Is silence golden? Of mobiles, monitoring, and rural water supplies

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Reliable and cost-effective monitoring of rural water supply infrastructure has long been hampered by the geographical curse of dispersed and low-income populations, and weak institutional performance. Recent advances in monitoring technology combined with mobile network expansion into rural areas has created an opportunity to bypass these seemingly intractable challenges. Mobile-enhanced technologies have the potential to produce data that is orders of magnitude richer, faster, and cheaper than that provided by traditional monitoring methods, which require costly field visits. However, more data does not equate to better data; information generated by crowd-sourced and automated systems each has its respective limitations. We propose a framework for analysing monitoring and surveillance systems, which can help assess the strengths and weaknesses of different emerging approaches. We suggest that these advancements present an opportunity to fundamentally change the way we consider and conduct rural water supply monitoring.

Keywords: development, sustainability, accountability, water, mobile

If you can't measure it, you can't manage it. So true, yet so elusive in so many sectors, perhaps none more so than for rural water supply where investments have long eluded objective outcome metrics. Four out of five of those who still lack improved water supplies are rural dwellers in the developing world (JMP, 2012), leading to well-documented health and welfare impacts on rural populations. With the chances of objectively monitoring outcomes of rural water investments over time close to zero, ensuring that the scarce resources available for rural water are used cost-effectively to achieve sustainable impacts remains a challenge, especially when the sector must compete with other development priorities, such as health or education.

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Advances in monitoring rural water supplies take advantage of mobile network expansion

Recent advances in monitoring rural water supplies, which take advantage of mobile network expansion, create an opportunity to bypass the institutional challenges posed by the highly dispersed nature of rural water infrastructure. Emerging evidence indicates that these advances provide a more encouraging basis for the evaluation of the performance and delivery of rural water services than the costly and infrequent field visits required by traditional monitoring methods. We propose a framework for analysing monitoring and surveillance systems, and how this can be applied in a rural water supply context. While the availability of cheaper, faster, and more reliable monitoring data afforded by new technologies is only one of many elements required to achieve sustainable water services, understanding the respective strengths and weaknesses of the novel approaches currently being developed is essential if they are to deliver the transformative benefits that they offer.

Monitoring benefits from the digital dividend

The mobile phone network is essentially information-transfer infrastructure, whether voice, SMS, or data services. Rapid growth in mobile network coverage and cheaper communications technologies have led to an upsurge in monitoring innovations in energy, finance, biodiversity, agriculture, and water. The digital dividend is generating multiple and unanticipated benefits; low-income groups are able to participate owing to increasingly low entry barriers, with the low cost of basic mobile handsets and growing network coverage. This is not just an urban story as mobile operators are now focusing more attention on the untapped market in rural areas. Villages that lack certain basic infrastructure elements, such as electricity or sanitation, now have GSM (Global System for Mobile Communications) coverage, providing the rural population with new opportunities for communication and commerce. With mobile network coverage expected to reach 90 per cent of Africa by 2014 if current growth rates continue (World Bank, 2010), the rural water sector is embracing opportunities to overcome its geographic disadvantage of remote, small, and dispersed settlement patterns. This coverage now reaches into areas currently reliant on handpumps for their water supply, the same areas currently struggling to maintain those handpumps on a sustainable basis. As well as the existing benefits mobile coverage brings to these areas, it also has the potential to be the means by which the 'objective, reliable and detailed information about water access', called for by Jimenéz and Pérez-Fouget (2010), can be transmitted and distributed.

