Journal of Health Informatics in Developing Countries

Submitted: August 1, 2011 *Accepted: September 26, 2011*

Real Time Health Informatics System for Early Detection and Monitoring of malaria in desert district, Jaisalmer, India

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Abstract. Paper describes the development and implementation of an Interactive Voice Response System (IVRS) Technology based health informatics system which can collect information for malaria from grass root level health workers through their mobile phones, save data on database server, generate online analytical and graphical reports and can link data with Geographical Information System (GIS) maps. The Block Pokaran of district Jaisalmer was selected as study area. The system developed has been installed at Desert Medicine Research Centre, Jodhpur and attached to a toll free telephone. The developed system is in operation for more than a year. The grass root level health workers of study area are submitting the primary malaria data through mobile phones to the above system as per the given questionnaire format. 92% of the total data generated was found authentic. The system received 98% reporting from 4 PHCs and 76% reporting from 1 PHC. The system could identify the 8 prime villages out of 181 contributing to 60% of total malaria occurrence, right at initial stage. The developed system has reported disease information in real-time. It is found faster, cost effective, flexible, easy to implement and expandable. The system provides online analytical and graphical reports, facilitate to understand the epidemiology of the disease, its early detection & monitoring, which helps decision makers to take appropriate control measures to intervene before there is any epidemic.

Keywords. Malaria Early Detection System, Health Management Information System, Geographical Information System, Interactive Voice Response System, Reporting through mobile phones

1. Introduction

Half of the world's population is at risk of malaria [1]. In India, malaria has been a problem for long [2]. Global strategy to control malaria emphasize on early detection of malaria right from its development stage [3]. In 1998, a study developed a district level disease surveillance system [4] by installing computer systems network. Another study developed early warning system in Africa [5] based on forecasting of environmental, social and epidemiological factors. In Thailand, a Poisson model [6] was developed for early detection of malaria. In Madhya Pradesh, India, a study developed a GIS based information management system [7] using six years secondary health data. Thus, various studies have encouraged computerization of health management information system and implementation of Geographical Information System for improving the health status of the community and to detect the malaria at its development stage [8, 9].

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Government of India is pursuing various health programmes to provide primary health care facilities to the population. The government has developed a hierarchy of health functionaries to execute health activities in the country. According to the hierarchy of health functionaries, Central government monitors the State government for execution of public health programmes, the State monitors Zonal level health functionaries, a Zonal level health functionary monitors health activities in a cluster of 5 to 6 districts. A District monitors Blocks, Primary Health Centres (PHC), Community Health Centre(CHC) and Sub Centres(SC). A Block is a health functionary which monitors the health care activities in around 100 villages covering around 100000 population through PHCs, CHCs and SCs. PHC/ CHC are hospitals, which provide health care facilities to 30-40 villages. A SC is a small dispensary, which provides nursing and health care to 3-5 villages. A SC has Multi Purpose Health Workers who executes house to house survey in the villages, provide first aid services and health education to the villagers.

The National Vector Borne Disease Control Program, one of the main public health programs, is carrying malaria surveillance in the country through the existing hierarchy of health functionaries [10]. Multi Purpose Health Workers perform periodic house to house surveys for detection of fever cases, collection of blood smear slides and send the collected blood smear to lab technicians at CHC/PHC for examination. These workers also provide radical treatment to the patients suffering from malaria, perform the anti-larval activities like putting *Temephos* (an organophosphate) or *Gambusia* fish in drains and monitor anti-malaria spray in their area. The lab technician at PHC examines the blood smear slides received from Multi Purpose Health Workers (*Active Slides*), out patient department slides collected at PHC (*Passive Slides*) and slides collected during mass survey in endemic zones (*Mass Slides*).

