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EDITORIAL

The use of GIS in leprosy control

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Mapping of diseases has, since John Snow produced his famous cholera maps of London in 1854,[1] been recognised as an essential tool in public health. A Geographical Information System (GIS) is more than mapping diseases: it manages, analyses and presents data that are linked to geographical locations. GIS enables creation of maps and can present data on national and regional level, but also on very detailed levels, such as households. Beyond administrative boundaries it can also present variables such as land use type and altitude. Its specific strength is that it can visualise, establish relationships and analyse different features that share the same location. The combination of person, time and space makes GIS a powerful epidemiological tool for disease prevention and control. In the last decade, epidemiologists increasingly recognised the importance of GIS. GIS has been applied in research, prevention and control of several infectious diseases such as malaria, tuberculosis, and HIV/AIDS.[2]

The added value of GIS for leprosy control programmes has not yet been recognised by all. Among people involved in leprosy control one finds those advocating the use of GIS and those with a critical attitude towards it as they see constraints in its implementation and no clear benefits. There are some examples of control programmes that use GIS[3] and WHO has also been promoting its use.[4] However, programmes often use GIS only on an *ad-hoc* basis.

In this editorial we want to discuss GIS in leprosy control: how it has been used so far, other possible applications, and its added value and limitations.

The main areas of application of GIS in disease control are: (1) research to generate new knowledge; (2) public health to design focussed interventions; and (3) management to plan and monitor control programmes. Apart from these three areas there is an important role for GIS in (4) advocacy.

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Research

In research GIS is used to understand and explain the spatial variation of diseases and its potential relationship with factors such as geographical, climatological, socio-cultural, and health system-related factors.[2]

The main added value of GIS in research is its ability to perform sophisticated spatial analysis and statistics. GIS can be used to generate new hypotheses and research questions by overlaying the different factors of interest, or to re-formulate and answer existing (longstanding) questions, such as whether leprosy transmission is related to certain environmental factors. A combination of molecular epidemiology and GIS can clarify issues related to occurrence and transmission of leprosy.[5]

Basic use of GIS in research is simple disease mapping.[6] Most researchers, however, go one step further: after identification of areas with apparent high numbers of leprosy cases, they perform spatial (cluster) analysis to find evidence for significant clusters of patients. In this way, 10 significant clusters were identified in Brazil using a spatial scan statistic (SatScan) based on the number of patients and population estimate for each municipality.[7] On a much lower level, namely on household level, three significant clusters of leprosy patients were detected by SatScan on five islands in Indonesia.[8] In one state of Brazil a spatial gradient in incidence rates was found using a locally-weighted regression model to smooth out spatial trends.[9]

Other researchers have also included time in understanding disease patterns. The spatio-temporal distribution of leprosy cases in Nilphamari district in Bangladesh was studied over a 15 year period (1989–2003). Based on the home locations of the patients at diagnosis, one purely temporal and many spatio-temporal clusters were identified.[10]

It is also possible to relate underlying factors to the identified space-time patterns. Using GIS, the marked variation in leprosy incidence rates in northern Malawi could not be related to socio-economic or cultural factors or population density, but incidence rates increased with increasing distance from a main road and with declining distance from a river or lake shore.[11] In Bangladesh a regression model showed that leprosy case detection was higher near towns. No relation with distance to water or clinics was found and the spatio-temporal clusters were possibly due to an underlying increase in leprosy incidence and could thus be seen as ‘outbreaks’.[10]

Identification of areas with high case detection rates and a better understanding of location-based risk factors can guide programme planning and implementation.

Public Health

In public health GIS is used to design appropriate interventions based on either results from research or space-time analyses of routinely collected data to reveal trends, disease clustering and potential risk factors. Possible epidemiological indicators for leprosy that can be visualised are new case detection rate (CDR), leprosy point-prevalence, proportion of child cases (<15 years), proportion of MB cases and the proportion of patients with a disability among newly detected patients.

The added value of GIS is that various epidemiological indicators and potential risk factors can be analysed together and specific techniques can be used to identify disease patterns and explanatory factors.[9,12] The modelling ability of GIS can be used to predict high risk areas and thus take appropriate action.[13]

Leprosy control strategies could be more cost-effective and sustainable when the control activities are linked to the epidemiological situation in a country. A simple GIS can categorise regions based on their case detection rates into regions with high, moderate and low case detection rates. Leprosy control can be adjusted to the situation from a blanket approach in areas categorised as ‘high’ to an outbreak approach in areas categorized as ‘low’.[14] Based on the spatial analysis of the epidemiological indicators over time, control programmes can plan specific active case finding activities such as Leprosy Elimination Campaigns (LEC), Rapid Village Surveys (RVS), mass surveys, school surveys or household screening.

In an urban municipality in Brazil GIS was used to select areas for active case-finding campaigns. The home location of newly detected cases in the period 1998–2002 was georeferenced: based on a density map, four areas were selected with the greatest concentration of cases to carry out active case-finding campaigns, under the assumptions that these areas represented areas with higher transmission risk resulting in more new patients.[15]

Management

In management of disease control programmes GIS can be used for planning, monitoring and evaluation to improve programme performance. In leprosy control GIS can be used to identify areas that are poorly covered, performing or reporting.

Areas with low CDRs could indicate areas with low leprosy endemicity or areas with a poorly performing leprosy control programme (little awareness among population, patients not recognised as leprosy suspects, poor diagnosis). The other epidemiological indicators could give an indication of the most likely explanation: the quality of health care, based on factors such as the proportion of patients with grade 2 disabilities among new cases, treatment completion rate, or results from quality control exercises, can be presented in maps, together with CDR. Areas with poor performance, but high CDR could be identified as priority areas for leprosy training.

