Int Health 2017; **9**: 195–201
doi:10.1093/inthealth/ihx018

ORIGINAL ARTICLE

Adaptation of a malaria surveillance system for use in a visceral leishmaniasis elimination programme

Geraldine M. Foster[a], Sophie. Dunkley[a], Rinki M. Deb[a], Edward Thomsen[a], Marlize Coleman[a], A. C. Dhariwal[b], R.K. Das Gupta[b], Sridhar Srikantiah[c], Pradeep Das[d] and Michael Coleman[a,*]

[a]Department of Vector Biology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, UK; [b]National Vector Borne Disease Control Program, Directorate General of Health Services, Ministry of Health & Family Welfare, Govt. of India, DMRC IT Park, Shastri Park, Block- III, Delhi-110 053, India; [c]BTSP, CARE India, House No-297, Patliputra Colony, Patna-800013, India; [d]Rajendra Memorial Research Institute Of Medical Sciences, Indian Council for Medical Research, Ministry of Health and Family Welfare, Agam Kuan, Patna - 800 007, India.

*Corresponding author: Tel +44 151 705 3302; E-mail Michael.coleman@lstmed.ac.uk

Received 11 November 2016; revised 24 April 2017; editorial decision 26 April 2017; accepted 22 May 2017

Background: Successful public practice relies on generation and use of high-quality data. A data surveillance system (the Disease Data Management System [DDMS]) in use for malaria was adapted for use in the Indian visceral leishmaniasis elimination programme.

Methods: A situational analysis identified the data flows in current use. Taxonomic trees for the vector of visceral leishmaniasis in India, *Phlebotomus argentipes*, were incorporated into the DDMS to allow entry of quality assurance and insecticide susceptibility data. A new quality assurance module was created to collate the concentration of DDT that was applied to walls during the indoor residual spraying (IRS) vector control programme.

Results: The DDMS was implemented in Bihar State and used to collate and manage data from sentinel sites in eight districts. Quality assurance data showed that DDT was under-applied to walls during IRS; this, combined with insecticide susceptibility data showing widespread vector resistance to DDT prompted a national policy change to using compression pumps and alpha-cypermethrin insecticide for IRS.

Conclusions: The adapted DDMS centralises programmatic data and enhances evidence-based decision making and active policy change. Moving forward, further modules of the system will be implemented, allowing extended data capture and streamlined transmission of key information to decision makers.

Keywords: India, Quality assurance, Surveillance, Vector control, Visceral leishmaniasis

Introduction

Successful public health practice relies upon the systematic collection, analysis and interpretation of health-related data, which, when used effectively, can monitor the impact of health-related interventions and delineate the epidemiology of disease.[1] However, despite the acknowledgement that data from surveillance is required to make informed decisions on a daily basis and drive policy change regarding vector control best practice, the full potential of information technology, data systems and data aggregation has yet to be applied effectively to a disease control or elimination programme.[2] Relevant data is often fragmented and stored in different databases within ministerial departments, and across other public and private sector stakeholders, rendering efficient data analysis difficult and effective vector control unlikely.

The Disease Data Management System (DDMS) was conceived as a data management and decision making tool which would harness the opportunities inherent in open source software for distribution to, and adaptation for, multiple users with disparate needs without incurring licensing costs.[3] Initially developed as a response to the need for standardised disease surveillance systems in resource-limited settings, particularly for vector borne disease control, the initial incarnation of the DDMS contained systems optimised for the collection, analysis and management of malaria and dengue data.[3,4] The technical development of the DDMS has been described elsewhere,[3] and it is currently implemented in 10 African countries and one Asian country.[5]

Visceral leishmaniasis (VL) is a neglected tropical disease of which there are 200 000–400 000 cases annually. The disease is endemic in the countries of the Indian subcontinent and East Africa, however 90% of cases occur in Bihar State in India.[6,7] A tripartite agreement between Bangladesh, India and Nepal was signed in 2005 with the aim of eliminating VL throughout the region by 2015 through combined enhanced diagnosis and treatment strategies and the standardisation and improvement of indoor residual spraying (IRS), the main VL vector control intervention.[8,9] The technical feasibility of this strategy was supported in 2014, when Stauch et al. found using statistical modelling that a reduction of sand fly densities of 67% through IRS would be sufficient to achieve VL elimination, lower than previously observed density reductions of 72%.[10,11] However, although the implementation of the elimination pledge resulted in a steady decline in VL case numbers,[12] the elimination target was not reached, suggesting either a reduced impact of vector control interventions due to insecticide resistance, poor intervention quality, or continuing residual transmission not captured by IRS.