Even after many advances in the information technologies, manual reports and registers are the primary method of data collection and communication in health sector in India. The Multi Purpose Health Workers working at SC level used to send the SC level malaria information manually once in a week to CHC/PHC. The CHC/PHC in turn sends manually the collected SC reports along with their PHC level malaria information weekly to the Block. The Block health functionaries have computers and they used to send the report in excel format through E-mail. As manual reporting or E-mail reporting does not facilitate any query, sorting, relating etc., there is immense need of computerization of disease data, which can analyze the data in real time so as to check for any outbreak. Government of India is making attempts to computerize the local health functionaries, but the computerization of health functionaries have many bottlenecks [11, 12].

The objectives of this study were to develop a faster, easy to implement and cost effective early detection and monitoring system for malaria using available resources. This paper describes the development of a Real-Time Health Informatics Management System (RT-HIMS) which can collect malaria information from root level health workers through their telephone/mobile phones, update it immediately on a database server and publish analyzed reports on website for the perusal of health authorities. This system was developed using Interactive Voice Response System (IVRS) technology. IVRS is a technology that empowers a computer to communicate with telephonic caller in human voice and to collect data by detecting the telephonic keys pressed by the caller. IVRS

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technology is being used for health surveys, sending reminder, monitoring of alcohol consumption and diabetes control [13].

2. Material and Methods

2.1 Study Area

Western desert part of Rajasthan has experienced several malaria epidemics in the recent past. Jaiselmer, one among the 11 desert districts in the western part of Rajasthan, has reported maximum cases of malaria. Jaisalmer has three Block level health functionaries, out of which Block Pokaran has been found most affective as compared to other Blocks. Based on the past malaria incidence Block Pokaran was selected for the study. The Block Pokaran [14] in Jaisalmer district is located at 26.92°N and 71.92°E. It has an average elevation of 233 metres and surrounded by rocky, sandy and five salt ranges. In summer average temperature ranges from 29.8°C to 45.6°C and in winter average temperature ranges from 9.3°C to 22°C degrees. Annual average rainfall is 62 centimeters.

Block Pokaran is providing health services to 181 villages through two CHCs, six PHCs and 50 SCs. The Multi Purpose Health Workers working at SC level send their SC level malaria information manually once in a week to CHCs/PHCs. The CHCs/PHCs compile the information and send it to Block head quarter at weekly intervals. The Block Pokaran E-mail the compiled malaria data to office of Chief Medical & Health Officer at district head quarter Jaisalmer. The data from district head quarter is transmitted to Zonal head quarter Jodhpur, which in turn transmit the report to State head quarter. The complete hierarchy of flow of information is shown in Figure 1.

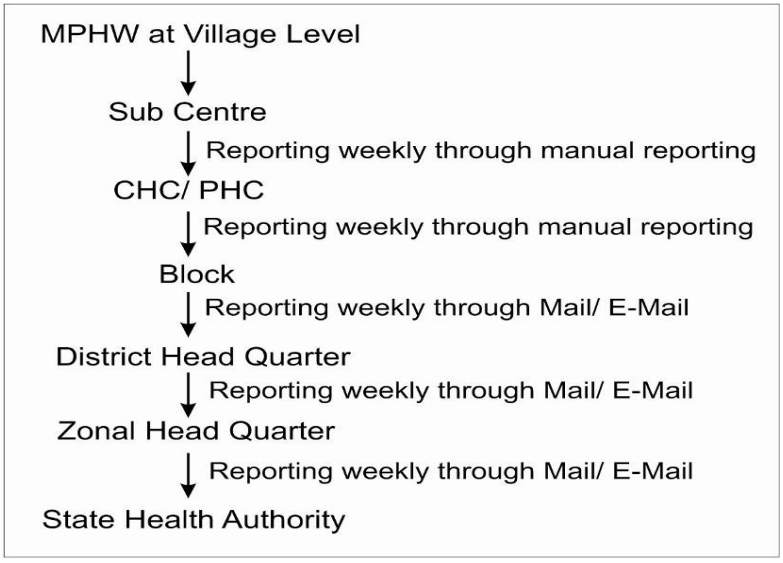

Figure 1. Flow diagram of Disease Information under existing system

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2.2 Development of Real-Time Health Informatics Management System