Accessibility to leprosy diagnostic and treatment services can be studied. With GIS the distance from residential areas to health facilities can be calculated. Buffers around health centres can be used to calculate coverage: the percentage of villages or population that fall within a certain buffer. Results can be used to justify the creation of a new health centre in areas of low accessibility.

Advocacy

In order to influence policy and decision makers, clear presentation of the burden and problems of leprosy in an area is required, making GIS an important tool for advocacy and programme planning.

The visual character of GIS makes it a preferable tool for presenting data to various audiences. The added value of GIS above more traditional disease mapping techniques is that the maps produced with GIS can be more easily communicated; GIS is able to visualise challenges such as high CDRs that cross administrative boundaries, which may not be picked up when data are presented in tables. The maps stimulate discussion when different indicators are presented together and may raise new questions to be explored.

Discussion

The added value of GIS in leprosy control cannot be denied anymore. Still its use is very limited. Implementation should be carefully planned at national or sub-national level. With leprosy being integrated into general health services it may be more sustainable to develop an integrated GIS system for infectious diseases. The purposes and the users of the system must be well defined as this will determine the design of the system. Adequate resources must be available to establish and maintain the required hardware and software, human resources and data collection mechanism. Data integrity must be ensured at all levels. Developing and regularly up-dating spatial datasets is expensive, but should be seen as a long-term investment for the health system.[13] The choice between freely available applications such as HealthMapper or commercially developed software such as ArcGIS depends on the level of implementation and the expected application of GIS.

As leprosy is a rare disease, with even in high endemic areas usually not more than 10 patients per 10 000 inhabitants per year, data analysis at sub-district or lower level usually has the problem of small numbers and appropriate data analysis methods have to be selected.

Conclusion

GIS must be considered as a tool for disease control and not as an end-product. Disease control is not complete anymore without visualising the spatial elements of disease occurrence and its determining or related factors. On lower administrative levels the old-fashioned hand-made maps may still be sufficient, but on higher levels the added value of GIS cannot be ignored anymore. GIS has become an essential tool to be used with care and wisdom to establish the burden of disease, identify risk factors, and to plan, monitor and evaluate control interventions.

References

1. Snow J. *On the mode of communication of cholera* 2nd edn., John Churchill, New Burlington Street, London, England, 1855.
2. Tanser FC, le Sueur D. The application of geographical information systems to important public health problems in Africa. *Int J Health Geogr*, 2002; **1**: 4.
3. Suresh B. *Role of GIS in planning and evaluation of leprosy elimination programme*; http://www.gisdevelopment.net/application/health/planning/healthp0004.htm
4. World Health Organisation. *Geographic Information Systems (GIS)*, 2009; http://www.who.int/lep/monitor/gis/en/index.html
5. Weng X, Wang Z, Liu J *et al.* Identification and distribution of *Mycobacterium leprae* genotypes in a region of high leprosy prevalence in China: a 3-year molecular epidemiological study. *J Clin Microbiol*, 2007; **45**: 1728–1734.
6. Gauy JS, Hino P, dos Santos CB. Spatial distribution of leprosy cases in Ribeirão Preto, Brazil, 2004. *Rev Lat Am Enfermagem*, 2007; **15**: 460–465.
7. Penna ML, Wand-Del-Rey-de-Oliveira ML, Penna G. Spatial distribution of leprosy in the Amazon region of Brazil. *Emerg Infect Dis*, 2009; **15**: 650–652.
8. Bakker MI, Hatta M, Kwenang A *et al.* Population survey to determine risk factors for *Mycobacterium leprae* transmission and infection. *Int J Epidemiol*, 2004; **33**: 1329–1336.
9. Montenegro AC, Werneck GL, Kerr-Pontes LR *et al.* Spatial analysis of the distribution of leprosy in the State of Ceará, Northeast Brazil. *Mem Inst Oswaldo Cruz*, 2004; **99**: 683–686.
10. Fischer E, Pahan D, Chowdhury S, Richardus J. The spatial distribution of leprosy cases during 15 years of a leprosy control program in Bangladesh: an observational study. *BMC Infect Dis*, 2008; **8**: 126.

[11] Sterne JA, Pönnighaus JM, Fine PE, Malema SS. Geographic determinants of leprosy in Karonga District, Northern Malawi. *Int J Epidemiol*, 1995; **24**: 1211–1222.

[12] Lapa TM, de Albuquerque Mde F, Carvalho MS, Silveira JC Jr. Análise da demanda de casos de hanseníase aos serviços de saúde através do uso de técnicas de análise espacial [Spatial analysis of leprosy cases treated at public health care facilities in Brazil]. *Cad Saude Publica*, 2006; **22**: 2575–2583.

[13] Cromley EK, McLafferty SL. *GIS and public health* Guilford Press, New York, 2002.

[14] Visschedijk J, van de Broek J, Eggens H *et al. Mycobacterium leprae*–millennium resistant! Leprosy control on the threshold of a new era. *Trop Med Int Health*, 2000; **5**: 388–399.

[15] De Souza Dias MC, Dias GH, Nobre ML. The use of Geographical Information System (GIS) to improve active leprosy case finding campaigns in the municipality of Mossoró, Rio Grande do Norte State, Brazil. *Lepr Rev*, 2007; **78**: 261–269.