Villages that lack certain basic infrastructure elements, such as electricity or sanitation, now have GSM coverage

Many innovative approaches use the mobile network architecture for enhanced monitoring and evaluation (M&E) often using GIS

Monitoring systems using mobile handsets are now a real option for rural water services

data, which allows information to be presented in an intuitive, spatial, and user-friendly manner. With mobile phone penetration reaching around one in two adults in rural Africa (Hope et al., 2012a), monitoring systems using mobile handsets are now a real option for rural water services. There are numerous examples of this in both urban and rural contexts, including Manobi's mWater in West Africa, the H2.0 initiative in Zanzibar, NextDrop in India, m-Maji in Kenya, Daraja's Maji Matone in Tanzania, Mobile4Water in Uganda, and Water SMS in Indonesia – to name but a few. While a detailed examination of these programmes is beyond the scope of this paper, and can be found elsewhere (e.g. Hutchings et al., 2012), it is helpful to note how these monitoring approaches differ in design and purpose. Some rely on end-users to collect and transmit water service information, while others are dependent on the service providers themselves. In crowd-sourced systems (e.g. Maji Matone, Mobile4Water) end-users act as monitoring agents to alert authorities or service providers to acute operational problems. Others instead rely on field staff, delegated operators or vendors to collect and transmit the data (e.g. NextDrop, m-Maji, Manobi). These variations are borne out of the different objectives that have inspired the development of the systems. In the Tanzanian cases of Daraja and H2.0, fault reporting is intended to spur prompt corrective action from the local authorities by disseminating the information widely, including through the media. The operators who subscribe to Manobi's service in West Africa seemingly submit information for national reporting and regulatory purposes. Meanwhile, the information submitted to the m-Maji and NextDrop databases is intended to aid customers in their purchasing and water use decisions.

Where users have access to mobile monitoring and have the right incentives to engage, crowd-sourcing is a credible and new way to shift from external and expensive snapshot monitoring to one of low-cost continuous monitoring. Notwithstanding the nascent nature of the above-mentioned systems, some common challenges have begun to surface. Some systems opting for this approach have found it difficult to mobilize end-users to report problems to local authorities. Socio-demographic barriers, such as literacy and familiarity with SMS, as well as entrenched political interests, have been identified. Low levels of participation may also be quite a rational response to the perceived likelihood of any corrective action being taken by a service provider or local authority. Where crowd-sourcing approaches prove unreliable, mobile technologies which automate data flows may provide an alternative to monitor cheaply, objectively, and universally. Understanding the risks and limitations of monitoring methods for rural water supply is essential to make appropriate policy and investment choices.

Where crowd-sourcing approaches prove unreliable, mobile technologies may provide an alternative

Risks and limitations of monitoring methods

One of the risks that comes with the power of information technology to generate unprecedented volumes of data is for the user to be able to understand how compelling outputs are related to the quality and selective choice of the primary data. While high-quality analysis and presentation of data is invaluable, it can only be genuinely helpful if we understand what the underlying data represent and their limitations. The quality of the raw source data must be considered, in terms of both accuracy and timeliness. Data that is out of date may be of little use, no matter how accurate it *was*. As important as the analysis of what it *is* telling us is the analysis of what it *is not* telling us, and what we should or should not infer from that.

The quality of the raw source data must be considered, in terms of both accuracy and timeliness

Figure 1 shows a structured way of looking at any form of monitoring where the primary aim is to know if a system is working or not.

The vertical axis has system performance split into binary states of 'good' and 'bad' and the horizontal axis has, at its extremes, continuous monitoring and a complete lack of monitoring. The middle state of 'Intermittent' can apply to either a system that has a strict and known regime of monitoring, e.g. checks every six month, or a system that is subject to *potentially* continuous monitoring but is known to be unreliable or inaccurate. Traditional systems of monitoring rural water projects using shoe leather and diesel will be towards the right of this figure, at best intermittent and in many cases non-existent as the location of pumps, wells, and tanks are forgotten or the costs of reaching them become impractical.

The dog that doesn't bark

An effective monitoring system would be alert to all credible problems and notify maintenance responses in a timely and consistent manner.

