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Introduction

Vector-borne diseases are of major health concern globally. With increasing developmental activities, industrialization, deforestation and rapid urbanization there is a steady increase in vector-borne disease incidence and also in the occurrence of epidemics in most countries in the world. Major vector-borne diseases prevalent in India are malaria, filariasis, dengue, Japanese encephalitis (JE) and leishmaniasis (kala-azar). Frequent occurrence of epidemics of JE and dengue and its severe forms, dengue shock syndrome (DSS) and dengue hemorrhagic fever (DHF), have become great concern to disease control personnel, programme planners and also public. Occasionally, other insect-borne epidemics, namely plague, scrub typhus, kyasanur forest disease, etc. have been occurring in India. After 35 years of gap, in 2006 chikungunya transmission occurred in large numbers in different states especially in southern states of India.

The complexities in disease transmission due to involvement of vectors, presence of animal reservoirs as in JE, special biological characters like trans-ovarian transmission and withstanding desiccation of eggs in vectors of dengue and chikungunya, development of resistance to insecticides in vectors of malaria and to some extent in kala-azar vectors, development of resistance to drugs in disease pathogens are some of the technical difficulties in effectively controlling vector-borne diseases. Due to fast changing environment there is a need for regular disease surveillance and especially vector surveillance. Monitoring of adult and larval densities by conventional methods in entomological surveys is labour intensive, time consuming and expensive. Similarly, delimitation of areas for endemic diseases using the night blood examination survey in filariasis, active surveillance for blood smear collection of fever cases in malaria and splenic and bonemarrow extraction in kala-azar for the diagnosis of the diseases are labour intensive, time consuming, logistically impractical and expensive, and are therefore, carried out mostly at the micro level. Factors responsible for disease transmission are governed by localized microenvironmental conditions which vary vastly in the country. Variability in disease endemicity and transmission patterns, variation in vector and pathogen responses to control tools and lastly human host sociocultural aspects demand situation-specific strategies. Hence, data collected from localized surveys can not be extrapolated to larger areas. For the national disease control programmes an important requirement is to have regular surveillance data and information on spatial spread of the disease risk factors for planning effective control/elimination/eradication programmes. Emerging and re-emerging vector-borne diseases are posing a great challenge to researchers, disease control programme planners and implementers in the region.

Geographic information system (GIS) and remote sensing (RS) are tools that can be used to provide solutions in vector-borne disease control programmes. GIS is an information technology tool comprising computer hardware and software to input, store, update, retrieve, analyze and output geo-referenced data. GIS has the potential to develop thematic maps of the input data and overlaying and integration of the maps, and has a strong statistical component to visualize, interpret complex real world situations to provide effective solutions. GIS has now emerged as an important tool in health research. For the data input for example, disease prevalence, risk factors responsible for the disease, vector distribution, environmental and climatic conditions relevant for vector prevalence, population characters and statistics, etc. can be used. GIS analysis helps to identify factors which will indicate disease threats and would also help in planning rational and suitable control strategies, and early preparedness in preventing outbreaks and epidemics.

Remote sensing is the science and art of collecting images of the earth's surface from satellite platforms, without being in direct contact with it, and transforming the images into maps. RS can generate data on landuse features—soil type, water bodies, vegetation, forest cover, human habitation, etc. which can be used as data bases in GIS for use in vector-borne disease analysis. The combined use of GIS and RS in addition to stratifying areas, identifying risk factors, etc., can help in identifying the priority areas for control and in the construction of spatial decision support systems for planning integrated disease control strategies.

Recognizing the high potential of GIS and RS technologies in vector-borne diseases, the advances in RS with the availability of IRS 1C and 1D satellites which have a better resolution, and the developments in GIS technology, the Epidemiology and Communicable Diseases Division of the Indian Council of Medical Research for the first time initiated Task Force projects in vector-borne diseases using GIS and RS application tools. Projects were initiated in malaria, filariasis and visceral leishmaniasis.