The RT-HIMS server was developed by programming computers to serve as IVRS, SMS system, Database server, Geographical Information System (GIS) and Web server [15]. The IVRS was connected to a toll free telephone to communicate with health workers in human voice and to collect data through their telephones/ mobiles by detecting the key tones pressed by the health workers. The SMS system was attached with a GSM mobile SIM through a GSM modem The SMS system was developed to acknowledge the data providers and to inform present situation to health authorities immediately. The Microsoft SQL Server was prepared as Database server to record the data provided by health workers. Web server was prepared to launch system website. Dynamic web pages were developed on system website to provide customized and graphical reports. The GIS was linked with Database Server to generate maps representing disease incidence distribution. The architecture of the developed RT-HIMS system is shown in the Figure 2.

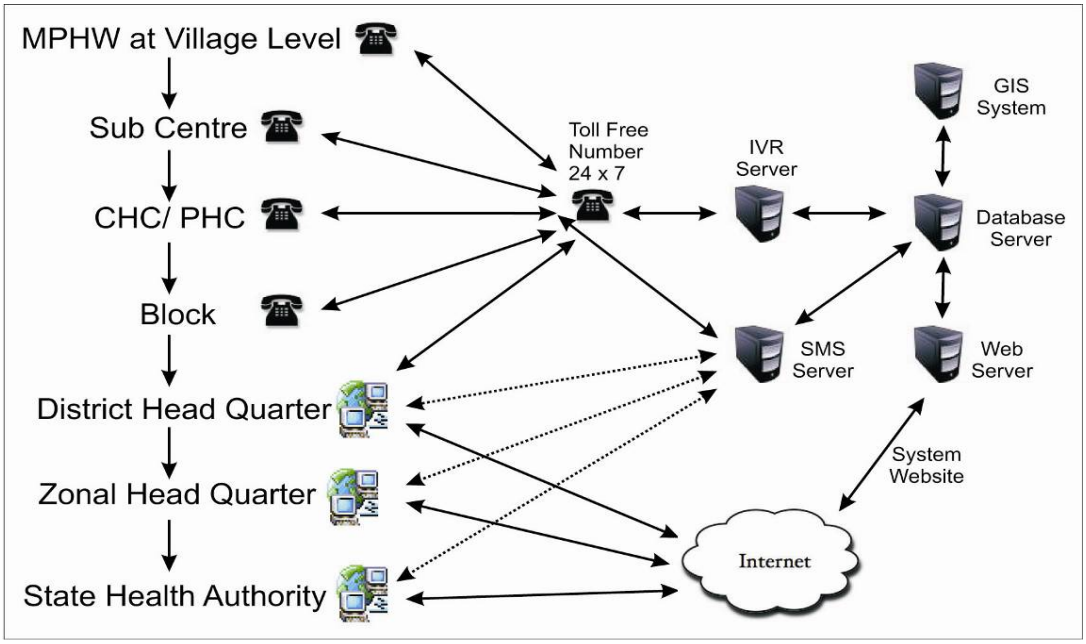

Figure 2. Flow diagram of Disease Information under RT-HIMS system

2.3 Development of Questionnaire for malaria data collection through RT-HIMS

Questionnaires were developed in human voice in hindi language for malaria data collection through IVRS of RT-HIMS (Table 1.). The brief of questionnaire is as follows.

- Questionnaire for collecting PHC Lab Report : This questionnaire was developed from MF-8 register being maintained by lab technicians in PHC. The

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questionnaire was prepared to collect the details of blood smears collection and examination from PHC lab.

- Questionnaire for collecting malaria positive case detail: This questionnaire was developed from MF-7 register being maintained by lab technicians in PHC. The questionnaire was prepared to collect age, sex, village & malaria species of the positive case from PHC lab.
- Questionnaire for collecting SC report from Multi Purpose Health Workers: This questionnaire was prepared to collect report from Multi Purpose Health Workers regarding blood smear collection during house to house survey, radical treatment given to malaria patient and anti-larval activity carried by them in the village.

