WATER Alert!: Using Mobile Phones to Improve Community Perspective on Drinking Water Quality in South Africa

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ABSTRACT
Drinking water quality, in many parts of South Africa, is far below acceptable standards. With a high number of illnesses and deaths in the country due to diarrheal diseases, the impact is critical. This research addresses the challenge of reporting complex and critical water quality information in a way that is accessible to all South Africans. High illiteracy rates, the presence of 11 official languages and limited-to-no access to technology in many areas, present some of the major challenges to the design of an alert notification and reporting system. We describe the design of *WATER Alert!*, a symbol-based prototype mobile phone application to alert and report water quality information to consumers and allow for citizen involvement in water management. Our findings from a preliminary evaluation revealed that *WATER Alert!* is simple to use and has a perceived usefulness amongst participants. The findings also suggest that such an application would help to improve consumers' understanding of water quality information leading to an improved Community Perspective on drinking water quality.

Categories and Subject Descriptors
H.5.2 **[Information Interfaces and Presentation]**: User Interfaces – *user-centered design*

General Terms
Design, Human Factors

Keywords
Low-literate user interfaces, water quality, ICTD, South Africa, user-centered design, mobile phones, HCI

1. INTRODUCTION
Safe drinking water is 'a source of life' [21]. Diarrhea, often caused by drinking dirty water, remains a major killer worldwide [1]. In South Africa alone, it is estimated that 3 million cases of illnesses and 43,000 deaths each year occur from diarrheal diseases with over half a billion US dollars being spent annually on treatment costs [20]. The most susceptible to diarrhea and other types of waterborne diseases are children and immuno-compromised individuals who make up a large percentage of the South African population. For these individuals, safe drinking water *is* their life. So, it is no surprise that the South African government has taken steps to ensure that Water Service Providers (WSPs) collect data about and communicate to the public the safety of their water [13].

But the most common way for the public to get that information is currently to request a paper-based report from the area Water Service Provider (WSP), which even our participants with a college-level education found challenging to interpret. Another means is for the consumer to bring water samples to the WSP to be tested, an option that is inaccessible to rural residents given the distance and costs required to make such a trip. Websites such as [5] and [30] provide urban consumers access to some water quality information. However, no online reports exist for water sources in informal or rural settlements where it is needed the most, nor is this medium accessible to low-income and low-literate residents who make up the majority.

Our research seeks to make a contribution by exploring the role of Information and Communication Technologies (ICTs) in water quality management and citizen involvement. In this paper, we set out to answer the question of whether, and if so, what role ICTs might play communicating this information to a diverse group, with an emphasis on residents who lack the ability to access current online information. This includes the low-income, the low-literate and those residents living in informal or rural environments. So, we uncover considerations for the design of a system to report water quality information to consumers and introduce, *WATER Alert!*, a prototype mobile phone application that issues locally relevant symbol-based message alerts and information to subscribers who can then forward the messages as multimedia text messages (MMS) or plaintext short messages (SMS) to non-subscribers. We chose to design for this platform due to the availability, widespread popularity and familiarity with mobile phones and the Mobile Internet in South Africa as well as the speed, reach, lower associated costs of use and simplicity of use. We foresee our design being useful to WSPs who could populate the application with the latest reports and risk alerts and disseminate them to consumers (who can share it virally) in a graphical and highly visual format.

The paper is organized as follows. In section 2, we present related work. In section 3, we discuss the user-centered methodology employed. In section 4, we enumerate design considerations developed from the interviews we conducted, which helped to guide the design *WATER Alert!* which we discuss in section 5 and 6. We then talk about the results of a preliminary user evaluation in section 7 before discussing our findings (section 8) and future direction (section 9).

2. RELATED WORK

The 1997 Water Services Act and the Compulsory National Standards for the Quality of Potable Water enacted three protective measures which Water Service Providers (WSP) are required to follow. These are to (i) Monitor and report water quality to authorities, (ii) Compare it to the national drinking water quality standards and (iii) Report water quality information to consumers in a comprehensible format [21]. Together these measures if employed, would encourage a reduction in the high number of deaths caused by drinking contaminated water. This is especially true in the townships (informal settlements, Fig. 1) and rural parts of South Africa where poor water quality is a major issue.

2.1 Why Communicate Water Quality?

Risk communication, is an identified area of water quality management practice that focuses on disseminating information between stakeholders (which include government, agencies, the media and citizens) about the levels and meaning of health and environmental risks and the decisions, policies and actions to manage or control them [8]. For such a program to be effective, it should be employed before, and not only during crisis management [8]. Even the World Health Organization (WHO) deems it necessary for risk communication to be a continual two-way activity between stakeholders as this increases involvement (particularly that of consumers) [2]. Moreover, ongoing pre-crisis communication between the parties of interest mitigates the effect of a real crisis as trust is developed and a communication channel built beforehand.