An integrated surveillance system that could combine VL case data, IRS monitoring and evaluation, and entomological monitoring was proposed in order to identify areas of possible improvement to assist the elimination programme to reach their target. Accordingly, in 2014 the malaria version of the DDMS was used as a starting point for adaptation of the system for a new purpose: integration into the Indian VL elimination programme.

Methods

Situational analysis

Prior to the project launch in late 2013, an informal situational analysis was performed to determine the existing surveillance capabilities of the Indian VL elimination programme and to identify any informational gaps that existed. A literature review to collate published data on IRS quality, IRS coverage and the insecticide resistance status of the VL vector, *Phlebotomus argentipes*, was performed and informal discussions were conducted with various elimination programme stakeholders: the National Vector Borne Disease Control Programme (NVBDCP); the Rajendra Memorial Research Institute of Medical Sciences (RMRI), who are part of the Indian Council for Medical Research (ICMR) and who hold the local Bihar State remit for performing IRS training; CARE Bihar, a subsidiary of CARE International NGO who are funded by the Bill & Melinda Gates Foundation (BMGF) to develop a VL case database and to perform IRS monitoring and evaluation during the IRS campaigns, and local BMGF representatives who were involved in supporting the VL elimination programme.

Following initial adaptation of the DDMS to contain local geography and Phlebotomine sand fly taxonomic trees, a workshop attended by representatives from NVBDCP, RMRI, CARE Bihar, BMGF, WHO and the Wellcome Trust was held in Delhi in 2014. The adapted DDMS was demonstrated and feedback was solicited during a discussion regarding the system's programmatic usefulness. Suggestions made during the workshop were incorporated into the final adapted DDMS. The adapted system was installed and used at RMRI in Bihar, India, to capture *Ph. argentipes* abundance, insecticide resistance, and IRS quality assurance data. Data captured by the DDMS at RMRI was converted into reports using the reporting software in the system; reports were shared with all project stakeholders to increase the data available for programmatic decisions within the VL surveillance programme.

Analysis and technical adaptation of existing malaria DDMS

Each module present in the existing DDMS was examined and cross-referenced against the data categories identified by the situational analysis in order to compile a master list of necessary adaptations. User customisable options and hard coded changes were used to update ontological definitions to allow the entry of sand fly taxonomic trees, enter new geographic entities to reflect the change in location to Bihar State, and develop new query structures. During the adaptation process, new report formats that covered the entomology, IRS quality assurance, qualitative household acceptability of IRS, and IRS monitoring data collected by CARE India were created by Liverpool School of Tropical Medicine staff using Business Intelligence and Reporting Tools (BIRT), the open source technology platform that is used to create reports from data stored in the DDMS. Reports formats were sent to all project stakeholders for feedback and approval prior to finalisation. All hard coded adaptations were incorporated into all versions of the DDMS to ensure that improvements were continuously rolled out across all users.[3]

Four types of surveys gathering a range of data in 2015 were used to validate the adapted DDMS. As the existing VL surveillance programme did not routinely collect entomology and IRS quality assurance data, entomology and IRS quality assurance surveys were performed in order to generate the data needed to adapt and validate the DDMS system modules. These data were also used, as previously reported,[13] to inform the NVBDCP and other project stakeholders of the current state of IRS quality, vector abundance and insecticide resistance, as captured by the validation surveys. Data from routine monitoring and evaluation surveys performed by CARE were used to validate the household acceptability and IRS monitoring modules.

Entomology surveys to measure vector abundance and insecticide resistance status to DDT and deltamethrin were performed in four districts at four time points: pre-IRS, and 1, 3 and 5 months post-IRS.[13] Vector insecticide susceptibility surveys to DDT were performed in four districts and to deltamethrin in three districts. The BIRT entomology report produced from the data contained aggregated data and dis-aggregated data to district level.

