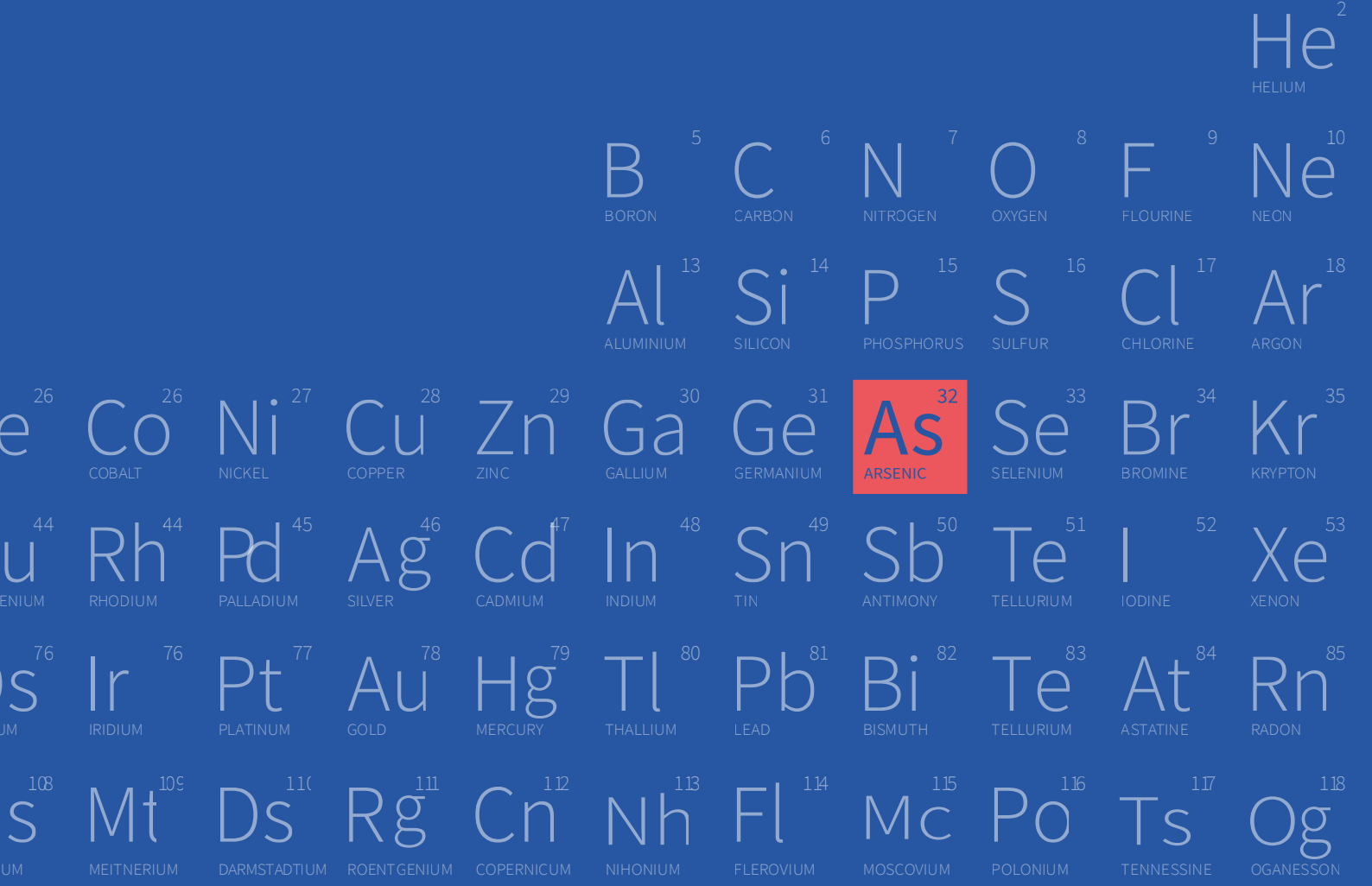

A digital intervention to test water quality in Bangladesh

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Master thesis | Design for interaction

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Preface

The report is the final report for the Design for Interaction graduation program of Cheng Guo, showing the process and outcomes of the design of the water quality monitoring part of TAPP, which is a digital intervention to test the water quality test in Bangladesh.