[14] discusses the role that citizen participation plays in environmental management specifically that of water management. House mentions that understanding and environmental awareness and education can be promoted through personal experience gained through direct involvement and participation. A system which sends water quality information directly to consumers would bring about awareness of what makes water safe or unhealthy, the level of monitoring that goes on and other information that will hopefully spark discussion and further engagement by consumers.

Providing a direct communication channel between consumers and Water Service Providers (WSP), will also provide an opportunity for trust to be cultivated and a more rapid and direct interchange of information. Water quality risk communication, specifically in the South African context, has made limited use of technology, to get the word out to consumers. For this reason, we wanted to not only leverage technologies, but those that are accessible to the vast majority of consumers regardless of their socioeconomic status.

2.2 User Interfaces for Users with Differing Literacy Levels

Given the diversity of our target audience (nurses, community leaders, low-literate, non-English speakers etc.) it is a given that literacy level and information needs will vary, hence a design needs to cater to these differences, the greatest challenge being making our design accessible to low-literate (basic literacy but not proficiency in reading and writing) and illiterate users.

The ubiquity of mobile devices and the rise in interest in leveraging them in emerging markets, has caused an increase in research looking at user interfaces for low-literate and illiterate users. Projects span banking and microfinance [24,28], health [32], agriculture, games and education [16], social networking [6], and post-conflict reconciliation [33]. Most have explored the use of interfaces that are text-free or minimal-text [27], multimodal audiovisual [9] or purely audio driven or conversational [32] and have developed frameworks such as the PACE Framework for language learning [17].

Several researchers have noted the complexity of designing interfaces to suit users of differing literacy levels [9,25,26]. [26] noted that illiteracy is not simply the inability to read *per se* but needs to account for cognitive differences between literate and illiterate people. Literate people are able to abstract information and transfer skills learned, traits likely gained through an education, while illiterate people learn better given concrete situations as abstraction for them is challenging [26]. Hence abstract icons and hierarchical menu structures pose difficulties for the illiterate user. Additionally, [25] highlights other factors mediating the interaction of low-literate users with technologies. Some of these include, the level of exposure to technology, motivation, collaborative user experiences, mediation, cultural etiquette, power relations and pricing.

In a controlled study [9] distinguishes between the needs of low-literate and illiterate users. Low-literate participants benefitted from interfaces that combined both audio and text and showed an improvement in visual word recognition and speed of use over time whereas illiterate users did not experience this improvement. As a result, interfaces that are to be used by both groups could incorporate the ability to toggle on and off text.

[27] offers a set of guidelines for the design of text-free user interfaces based on work done with illiterate women in an urban slum in Bangalore. The guidelines include avoiding text, using semi-abstracted graphics and subtle graphical cues, providing voice feedback and "help" instructions. Even though this work is done for PC applications we find it applicable to the design of our mobile phone application as it demonstrates the feasibility of designing interfaces for low-literate and illiterate groups, the distinction being our application of these principles in the context of water quality alerts.

2.3 ICTs and Water Management

The Aquatest project to which this study is connected, seeks to develop a low-cost water quality test kit and information management solution for drinking water quality management accessible to low-income and rural communities [29]. As part of the information management solution, water quality test results need to be disseminated by WSPs to Water Authorities as well as to consumers. [19,21] have explored a simple, low-cost way of collecting water quality information using mobile phones and reporting it in real-time to Water Authorities. This project, aims to satisfy the latter goal, i.e. disseminating the information in a simplified way at point of testing to consumers, thereby reducing the delay in issuing alerts.

ICTs have also been used extensively to do real-time remote monitoring of water quality for a variety of applications. For instance, it has been used to support monitoring of harmful algal blooms, coastal waters, stream restoration projects, fish behavior and drinking water reservoirs [10]. What we can learn from these applications is that the immediate availability of information can facilitate early warning notification (such as public advisories), rapid response, public education and the development of mitigation strategies [10] which in this case could potentially save lives.

2.4 Mobile Phones in the South African Context

Given the tremendous growth in mobile phone subscriptions in Sub-Saharan Africa [7], there has been a surge in using mobile phone-based reporting or information systems [6,31]. In South Africa in particular, researchers have deemed the mobile phone as a suitable platform for the dissemination of information to the masses [6,15] given that it is highly accessible, widespread and familiar to South Africans. Additionally, the number of mobile-only Internet users surpass traditional PC-based Internet users in South Africa and have begun to diversify their usage of the Mobile Internet [7].

We acknowledge, as do other researchers, that the mobile phone is not a panacea [7,15], but the drawbacks of the platform (interoperability, small screen size, etc.) are not as pressing in this situation as in others. For *WATER Alert!* despite these limitations, mobile phones remain the technology that is most likely to "be there" for issuing water quality alerts. The sending of short broadcasts or alerts as well as advisories are suited to the small form factor of mobile phones as the application is not intended to be a full interactive web experience. Additionally, the application does not require extensive use of passwords or an email address and by leveraging viral communication practices, the proposed ability for subscribers to forward alerts to non-subscribers via SMS/MMS text messages, extends its reach to users with very basic phones. Moreover, we can leverage the benefits of the mobile phones — speed, reach, familiarity, and lower associated costs of use over, for instance, paper-based alternatives to disseminating critical information. In fact, doing this via Mobile Internet technology (which is increasingly being adopted even among low-income groups [7]) have very low associated costs over regular SMS/MMS.