3.4 Implementation of RT-HIMS for collecting malaria information from study area

The developed RT-HIMS was installed at Desert Medicine Research Centre, Jodhpur. Trainings were organized for lab technicians and multi purpose health workers of the study area to demonstrate the details and working of the RT-HIMS system, method of interacting and procedure of providing information to RT-HIMS through telephone. After training the health workers started providing malaria information through their mobile phones to the RT-HIMS system.

3.5 Data collection through RT-HIMS

Whenever a health worker made a call to the toll free telephone attached to the RT-HIMS system, the system received the call, registered the incoming telephone number, date & time of call in a CALL LOG BOOK. The system welcomed the caller and read a menu message in human voice. The caller responded to system questionnaires by dialing number keys on his mobile phone. The system and the caller responded turn by turn as per the set questionnaire. The complete interaction between the system and the callers were recorded by the system in INTERACTION LOG BOOK. After completion of a questionnaire session the system arranged the answers of all the questions in a text string in comma delimited format and wrote it into a FINAL LOG BOOK. The data from FINAL LOG BOOK was then transferred to database server automatically by the RT-HIMS system within a minute. The database server was connected to RT-HIMS website. RT-HIMS website generated online interfaces to validate data, view malaria information, customizable reports in tabular format and graphical format for better analysis. The village codes, PHC/ CHC codes were linked with polygon codes of GIS maps which enabled to associate malaria data immediately with GIS maps to generate disease spatial distribution maps. GIS reports were uploaded manually.

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Table 1. Questionnaire for malaria data collection through RT-HIMS

Questionnaire for collecting PHC Lab Report	Questionnaire for collecting detail of confirm malaria case	Questionnaire for collecting grass root level worker's daily report
Q1. PHC Code Q2. Date of Report Q3. Month of Report Q4. OPD Cases Q5. Fever cases Q6. Active Slides Collection Q7. Passive Slides Collection Q8. Mass Slides Collection Q9. Total Slides Collection Q10. Slides Checked Q11. Slides Balance for Testing Q12. Positive in Active Slides Q13. Positive in Passive Slides Q14. Positive in Mass Slides Q15. Total Positive Slides Q16. Pv Case found Q17. Pf Case found Q18. Mix Case found	Q1. PHC Code Q2. Date of Report Q3. Month of Report Q4. MPC Number (Malaria Positive Case Number) Q5. Male/Female Q6. Age Q7. Village Code Q8. Pv/ Pf/ Mix	Q1. User Code Q2. Date of Report Q3. Month of Report Q4. Village Code Q5. Active Slides Collected Q6. Radical Treatment (RT) Given Q7. Contact Slides Collected Q8. Falciparum RT Given Q9. No. of Temephos applied Q10. No. of *Gambusia* fish applied Q11. Routine Spray (Number of Households) Q12. Focal Spray (Number of Households)

3.6 System Functioning Validation

The functioning of the RT-HIMS system was validated by examining INETARCTION LOG BOOK. Any abnormal functioning of the system or mistake made by the caller during interaction with the system was checked through this log file. In case of abnormal function of the system, the system was corrected by taking appropriate action. In case of caller's mistake, the respective caller was re-trained telephonically.

3.7 Data Validation

Received data was made available online on the RT-HIMS website. Authorized persons validated the received data through the system online web pages. There were many validation points by which the data was validated for appropriateness of reports. For example, in the first questionnaires, if the sum *Active Slide Collection + Passive Slide*

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Collection + Mass Slide Collection matches with the *Total Slide Collection* asked in the questionnaire, then it partially confirmed the validity of the data. But, if *Total Slides Checked + Total Slides Left for Testing* also match with the *Total Slide Collection*, then it fully confirmed the validity of the data received. Similarly data was validated by inspecting other logical points.

4. Results

The developed RT-HIMS is in operation for more than a year. Lab technicians started providing lab report to the system through their mobile phone in December, 2009. Initially the lab technicians made more mistakes in sending reports. Such mistakes were identified through INTERACTION LOG BOOK of RT-HIMS system. The respective callers were made aware telephonically about the mistakes made by them. Soon the lab technicians got familiar with the RT-HIMS system and the quality of the data got improved. The total calls received during the period from Jan to July, 2010 were analyzed and it was found that 92% of total calls were correct. Similar was the case with the Multi Purpose Health Workers who started reporting to the system in May, 2010.

