Accuracy and Reliability of Operator-Assisted (SMS) Data Collection in Community-Managed Water Supplies

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Abstract

Water Missions International has developed a low-cost information system that allows water system operators to send performance data via SMS directly to a centralized database. The primary objectives of this study were to determine the validity of the data collection system over an extended period of time, to identify methods that increase the reliability of receiving the data, and to observe country-specific differences in data accuracy and reliability.

Thirty three rural communities from among those in Haiti, Honduras, Indonesia, and Malawi where Water Missions International installed water treatment systems between 2009 and 2011 were selected for inclusion. Each community was assigned a particular reporting frequency, airtime payment method, expense coverage method and follow-up frequency. A water system operator in each community was trained to collect and send specific information to the data collection system in SMS format. SMS data was monitored for 8 weeks. Each community was visited by Water Missions International technicians 4 and 8 weeks after the system was introduced in order to verify data . Reliability of the SMS messages was evaluated based on the percentage of scheduled messages that were received and on the tardiness of the messages.

Performance data reported via SMS was found to be in agreement with that which was collected by Water Missions International technicians. The percentage of scheduled SMS messages received was significantly improved when a weekly reporting structure was employed compared to a daily reporting structure. In addition, the water system operators in Malawi appeared to be much more reliable than those in the other countries that were studied.

The SMS data collection system evaluated in this study is a viable tool for monitoring the technical performance of rural water supply systems. Although further evaluation is needed to determine the system's applicability to complex distribution and water fee structures, this low-cost technology is already a critical component of Water Missions International's monitoring and evaluation strategy.

Background

Collaborative efforts by the IRC International Water and Sanitation Centre and the Water Supply and Sanitation Collaborative Council have estimated that 30% of all handpumps installed in sub-Saharan Africa over the past 2 decades have failed prematurely and that waterpoints in some areas of the continent are even less than 50% functional. Although there are myriad factors that result in such breakdowns, many would be avoided if reliable systems were in place to monitor the ongoing status of water supply systems.

Water Missions International is a nonprofit Christian engineering ministry providing sustainable safe water solutions to people in developing countries and disasters. The organization has developed a low-cost information system that allows water system operators to send performance data, such as volume of water distributed and residual concentration of free chlorine, directly to a centralized database via SMS. In early 2012 a study was conducted to determine the validity of the data collection system over an extended period of time, to identify methods that increase the reliability of receiving the data, and to observe country-specific differences in data accuracy and reliability.

An operator of a water system in Honduras tests the free chlorine concentration in treated water (left); water system operators in Indonesia monitor a water meter while filling bottles for distribution (right)

Methods

Thirty three rural communities (average population 2030) from among those in Haiti, Honduras, Indonesia and Malawi where Water Missions International installed community-managed water treatment systems with point source distribution between 2009 and 2011 were selected for inclusion in this longitudinal study. Each community was assigned a particular reporting frequency (daily or weekly), airtime payment method (prepaid or postpaid), expense coverage method (by the community's water committee or the Water Missions International country program), and follow-up frequency (daily, twice per week, or when no SMS messages were sent).

Table 1: Study Population

Country	Study Communities	Mean Population
Haiti	8	1900
Honduras	10	2080
Indonesia	5	1640
Malawi	10	2290
Total	33	2030

Table 2: Distribution of Study Variables

Country	Water Fee Structure	Reporting Frequency	Payment Method	Expense Coverage	Follow-Up Frequency
Haiti	Container	Daily	Prepaid	Country Program	Daily
Honduras	Container, Monthly	Daily	Prepaid, Postpaid	Committee	Daily
Indonesia	Monthly	Daily	Postpaid	Committee	Twice Per Week
Malawi	Monthly	Weekly	Postpaid	Committee	When No SMS Sent

A water system operator in each community was trained to collect and send specific information (free chlorine concentration in treated water, totalizing flow meter reading, number of transactions and income collected) to the data collection system in SMS format. Operators were not informed of the study or of their involvement in it.

SMS data was monitored for 8 weeks. Each community was visited by Water Missions International technicians 4 and 8 weeks after the system was introduced. Independent free chlorine concentration samples, totalizing flow meter readings, and water sales observations were collected and system performance logs were copied. Daily volume of water distributed, free chlorine concentration, number of transactions, and income were calculated from SMS data for each community and compared to the data collected during follow-up visits. Recurring errors in the SMS messages were also recorded and tallied. Reliability of SMS messages was evaluated based on percentage of scheduled messages received and on tardiness of the messages. One-way analyses of variance were conducted using Microsoft Excel.

Results and Discussion

Average daily values reported via SMS are summarized in Table 3. Operators in Indonesia and Malawi were unable to report daily number of transactions and income because the water systems in these countries were operated under a monthly water tariff structure. Except for incorrectly reported flow meter readings, all reported data was included in subsequent analyses.

Table 3: Average Daily Values Reported via SMS

Country	Volume Distributed [L]	Transactions [No.]	Free Chlorine [mg/L]	Income [USD]
Haiti	1610	175	1.5	$1.28
Honduras	739	27	0.9	$8.94
Indonesia	2378	-	0.4	-
Malawi	6806	-	0.8	-
All	3037	106	0.9	$4.23

Results and Discussion (continued)

Performance data reported via SMS was found to be in agreement with that which was collected by Water Missions International technicians. However, negligible differences between water meter readings reported via SMS and recorded in operator log books, likely occurring when SMS messages were sent before daily distribution was complete, resulted in apparent errors when daily volumetric distribution estimates were calculated. The apparent discrepancies between distribution estimates calculated using water meter readings in SMS reports (colored markers and lines) and operator log books (open markers) from four communities in Malawi are illustrated in Figure 1.

