Monitoring drinking water quality in South Africa: Designing information systems for local needs

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Abstract

In South Africa, the management and monitoring of drinking water quality is governed by policies and regulations based on international standards. Water Service Authorities, which are either municipalities or district municipalities, are required to submit information regarding water quality and the management thereof regularly to the national Blue Drop System (BDS). Since 2009, a trend has emerged in which urban municipalities have been shown to consistently improve their water quality management whilst some of the rural and under-resourced municipalities are falling behind. A major concern has been that rural municipalities are failing to report the required information and are not complying with some of the regulator's requirements that speak to the overall management of water quality monitoring rather than the actual water quality itself. This paper reflects on a case study undertaken in four rural municipalities in South Africa where a cellphone-based information system was implemented to collect information relevant to the municipality. The study was conducted by the Information for Community Oriented Municipal Services (iCOMMS) research team based at the Department of Civil Engineering at the University of Cape Town. The hypothesis for the research was that improved information flow within rural municipalities – from water supplies in outlying areas to the municipal government office – can improve the efficiency of existing monitoring, if the design, development and implementation of such a system are based on collecting appropriate and locally relevant information. Water service authorities at the four field sites managed the process of monitoring in very different ways due to limited resources as well as structural challenges within each government department. The variety of stakeholders involved in water quality monitoring programmes, and the alternative methods and processes used, challenges the current understanding of information system design as well as the notion of developing a single national information system. The decentralisation of national water quality monitoring to municipal level was assessed in this research, which concluded that the BDS was of limited usefulness to water quality monitoring in the rural municipalities partaking in this research.

Keywords: water quality monitoring, information management, Blue Drop System, decentralisation, rural municipalities

INTRODUCTION

Between 1994 and 2012 over 21 million people in South Africa were given access to an improved water source (DWA, 2012), and in 2008 the initiative of Blue Drop Certification tackled the challenge of decentralising the monitoring of water sources (DWA, 2009). The national Government has implemented regulations and policies to deliver safe water to all, but some local municipalities have not necessarily caught up with the national guidelines. This is particularly true for rural communities and municipality structures where water supply is only partially reticulated and treated, and a majority of the population still rely on individual boreholes. The low compliance rate is generally explained using reasons such as under-resourcing, skill shortages, lack of understanding of required standards, lack of intervention to address problem areas, inadequate management, and limitations on finances, assets and fiscal accountability (DWA, 2012).

It is widely accepted that rural areas in South Africa are more difficult to manage and monitor due to the limitations highlighted above, as well as the geographical layout of a dispersed population and the historical set-up. Muller (2007), Atkinson (2009), and Metha (2004) noted that this may be exaggerated by management practices of controlling limited resources, rather than managing policy implementation. Rural authorities are also not always responsive to legislation and regulatory requirements and consequently water quality monitoring of outlying supplies might only be conducted on an ad-hoc basis (DWA, 2012). Such ad-hoc information has very limited impact on the identification and prevention of microbiological contamination or on the overall management of water supplies.

This paper presents findings of a study that investigated the use of a cellphone-based information system which was implemented in 4 rural municipalities in South Africa. The study formed part of the Aquatest project, an international research programme, which was established to develop a low-cost water test for the developing world. It was initiated in 2006 under the European Union Sixth Framework Programme. In 2007 the project secured funding from the Gates Foundation for the period from 2008 to 2012. The project consortium included universities in the UK and US, two US-based non-profit organisations, and the iCOMMS team at the University of Cape Town (University of Bristol, 2012).

During the course of the research it was observed that the apparent inability of rural municipalities to respond to regulations might be closely linked to the structures for decentralising water quality monitoring to local municipalities. The national monitoring systems that have been put in place in

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order to maintain an overview – such as the Blue Drop System (BDS) – may in their reporting requirements disadvantage under-resourced municipalities.

As described by Brett (2009), decentralisation of a national function can either be merely bureaucratic or can be part of a process of ceding power to a community. Depending on which of the two forms is the basis for the decentralisation, the national monitoring of the decentralised function will vary.