The quality assurance module was used to capture high performance liquid chromatography (HPLC) and Insecticide Quantification Kit insecticide concentration data from eight Bihar districts. Surveys were performed pre-IRS, to assess the level of residual insecticide present in houses from previous IRS campaigns, and post-IRS. Two BIRT reports were created to display the data: a pre-IRS quality assurance report and a post-IRS quality assurance report. Both reports contained aggregated data at district level and disaggregated data at primary health centre and village levels.

The IRS monitoring module was used to capture monitoring and evaluation data from CARE Bihar household surveys performed pre-IRS and during IRS and was reported at district level. These data were reported using the household acceptability and IRS monitoring reports.

Implementation of the adapted DDMS for use in capturing VL elimination programme data from eight Indian districts

The adapted DDMS was installed on PCs running Microsoft Windows 7 (Microsoft Corp., Redmond, WA, USA) with the Mozilla Firefox (https://www.mozilla.org/en-GB/) internet browser installed, according to system requirements and standard installation procedure as previously reported.[3] Installations were performed on nine computers located in RMRI offices in Patna, Bihar. Data from CARE Bihar were imported into the DDMS using custom-designed Microsoft Excel worksheets.

Results

Situational analysis

The informal situational analysis identified a lack of capacity to capture detailed entomological abundance and insecticide resistance data as the major informational gap in the VL elimination programme. The software that is in use for VL surveillance by the elimination programme, the District Health Information System (DHIS2),[14] has the ability to capture a range of health-related information, but lacks the specific ability to capture entomological collections, field tests for insecticide resistance and IRS quality assurance data, which are all crucial to constructing an overarching picture of the VL elimination programme. Therefore, the DDMS, which was designed to capture and integrate entomological data,[3] was selected for adaptation for the VL setting. Although this required adapting a new system for implementation, the DDMS has the capacity to accept downloads of health information from the DHIS2 system, meaning that running the two systems in parallel would not result in increased data entry requirements or in duplication of surveillance efforts.

The review of published literature regarding IRS in Bihar showed that the reported coverage could be as low as 12% in some areas,[15] indicating a performance gap that was crucial to capture within an integrated data system. Reviews of published insecticide resistance papers further indicated that *Ph. argentipes* resistance to DDT was historically and contemporaneously present,[16–27] and therefore an essential component within a data surveillance system was the capability to capture and integrate coverage data and insecticide resistance data in order to disaggregate entomological sand fly abundance results post-IRS from either poor insecticide coverage or the effects of DDT resistance.

Discussions with NVBDCP, RMRI, and CARE showed that each organisation collected different types of data and that no integrated system to allow overall programmatic analysis was in place.

IRS monitoring and evaluation data

Monitoring and evaluation data collected by CARE: CARE-employed Kala-azar link workers located in in the field collected data on three separate forms: A, B and C (Table 1). Each link worker was responsible for supervising 4–6 spray squads and each of forms A, B and C were completed for each spray squad each week of IRS. Following data collection, the link worker reported to the Medical Officer in charge via telephone (Figure 1A). Simultaneously, local front line health workers located in the villages referred residents with VL symptoms to the closest Primary Health Centre for laboratory diagnostic VL confirmation (Figure 1B). Although a defined and systematic data flow existed for the reporting of IRS and case data, and despite both types of data passing through two identical stages (reporting to the Kala-azar Technical Supervisor and the Vector Borne Disease Consultant), the two types of data were not integrated, and sent separately to different final destinations (Figure 1). Furthermore, informal discussions indicated that discrepancies existed between overlapping data points within datasets; e.g., estimates of IRS coverage.

Creation of a quality assurance module to accept HPLC and Insecticide Quantification Kit data

Review of the data collected by the stakeholders of the VL elimination programme showed that there was no procedure in place for quality assurance of the IRS programme in terms of concentration of insecticide applied to walls. The elimination programme used population numbers and an average structure size to calculate the weight of insecticide required for each district to perform IRS at the correct concentration, and comparison of the insecticide ordered versus insecticide expended at the end of each spray round functioned as a crude calculation of the concentration of insecticide delivered during the spraying season.