3. METHODOLOGY

ICTD researchers have observed that conventional user-centered design (UCD) methods do not hold up well in developing county contexts – there are language, literacy and cultural barriers to overcome [4,12,22,23]. As a result some have come up with hybrid approaches based on what has worked for them in the field [23,28]. For instance, [23] has found that employing approaches such as contextual design, which is both user-centered and based on ethnographic principles effective in gaining insight into a population, a useful practice in cross-cultural design. In our study we have employed a mix of ethnographic (interviewing) and Contextual Design (work modeling) methods. We introduce our process in the next paragraph, and further detail each step in the upcoming sections.

To first understand our users and their context, we conducted interviews, which we used to create work models (found in contextual design). We also photographed and analyzed dozens of road signs around Cape Town to understand how best to visually communicate water quality information using symbols with which our target users may already be familiar. We then iteratively developed a set of symbol-based messages with input being provided from locals between consequent iterations, leading to the design of our high fidelity prototype application. Finally, we conducted limited user testing of our prototype design.

3.1 Interviews

Given the diversity of the audience in water quality risk communication, messages should be modified to suit a wide spectrum of education levels, intelligence and understanding and adapted to the values and interests of the recipients [18]. This is especially true given the diversity in the South African context. As a result, we conducted semi-structured interviews with 12 participants in Cape Town to gain an understanding of our target users and their context. To better inform our design, we wanted to understand users'

1. level of concern and perception of drinking water quality in their area,
2. mode of keeping informed about drinking water quality in their area,
3. level of knowledge about water quality testing and purification techniques and desire to learn,
4. preferences for mode and frequency of dissemination of water quality information and alerts, and
5. general level of access to and use of mobile phones and the internet.

Additionally, we collected demographic information to help us identify the unique needs of users' based on their area of residency (e.g. urban city, informal settlement) and drinking water source (e.g. in-home tap, communal stand pipe).

3.2 Participants

Since we wanted to design an application that would be suitable for all South Africans, we tried to choose a mix of participants within the constraints of the study. There were ten females and two males ranging in age from 18 to 45. This included a Nokia consultant, two sanitary workers, three security officers and six students at a local university in Cape Town one of whom is also a lecturer. Five participants lived in a formal area in a city, four in an informal settlement in a city (also termed a township or squatter settlement with makeshift housing and little to no infrastructure, Fig. 1) and one person lived in a small town. Seven of the participants started or completed secondary schooling but went no further, while five completed or were currently completing a university degree or diploma. Two-thirds on them spoke English and one or more languages, while the rest spoke English only. All but one participant owned a mobile phone.

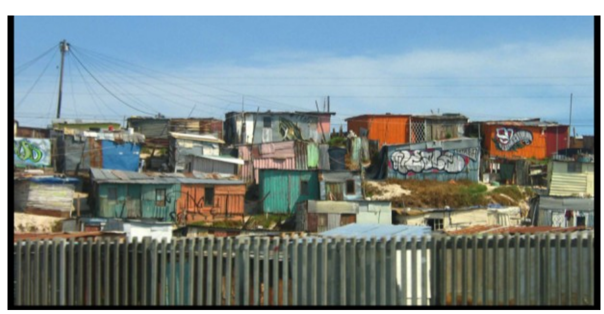

Figure 1. An informal settlement in Cape Town also called a township.

4. RESULTS

4.1 Requirements Analysis

Following a practice adopted from Contextual Design (CD), that of drawing models based on the consolidated responses provided by interviewees, we came up with a set of models including the consolidated flow model in Fig. 2 and the consolidated cultural model in Fig. 3.

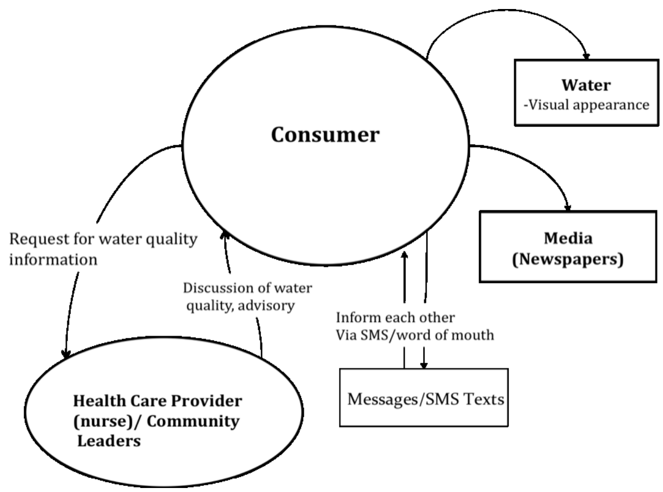

Figure 2. Consolidated flow model showing how the participants in our interview went about obtaining water quality information.

