing the source and spread of cholera. The results of this study indicated that Tondiarpet, Basin Bridge, Pulianthope areas had the highest cholera incidences. However there was a decreasing trend in 2003, 2005 to 2009 and 2011 and highest incidence was associated with heavy rainfall. The findings demonstrated the potential of GIS in monitoring the source and spread of cholera which would help to take necessary preventive measures in future.

Key words: cholera, GIS, spatial distribution, intestinal infection

INTRODUCTION

Cholera is a severe diarrhoeal disease caused by the bacterium *Vibrio cholerae* [1]. A patient may lose up to a litre of fluid per hour, which can lead to death in less than 24 hours if untreated [2]. The cholera is transmitted through consumption of food or water, contaminated with human waste [3, 4] and through direct person-to-person contact among individuals living in overcrowded and unhygienic conditions. Over one billion people currently live in urban slums; 300 million of them do not have access to a clean water supply, while 400 million people do not have access to improved sanitation [5]. In the Asian region, *Vibrio* spp have been recognized as the leading cause of food borne outbreak in many countries such as Japan [6-8], India [9,10], China [8,11], Taiwan [7], Korea [12], Thailand [13], and Iran [14, 15]. There has been an estimated death of 120,000 globally every year [16] and still continues to be a scourge worldwide covering all continents. Also, factors like global shortage of water and sanitation account for children dying daily on an average of 5000 due to illnesses related to poor access to water and hygienic sanitation [17].

Over a period of 2000-2011, 7839 cholera cases were reported in Chennai; out of this, during 2000-2002 alone 3,534 cases were reported.

Weather, socio-economic conditions and sanitation largely contribute to the outbreak of the disease. However, monsoon serves as the primary cause for the source and spread. The bacterium present in stagnant waters starts spreading by unhygienic behavior, dense population, absence of safe drinking water, proximity to surface water and lack of awareness about the ill effects of the disease [18]. The recent advances in Geographical Information System (GIS), Mapping Technologies and increased awareness have created new opportunities for public health administrators to strengthen their planning, analysis and monitoring capabilities [19]. Many researchers across the

globe have used GIS tool for mapping cholera incidence [20, 18, 21, 2, 22]. This present study has mapped zonewise incidence and spatial distribution of cholera in Chennai from 2000 to 2011 using GIS techniques.

Study area

Chennai (= Madras), the capital of Tamil Nadu State (latitudes $12^{\circ}57'30"-13^{\circ}8'50"$ North and longitudes $80^{\circ}12'10"-80^{\circ}18'20"$ East) is the fourth largest metropolitan city in India and 37^{th} largest urban area in the world. According to 2011 Census the total population of Chennai is 46,81,087 Situated at an average altitude of 6 m above mean sea level it has a total area of about 178.2 sq km and has been divided into 10 zones consisting of 155 wards. It has a hot and humid weather for the most part of the year. The maximum temperature recorded is $35-40^{\circ}$ C during May-June and minimum temperature of $15-22^{\circ}$ C during December-January. The average annual rainfall is about 1300 mm, in which ~800 mm is received during the North-East (NE) monsoon in October-December. Three rivers *viz.*, Kosasthalaiyar, Cooum and Adyar pass through Chennai before they merge into the sea. Buckingham Canal, a man made canal, is another large waterway

which runs North-South through this metropolis. Sholavaram, Red Hills and Chembarambakkam are the three major lakes which meet out the drinking water requirement of Chennai. The major threats faced by Chennai are dense population, erratic weather patterns, waste disposal, water contamination and lack of drinking water. These are the major reasons for high incidence of water borne infectious diseases particularly cholera in this city. Hence the present study aimed to screen the seasonal occurrence of such disease in the 10 zones of Chennai using GIS application.

MATERIALS AND METHODS

Surveillance data on cholera outbreak from 2000 to 2011 and the administrative map of the study area were obtained from the Health Department of the Chennai Corporation, while the population data (2001) for Chennai was obtained from the Directorate of Census Operations, Chennai. The map was scanned, imported into ERDAS IMAGINE 8.5 and geo-referenced using point with known geographical co-ordinates. The scanned map was then captured by on screen digitizing at a scale of 1:20,000. The average annual rate of cholera cases was linked into spatial database. Arc View 3.2a software was used as basic GIS Software for preparation of thematic maps from 2000-2011.

Average Annual Rate =

Total number of cholera cases \times 1000

Total Population

Whereas total number of cases: Identified cholera cases in the zone. Total population: Total Population of each zone. 1000: cholera attack rate per 1000 persons.