Prior to adaptation for VL, the existing IRS module in the DDMS was developed to incorporate standard operational activities in place by 2010, including the capture of data from standard WHO/TDR IRS monitoring assays. However, although the procedure for performing IRS had not changed between 2010 and 2014, the available methods for quality control of the intervention had with the development of the Insecticide Quantification Kit (IQK), a field-based method for quantifying insecticide residues present on wall surfaces post-IRS.[13,28,29] IQK results are reported in units of active ingredient (mg or g) per square metre of wall covered (m^2), in the same manner as insecticide residues recovered from pre-spray WHO filter papers which have been tested using HPLC. The IQK test represents an inexpensive, field-based method for quantifying insecticide residues that presents fewer operational requirements than standard WHO-cone bioassays.[28,29]

As part of the programme of activities to support the VL elimination programme that was reported in Coleman et al., the IQK test, validated by WHO papers tested using HPLC, was rolled out across eight sentinel sites in Bihar.[13] A new quality assurance module was created in the DDMS which could capture both IQK and HPLC data, in addition to data from WHO/TDR cone bioassays, creating a system that allowed capture of IRS insecticide concentration, insecticide susceptibility status and

Table 1. Monitoring and evaluation data collected by CARE link workers pre-, during and post-indoor residual spraying (IRS)

Form	A	B	C
Purpose	Collate community awareness of IRS and previous exposure to Kala-azar and IRS	Check the quality of IRS and the spray team	Assess quality and coverage of IRS in the village
Performed	Prior to IRS	During IRS	Post-IRS
Main data collected	Awareness of IRS campaign; Awareness of IRS spray date; Awareness of IRS requirements, e.g. moving furniture and spraying all rooms where people sleep; Awareness of VL disease; Awareness of sand fly vector as agent of VL disease; Ability of householders to identify sand flies; Presence of livestock in households; Number of VL cases in previous 3 years.	Time of spray team arrival in the village; Spray team start time; Spray team end time; What items of personal protective equipment were being used; Number of extra components for stirrup pumps carried by team; Whether standard measures were used to make insecticide suspension; Whether correct technique was used while spraying.	Whether the spray team visited the village; Which coverage area the household belonged to; Caste category of the household; Whether the household allowed spraying; Whether all rooms in which people sleep were sprayed; Whether any cattle sheds present were sprayed; Whether food/utensils/cattle feed were covered by the spray team prior to spraying.

IRS: indoor residual spraying; VL: visceral leishmaniasis.

vector abundance data from both current gold standard methodologies and emerging IRS monitoring technologies. As the system is flexible, users can select the method of IRS monitoring most appropriate to their setting, and enter data into the DDMS accordingly.

Implementation of the DDMS into the Indian context

The DDMS was installed in the offices at RMRI for the purposes of the adaptation of the malaria system into a VL system. During the software adaptation, nine system installations were completed, and the DDMS was used by eight data entry operators. The reports generated from data entered into the DDMS were sent to NVBDCP and other project stakeholders to increase the amount and nature of programmatic data available to elimination programme decision makers.

Use of the DDMS in the Indian context

As part of an impact assessment done across DDMS users in seven countries for Thomsen et al.,[5] a survey recording the ease of use of the DDMS was sent to the eight Indian users who used the installed systems at RMRI. Four responses were received, representing a response rate of 50%. All response were from data entry operators. Disaggregating the Indian responses showed that 4/4 (100%) of respondents agreed with the statement, ‘Using the DDMS allows me to accomplish tasks more quickly’. Respondents also unanimously agreed that the DDMS improved the processes of entering data, checking data accuracy, modifying or cleaning data, and querying, summarising and tabulating data. However, no respondents agreed that the DDMS made creating charts or generating reports easier, or that programmatic decision making was improved.

Impact of improved data surveillance on VL elimination programme policy

As reported in Coleman et al.,[13] the quality assurance surveys of IRS in eight Bihar districts showed that the concentration of DDT delivered during IRS was an average of 0.37 g/m^2, far lower than the target dose of 1 g/m^2. Insecticide susceptibility testing revealed high levels of DDT resistance, in line with the historical review of insecticide resistance data, and the vector abundance data demonstrated that IRS was only effective for one month post-spray.

DDMS reports for each dataset were presented to the VL elimination programme and other stakeholders. The data captured highlighted that the reduced impact of IRS on vector control was due to both *Ph. argentipes* DDT insecticide resistance and to poor application of insecticides to wall surfaces during IRS. Accordingly, the programme was able to make policy decisions to target both issues. A switch from DDT to the pyrethroid insecticide alpha-cypermethrin was initiated in 2015 to combat existing DDT insecticide resistance. Poor application of insecticide during IRS was combated by implementing a change from using stirrup pumps as the application method to using Hudson compression pumps. Spray operators were trained in use of the new compression pumps by WHO to ensure that the new pumps were used correctly.