It is argued here that the current information systems implemented to monitor drinking water quality compliance nationally are designed for the economically affluent municipalities who have the ability and means to implement policy and best practices. Small and under-resourced municipalities, on the other hand, could be negatively impacted by these systems to the extent that water quality monitoring has turned into a bureaucratic function that has limited impact on decision-making at local level.

RESEARCH METHOD

National Government has highlighted the shortcomings of rural municipalities in providing accurate and up-to-date information on all water sources in the BDS (DWA, 2009). Using this statement of Government, the study investigated if one of the reasons for failing to supply information lie with the usefulness of the information to local decision-making.

In order to establish this, an information system was designed which provided rural Water Service Authorities (WSAs) with regular and accurate information on the drinking water quality in the communities they served. The hypothesis was that such information would improve existing monitoring programmes and support local decision makers in managing policy implementation as well as controlling limited resources. The basic premise was that a key reason for municipalities not providing information to national Government was due to the low priority that national information collection has in rural municipalities.

The research was structured around a case study of 4 field sites in rural South Africa. The scope of each case was a single WSA, which was responsible for multiple communities in outlying areas and with a dispersed population.

The researchers had observed during the first site visits to the rural WSAs that there was little commonality in monitoring programmes between the different WSAs. Thus, one requirement for the system design was that it had to cater for local data and information needs.

The measures for improvement of monitoring were:

- An increase in reporting of the water quality standards in rural areas with borehole water supply
- An increase of awareness at managerial level of the status of rural water supply
- An increase of awareness at borehole operator level of the requirements of management and the need for data collection for national monitoring purposes
- An increase of awareness regarding problems and issues at the water supply site
- An experience of accountability and transparency of the authorities responsible for water quality monitoring
- An experience of usefulness of the information for decision making

The following generic procedures were followed to develop the system as well as monitor the changes at each of the four WSAs:

1. Documentation of existing monitoring programmes
2. Identification of relevant actors within the monitoring and water quality management structures
3. Analysis of the information needs as identified by local managers, borehole operators and other stakeholders
4. Analysis of the differences between local monitoring practices and national guidelines
5. Re-framing of the findings of the analysis into an information system design that responded to the identified needs
6. Development of a first software application, implementation of the application and observation of the use of the system for a defined period
7. Analysis of the appropriateness of the design and functionality of the system through interviews with all users and stakeholders
8. Response to findings by refining the design of the system, implementation of the revised application and subsequent observation of the system application for another period of time
9. Assessment of the improvement of the measures above through another set of interviews with managers and borehole operators as well as analysis of the data flow between the various stakeholders by analysing the information available on the database

Important to note is that the research design was kept flexible in order to respond to the varying local needs at each site. Whilst the procedures outlined above were adhered to broadly, the number of interviews or the number of stakeholders interviewed varied slightly between sites. The frequency of reporting of water quality parameters was decided together with the municipalities, based on local needs.

As outlined in Steps 6, 7, and 8 above, the design, development and implementation of the information system was undertaken as participatory action research (Avison et al., 1999), where a functional prototype of the software was developed, used and evaluated in an iterative and incremental process.

The information system was designed using cellphones as the tool for data collection, information transfer and analysis. The cellphone applications were labelled: the Water Quality Reporter (WQR) and the Water Quality Manager (WQM).

THE WQR AND WQM SYSTEM

The WQR cellphone application was installed on the phone of the water supply caretaker, who was usually a borehole operator. The water supply caretaker was guided through a number of questions regarding the water quality of the water supply and was asked to select a response.

The questions for the operators varied between the WSAs and were decided on in collaboration with the managers and borehole operators. Aspects such as questions relating to water safety plans or best practices were included and comment boxes allowed operators to provide additional information relating to the physical elements of water quality monitoring, such as pH, turbidity and electrical conductivity.

Once the water supply caretaker had collected the data, a completed form was sent via GPRS to a central server. Once the form was received at the server, a 'message manager' verified the data and checked its integrity before storing it in the database.