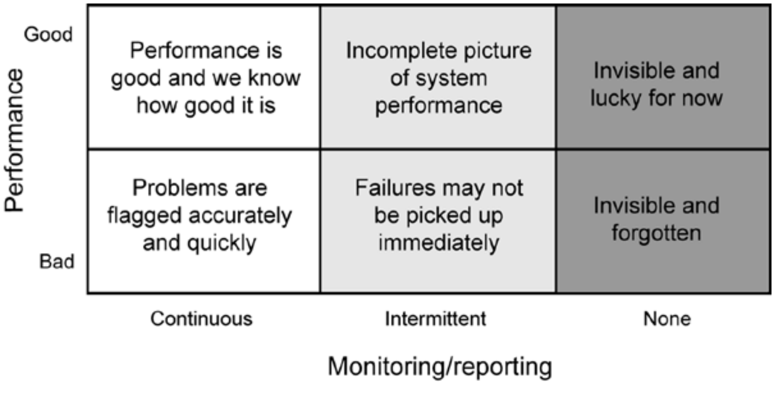

Figure 1 System performance and monitoring/reporting

In the same way we might assume that our guard dog is alert, but cannot be sure that he is in fact asleep, we may have intermittent or unreliable fault monitoring, so we cannot be sure of a system's status. As stated earlier, crowd-sourcing techniques assume that people have the right incentives to call in faults when performance drops below a certain level. Where incentives, behaviour, and responses to alerts are aligned, this approach is likely to be cost-effective. For rural handpumps, which are used by different people in different ways at different times, and where those responsible for maintenance may have a chequered history of accountability, it is unclear whether simply 'empowering' people to report failures will deliver the reliable and timely information needed to support governments' efforts to deliver universal and continuous supplies of safe water to their citizens. In describing the various challenges of maintaining water systems in rural Malawi, Kleemeier (2000) notes that users undermine a system's performance by failing to report faults, even when a credible reporting mechanism is in place, and that such inaction can be as damaging as wilful vandalism.

It is unclear whether simply 'empowering' people to report failures will deliver the reliable and timely information needed

As the Maji Matone project in Tanzania reported in 2012 on a trial of 'crowd-sourcing' handpump failures, systems relying on user feedback are not purely technical, and reside within existing social and political structures. Strengthening 'agency' without understanding existing 'structures' addresses only part of the inevitable and uneven interplay between social practices and processes. Where crowd-sourcing may either challenge or inadequately address existing and established social norms and power relations, a system that is well-designed technically may still under-perform. Daraja discusses these challenges in its admirably self-reflexive blog (Daraja, 2012). In these cases we know that there is the *potential* for the system to be monitored, but we do not know if it is actually being monitored, and therefore the assumption that 'no news is good news' is a dangerous one. As such, crowd-sourcing methods can only be viewed as intermittent reporting mechanisms that report failures only.

Also, when users are responsible for reporting faults careful consideration should be made of which sub-groups of users may or may not be reporting. The communities least likely to be able to maintain their water systems without outside support in the first place may well be the least likely to effectively use a new type of reporting system. As a result even as average metrics for performance and fault reporting may increase, the most vulnerable communities who are most in need of outside assistance may remain the least well served.

Communities least able to maintain their water systems may also be the least likely to use a new reporting system

A slightly different situation arises where the official definition of whether a system is functioning well does not coincide with the users' implicit definition, or there is a range of performance which is below the standard it should be but not low enough to warrant users to complain about it. In the case of a truck fleet with 'How is my driving? Call this number' signs on the back of their vehicles, the managers of this fleet probably only get called when one of their drivers has made a display of spectacularly inconsiderate driving, way over the line between good and bad. A slow deterioration of water pressure in a piped system to a state where it works, but works only badly may not induce any complaint from the users. While it can be argued that it is the users who should be the ultimate arbiters of whether a system is functioning well, the health and economic impacts of low, but 'acceptable' water quality and quantity may be significant. From an economic point of view there may be a societal cost being incurred from this deteriorating performance even if the water users are acting rationally from a personal point of view by not flagging a fault.