Increased roll out of adapted system following adaptation for VL

Following the completion of the adaptation to VL and the impact assessment, the system was installed in CARE offices in Bihar, New project means that reports are sent to NVBDCP monthly.

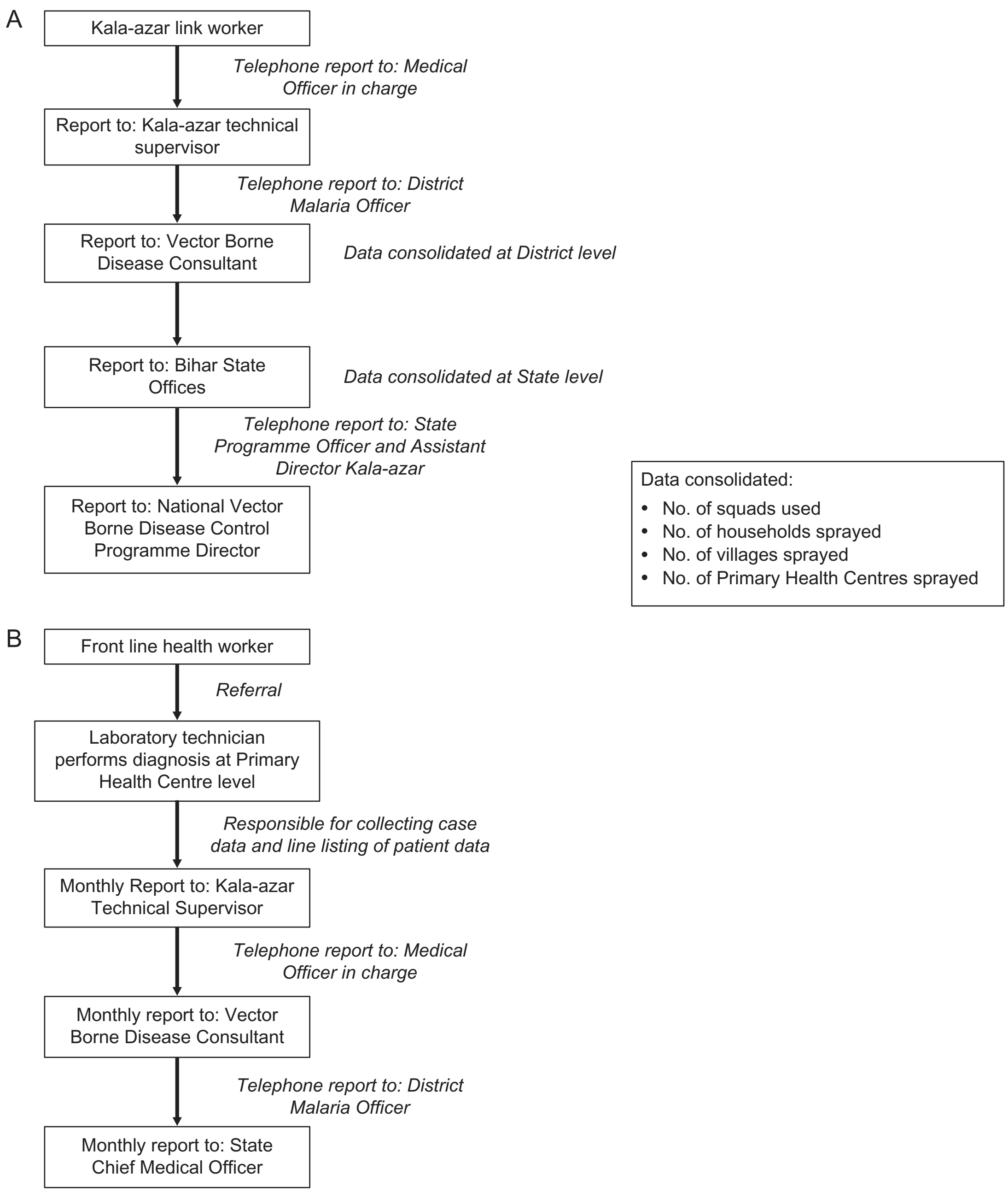

Figure 1. Data flows for visceral leishmaniasis monitoring. (A) From Kala-azar link worker to National Borne Disease Control Programme; (B) Front-line health worker to State Chief Medical Officer.