SMS server acknowledged the callers regularly. Confidentiality of the data was maintained by authorizing the users. The data was inspected and validated by authorized users. It was expected from lab technicians to report daily to the system. However, the system received 98% reporting from 4 PHCs and 76% reporting from 1 PHC. The reason was administrative. Web pages available on the system website for the perusal of health authorities and decision makers are as follows.

- Data Validation Pages: These pages provide interface to edit/delete malaria information.
- Tabular Reports: In the tabular format reports, the validated malaria information can be viewed for the desired CHC/PHC and the desired month/ period, which enables to understand the trend of disease occurrence and to assess the effect of intervention.
- Graphical Reports: In the graphical format reports, the disease information is represented in bar diagram. This report can be viewed for the desired CHC/PHC and the desired month/ period, which enables to study the trend in disease occurrence.
- GIS Report : In the GIS reports, the disease distribution is represented on the map of the study area. This report enables to identify the spatial disease distribution.

5. Discussions

Many studies are using computers [16], web based techniques [17] and handheld computers [18] for health data collection from remote locations. Providing computer facilities at each health centre is difficult as it involves hardware cost, maintenance cost, software updates, skilled persons and network connection. This study has used IVRS technology to collect information on malaria from root level health workers, Microsoft SQL server as database

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server and web technologies to generate real time tabular/ graphical reports and GIS technology to map distribution of malaria cases. IVRS technology with Toll free telephone line has empowered grass root level health workers to report malaria information by using their own mobile phones or public phones, which subsequently not only reduce the need of the computerization but also decrease the cost of transmitting the information.

IVRS has been used for health surveys, sending reminder, monitoring of alcohol consumption and diabetes control [13]. In a study IVRS was used to generate telephonic reminders to the parents of children whose age were below 2 years and were due or late for immunization [19]. In 1994, IVRS was used to monitor recovering drug users and alcoholic population to estimate the probability of relapse [20]. IVRS technology was also used in a study to assess the impact of automated telephone reminders on 2,008 patients scheduled for appointments in a public health tuberculosis clinic and it was found that reminders increased appointment attendance from 52% to 62% [21]. Though IVRS is used in many research studies, however, this would be for the first time when IVRS technology has been used for malaria early detection and its monitoring.

Before installation of the RT-HIMS system, the malaria information moved manually from grass root level to the top level of health functionary's hierarchy. It was also observed that the manual movement of reports was delayed by a week or more and that due to merging of data at each level, the focus of the disease incidence was lost.

After installation of RT-HIMS system, the manual system of data collection was also continued and RT-HIMS system also generated the disease database. Disease information was collected from the grass root level health functionaries in real-time through IVRS. RT-HIMS stored malaria data collected through IVRS immediately in the Microsoft SQL server database, which was capable of querying, sorting, relating and data analysis. The System website retrieved disease data from database server and generated online real time disease reports. The availability of online reports reduced the delay in reporting at the level of health functionary hierarchy. The online customized tabular, graphical and GIS reports helped the decision makers to plan the intervention program more efficiently.

The RT-HIMS provides malaria information on daily basis and up to village level, which helps in early detection and monitoring of the malaria occurrence and to focus on the population at risk. These features of RT-HIMS make it different from all previous studies. While analyzing RT-HIMS online tabular reports it was observed that malaria suddenly rose on 30th August, 2010 and increased day by day. The RT-HIMS village wise distribution report was further analyzed for 30th & 31st August, 2010, to study the focus of malaria. It was noticed that total 90 cases of malaria were occurred during the period. The study area was having 181 villages but the villages which contributed to 60% (56 cases) of the total cases of malaria were Gomat (10 cases), Pokaran (10), Unjala (10), Mandva (6) and Lewan (4), Maurani (4), Kelawa (4), Jaimla (3) and 4 cases were diagnosed from the persons who were non-resident of study area. Thus the focus converged on these 8 villages. The situation was immediately brought into the notice of the Zonal health authority who in turn took immediate relevant control measures and brought the situation under control. The RT-HIMS reports were monitored continuously and observed that malaria increased on daily basis to its peak on 16th September, 2010 and then stepped down by 5th October, 2010. In this manner the RT-HIMS system helped health department to detect malaria occurrence