The projects in malaria were conducted by the National Institute of Malaria Research (the then Malaria Research Centre), Delhi; the filarial projects by Vector Control Research Centre, Puducherry; and the kala-azar project by Rajendra Memorial Research Institute of Medical Sciences, Patna. Basic findings of the projects and their possible applications were communicated to the National Vector Borne Disease Control Programme (NVBDCP) and to the respective State Health Departments to which the results are applicable. It is hoped that the results from these projects will be utilized by the national disease control programmes. The salient findings of the projects are as follows.

A project on malaria was planned to analyze an epidemic that occurred in Mewat region in Haryana state with an aim to stratify the area to delineate malaria paradigms, and to identify their receptivity and vulnerability to malaria. Five eco-epidemiological paradigms were recognized in the area which differed in eco-environmental characters, and were analyzed for their potential to harbour malaria transmission. The study has led to the identification of areas that require strengthening of surveillance to monitor malaria in order to take cognisance of changes in malaria incidence to avoid increase in the incidence and to plan suitable control operations in the region.

In an another study in Koraput district of Orissa state, malaria receptivity was identified in the Blocks/PHCs based on ecological profile and other attribute information. GIS analysis of thematic maps in this study has brought out a good correlation between malaria and the presence of forest cover, network of streams, water reservoirs and valleys. In the PHCs where malaria transmission was low, forest cover was low and drainage net work was good, and in the PHCs with not very high API (10–20) the ecological and geo-morphological factors that correlated with high malaria were found to be of medium occurrence compared to their occurrence in the PHCs with API >30.

Keeping in view the increasing trend of change in environment which is rapidly changing vector distribution and the need for frequent surveys to monitor vector distribution, a study was initiated to map the distribution of malaria vectors in India using GIS based technique. The study has identified the areas favourable for each species, and the findings were validated both by ground surveys and from earlier records of species prevalence in the areas. The technique developed was found to be fast, and the technology developed could be applied for mapping the distribution of other vector species as well.

In view of the importance of *Anopheles culicifacies* as a major malaria vector in India, a project was developed for Tumkur district in Karnataka state using IRS IC/D LISS III satellite images and PAN data. Landuse characters of different villages were extracted from remotely sensed satellite images, and major breeding sites of *An. culicifacies* were identified in the images. The heterogeneity that was observed in landscape elements in the satellite images of the villages within a PHC, was also seen in malaria incidence and *An. culicifacies* densities in ground surveys. Thus, the study has shown that the remote sensing tool can be used to monitor village-wise landuse features relevant to vector population densities, and based on which villages can be classified as high, medium or low malaria risk villages.

In filariasis, a project was designed to have a better understanding of epidemiology of the disease and develop strategies for its control. A Geo-Environmental Risk Model (GERM) was developed with the aid of RS and GIS using a range of variables for geo-environmental factors for predicting filariasis risk areas in Tamil Nadu region. A ground survey carried out using Immuno-chromatographic test (ICT) kit to validate the model has demonstrated that transmission areas can not be accurately delineated but the 'non-risk' areas can be. Since the negative determination of this model is excellent, all the 'non-risk' areas could be omitted for mass drug administration, the strategy being used under the Lymphatic Filariasis Elimination Programme. Thus, this model would help in saving control efforts in non-transmission areas.

A project in visceral leishmaniasis was planned using satellite images to determine land use features that correlate with the vector species, *Phlebotomus argentipes* abundance. The study was carried out in Vaishali district, a highly endemic kala-azar focus in Bihar state and in Lohardaga district, a non-endemic focus in Jharkhand state. The study has identified water bodies, marshy areas, vegetation and soil type to be the significant features related to the abundance of the vector. Thus, the satellite imaging system can be used to map the distribution of sand fly vector which will correlate with the endemicity of the disease.

This document has been compiled based on the final reports available at the Indian Council of Medical Research, New Delhi. Publications which have emanated from these projects have also been used in the preparation of this document. The main objective of this effort has been to bring to the notice of researchers, field workers and programme organizers the usefulness and the potential of GIS and RS technologies in vector-borne disease control programmes.