Discussion

VL elimination in the Indian subcontinent should be feasible using IRS as the sole vector control intervention, provided that IRS is able to reduce sand fly densities by 67%.[11] Density reductions of a greater scale have been observed in IRS trials conducted across the Indian subcontinent for VL control[10] and in Morocco for cutaneous leishmaniasis control,[30] indicating that IRS of satisfactory quality, using an insecticide to which *Ph. argentipes* remains susceptible, ought to be sufficient as a vector control intervention to achieve VL elimination. However, despite an intensive campaign to eliminate VL in India, Bangladesh and Nepal, the elimination targets have not as yet been reached as a whole across the subcontinent. To identify whether a reduced impact of vector control interventions was contributing to continued VL persistence in India, and to close informational gaps present in the existing routine monitoring that was implemented as part of the Indian VL elimination programme, a data surveillance system implemented in several African countries was adapted for VL use and implemented in eight districts in Bihar State, India.[3,5,13]

As the data system adaptation was primarily focused on closing informational gaps, creation of new modules within the system concentrated on creating data capture capacity for interventions currently implemented with the Indian VL surveillance programme. Although the Indian VL strategy currently recommends an integrated vector management approach, IRS has been implemented as the cornerstone intervention of vector control.[8] Therefore, the current adaptation has primarily created capacity for data capture related to IRS activities. However, the nature of the DDMS is such that additional modules can be created for any intervention implemented at a programmatic level.

Capturing surveillance data from various programmatic aspects (quality assurance, insecticide resistance status and entomological abundance assessments) demonstrated a reduced impact of IRS due to widespread DDT resistance and suboptimal application of insecticide to wall surfaces during IRS.[13] Identifying the reasons for the reduced impact of IRS enabled the VL elimination programme to initiate major policy change by switching from using DDT to a pyrethroid insecticide and by changing from the use of stirrup pumps to Hudson compression pumps. This policy change would not have been possible without the additional data collected as part of the software adaptation process, and the data management and surveillance capabilities of the adapted system.

The initial adaptation of the DDMS for use in the Indian VL programme was focused on optimising the system to identify operational aspects of the elimination programme with reduced vector control impact. However, the optimised system has additional capabilities that would be of benefit in supporting the Indian government to reach the elimination targets, but which are not currently implemented within the elimination programme. Chief among these is the ability of the DDMS to produce integrated data reports that function as a 'dashboard snapshot' of programmatic activities.[3,5,31] To this end, eight sentinel sites located across three Indian States (Bihar, Jharkhand, and West Bengal) have been created. Each sentinel site will collect several types of data, including VL case data, vector abundance, vector insecticide susceptibility status, IRS quality assurance, and IRS monitoring and evaluation data. The captured data will be used to produce an integrated data report for VL elimination stakeholders, empowering the elimination programme to make evidence-based policy decisions.

This paper reports the process and results seen during the adaptation of the malaria DDMS to the VL DDMS. Of necessity, the user base during the adaptation process was small; however, responses from the user survey indicated that the DDMS is a useful software system for entering, cleaning and tabulating data. Respondents did not generally agree that the DDMS enabled programmatic decision making; however, none of the respondents surveyed were employed at a sufficiently senior level to be privy to decision making processes. Now that the adapted system is complete, a wider implementation of the DDMS at central programmatic level would allow a more detailed user impact assessment to be performed.

The DDMS also has in-built capability to send automated text message alerts once outbreak thresholds are breached.[3] Implementing automated alerts into the Indian VL reporting tree would remove existing data flow bottlenecks and ensure that relevant programmatic data was delivered to every level simultaneously, speeding up potential programme response. This is especially relevant as the programme achieves its elimination targets and moves into a sustained phase of active monitoring.

The need for spatial decision support tools such as the DDMS to integrate with existing health information systems has long been identified,[32] as has the capability of the DDMS to integrate with such systems thanks to its open source software base.[5] Liverpool School of Tropical Medicine and the University of Oslo are currently collaborating on a project to integrate some of the functionality of the DDMS with the DHIS2, which has a much larger global reach than the DDMS. This will enhance the functionality of both systems and ensure that the DDMS continues to meet programmatic needs and promote evidence-based policy decision making.

