Mobile data tools for improving information flow in WASH: Lessons from three field pilots

Authors

Matt Ball[1], Zarah Rahman[2], Michael Champanis[3], Ulrike Rivett[4] and Ranjiv Khush[5]1

Abstract

The application of information and communication technologies (ICT) to support the delivery of water and sanitation services is a growing area of interest in the WASH sector. To study how these tools might be incorporated into existing management structures, we conducted field pilots of a mobile phone based application for transmitting water quality data in three distinct water supply structures: a large provincial utility in Vietnam, rural NGO operations in Cambodia, and district health authorities in Mozambique. The use of the application improved the efficiency of information flows in all three settings, and increased data availability at upper administrative levels in Mozambique. Implementing and trouble-shooting the application revealed unexpected weaknesses in local cellular networks, and the requirement for clear phone management procedures. The limited information technology support services within local institutions might favor external service providers to ensure the sustainability of mobile applications, but we noted reluctance to develop formal service relationships among participating institutions. Beneficial outcomes from the pilots included increased awareness among senior managers of monitoring activities and of water quality data, and greater reflection upon data requirements and reporting methods by water quality units within participating institutions.

Introduction

The potential for ICT tools to improve the quality and sustainability of water and sanitation services in low-resource settings is gaining increasing attention (Hutchings et al. 2012). This interest is driven by the often-successful application of digital tools in the health, agriculture and education sectors, and by the increasing availability and relative low cost of mobile phones. In Africa, for example, mobile phone penetration was approximately 65% in 2011 and is predicted to rise to over 85% by 2015 due to improved coverage and affordability (Biosca 2012). A randomized controlled trial in Kenya has shown that text-

[1] The Aquaya Institute, 1004B O'Reilly Avenue, San Francisco, CA 94129 USA
[2] The Aquaya Institute, 1004B O'Reilly Avenue, San Francisco, CA 94129 USA
[3] iCOMMS, Department of Civil Engineering, University of Cape Town, Private Bag, Rondebosch, 7701, South Africa
[4] iCOMMS, Department of Civil Engineering, University of Cape Town, Private Bag, Rondebosch, 7701, South Africa
[5] The Aquaya Institute, 1004B O'Reilly Avenue, San Francisco, CA 94129 USA

message reminders sent to health workers could improve their management of outpatient pediatric malaria (Zurovac et al. 2011). Broadly, mobile phone applications for public health have proven useful for connecting remote groups with central operators, helping to improve the turnaround time between data collection and reporting, increasing the accuracy of collected data, and reducing the cost of monitoring programs (Conley et al. 2010).

In the WASH sector, ICT tools have been adopted on a limited scale to track the performance of NGO projects, to "crowd-source" information from the public on water supply function, and to report operational data from small dispersed water supplies (Hutchings et al. 2012; Thompson et al. 2012). For example, an ICT company in Senegal, Manobi SA, has developed the mWater mobile phone application for the Senegalese Water Ministry's Operations & Maintenance division. mWater allows water utility managers to submit operational data for analysis and display through the internet (Gia & Fugelsnes 2010). In Uganda, the National Water and Sewerage Corporation (NWSC) has partnered with different mobile network providers to implement ePayment, which is a facility for paying water bills through mobile money direct remittances.

The use of ICT tools and applications for WASH management in low resource settings is likely to increase, driven in part by the current emphasis on sustainability monitoring and by pressure to collect, process, and present more information for the benefit of the public, funding organisations, and regulatory agencies. This growth could prove quite rapid because many of the mobile tools developed for the health sector provide crossover functionality. These tools include the data gathering systems provided by CommCare (DeRenzi et al. 2011) and the data-based alert functionality developed by RapidSMS (Ngabo et al. 2012).

We seek to evaluate how mobile data tools can support WASH data collection and management. Experience from mobile health initiatives suggests that open standards (Braa et al. 2010) and automated quality control (Birnbaum et al. 2012) are technical features that can promote smooth integration, but we must still identify the full range of steps necessary to ensure mobile data tools are effectively integrated into WASH institutions. Additionally, identifying the technical requirements to support mobile data initiatives, and financing options for these projects, including training of users and provision of long-term technical support, are vital for ensuring long-term success.