Fig. 3 reveals how water service providers take advantage of 'viral communication' as a means of disseminating information. They provide information to conduits such as the media, heath providers and community leaders with the expectation that this information is passed on to consumers. This, of course is done mainly when critical.

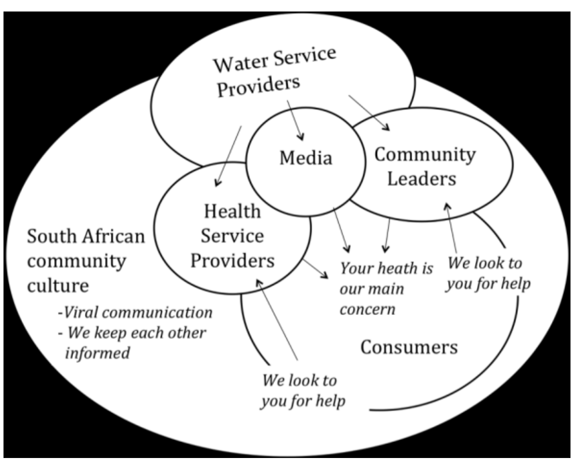

Figure 3. A consolidated cultural model showing how water quality information flows from water service providers to consumers via conduits (media, community leaders, nurses).

4.2 Design Considerations

The data collected from our field interviews and work models presented some useful design considerations for our prototype. We discuss the findings below and briefly mention the portion of our final prototype (detailed in section 6) it informed.

a) Viral Alerts Through Trusted Networks: Water quality dissemination systems, can introduce a more direct flow of communication, from service providers to consumers, while respecting the existing practice of viral communication that occurs within a consumer's trusted network (of friends, neighbors and community leaders) as noted in Fig. 2 and 3.

Fig. 2, which is a consolidation of the responses received during our interviews, revealed that consumers in various areas of Cape Town obtained their water quality information from three sources: Health Care Providers/Community Leaders, Media, and other consumers. One participant discusses this,

> *[I03] Sometimes someone [friends] sends you an SMS and say …you mustn't go to this area because there is something there…There's a community leader in our area…When there is a mess of water then they come to your house and bring something and tell you what must you do...Yeh like someone with a word of like, in the street.*

A proposed ability for subscribers to forward alerts from within the application to non-subscribers via SMS (text only), MMS (multimedia/picture) messages or a personal voicemail makes use of viral communication as a means of extending the reach of alerts and messages to non-subscribers and to users who still own very basic phones.

b) Don't just Alert, Educate: We found that people were not just interested in learning if the water was contaminated, but also wanted to see things like the trend over time and learn purification techniques that could be employed when risks are present. One participant offered questions he would want to be educated on as a consumer:

> *[I08] What is water quality? How should water taste?*

The addition of an 'Advice' section in our application and brief explanations of the effects of noncompliant parameters (turbidity, E. Coli, etc.) stems from this observation.

c) Customizable Alerts: On the survey portion of our interviews, only respondents living in informal settlements (squatter settlements) or small towns rated any aspect of their drinking water fair to poor or reported having any concerns about the quality of it. As expected, even though the majority of the participants thought it was important for them to be informed about the quality of drinking water in their area, there was a clear difference in the frequency with which users would like to receive such information. The majority of participants living in informal settlements, (where access to water is typically from communal 'stand pipes' due to the non-permanent structure of dwellings), wanted to be notified daily or weekly of the result of testing done and when critical, reflecting high levels of concern about water quality. On the other hand, residents living in formal urban areas (where there is often at-home access to water via faucets) wanted notifications sent at less frequent intervals, i.e. i) only when critical, ii) once a year and when critical, or iii) never. One participant living in an urban area with less concern about the water quality in his area made the following remark:

> *[I11] I'd like to be able to monitor water quality in a non-obstrusive manner i.e. I have to check on a site (no*

emails, or smses) I would like to see results as a graph over time, and comparisons with other areas.

Alerts should be customizable to suit each individual's level of concern. For more concerned users we propose the final application would 'push notify' (server initiated request) consumers (e.g. pop-up message, sounds), while others could set it to only receive alerts when critical and 'pull' (client initiated request) information otherwise.

d) Personalization and non-personalization: Users noted differing scenarios of use that have an impact on the design of the application.

i) Mobile verses fixed-location users: Users who obtain their drinking water from communal pipes, need the ability to easily switch between different locations while users who access water at-home will likely prefer the ability to set a location once. We designed for this flexibility.

[I03] Because sometimes their area is not like my area. And the cleanest one in my area is dirty. If mine is dirty and that one is the cleaner one.

ii) Ownership versus shared-phone access: [7] notes the popularity of phone sharing. Hence, in some cases, too much personalization may actually not be desired as more than one person may be accessing the application from different areas.