Conclusions

The DDMS has been successfully adapted to incorporate data on VL monitoring and control. Programmatic data entered into the system as part of the Indian VL elimination programme has offered an overview of the available information, enhancing evidence-based decision making. The comprehensive surveillance system offered by the DDMS has promoted active policy change and improved vector control practices. Moving forward, further modules of the system will be implemented, allowing extended data capture and streamlined transmission of key information to decision makers.

Authors' contributions: MC and MC conceived the study; MC designed the study protocol; RMD, GF and SD carried out the quality assurance and collected data; GF, MC interpreted the data; GF, MC and SD drafted the manuscript; MC, MC, RMD, ACD, RKDG, SD, ET, SS, PD critically revised the manuscript for intellectual content. All authors read and approved the final manuscript. MC is the guarantor of the paper.

Funding: This work was supported by the Bill & Melinda Gates Foundation [grant number OPP1095868].

Competing interests: None declared.

Ethical approval: Not required.

References

1 WHO I Public health surveillance. Geneva: World Health Organization. http://www.who.int/topics/public_health_surveillance/en/ [accessed 8 November 2016].

2 Moonen B, Cohen JM, Snow RW et al. Operational strategies to achieve and maintain malaria elimination. Lancet 2010;376: 1592–603. doi:10.1016/S0140-6736(10)61269-X.

3 Eisen L, Coleman M, Lozano-Fuentes S et al. Multi-disease data management system platform for vector-borne diseases. PLOS Negl Trop Dis 2011;5:e1016. doi:10.1371/journal.pntd.0001016.

4 Hemingway J, Beaty BJ, Rowland M et al. The Innovative Vector Control Consortium: improved control of mosquito-borne diseases. Trends Parasitol 2006;22:308–12. doi:10.1016/j.pt.2006.05.003.

5 Thomsen EK, Deb RM, Dunkley S et al. Enhancing decision support for vector-borne disease control programs—the disease data management system. PLOS Negl Trop Dis 2016;10:e0004342. doi:10.1371/journal.pntd.0004342.

6 Desjeux P. Leishmaniasis: current situation and new perspectives. Comp Immunol Microbiol Infect Dis 2004;27:305–18. doi:10.1016/j.cimid.2004.03.004.

7 Joshi A, Narain JP, Prasittisuk C et al. Can visceral leishmaniasis be eliminated from Asia? J Vector Borne Dis 2008;45:105.

8 WHO. Regional strategic framework for elimination of kala-azar from the South-East Asia region (2005–2015). New Delhi: World Health Organization, Regional Office for South-East Asia; 2005.

9 WHO. Regional Technical Advisory Group on Kala-azar Elimination. Report on the First Meeting Manesar, Haryana, 20–23 December 2004. New Delhi: World Health Organization, Regional Office for South-East Asia; 2005. http://apps.searo.who.int/pds_docs/B0212.pdf [accessed 5 October 2016].

10 Joshi AB, Das ML, Akhter S et al. Chemical and environmental vector control as a contribution to the elimination of visceral leishmaniasis on the Indian subcontinent: cluster randomized controlled trials in Bangladesh, India and Nepal. BMC Med 2009;7:54. doi:10.1186/1741-7015-7-54.

11 Stauch A, Duerr H-P, Picado A et al. Model-based investigations of different vector-related intervention strategies to eliminate visceral leishmaniasis on the Indian subcontinent. PLOS Negl Trop Dis 2014;8. doi:10.1371/journal.pntd.0002810.

12 Muniaraj M. The lost hope of elimination of Kala-azar (visceral leishmaniasis) by 2010 and cyclic occurrence of its outbreak in India, blame falls on vector control practices or co-infection with human immunodeficiency virus or therapeutic modalities? Trop Parasitol 2014;4:10. doi:10.4103/2229-5070.129143.

13 Coleman M, Foster GM, Deb R et al. DDT-based indoor residual spraying suboptimal for visceral leishmaniasis elimination in India. Proc Natl Acad Sci 2015:201507782. doi:10.1073/pnas.1507782112.

14 University of Oslo. District Health Management System Collect, Manage, Visualize and Explore your Data. /home. Oslo, Norway: University of Oslo. [accessed 24 April 2017].