Automated monitoring systems may overcome some of the shortcomings inherent in crowd-sourced approaches

Automated monitoring systems may theoretically overcome some of the shortcomings inherent in crowd-sourced approaches but also have limitations. They can simply break: for example communication is lost or a sensor becomes fixed in a certain state, and this may not be apparent from the data being received. They also rely on certain features being set at the design stage and thus rely on the expertise of the designers and the effectiveness of the design process in taking into account potential operational and failure state. A failure may be defined at the design stage as, for example, a certain water pressure at which the system raises an alarm and maintenance or corrective action is undertaken. However, users may face problems before this point is reached, but those managing the system do not realize this, and so from the point of view of the users, the system is failing and nothing is being done about it. In this situation the likelihood of damage to the system by ad hoc repairs, get-arounds, or straight vandalism is increased and thus the system can enter a downward spiral of performance and trust between the service provider and customers (Rouse, 2007).

Inferences about the system's functionality can be made if the data generated is combined with historical system statistics

Waterpoint mapping techniques and more advanced systems, such as Akvo FLOW (Field Level Operations Watch) originally developed by Water For People, have a different limitation, which does have the advantage of being known and explicit. While they provide a significant amount of information, this is just for one snapshot in time. As time moves on from the snapshot the likelihood of the data remaining valid diminishes. Inferences about the system's functionality can be made if the data generated is combined with historical system statistics. These inferences may be quite accurate and may provide a very good *average* picture of a system with many similar elements, for example a large network of handpumps. However, there will be little confidence in predicting the status of an individual element, i.e. an individual pump. Indeed, FLOW does not claim to be an incident reporting system (Cohen, 2012), so the danger here can be one of misunderstanding a system's purpose rather than an inherent flaw in the system itself. While these are invaluable tools for conducting baseline and periodic assessments of rural water infrastructure, to view them as an effective monitoring tool for the surveillance of individual systems is problematic, unless frequent and reliable updates can be guaranteed.

Measuring performance rather than flagging failure

For systems where there are simple binary conditions of working or not working, and where we are confident that our monitoring system will flag a failure, either automatically or through user feedback, active monitoring while the system is working well may not be necessary. If no fault is flagged, the system must be working. Crowd-sourcing solutions generally make this assumption either implicitly or explicitly, and this assumption may well be correct, although it may not be, as discussed previously. While this may be good for reporting and responding to system failures, it does not provide incentives to provide performance that is anything more than merely acceptable. Even when a system is functioning well, there will often be a range of performance within the definition of acceptable in which it may be operating. There may be a minimum level at which a certain characteristic becomes unacceptable and deemed to be in a failure state, but the users will benefit if these characteristics rise above those minimum thresholds. Likewise, two similar handpumps may both be producing sufficient water for user needs, but the level of effort required to abstract that water may be very different, depending on the condition of the pump components. If system performance can be comprehensively measured then this permits a broader array of monitored standards that can guide clearer incentives in service level contracts. In the absence of incentives aligning with measurable and enforceable maintenance service levels, some handpump users may reap the benefits of the more diligent mechanic or better quality components, though if performance differences are not acknowledged there is a real risk that service levels will vary as classic 'principal–agent' problems emerge (Hope et al., 2012b).

Even when a system is functioning well, there will often be a range of performance within the definition of acceptable

Measuring certain performance characteristics, preferably continuously, also opens up the possibility of predictive maintenance. If performance characteristics are understood, or historical data is analysed and statistical models are made, it is often possible to predict a system failure. For example, before an electric pump fails as a result of worn bearings or bushes, it may start to vibrate in a distinctive known manner, so monitoring this vibration will allow the pump to

Measuring certain performance characteristics opens up the possibility of predictive maintenance

be replaced in a controlled manner before it completely fails. Outside the water sector, low-cost remote monitoring is also demonstrating its worth. CareMore, a US healthcare provider, uses wireless scales and blood pressure cuffs to remotely monitor its patients/customers on a daily basis, enabling medical interventions to take place before serious events, such as heart attacks, occur. As well as reducing the catastrophic impacts to the patients this reduces high downstream costs associate with hospitalization and surgery (Main and Slywotzky, 2011). In this way the increase in the speed of data flow made possible by new technologies creates a much tighter feedback loop, which allows for a step change in the way data can be used. The monitoring of a rural water supply system, under what could be called a traditional project model, will often be too late to benefit the users of the system that is being evaluated. A report will be produced on how the system is doing which will hopefully inform future projects and investments decisions. Slow data leads to slow improvement with the risk that system features, good or bad, become 'baked-in'. With near real time performance data integrated into the management of a system, a 'monitoring and evaluation leading to lessons learnt' paradigm gives way to a 'surveillance-response' paradigm. On top of the simple speed and efficiency benefits gained from simply knowing things faster, continual improvement and learning is possible, for both technical and institutional issues. This tighter feedback loop also allows more flexibility as the effect of different decisions or management rules is known quickly and can be changed accordingly, rather than sticking, quite rationally, to the risk averse 'if it ain't broke don't fix it' mentality.