A notification and feedback subsystem was configured to send various messages when the sample data were received

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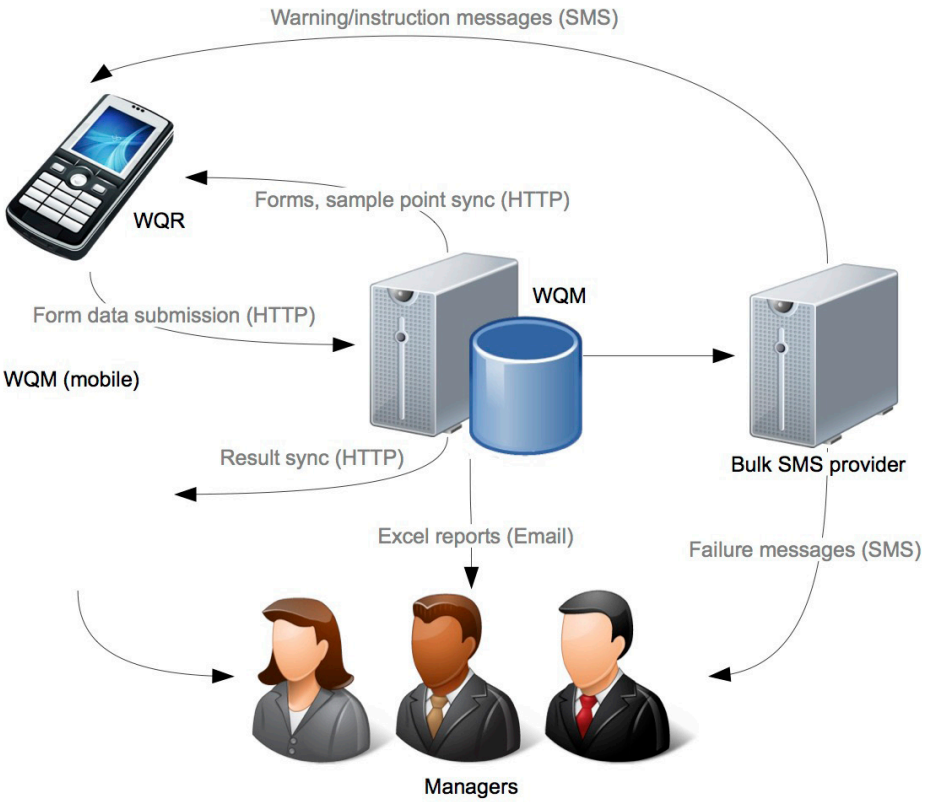

Figure 1
Overview of the WQR and WQM system

centrally. The borehole operator sending the data received either a message confirming that the data had successfully been received or a message requesting re-capturing if a value was above a limit or appeared erroneous. The manager with the overall responsibility for water quality monitoring also received a message, in case a result was outside the acceptable parameters.

After the first phase of implementation it was realised that most of the managers required a mobile application that allowed them to check the status of their various sites whilst being outside the office. Thus, the four managers of the municipal field sites were provided with Android phones that had the WQM application loaded. This application allowed each manager to review water quality testing across all relevant water sources in real-time.

The system also provided spreadsheets for reporting that could be downloaded via an Internet application. Users were able to decide on the relevant data points and could download reports for a chosen time period for each site.

Below is an overview of the functionality of the system (Champanis and Rivett, 2012):

A detailed description of the technical specifications and the system design can be found in Champanis and Rivett (2012).

OBSERVATIONS AND DISCUSSION

The observation that different government departments manage water quality in each of the rural municipalities indicates that an understanding of the decentralisation of water quality management is vital if a national monitoring system is to be successfully implemented.