[I03] It's not my phone, it's my boyfriend's phone. I have it after every other day. [Like I have it today], He has it tomorrow.

f) Flexibility to support all phone types: One participant called her phone a '*scoro scoro*' referring to its inability to do anything more than receive text-only SMS and make calls. Even though GPRS phones are becoming pervasive, an alert system needs to be multi-modal so that these basic models are included in the ecology. As mentioned before we propose the ability for subscribers to push messages to others via SMS for instance.

This set of design considerations, though valuable, still left questions about how to communicate water quality information in a visual format. Hence in the next section, we discuss the process of compiling symbol-based message templates to convey water quality test results, alerts and advisories.

5. DESIGN AND PROTOTYPE

To gain an understanding of what symbols were present in the context of our users, we decided to gather artifacts by taking photos of traffic and information signs around on the streets and in buildings around Cape Town (a step we anticipate would prove especially useful when exploring more rural contexts in the future).

We ended up with 87 photos which we analyzed to help guide the design of our symbol-based messages. This led to a set of symbols and a color palette that is locally and likely universally understood. These categories are in line with previous research on traffic signs [34].

Figure 4 shows the three categories of symbols found:

- Regulatory/Prohibitory: Red/black circle-slash over object; minimal/no text; white/amber background
- Warning: Amber triangle with black border; cross symbol for health caution signs; numbers and pictures instead of text
- Informational: Green background, white text; checkmarks affirm correct procedures; arrows show motion

Figure 4. Categorized snapshots of 87 signs and symbols taken around Cape Town.

5.1 Low-Fidelity Prototype Messages

Utilizing unique visual characteristics from the three categories above, we developed some low-fidelity sketches (Fig. 5) of the graphics that would form the meat of the alert messages for our prototype.

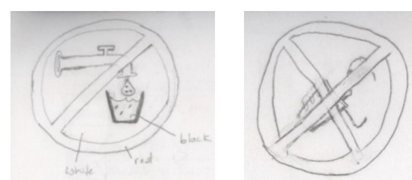

Figure 5. Paper Prototypes

[15] spoke about the importance of including local participants in the design process. Since this is unlike participants required for an evaluation, small numbers are ideal. Hence, we engaged two participants between consequent iterations to first see if they understood the message we were trying to convey and help us ensure the depictions were culturally appropriate. This led to a redesign of some of the images and our first high-fidelity prototype (Fig. 6) which we showed to two new participants.

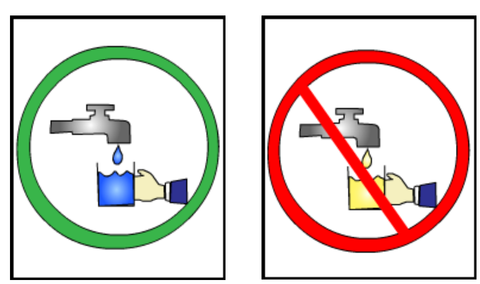

Figure 6. 1st iteration – Messages were very detailed, colorful and text-free. Users were confused by the color of the water and did not correctly interpret the action as 'Do not drink.'

As a result of the participants' feedback, we made the following changes:

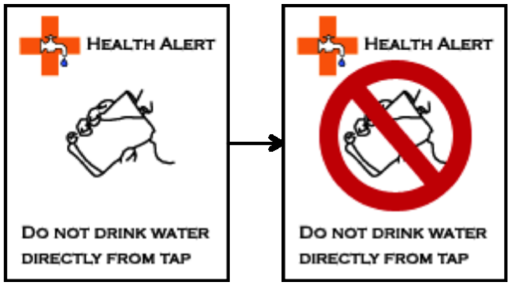

Figure 7. 2nd iteration – Messages were more abstract, used fewer colors, had minimal words, and were animated.

- *Abstract image and used fewer colors* (Fig. 7): In line with previous research [27], we noticed that that very detailed images (gradient, many colors etc.) distracted participants from the message. For instance one user did not pick up on the 'dirty water' analogy and so questioned why we used the color yellow for the water on the right in Fig. 6 instead of blue.

- *Redesigned some of the graphics*: We substituted objects that were more appropriate in the graphics. For example, one participant commented that the use of a kettle is more suitable for the boil water advisory, as the use of a pot was ambiguous (Fig. 8).

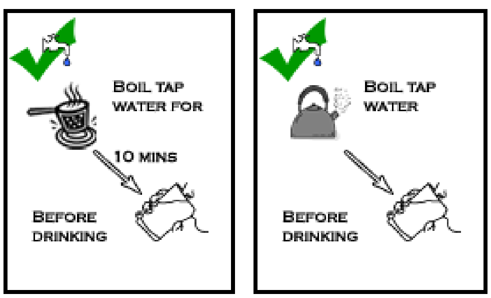

Figure 8. Initial and redesigned versions.

Additionally, following the advice of [27] we made use of animation to increase understanding of images.