Methods

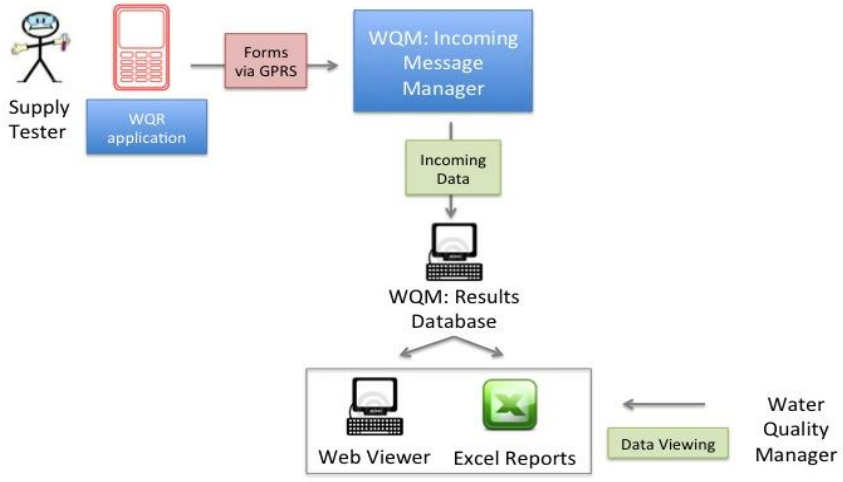
In this study, we piloted a mobile phone based data reporting system in three distinct water sector contexts: with the Thua Thien Hue Water Supply and Construction Company (HueWACO) in Vietnam; with the non-governmental organisation, Teuk Saat 1001, in Cambodia; and, in collaboration with UNICEF, with the Ministry of Health (MISAU), and the

Ministry of Public Works' National Directorate of Water (DNA) in Mozambique. This study was conducted as part of the Aquatest research program, an effort to develop low-cost microbial water quality testing tools and data collection systems. The Aquatest programme was led by the University of Bristol, UK, and funded by the Bill & Melinda Gates Foundation.

Software solutions

In each of the study settings, we supported the configuration and use of the Water Quality Reporter (WQR) mobile phone application. This application operates on Java-enabled feature phones and is associated with a corresponding backend web service, the Water Quality Manager (WQM) (Champanis & Rivett 2012). This system is based on an early version of the CommCare platform, a tool developed and maintained by Dimagi Inc. (Cambridge, MA, USA) that initially targeted data collection by community health workers and was adapted for water quality data reporting by the iCOMMs group at the University of Cape Town in South Africa. The WQR/WQM application was developed and refined with input from early users in South Africa prior to its use in this study. The WQR application presents a simple set of questions via forms to end users, and the WQM provides form-generation services and retrieves and collates data from devices running WQR. Data entered into WQR forms is transmitted to WQM via the mobile data (GPRS) network. If necessary, forms can be saved to the phone until connectivity is available. Question types include freeform text entry, select one or many, and numerical input, among others. WQM is hosted and maintained by the iCOMMS group. Figure 1 illustrates the flow of information within the WQR/WQM system and Figure 2 provides an example of a question on the WQR form. The WQR application and WQM reporting protocols were configured with input from managers and users in each of the three settings. The three institutional partners were selected based on an evaluation of the potential applicability of the WQR/WQM system for each context.

Figure 1: The flow of data through the WQR/WQM



Vietnam

HueWACO is a large semi-autonomous water utility that serves twenty-two urban centers within Hue province in central Vietnam. As part of their quality control program, operators at each of HueWACO's satellite treatment plants collect water samples from the treatment plant and distribution networks and analyse these samples for eight physiochemical parameters. In addition to this on-site testing, operators send weekly water samples to a central laboratory in Hue City where laboratory technicians conduct more complex analyses. In the pre-existing workflow, treatment plant operators compiled water quality data in hand-written logbooks, computed basic summary statistics (averages, minimum and maximum values) and conveyed results to the company's Quality Assurance Manager at the central laboratory via a weekly phone call. Operators also reported inventory information for five water treatment chemicals and figures for daily water production. HueWACO's goal in this project was to evaluate the use of mobile data tools for improving the efficiency of this data reporting process. The Quality Assurance Manager selected sixteen of the twenty-two treatment plants for participation.