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in its early stage, to focus on the root of the problem and to monitor the impact of intervention actions. The bar diagram of datewise occurrence of malaria cases from 10th Aug to 25th Oct, 2010 is shown in Figure 3.

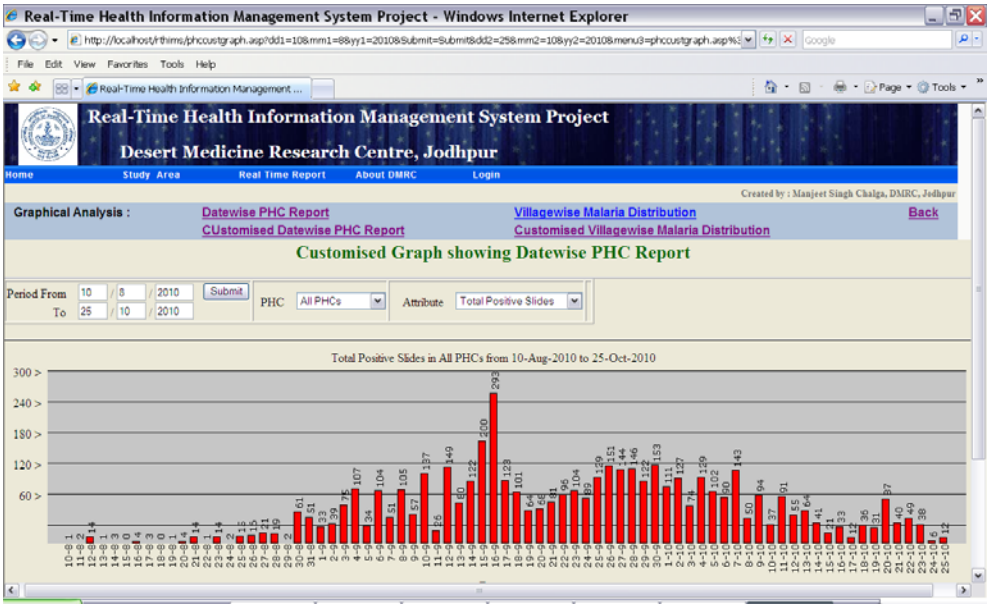

Figure 3. System Website graphical report showing bar diagram of datewise occurrence of malaria cases from 10th Aug to 25th Oct, 2010.

Malaria information collected through the developed system was presented on GIS maps, which helped to identify the spatial relationship between disease occurrence and disease distribution. The GIS map representing distribution of Pv and Mix cases of malaria in study area from 10th Aug to 25th Oct, 2010 is shown in the Figure 4.

6. Conclusion

The system is found to be faster, cost effective, more advantageous and an adjunct to the existing health information system. The main advantage of the system is that it empowers the grass root health workers to report through their mobile phones. Health workers can use their personal phone or public phones for reporting as the system telephone is kept toll free. System is very fast and it uploads the received report immediately on the database. It is cost effective as it doesn't involve the expenditure of computerization and human resource at root level. It doesn't have the limitation of distance. System questionnaire is flexible as any number of variables or health units or diseases can be added or removed at minimal or no extra cost. The questionnaire can be developed in the desired regional language. Online tabular and graphical reports facilitate data users to detect the trend of disease occurrence in real-time, to focus on the spatial distribution of disease, to understand its epidemiological base

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and to assess the effect of intervention. Moreover the system can operate on itself for 24 x 7 hrs. It needs further exploration by meta analysis or data mining as well as comparative studies be carried out.