5.2 Interaction Design

Following this, we built an interactive prototype in which we employed several metaphors. Visual metaphors help the user to make meaning of information when there are similarities between the design and a familiar object [3]. We describe two of those we used below:

a) Viewing the water quality report is like browsing through a mobile phone calendar application. Colored dates (red, orange or green) show the overall status on a day testing was conducted and selecting that date shows detailed results, as shown in Figure 9.

Figure 9. Interaction design.

b) Subscribing to the application (Fig. 11) is like sending an SMS text message.

6. FINAL PROTOTYPE

We ran our prototype on a Nokia 3110 (Fig. 10), which is a basic camera-ready handset supporting Flash 2.0, SMS and MMS text messaging. It is GPRS enabled, allowing the user to access the Mobile Internet. The handset had a relatively small screen, so that we could remain sensitive to the size constrain many users will face.

Figure 10. Nokia 3110 handset.

We used Adobe Flash Lite, a lighter version of Adobe Flash Player, to develop our high-level prototype. Since Flash has an emulator for our handset model, we were able to test our application on the fly before loading it unto the phone.

6.1 Subscribing to WATER Alert!

An application like this would be downloadable from a site accessed from the browser on a user's phone, similar to how some already download the popular Opera mini browser and MXit mobile instant messaging application (available for even basic GPRS enabled handsets). They would launch the application, and fill out a short subscription form (Fig. 11). The page consists of fields for cell phone number, choice of language and choice of location for which the user wants to receive alerts. This can be set once or updated to another location if desired. Illiterate users can leverage proximate literacy (literate family members) to complete this step though they may be able to do this on their own as they gain familiarity with place names. In a future functional version of the app, users with GPS enabled phones, could have it automatically select the closest municipality to their current location.

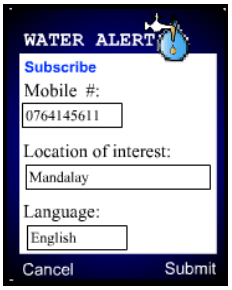

Figure 11. Subscription screen.

Once the user submits the form, the Main page shows the current water quality status of the user's area of interest. From this screen, the user can opt to get 'Advice' or to view the Water Quality Report (Fig. 12).

Figure 12. Current water status in Mandalay municipality. The red circle-slash flashes briefly then stays fixed.

6.2 Advice Screen

The user is taken to a series of picture messages when they select 'Advice'. The advice given here serves as an example of messages that could be shown. The user can navigate between screens using the right and left soft keys and exit once the first or final advice screen is reached.

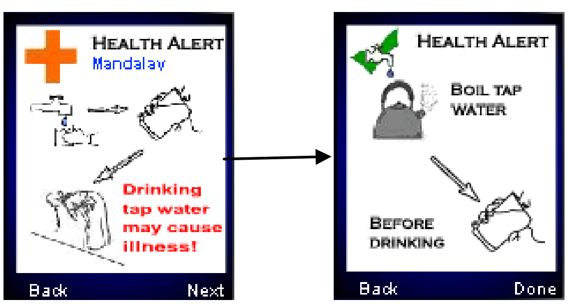

Figure 13. Advice screen showing warning and boil advisory.

6.3 Water Quality Report Screen

'Report' on the main screen, gives access to the water quality report. As mentioned earlier, we opted to use a calendar metaphor to translate a paper Water Quality Report into a cell-phone-based report. The main reason being increased usability and understandability. The navigation style on many calendar applications is similar and already familiar to many mobile phone users (as we learned during the interviews). Furthermore, since the reports are issued on a monthly basis, with tests performed on different days, this mapped well to the calendar metaphor. Fig. 14 shows the report in a calendar-like format. The day of the last test is automatically selected and other dates on which a test was done can be selected. The color-coding of the dates and a brief note below the calendar, convey the overall water quality status for a given day a test was conducted.

Figure 14. Browsing test results for a specific month.

We used a color scheme similar to that shown on an actual paper-based report (Fig. 15), omitting blue, however, which stood for excellent, as we felt green was sufficient for labeling all compliant parameters. We explain the categories below:

- Red: one or more parameters tested resulted in health failures.
- Amber (orange): one or more parameters tested resulted in non-health failures, such as aesthetic or chemical failures.
- Green: all parameters tested were within compliance (passed).

Quality of Water System	Microbiological requirement
	Column 5 of Table 1
Excellent>	>= 99%%
Good	>= 98%%
Fair	>= 97%%
Poor	<97%%

Figure 15. SANS 241 Compliance frequency targets in respect of microbiological requirements that have health implications.

A more detailed report for a specific testing day is accessible by selecting view from the calendar view. This brings up a symbol-based report of each parameter tested for indicating the result of the test (Fig. 16) In the cases of a poor or fair test result, a status indicates whether the issue is 'resolved', 'unresolved', or 'no comments'. A brief explanation below each result subtly educates the user on the meaning of the parameters such as E. coli or Turbidity, which may be unfamiliar to many users.