The discipline of e-government and e-governance offers some findings with regards to the implementation of national government systems: Heeks and Bailur's (2007) study of the e-government literature reveals an academic discourse of overwhelming optimism about the potential of e-government for development. Yet, in over a decade of e-government research, most government information systems projects in the developing world have ended in either partial or total failure (Moodley, 2005; Heeks, 2003). Systems failure is ascribed to enforcing unwanted or contentious change in organisational processes, or because the technology requirements, such as hardware and connectivity, did not exist or were not maintainable due to limited human, technical and financial resources. In general, the literature on information systems failure suggests that failure occurs because some aspect of the system context – social, technical or political – is inadequately understood, ignored or underestimated (Dada, 2006; Pardo, 2002; Maumbe, 2008)

Based on the literature review, the researchers identified that e-government literature does not discuss the contentious nature of government information system successes. For example, is a project successful if it helps government to carry out a function more effectively, but results in job losses or redundancy in specific social groups? This question is not to underestimate the value of efficient and effective technical systems. For example, most people would agree that a system that improves the delivery of basic services, or helps citizens hold public bodies to account, supports development and is broadly desirable. However, if the information system results in already constrained resources being used to collect information that is only relevant for bureaucratic and reporting purposes, the effectiveness and desirability of a government system could be questioned.

Information systems can be experienced as an appropriate tool to support decentralisation of core government functions since the design and structure of information systems is

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hierarchical in nature, which is often experienced as a mirror to the monitoring of a decentralised national function. By collecting appropriate information at local level, national government is able to 'track progress'. The experience of the information system in this context is that, due to the system, information is collected that allows the citizen to hold politicians, municipal officers and other public organisation accountable. However, if the system design fails to address the notion of devolving responsibility as part of the decentralisation, it could be argued that the system might be doomed to fail.

According to Brett (2009) there are three justifications for decentralisation:

- It should improve democratic accountability by allowing the local community to exercise closer control over local politicians.
- It should improve management of local services by making local officials directly accountable to local politicians and society at large.
- It should help overcome possible ethnic or sectarian divisions by allowing minority communities to control political decisions.

Brett (2009) makes the argument that, whilst certain aspects of central government have to be delegated to local bureaucratic structures, a devolution also means that there is an obligation to cede control to a local municipality that may have differing political structures, different resources or management structures.

In the context of water provision in South Africa, the Constitution, in Schedule 4B (Republic of South Africa, 2004) makes clear that the function of providing safe water rests with both national and provincial government. The decentralisation to local level is facilitated based on the notions that Brett (2009) has highlighted above. By allowing municipalities to design their own water quality management structures, it can be expected that municipalities would respond more appropriately to the local needs, that resources would be allocated appropriately and that functions between various stakeholders and participants (e.g. engineers and environmental health officers) would be allocated to respond to the local needs appropriately. Thus control would be ceded to local municipalities and it can be expected that other variables such as resources available to local authorities, the political autonomy and the local democratic process would be taken care off by the people who know their environment best.

However, the challenge of the ceding of control becomes apparent, when the national government expects to maintain a level of control by monitoring the municipality from a distance through a centralised information system. The BDS was designed as a generic monitoring programme, based on the outline of best practices at national level (SABS, 2006). This research confirmed that the water quality monitoring programmes employed in each of the municipalities varied greatly. None of the four municipalities monitored water quality using similar structures, or a generic programme. For example, in one of the study sites the manager visited each supply site once a month for compliance monitoring, whilst in another site environmental health officers were tasked with compliance monitoring. Since there were very few environmental health officers, compliance monitoring was often only performed annually. Borehole operators performed weekly operational monitoring tests (e.g. measurement of pH, turbidity, and electrical conductivity) at some sites, yet these tests were not performed at all at other municipalities. Formal workflows only existed in one of the municipalities. In three of the four municipalities, the person managing the borehole operators and managing the water supplies was also directly involved in the water quality compliance monitoring. The managers of water supplies were employed through the Department of Health, the Department of Social Works, the municipality, or the district, in the different cases. There was no consistency in the requirements of the management function – water quality monitoring was a minor part of the work load in some instances due to other job requirements. For the design of an information system that would be applicable nationwide, the functionality and the information collection would be based on assuming a certain set of common denominators. For water quality monitoring, these denominators exist in the urban environments where departments are tasked with the various functions. In rural communities, one person often fulfils multiple functions due to limited resources, but also because it is often sufficient to have one person doing multiple tasks.