Figure 2: An example question asking for pH testing values from the Vietnamese WQR form.

Cambodia

Teuk Saat 1001 is a Cambodian non-profit organisation that partners with local communities to develop and manage rural water treatment and vending kiosks. Under Teuk Saat 1001's model, local operators/entrepreneurs oversee simple purification systems and sell bulk bottled water at an affordable price to community members. The operators carry out regular basic bacteriological water quality tests and compile test results, along with other data on system operations and sales, in logbooks. Staff from the Teuk Saat 1001 central office travel to each rural site approximately once a month to provide technical support visits and collect logbooks. The collation and reporting of the large number of test results is a time-consuming effort and Teuk Saat 1001 managers only receive data approximately once every month. The managers were interested in more rapid access to tests results and sales data and in tools that could improve the efficiency of collating data for donor reporting. They selected ten operators to pilot the mobile phone-based data collection system.

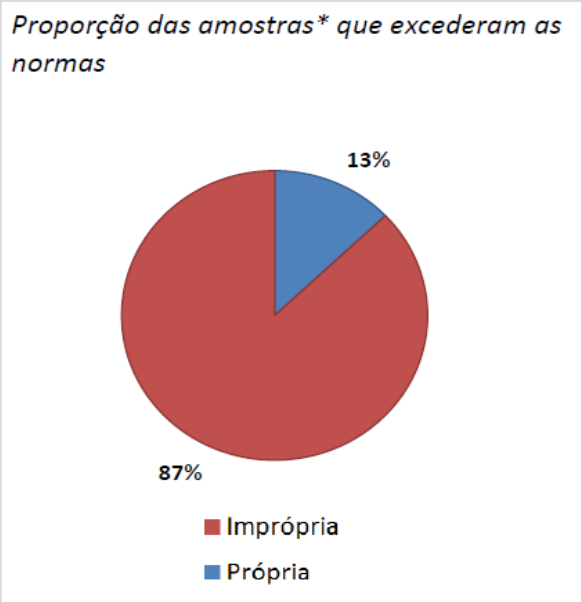
Mozambique

District environmental health technicians in Mozambique play a central role in monitoring rural drinking water supplies; their responsibilities include both water quality testing and source inspections. With the support of UNICEF's One Million Initiative, a large rural WASH

improvement program, environmental health technicians in selected districts were provided with portable water quality testing kits and other resources to support this monitoring activity. Their results are recorded in paper logbooks and records are only maintained in district health offices. In this study, we collaborated with UNICEF and responsible government agencies to incorporate mobile phone based data recording and reporting into water quality monitoring activities in six districts. Data submitted using the mobile phones was sent via email to senior administrators at the district, provincial and national levels.

Implementation

Figure 3: Example graph from the Mozambique water quality report showing the percentage of samples that exceed acceptable limits for microbial water quality.



In order to integrate the WQR/WQM system into existing institutional processes, relevant managers were asked to define their data reporting requirements, including desired form content. Hardware was distributed and forms and reporting features were configured to support stated needs. The questionnaires developed for the mobile interface often made use of the same structure as the paper forms and no new staff members were recruited into reporting roles. Local languages were also used in Vietnam and Mozambique, though this was not possible in Cambodia because the phone application was unable to support the Khmer script. To support the shift to mobile devices, end-users were trained and troubleshooting support was provided. After an initial trial period, modifications and improvements were made to the forms and reporting configuration based on user feedback.