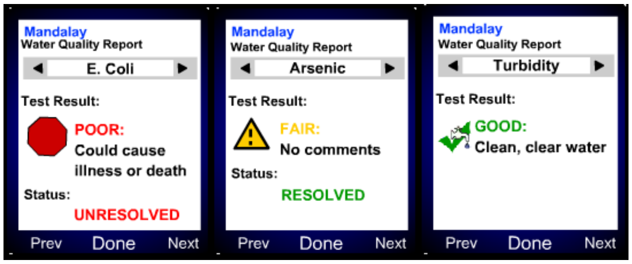

Figure 16. Detailed report of water quality testing for a specific day with explanations of the parameters. This is suitable for advance need users such as nurses.

7. EVALUATION AND INITIAT FINDINGS

We performed a preliminary evaluation to gain an understanding of a much broader question: Can communicating complex water quality information to South African residents through simplified and culturally-appropriate graphical messages increase their understanding and level of engagement with water quality information, and improve Community Perspective on drinking water quality (as required by South African law)? We started out by evaluating five participants.

7.1 Participant Demographics

Our participants included two men and three women, between 18 and 45 years of age. Three participants (sanitation workers) either completed or had some secondary-level education, while the other two participants were college students. Two users lived in a formal area in a city, one in a small town and one in a rural area or village. All spoke English and were fluent in one or more languages, the most popular being Afrikaans. All were able (though not required) to read our simple test questions written in English. Additionally, all but one user owned a mobile phone and reported having downloaded applications to it such as MXit and Opera.

Figure 17. Evaluation Session with Participant and Moderator.

7.2 Session Structure

We issued a set of tasks (each followed by a quiz question) for participants to complete using a real paper-based water quality report and then a similar set of tasks and quiz questions to complete using our *WATER Alert!* prototype. Present at the test was the moderator who conducted the study and a timekeeper who tracked the time taken on tasks by the participants. A number of tools were used to collect data – an answer sheet, a voice recorder, a video camera and a stopwatch. Tasks were assigned in random order to prevent bias. The quiz questions were to:

1) Interpret the contaminant that likely caused a set of patients to be sick after drinking tap water;
2) Determine the overall quality of water for a municipality based on the percentage compliance of a set of samples taken over a period of 12 months;
3) Rate a set of parameters (E. Coli, arsenic, turbidity) as excellent, good, fair or poor based on the results reported on a given day;
4) Determine the current water quality for a given area; and
5) Interpret the current warning and advice given (on the *WATER Alert!* application).

7.3 Usability and Understanding

During our evaluation, we kept track of the following quantitative measures: i) task completed, ii) time per task, iii) quiz scores and iv) subjective user responses (ratings)

Overall, based on the quiz scores, three of five users experienced an increase in their level of understanding of water quality information using our prototype, while one experienced neither an increase nor decrease. And the other a decrease. The two that did not experience an increase were both college participants, who received higher scores on the paper-based test than the other participants. It is also important to note that these two participants still recorded high scores for the phone-based test, either the same or slightly lower than their scores on the paper-based test.

We also found that participants completed all tasks using our prototype in less than two-thirds of the time it took them to complete a similar set of tasks using the paper-based water quality report. We recorded four instances of users guessing an answer to a question while using the paper-based report, while only one reported instance of guessing occurred during the phone-based test.

Moreover, all participants were able to correctly interpret the current alert status (safe, caution or unsafe) of the drinking water, the potential danger (e.g. may cause illness) and the advice given (e.g. boil water before drinking). As for usability, we saw that making use of visual metaphors in our prototype design contributed to the effectiveness of the application and empowered users. We saw even our most novice user who did not own a mobile phone navigate through our application with few errors after minimal exposure to it.

In addition to the test scores, we asked users to rate on a scale of 1 (very difficult) to 10 (very easy) how easy it was to understand the information shown in each task. Since most of the participants were new to the rating system, we had to explain how it worked and used a color-coded scale with ratings 1-3 in red, 4-7 in amber and 8-10 in green. This self-analysis helped us to understand whether our participants felt a personal improvement in their understanding of water quality information having used our *WATER Alert!* prototype application. We found the self-reported ratings to be consistent with the results on the test. Overall, participants experienced an improvement in their understanding of water quality information. For Task A and B using the paper-based report, participants reported an average rating of 4.75 and

5.25 consecutively for ease of understanding the water quality information presented. They made comments such as:

> *"It is hard"[P1];"But how must I know what's the meaning of this [E. coli] ...I just choose one, too hard to figure out" [P2]; "I cannot understand this" [P5].*

For Task A and B using our *Water Alert!* Application, the participants reported an average rating of 9.5 and 7 consecutively, an increase over the ratings given for the paper-based tasks. They made comments such as:

> *"It was easy to understand because the report tells me everything what was wrong with water"[P3]; "It wasn't so difficult"[P5].*

7.4 User Perception

Throughout the evaluation, we also made qualitative observations through videos of the evaluation session and by documenting user comments and feedback. The comments we received were all positive.

i) Usefulness and simplicity: All participants commented on how useful and simple our prototype was to use especially in comparison to the paper-based report. They felt it tailored to their specific level of interest in knowing and understanding the water quality in their area.