15 Hasker E, Singh SP, Malaviya P et al. Visceral leishmaniasis in rural Bihar, India. Emerg Infect Dis 2012;18:1662–4. doi:10.3201/eid1810.111083.

16 Das Gupta RK, Saxena NB, Joshi RD, Rao JS. DDT resistance in *P. Papatasi* in Bihar. J Commun Dis 1995;27:124.

17 Dhiman RC, Raghavendra K, Kumar V et al. Susceptibility status of *Phlebotomus argentipes* to insecticides in districts Vaishaii and Patna (Bihar). J Commun Dis 2003;35:49–51.

18 Dinesh DS, Das ML, Picado A et al. Insecticide susceptibility of *Phlebotomus argentipes* in visceral leishmaniasis endemic districts in India and Nepal. PLOS Negl Trop Dis 2010;4:e859. doi:10.1371/journal.pntd.0000859.

19 Joshi GC, Kaul SM, Wattal BL. Susceptibility of sandflies to organochlorine insecticides in Bihar India - further reports. J Commun Dis 1979;11:209–13.

20 Kaul SM, Wattal BL, Bhatnagar VN, Mathur KK . Preliminary observations on the susceptibility status of *Phlebotomus argentipes* and *Phlebotomus papatasi* to DDT in two districts of north Bihar. J Commun Dis 1978;10:208–11.

21 Kaul SM, Das RK, Raj S et al. Entomological monitoring of kala-azar control in Bihar State, India: observations in Vaishali and Patna districts. J Commun Dis 1993;25:101–6.

22 Kishore K, Kumar V, Kesari S et al. Susceptibility of *Phlebotomus argentipes* against DDT in endemic districts of north Bihar, India. J Commun Dis 2004;36:41–4.

23 Kumar K, Singh K, Das RK et al. Laboratory and field observations on the effectiveness of DDT for the control of the vector sandfly, *Phlebotomus argentipes* in the kala-azar endemic state of Bihar. 1995. http://www.who.int/iris/handle/10665/60343 [accessed 5 October 2016].

24 Mukhopadhyay AK, Saxena NB, Narasimham MV. Susceptibility status of *Phlebotomus argentipes* to DDT in some kala-azar endemic areas of Bihar (India). Indian J Med Res 1990;91:458–60.

25 Mukhopadhyay AK, Saxena NBL, Narasimham MVVL. Susceptibility status of *Phlebotomus argentipes* to DDT in some kala-azar-endemic districts of Bihar, India. New Delhi, India: World Health Organization; 1992. http://www.who.int/iris/handle/10665/61452 [accessed 5 October 2016].

26 Singh R, Das RK, Sharma SK. Resistance of sandflies to DDT in Kala-azar endemic districts of Bihar, India. Bull World Health Organ 2001;79:793.

27 Singh RK, Mittal PK, Dhiman RC. Insecticide susceptibility status of *Phlebotomus argentipes*, a vector of visceral leishmaniasis in different foci in three states of India. J Vector Borne Dis 2012;49:254–7.

28 Ismail HM, Kumar V, Singh RP et al. Development of a simple dipstick assay for operational monitoring of DDT. PLOS Negl Trop Dis 2016;10:e0004324. doi:10.1371/journal.pntd.0004324.

29 Russell TL, Morgan JC, Ismail H et al. Evaluating the feasibility of using insecticide quantification kits (IQK) for estimating cyanopyrethroid levels for indoor residual spraying in Vanuatu. Malar J 2014;13:178. doi:10.1186/1475-2875-13-178.

30 Faraj C, Yukich J, Adlaoui EB et al. Effectiveness and cost of insecticide-treated bed nets and indoor residual spraying for the control of cutaneous leishmaniasis: a cluster-randomized control trial in Morocco. Am J Trop Med Hyg 2016;94:679–85. doi:10.4269/ajtmh.14-0510.

31 Chanda E, Thomsen EK, Musapa M et al. An operational framework for insecticide resistance management planning. Emerg Infect Dis 2016;22:773–9. doi:10.3201/eid2205.150984.

32 Kelly GC, Tanner M, Vallely A, Clements A. Malaria elimination: moving forward with spatial decision support systems. Trends Parasitol 2012;28:297–304. doi:10.1016/j.pt.2012.04.002.