The data collected by WQR was delivered to managers in various ways. The WQM application was designed with very basic reporting functionality because of an initial prioritisation of the design of the data collection aspect of the system. The WQM system can collate and email raw data (in excel or cvs files). In Vietnam, the HueWACO Quality Assurance Manager opted to receive a weekly email with raw information. Her staff were then responsible for combining data received through the WQR/WQM system with other relevant data, for example, test results from the central laboratory, and for compiling reports for regulatory authorities. In Cambodia, Teuk Saat 1001 managers received a similar weekly update with the reported values from their WQR-equipped operators. Managers and field staff in Mozambique requested a more complex reporting format, in

which data summaries could be provided to supervisors at upper administrative levels. Additional efforts were made to develop an Excel macro for generating such reports. The macro was used to compute several broad statistics, render graphs and display a map to illustrate the weekly and monthly test results (Figure 3). Aquaya manually generated several reports of this type using the macro on weekly and monthly schedules, with each being delivered to different sets of relevant stakeholders. For instance, weekly reports from a specific province were distributed to technicians and managers in that region and to UNICEF staff; monthly program-wide reports were be sent to all parties, including national administrators.

Data collection

Interviews and informal conversations were held with managers and end-users from the three organisations during all phases of the deployment of the mobile data tools. These discussions centered on the perceived utility of the system and on strategies for managing and maintaining consistent use of the tools. The reported data itself was regularly reviewed to analyse the operational status of the programs. Stakeholders in the various institutions are not identified by name to protect their privacy. Data submitted to the system was stored in a secure fashion to prevent unauthorised access.

Results and discussion

Impact of introducing mobile data tools

The use of mobile data tools can improve the consistency and efficiency with which decentralised agents report monitoring data. In the case of Mozambique, data collected by district health and water technicians was previously maintained only in paper logbooks at the district level. As a result, provincial and national level officials, and even senior district level officials, had limited access to information on how monitoring programs were being implemented and to results from such monitoring. We have observed similar gaps in availability of water source monitoring data at upper administrative levels in other countries, including Ecuador, Bolivia and Sri Lanka (Rahman & Khush 2012). With the introduction of the mobile phone reporting system in Mozambique, field technicians submitted over 1000 forms using WQR in just over a year and this field data was made available, for the first time, to decision-makers at multiple administrative levels. These results represented a significant improvement in data availability.

The improvements in overall data availability were less significant for HueWACO and Teuk Saat 1001, each of which already had effective systems in place for obtaining data from their satellite water systems. In the case of Vietnam, the central laboratory was already obtaining data from satellite treatment plants through weekly phone calls. HueWACO's demonstrated commitment to data reporting is likely a result of sector regulations; in Vietnam and many other countries, regulations require water service providers such as

HueWACO to demonstrate water quality compliance by providing data summaries to oversight agencies. Where enforcement of such regulatory requirements is strong, there is external pressure for utilities that operate numerous satellite systems to obtain and manage internal data despite the inherent logistical challenges. NGOs such as Teuk Saat 1001 also generally have strict requirements for reporting program outputs to funders.

Nevertheless, even where the mandate or desire to obtain data from field sites is strong, logistical limitations do affect the efficiency of reporting. For example, Teuk Saat 1001 sends staff from their central office to each of their remote sites to collect paper forms. Due to the distances involved and the transportation and human resources required, they are only able to undertake these data collection visits once a month. Using WQR, data was sent as soon as it was obtained, giving managers the ability to monitor numerous rural sites in nearly real-time. In the case of Teuk Saat 1001, managers at the central office indicated that such real-time data availability enabled them to provide immediate support to rural operators if water quality data indicated failures in the treatment systems. There were no specific examples, however, of such real-time support during this project implementation.

Implementation Challenges

Experience from these pilots indicates that mobile data systems can be difficult to implement and maintain by local actors. Common challenges related to network connectivity, phone and application settings and phone management.

Technical Challenges

Across the three project sites, the cellular data network was weak in some locations, even when there was sufficient bandwidth for voice calls. As a result, several attempts were often required before data was successfully submitted. Although network connectivity issues came up across all settings, they were especially prominent in Mozambique, where the connectivity was extremely poor in one of the three program provinces. Although delayed submission did not fundamentally undermine the monitoring programs, this poor network reliability frustrated technicians and reduced their confidence in the system. In cases where connectivity was especially poor, some technicians quickly stopped using their mobile phones to submit data. Data connectivity also delayed the transmission of confirmation messages, which confused users and caused them to send duplicate data.