> *"I like that it just boils down the numbers. I mean I wouldn't care if E. Coli is at 75 or 73, I just want to know can I get it, what's my risk?" [P1].*

ii) Eagerness to use application: All offered positive feedback and were eager to get the *WATER Alert!* application on their phone.

> *"I like the thing that you do here and I would like to have it on my phone to see what maybe if I'm sick today, my tummy is running, is the water okay to drink or what" [P2].*

iii) Usefulness of symbols: Participants found the symbols we used appropriate and understandable.

> *"The pictures are easy to understand" [P1].*

iv) Appropriateness of advice given: One participant spoke about the added benefit of being able to learn purification techniques she could use in case her water is contaminated.

> *"I like the instructions… does not just say your water is unsafe to drink, also says well here's what you can do" [p2].*

8. DISCUSSION

Clearly, the work here is preliminary, with a small user group. Our work is essentially a design exploration but from our experience with existing systems, the *WATER Alert!* application would be an enhancement over the existing paper-based water quality report. It suggests that such an application could help to improve consumers understanding of water quality in their area and correct misperceptions.

A key area for emphasis is in designing such an application for a diverse user group (in terms of literacy levels and area of residence (rural vs urban, low-income). Previous work on alert notification systems tends to assume user homogeneity. Our application reveals consumer interest in receiving water quality alert notifications and accessing test reports, albeit of varying degrees. This necessitates attention to the different needs of target users.

In our interviews, we found that those most concerned with getting frequent water quality notifications were consumers in low-income informal areas for whom access to safe drinking water is an ongoing cause of concern. They were also more willing to absorb the costs to use such as system if necessary (such as the cost of a call or text message to request information if necessary). Our participants in formal areas, associated with higher levels of economic status, though interested in having access to water quality information, did not want it as frequently nor were willing to pay for such a service.

Initially we perceived *WATER Alert!* as a one-way notification system but during our exploration found that users (specifically those in low-income informal areas) would like the ability to communicate with WSPs when concerns arise or to get more information following an alert notification, such as when the water service will resume following suspension due to a failed test. It would be interesting to observe the types of discussions that go on given this feedback loop. Are consumer requiring more of WSPs in terms of testing? Is trust between WSPs and consumers improving as a result of a direct channel of communication?

9. CONCLUSION AND FUTURE WORK

We described the user-centered design of a prototype alert notification and reporting application for disseminating water quality information to South African consumers. This work builds on the small body of knowledge in the area of water quality management and citizen involvement through ICTs. We hope to expand our research into more rural areas with the aim of developing a framework Water Service Providers could use to disseminate water quality information to consumers.

For instance, the set of symbol-based messages developed for users in Cape Town, an urban city, may not be relevant to users in more rural parts of the country. Hence tailoring content to suit local context is important.

Though a major concern for our project was ensuring accessibility to illiterate and low-literate users, which resulted in us evaluating text-free versions of our messages with users prior to including them in the final prototype, we did not specifically evaluate these messages with low literate or illiterate users, a limitation we hope to address in the future.

Additionally, future research could look at even more opportunities to allow for citizens to be involved in water management, such as providing a feedback loop for citizens to report concerns or request a particular action be taken based on water quality observations or patterns for instance. Consumers take risk when they drink water, so a good consumer-supplier relationship is necessary to trust building and enabling suppliers to maintain good-quality water [11]. Allowing consumers to provide feedback to WSPs about water quality helps suppliers to satisfy their legal obligation to provide safe drinking water.

The ability to issue alert notifications in real-time is key to improving mitigation efforts and reducing the number of deaths and illnesses associated with drinking contaminated water. Existing methods such as posting fliers and relying on the media are insufficient and Water Service Providers should consider the potential use of ICTs in disseminating critical information faster and tailored to the specific needs of users based on different parameters such as location, level of interest, literacy level and specific needs, a limitation of existing practices. Additionally,

Our next steps are to develop more symbol-based messages, specific to the area where tests will be conducted (rural vs. urban) and implement a functional version of the *WATER Alert!* application for the purposes of a formal evaluation. Our end goal is to integrate the application with a mobile phone-based data collection platform and low-cost test kit as in [29], to allow for the real-time dissemination of water quality test information to consumers from the point of collection.

10. ACKNOWLEDGMENTS

Many thanks to Dr. Chance Glenn and Dr. Anne Haake for their guidance and support and to Dr. Rebecca E. Grinter, Indrani Medhi and Melissa Loudon for their valuable feedback during the writing of this paper. This project falls under the Bill and Melinda Gates Foundation funded Aquatest Project.

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