RESULTS AND DISCUSSION

I. Incidence of cholera in Chennai during 2000-2011

The rate of cholera attack per 1000 persons in ten zones during the period 2000 – 2011 was studied. It was observed that overall attack rate of cholera decreased gradually from 2000-2002. It was noted that cholera reached its peak in 2000 and 2002 followed by a lesser peak in 2003. Again, there was increased incidence of the disease n 2004 and 2010; however there was a gradual decrease in 2005-2009 and 2011 (Figure 1). The year 2000 witnessed highest number of attacks which claimed 1235 lives. The probable reasons for this epidemic may be high urbanization rate and high density of population which strain existing resources meant for providing better sanitation systems and portable water. Inadequate sanitation systems coupled with intermittent supply of pipe borne water in urban areas puts the population at risk of cholera [22]. Surface water pollution becomes worse where rivers pass through urban and overcrowded cities, and the commonest contamination is from human excreta and sewage [23]. Studies of cholera over a period of 2000-2011 showed that there was occurrence of the disease on more than 12 occasions which took epidemic form. Although the number of cholera cases reported has decreased since 2003 (290), it was slightly erratic thereafter up to 2011 which are as follows: 2004 (968), 2005 (393), 2006 (59), 2007 (503), 2008 (441), 2009 (446), 2010 (1102) and 2011 (103). Similar observations of cholera incidences were reported in South

Africa and Bangladesh [2, 18]. It is a proven fact that improved health facilities and preventive measures have largely contributed in reducing the incidence rate. The epidemic status has declined progressively since 2002.



Figure 1: Temporal patterns of Cholera in Chennai

II. Incidence of cholera in Chennai 2000-2011(number of cases per 1000 population)

The spatial pattern of cholera over more than a decade viz., 2000 to 2011 was studied in detail using GIS techniques. Thematic maps prepared indicated number of individuals affected by cholera per 1000 persons. The results (Figure 2) in the selected 10 zones of Chennai traced the endemic tracts at one year interval. GIS offers spatial information of cholera occurrence and helps in carrying out predictive modelling. It determines geographical distribution and variation of diseases, and their prevalence [24, 25]. GIS based thematic maps denoted the intensity of diseases in different colours and it is proved to be very useful to perceive clearly even by those who are not familiar with the technology. GIS permits dynamic link between databases and maps so that data updates are automatically reflected on the maps [24]. This provides an epidemiologist with real time mapping of epidemics, progression of disease, areas of specific environmental conditions, prediction of vulnerable populations, and support in decision making with rapid and effective communication for quick planning. [26]. The maps of Chennai zones clearly showed that the Tondiarpet had the highest intensity of the cholera followed by Basin Bridge, Pulianthope, Kilpauk, Ice House, Ayanavaram, Nugambakkam, Kodambakkam, Adyar and Saidapet. The decline in incidence in the rest of the zones might have been due to the preventive measures that were introduced. Tondiarpet, Basin Bridge and Pulianthope continued to be endemic and occupied the first three positions. The probable reason may be presence of other acute enteric infections, dense population, poor hygienic situation and socio-economic conditions coupled with consumption of contaminated food and water in North Chennai (1, 2, 27, 28).

Cholera is a disease, which is not only influenced by geographic factors but also has a strong association with the weather parameters such as rainfall, and temperature which determine the outbreak, prevalence and spread [2, 28, 29, 30]. Among the weather factors, rainfall has been proved to aggravate the disease as it is commonly witnessed in areas immediately after heavy rainfall [2]. To validate this factor, the present study mapped the disease incidence during the major four seasons namely winter (mid December to mid February), summer (mid February to the end of May), monsoon (June to August – South-West Monsoon) and post monsoon (September to November- North East monsoon). The coastal district of north Chennai receives the most part of the rain during North-East monsoon and one can observe highest peak of incidence in places such as Tondiarpet (704), Pulianthope (443) and Basin Bridge (365) during that period, and (Figure 3). Occurrence of peak incidence of cholera during the rainy season is most probably caused by surface waters resulting from rainfall; it plays a major role in disease transmission [25, 31]. The results indicated that the cholera incidence reached its peak invariably in all the zones studied during the monsoon and post monsoon periods *viz.*, June through November. Over all, the seasonal incidence was less in Adyar, Saidapet and Kodambakkam zones. However, according to other studies the highest number of cases was reported in the month of February, which falls between the winter and summer [2].



Figure 2: Incidence of Cholera in Chennai during 2000-2011 at one year intervals



2009











III. Zone wise seasonal incidence of cholera in Chennai

Figure 3: Zone-wise seasonal incidence of Cholera in Chennai during 2000-2011

CONCLUSION

The findings have demonstrated the potential of GIS tools in mapping the disease occurrence and its intensity across different zones in Chennai. Thus the high prone areas can be brought under close monitoring for disease prevention and integrated management. The worst affected areas by cholera were Tondiarpet, Pulianthope, Basin Bridge, Ayanavaram and Ice House zones, while lesser incidence was recorded in the southern part of Chennai. It can be concluded that human consumption of contaminated water could be one of the primary reasons for the spread of this disease. Another significant factor that the study demonstrated is the possibility of integrating such data base into the primary data of the health sector for early prediction and plan out precautionary measures to eliminate the disease. This sector can use the GIS database and streamline it's planning for effective predictions and carry out precautionary measures to prevent the disease.

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