> The increased speed of data flow creates a much tighter feedback loop, allowing for a step change in the way data can be used

Closed turn-key systems, such as the LIFELINK offered by Grundfos, have system surveillance built into their design, so that engineers locally or internationally can monitor performance. This is very much the exception in the rural water sector rather than the rule and is possible because a communications link to manage the billing and system monitoring was designed in from the start. Moving beyond purely technical aspects, what LIFELINK is now offering is guaranteed water services for an agreed number of years. This service level approach is redefining operational and economic performance for users and investors. Water Health International and Sarvajal also have offerings that provide new water infrastructure with mobile technology designed in. Other initiatives are also exploring the potential of automated monitoring of *existing* rural water infrastructure. Oxford University is developing and trialling a system that records hourly pump usage, reporting this information to a central server via SMS (Thomson et al., 2012). As well as its primary aim of automatically flagging pump breakages in near real-time, the hope is that accurate usage patterns and approximate volumetric

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usage figures can be generated with finer temporal precision than is currently possible to generate without frequent, expensive field surveys. Portland State University is currently running field trials on a universal, low-cost, automated monitoring system for development projects that uses the mobile phone network for communications. This multi-purpose modular design is being adapted to monitor water projects.

Accountability

In the rural water sector much of the investment and service provision is driven externally rather than in *direct* response to local user needs. In a situation where the customers (governments/donors) are not the same as the consumers (water users), the usual two-way relationship between customer/consumer and service provider does not exist. The resulting three-way relationship leads to an information asymmetry. The customer, who has contractual or financial power over the service provider, whether a private supplier or other government agency, will not know the level of service that the consumer is being provided with, unless specific effort is made to find out. In such a situation it is also unlikely that the consumers have a choice of service provider, and thus have little power of their own to incentivize them to improve service levels. If performance data is made available to those who are contracting the service provider, contractual incentives for high performance and penalties for poor performance can be imposed. Performance data of well-functioning systems can provide insights into how the system is used which can inform longer-term investment and policy decisions. When there are systems that are similar but geographically dispersed, benchmarking of different providers of comparable systems can be made by a regulatory body. Performance benchmarking has long been done by regulators of utilities across the world, including urban water supply in Africa (e.g. NWASCO in Zambia, or WASREB in Kenya); however, benchmarking has yet to become a significant feature of rural water supply.

Performance data of well-functioning systems can inform longer-term investment and policy decisions

That central governments, donors, and NGOs are driving investment in and are implementing rural water supply projects brings out another reason why the monitoring of performance rather than of failure is essential. Governments have obligations to provide water to their people, which are derived from constitutional obligations and national policy, or shaped by international laws and norms. General Comment 15 (UN Economic and Social Council, 2003) builds on the Economic Social and Cultural (ESC) Covenant (1966) and states nine core obligations that fall upon state parties. Of these, a number are very pertinent to the rural sector: 37(a), (c), (d), and (h); but it should

Governments have obligations to provide water to their people also be noted that 37(c) refers to the obligation 'to monitor the extent of the realization, or the non-realization, of the right to water'. While General Comment 15 is not a binding document and obligations under the ESC Covenant are qualified by the 'progressive realization' clause, they are increasingly being observed. As well as monitoring being an essential management tool for delivering improved water services, it is arguably an obligation itself. This may have practical implications for rural water policies. Community management and self-supply may be the most effective means of providing rural water services to the rural poor, and government policy and legislation may reflect this, for example in Zambia. However, core obligation 37(c) suggests that this delegation of management responsibility down to local communities does not absolve governments of their responsibilities to their citizens. This point is reiterated in Human Rights Council Resolution A/HRC/RES/15/9 (2010) that states that 'the delegation of the delivery of safe drinking water and/or sanitation services to a third party does not exempt the State from its human rights obligations'. Therefore the implementation of arms-length policies must be monitored and governments must provide necessary support to ensure that safe water supplies are sustained into the future.