In order to confirm the researchers' assumption that the failure of municipalities to provide water quality information lies with the design of the national monitoring system, the design of the WQR and the WQM was focused on the local information requirements. Based on the local context, all municipalities documented the existing workflow and communication requirements between managers and local borehole operators. The system was then designed using the agreed information requirements, some of which included national monitoring requirements.

All managers reported an increase in regular communication and an increase in awareness of the status quo of water quality at the various field sites. Since only one of the field sites had a monitoring procedure in place, the reporting of water monitoring information increased in all of the WSAs. The WQM as well as the WQR were experienced as easy-to-use, due to replicating already existing workflows. Three of the municipalities improved their workflow by amending data requirements after the first revision of the software. Managers also reported that the amount of travel to remote sites was reduced due to being able to assess sites from the office. Managers felt that their confidence in water quality had increased and the system was experienced as providing relevant information for decision-making. All managers felt that they had a better understanding of the movements of the borehole operators and their needs. In some of the sites, the system became an HR management tool and one manager commented that the tool had increased his workload due to him being more aware of the challenges in one of the outlying villages.

One of the issues highlighted by Brett (2009) is the notion of 'democratic accountability'. The tension here lies in thinking of accountability in terms of improved management and bureaucratic efficiency and accountability in terms of improving the accountability of government service providers to the public. Much investment is spent towards addressing the aspects of improved management and bureaucratic efficiency as a measure of improved accountability. This can often be achieved by designing systems which allow tracking of progress or communication of the latest statistics. For example, the Blue Drop System communicates to the public the status of water quality in each municipality of South Africa; however, it does not communicate who is responsible and who the various government structures at local level are that should be held accountable.

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The study of the WQR and WQM implementation pointed towards a need to improve the second aspect of accountability regarding government providing services to the public. The ability to keep local records and download reports was experienced as increasing transparency as well as accountability – which was confirmed by both managers and borehole operators. One of the borehole operators had used the WQR application to show community members how water quality information was communicated to the municipality and expressed that this resulted in the community feeling more closely linked to the government authorities. Managers felt that national government should include the information collected at local level into the national system in order to understand the information needs at rural level.

CONCLUSION

This paper reflected on the experience gained by implementing a cellphone tool in rural municipalities, which vary greatly in their management of water quality. By observing how the tool affected the decentralisation of water quality monitoring within each municipality, conclusions regarding the challenge of developing information systems for a decentralised function can be drawn.

Information systems are inherently hierarchical and usually a 'one-size-fits-all' rule is applied when designing such systems. As indicated in the literature review, the number of failed information system projects in the government sector speaks to a need to re-look at how such systems are designed.

Rural municipalities face different challenges to urban environments. However, the systems implemented at national level to monitor municipalities from a distance do not necessarily differentiate between an urban and rural context. As a consequence, rural municipalities often fail to provide information or the information provided is limited since the management of water quality differs substantially between urban and rural environments. The rural WSAs under-perform even if the water quality itself is of an appropriate standard. If a national information system can be designed in an inclusive manner, where the information relevant to local WSAs serves as a monitoring indicator to national level, it is reasonable to expect an increase in the information and the quality of the information.

This study set out to understand if the failure of rural municipalities to provide information is based on the experience that such information has no relevance to local decision making. It is argued here that water quality monitoring could be improved by designing systems that respond directly to local needs. The findings showed that monitoring did indeed improve when using the measures indicated in the research methodology section. Reporting of water quality standards increased in all four municipalities, and managers and borehole operators reported an increase of awareness and appreciation for the need to collect information for monitoring purposes. Problems faced at water supply sites were identified sooner and the experience of accountability increased, not only for the government employees but also for the communities involved. The information collected was experienced as useful for decision-making and resulted in an overall increase in communication between the various stakeholders.

The WQR and WQM application has shown the importance of designing a system that responds to local needs, leading to positive feedback from operators and managers expressing that the information and data received supported their job functions.

If accountability is remotely managed, systems have to be introduced that allow each stakeholder to receive relevant information. If the decentralisation of water quality monitoring is indeed intended to be more than a bureaucratic structure, the systems designed to monitor and evaluate the success of water quality monitoring programmes need to respond to the decentralised information needs.

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