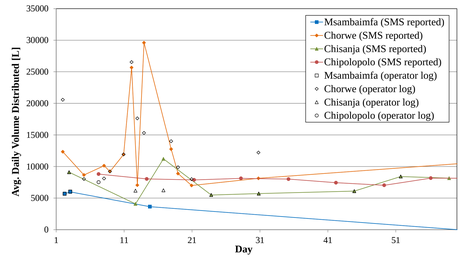

Figure 1: Validation of Volumetric Distribution Data (Malawi)

Free chlorine concentration values reported via SMS were in agreement with data recorded in system operation logs in all study communities. However, 14 of the 33 study communities (42%) reported the same value for free chlorine concentration in every SMS that was sent over the 56-day study period. While this finding could be interpreted to indicate high reliability of water quality in the 14 water treatment systems, it also raises some concern as to whether or not free chlorine concentration was being falsified in SMS messages or even sampled by the operators at all. In fact, the free chlorine concentration sampled by Water Missions International technicians differed from that which was reported and logged by water system operators during at least 1 of 2 follow-up visits in 5 of the 14 communities that reported no change in free chlorine concentration over the study duration. An example of the typical free chlorine concentration values reported via SMS in Haiti is shown in Figure 2.

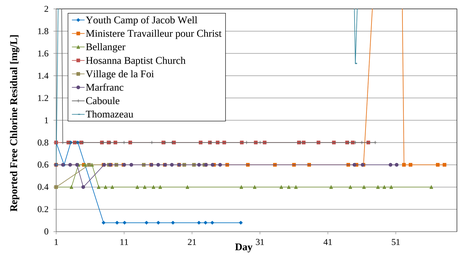

Figure 2: Reported Free Chlorine Concentration (Haiti)

Trends in reported daily income generally followed the number of transactions in communities where the two variables were able to be reported, as exemplified by Bo. San Isidro, Honduras in Figure 3.

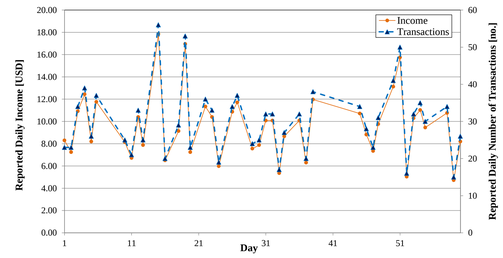

Figure 3: Reported Income and Transactions (Bo. San Isidro, Honduras)

Results and Discussion (continued)

The measured indicators that were used to determine accuracy and reliability of SMS messages sent by water system operators are presented in Table 4.

Table 4: Measured Indicators of SMS Accuracy and Reliability

Country	SMS Without Error	Scheduled SMS Received	Avg. Days Late
Haiti	83%	63%	1.6
Honduras	79%	63%	3.6
Indonesia	79%	77%	1.0
Malawi	92%	91%	1.6
All	84%	74%	2.1

Occurrence of errors in SMS messages was used to evaluate accuracy of the data collection system. The following summarizes errors that were observed:

- Errors in the reported free chlorine concentration, including values reported to be greater than 2 mg/L and that disagreed with samples taken by Water Missions International technicians, contributed 25% of all errors
- Errors in the reported totalizing flow meter reading (i.e. values less than the previous reading) contributed 20% of all errors
- Duplicate SMSs sent in a single day contributed 47% of all errors
- Although there were only three communities that committed errors when reporting number of daily transactions (i.e. SMS reported values disagreed with what was recorded in the system operation log book), these contributed 7% of all errors.
- There were no apparent errors in the reported daily income

None of the study variables (water fee structure, reporting frequency, payment method, expense coverage, follow-up frequency) significantly affected the number of errors observed in the SMS messages. This finding indicates that the operator-assisted data collection system can be considered accurate in spite of observed reporting errors and the implications that these errors had with respect to calculating metrics such as volumetric distribution.

The study variables did not have a measurable effect on tardiness of the messages. However, the percentage of scheduled SMS messages received was significantly improved when a weekly reporting structure was employed (66% scheduled SMS messages were received when reported daily vs 91% when reported weekly, p=0.004). It is possible that this effect was observed because the only country where a weekly reporting frequency was adopted was Malawi, where the operators appeared to be significantly more reliable than the other countries (63% of scheduled SMS messages were received in Haiti, 63% in Honduras, 77% in Indonesia and 91% in Malawi, p=0.002).

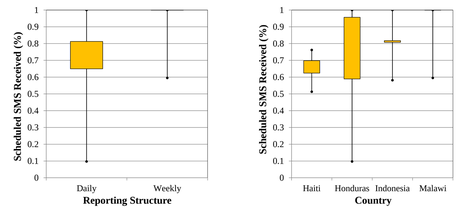

Figure 4: Effect of Reporting Frequency (p=0.004) and Country (p=0.002) on Percentage of Scheduled SMS Messages Received

Conclusion

The SMS data collection system evaluated in this study is a viable tool for monitoring the technical performance of rural water supply systems and engaging local operators on an ongoing basis. Based on the findings of this study, Water Missions International plans to standardize to weekly reporting of water meter reading and free chlorine concentration. However, alternative means for tracking free chlorine concentration will also be explored due to its questionable accuracy when reported via SMS. Although further evaluation is needed to determine the system's applicability to complex distribution and water fee structures, this low-cost technology is already a critical component of Water Missions International's monitoring and evaluation strategy.