WQR bundles and sends information entered into a form over the packet data network. This process requires a specific phone settings configuration. In all three pilot sites, the required configuration was sometimes lost, preventing WQR from connecting to the system's servers. We suspect that network configuration was lost when users switched SIM cards, manually changed settings, or exhausted their airtime credit. Users in all settings were approximately equal in their familiarity with using mobile phones, and none were previously familiar with processes for configuring phones for network access. In addition,

they were not sufficiently trained under this project to identify configuration errors. As a result, technical setbacks such as these sometimes kept users from sending data until managers could provide assistance, which could take several weeks.

Management challenges

Our study identified the importance of establishing clear overall management procedures for phone usage. In some pilot sites, managers failed to establish processes for purchasing additional phone credit. Although sending forms costs very little, users frequently ran out of credit, either because they made both personal or professional voice calls or because their credit expired. The inconsistency in submissions that resulted from poor connectivity, changes in phone settings and lack of phone credit is illustrated in Table 1.

Table 1: WQR Submissions by District, Mozambique

District	2011								2012								Total
	may	june	july	aug	sept	oct	nov	dec	jan	feb	mar	april	may	june	july	aug	
Guro						4			2	42	11		1				60
Manica				7		3	24	3	13	14	27	28	30	28			177
Angonia	1	15	9	15						3			32	34	31	31	171
Gorongosa	1	1	4	6	11	28	30	26	36	27	30	32	43	16	30	11	332
Nhamatanda							41	40	60	23	34	30	21		11		260
Tsangano																	0
Total	2	16	13	28	11	35	95	69	111	109	102	90	127	78	72	42	1000

Observations made during field visits also suggested that many of the participants used the WQR phones for personal use. While not necessarily problematic, personal use can lead to damaged or lost phones, changes to the phones' settings, and overuse of the phone memory (which can also affect application functionality). To avoid program disruption due to personal phone use, managers must be prepared to establish clear rules regarding phone usage when implementing mobile data reporting programs.

Implications

The technical and managerial challenges noted above had several consequences: managers were unable to rely completely on WQR for data collection; managers were unable to differentiate between technical failures and true lapses in monitoring; and field staff became frustrated with the system. The ubiquity of these challenges suggests the need for workflows that allow for intermittent failure of the technology. For example, after several months, we established a workflow in Vietnam where the Quality Assurance Manager received a scheduled alert that listed sites that had not yet reported for the week. The manager was then able to respond efficiently by calling the operators at these specific sites to obtain the missing data. Technical solutions such as an automated, regular signal from the phone that indicates whether the application is operational could also help distinguish between technical problems and user performance. In addition, dedicated project managers should be available for intensive troubleshooting during the initial launch period. Finally the cost effectiveness of such intensive program management should also be evaluated.

Long term service provision

Appropriate long terms strategies are also required for managing the software tools themselves. In these pilots, partner organisations were not responsible for form development and system hosting. While consultants can generally be employed to assist with the initial configurations and deployment of a mobile data tool, system hosting is more challenging to manage. Java and Android questionnaire applications can be deployed using at least two options: 1) a local institution can obtain the software source code and fully host and manage the application; or 2) an external actor can provide the application as a service and manage both hosting and maintenance. As an example of this second option, the CommCare application, from which the WQR/WQM system was originally derived, is now available as a service: users can create accounts, build forms, deploy the software and manage incoming data through a web interface. Dimagi Inc. hosts the data and maintains the required servers. They also offer different service levels, with basic deployments supported for free and fees applied for larger scale programs. We have observed that government agencies in developing countries generally have limited capacity to host and maintain these types of applications. They also appear to be institutionally unprepared to utilise the 'Software as a Service' model.