In the case where much of rural water investment is through NGOs and bilateral aid, organizations have obligations to deliver project outcomes to their donors, who in the case of government donors have corresponding obligations to taxpayers to spend aid budgets effectively. For example, the current UK government has committed to meeting agreed funding targets for international development. However, especially in a climate of budget cuts and austerity, this is not a universally popular policy, and so the need to deliver value for money in aid is increasingly important. Previously, in the absence of 1) much rigorous scrutiny from donors; and 2) the ability to conduct meaningful long-term monitoring at reasonable cost, the one-year-on project report with inevitably glowing results was the norm. Amongst others, Breslin (2010) eloquently and robustly critiques this short-term project mentality, echoing insights by Therkildsen (1988) into 'watering white elephants' in Africa a generation earlier. With aid effectiveness driving competition between sectors, a pound spent on rural water supply has to demonstrate impacts and outcomes comparable to a pound spent on a health or education project. By their nature, water programmes only deliver benefits in the future if boreholes, pumps, and standpipes continue to work into the future. So to compete with, say, a measles vaccination campaign which provides a long-term benefit through a one-off action, we must ensure that water supply projects remain effective over time, and *be able to prove* that effectiveness.

A pound spent on rural water supply has to demonstrate outcomes comparable to a pound spent on a health or education project

Conclusion

Falkenmark (1982) identified at the start of the International Drinking Water Supply and Sanitation Decade that operations and maintenance problems would become increasingly of concern. Thirty years on we are still struggling with them. Fortunately the paradigm of buy, install, train, handover to the community, and then head back to the capital city for sundowners appears long dead. Effective monitoring of rural water supply projects is rapidly becoming the 'new normal'. Monitoring is required for the long-term management of projects, for accountability to donors and users, and to inform future investment decisions. Fortunately, the mobile phone revolution across Africa provides an opportunity for the quality of monitoring to increase by orders of magnitude at relatively low cost. The marginal cost of sending data across hundreds or thousands of miles of Landcruiser-killing terrain by text message or GPRS (General Packet Radio Service) is negligible, allowing for a move towards continuous monitoring and surveillance. The ever-decreasing cost of ICT enables us to generate and crunch these data cheaply, and social media allows us to quickly disseminate information to users, donors, and other stakeholders.

Effective monitoring of rural water supply projects is becoming the 'new normal'

However, the history of rural development projects provides a veritable graveyard of examples of well-intentioned projects and innovations that have met harsh reality and been found wanting. Care must be taken in understanding the nature of the monitoring system being implemented: its strengths and weaknesses; what is explicit vs. what is only implicit; the reliability and currency of the data. Monitoring systems can produce a deluge of data whose quality must be assessed, so that only valid conclusions are drawn from it. In the case of automated systems, they may be telling us objective facts, but are these really what we need to know? In the case of crowd-sourced data, has the system design fully accounted for existing social structures and norms? What are the reporting biases of those using the system? As the amount of monitoring data we can generate increases, along with the ways in which we can process, manipulate, and present data, understanding what is behind the final 'product', whether a map, chart, or graphic, becomes more and more important and less immediately apparent. We must know what we are explicitly monitoring and what we are merely inferring, even if that inference is most likely correct. Rather like water, low-quality data is preferable to no data, and can be extremely useful, but the consequences of assuming it is of high quality and using it accordingly can be fatal.

Monitoring systems can produce a deluge of data whose quality must be assessed, so that only valid conclusions are drawn from it

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