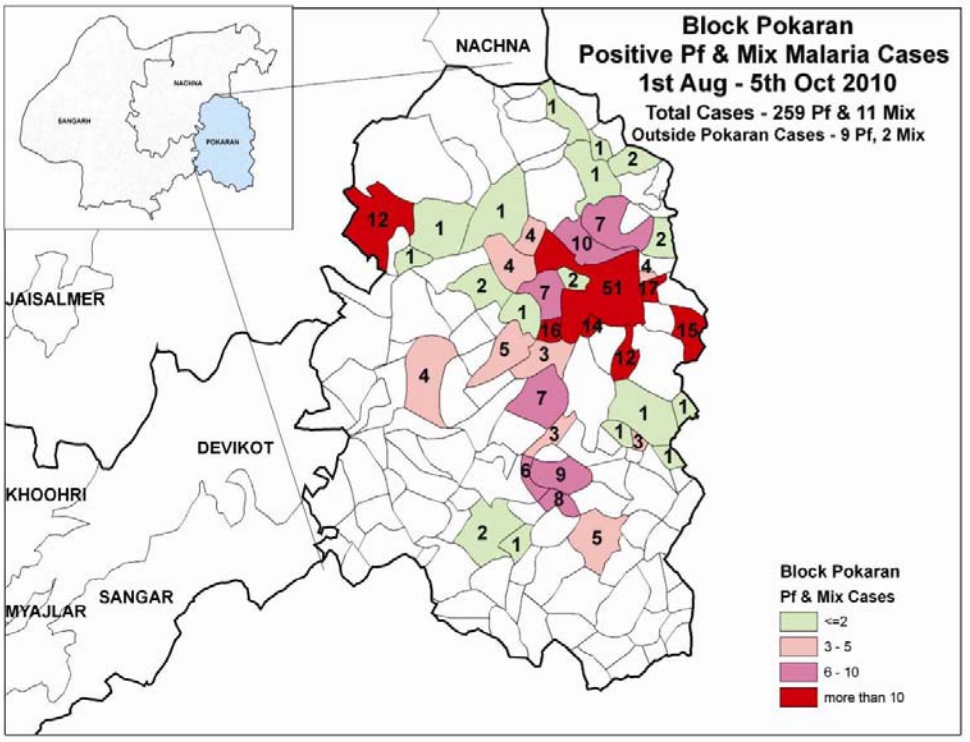

Figure 4 : GIS Map showing occurrence of malaria cases (Pv & Mix) in study area

7. Limitations of Study

- In this study data providers are the State health workers and data users are State health authorities. Thus active participation of State health workers and authorities play the key role in the success of the project.
- It was more suitable to collect numeric data through IVRS, thus alphabetic information were given numeric codes such as gender of patient, village name, health centre name etc. Alphabetic information, which cannot be given codes were not collected such as Patient's name, address etc. In such cases, it was observed that these patients were given a unique Malaria Patient Case number by the health department. Thus, this Malaria Patient Case number was collected through IVRS, which made a link between malaria information in IVRS database to the patient information in health records.

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- In this study single telephone line was used to connect IVRS through voice modem which limited the IVRS to communicate only with one caller at a time. However, this problem can be solved by adding more telephone lines or connecting PRI ISDN telephone line to the RT-HIMS system through telephony board. PRI ISDN telephone line is capable to manage 30 callers in parallel at the same time on a single telephone line.

Acknowledgements

We gratefully acknowledge DG, ICMR for providing necessary financial support. We are grateful to Director (Public Health), Health & Medical Services, Government of Rajasthan, for providing necessary facilities for conducting the present investigations. We are also thankful to Dr R C Sharma, ex-officer-in-charge, DMRC, for his support in the study. We are specially thankful to the health functionaries of Block Pokaran and their staff for their continuous support and cooperation during the study.

Conflict Of Interest

We don’t have any conflict of interest.

Funding

This project was funded by Government of India through Indian Council of Medical Research to Desert Medicine Research Centre, Jodhpur, in public interest.

Ethics Committee Approval

The study was approved by Ethics committee, Desert Medicine Research Centre, Jodhpur

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