The costs of implementing and maintaining mobile data solutions are not insignificant. In this study we purchased a dedicated phone for each participating user, with phone prices ranging from USD 70 - 120 per phone. We avoided the use of personal phones due to the technical challenges of installing the WQR software and configuring network settings on a variety of phone makes and models. Due to the nature of the WQM interface, a software development expert was required to create the institution specific phone-based data entry forms for this study. However, similar questionnaire applications such as CommCare, now

provide user-friendly form building interfaces that can be navigated by non-technical users. In this study we allocated significant time to assessing institutional information reporting needs and to translating those needs into the phone-based forms. Similar external assistance will likely be required for many institutions.

We do not have sufficient data to directly compare the costs of using the mobile data system with costs of traditional reporting mechanisms. We suspect that the primary expense of HueWaco and Teuk Saat 1001's previous data collection system was the time spent manually entering data. For both HueWACO and Teuk Saat 1001, the direct costs of transmitting data were negligible: in HueWACO, this was done by voice calls, and Teuk Saat 1001 staff collected logbooks during scheduled site visits that included other activities. In the case of Mozambique, data was not previously reported upwards from district health offices nor was it digitised or analysed. In summary, the benefits of improved data flow and data availability with respect to WASH service provision have to be evaluated and quantified to determine the cost-effectiveness of mobile data reporting.

Benefits of Improved Information Flow and maximising the value of mobile data collection

Evidence from the three pilot sites indicates that mobile data reporting tools can add value to WASH monitoring programs. Where data reporting from remote sites was previously limited, the use of a mobile data tool allowed information to be digitised and made available at multiple administrative levels. In at least one instance in Mozambique, a senior official responded to a report generated through this study by sending a notice to a district health office directing them to respond to high levels of contamination. Although the "real time", nature of mobile data reporting is not critical for many monitoring activities, a simple tool that limits the steps in the reporting chain generally promotes better availability of data.

Improving information flow not only improves data availability but also draws attention to the status of monitoring programs themselves and to staff performance. Feedback from UNICEF suggests that the WQR/WQM system contributed to the momentum for the water quality surveillance program as a whole: data reporting requirements motivated technicians to maintain targeted testing levels and prompted senior managers to remain engaged in and aware of activity on the ground. Across the WASH sector, there is a recognition that consistent monitoring, especially of remote point water sources, is challenging and often overlooked (Steynberg 2002, Lloyd & Helmer 1991). Greater awareness regarding the actual status of current monitoring programs will emphasise the importance of this issue among decision makers.

Mobile data tools will likely be most valuable to both field staff and managers if they address a range of data collection activities. For example, public health technicians

responsible for water source monitoring commonly have multiple responsibilities, such as disease surveillance, restaurant health inspections, and vaccine campaigns. We also found that institutions (and management tiers within each institution) have different requirements for utilising data generated by monitoring programs, suggesting that technical solutions should be designed to accommodate these varying needs. In particular, the institutions involved in this study expressed interest in obtaining both raw data for direct analysis and data summaries that included visual data representations for more senior administrators. Finally, in the health sector, mobile data systems are often designed to both collect data and provide community health workers with decision support and reminders (Mahmud et. al., 2010). This two-way information exchange has been well received in the health sector and this principle should be evaluated for mobile data initiatives in the water sector.

A tool is only as strong as the monitoring program it supports

This experience of integrating a mobile data tool into existing monitoring programs has drawn our attention to the monitoring programs themselves. The uptake and impact of these novel ICT applications may largely depend on the strength of the monitoring programs that they support. For example, a mobile data tool cannot, in and of itself, make a field agent prioritise water sector data collection; it cannot address the issue of staff turnover; and it cannot increase the resources available for monitoring. However, the use of mobile data tools can draw attention to the needs of well-functioning monitoring programs by making information more readily available and by emphasising information gaps. The process of configuring a mobile data tool can also drive self-reflection and prompt institutions to reevaluate what data to collect and how to optimise the use of data.

Acknowledgements

This study was conducted under the Aquatest research program, an effort to develop low-cost microbial water quality diagnostics and data collection systems that was led by the University of Bristol, UK, and funded by the Bill & Melinda Gates Foundation. We thank our colleagues at HueWACO, Teuk Saat 1001, UNICEF Mozambique, and the Ministries of Health and Public Works, Mozambique for their willingness to collaborate on this project.

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