I would like to thank my supervisory team, Jan Carel Diehl and Gert Pasman, from TU Delft IDE, Annemarie Mink from TU Delft CiTG, Bilqis Amin Hoque from EPRC, Bangladesh. I could not finish the project alone without their critical advice, valuable inputs, and warm supports.

Thanks to Nayantara from TU Delft IDE, responsible for designing the TAPP project's educational package, it is nice to have her as a teammate. Thanks to the help of Maruf Hossain, the project programmer, and Sohel Ahmed from EPRC.

Thanks to all the participants that have joined the research and helped me to improve my work.

Finally, thanks to all my family members and friends who always love me and support me.

With the Covid-19, 2020 is a challenging year for most people, thanks to all the people who fought against the virus. I wish the world love, health, and peace.

Summary

The Graduation project is part of the research project TAPP-BDP, which is a NWO-funded joint project of TU Delft faculties of CiTG and IDE in collaboration with the Environment and Population Research Centre (EPRC), a multi-disciplinary research, education, training, and networking non-government and not-for-profit organization in Bangladesh.

The project is about developing the TAPP-BDP application, an android application that will be launched in the Bangladesh market, aiming at improving the operation and maintenance of piped water supply (PWS) systems in the Peri-urban areas near the Ganges-Brahmaputra-Meghna Delta in Bangladesh.

The graduation project addressed three design questions.

1, In which ways can a digital intervention assist the local operator in testing water quality and in monitoring the water supply system?

2, In which ways can a smartphone app enable households to engage in the monitoring, operation, and maintenance process of their own piped water supply systems?

3, How would a monitoring model and maintenance process work for the PWS system after implementing the TAPP application and field test methods?

The final deliverables of the project included the water quality monitoring part of the TAPP operator application that simplifies the test process and enables local operators to arrange water quality tests. The deliverables also includes the water quality monitoring part of the TAPP customer application that builds a communication channel for local households to engage in the monitoring process. At last, a standard monitor model and maintenance process were also created for improving the efficiency of the monitor and maintenance process.

Due to the COVID-19 outbreak it was not possible to visit Bangladesh and gather contextual information first hand. Instead, the contextual information presented in the report comes from discussions with prof. B.A. Hoque (EPRC Bangladesh), Mr. S. Ahmed (EPRC Bangladesh) and Dr. A. Mink (TU Delft). They have been working on the NWO-funded DELTAP research project, which led to the NWO-funded follow-up project TAPP-BDP of which this graduation project is part. Prof. Hoque and Mr. Ahmed have extensive experience with managing and implementing WASH projects in different Bangladeshi regions. In collaboration with EPRC, Dr. Mink conducted extensive fieldwork and organized several stakeholder workshops for the DELTAP project in August 2017, November 2017, July 2018 and November 2018.

Abbreveation

PWS system	Piped water supply system
DPHE	Department of Public Health Engineering, People's republic of Bangladesh
EPRC	Environment and Population Research Centre
NWO	Dutch Research Council
MC	Mobile Crowdsensing
MCP	Mobile crowd participation
AAS	Atomic Absorption Spectrophotometer
AS	Arsenic
Mn	Manganese
Fe	Iron
Cl	Chlorine
EC	Electronic conductivity
P/A	Presence / Absence
MPN	Most Probable Number
E.Coli	Escherichia coli

Index

Chapter 1
Introduction

Bangladesh is a South Asian country that faces severe groundwater contamination problems. To provide local Bangladeshi households with access to safe drinking water, piped water supply (PWS) systems were installed in Bangladesh urban areas, and also in part of the rural areas. However, in the rural areas some PWS systems fail to fulfil their tasks.

This chapter will introduce the current problems with the PWS systems and how two NWO funded research projects plan to improve them. This graduation project is part of these two research projects, aiming to improve the monitoring and operation & maintenance of the PWS system by solving three design questions raised at the end of this chapter. A summary of the design process is also presented in this chapter, explaining how the project comes to three concepts to address the three design problems.

Figure 1. A Bangladeshi local household used water from a tube well. (Picture by A. Mink, 2018)

1.1 Bangladesh & groundwater contamination

About Bangladesh

Bangladesh is a South Asia country with 161 million people in a landmass of 147,750 km2 and ranked the eighth most-populated country (World Bank, 2018; MoEF, 2012). Islam is the state religion of Bangladesh, as 88.4% of its population is Muslim (BBoS, 2018). Bangladesh is using Bangla as its official language (MoFA, n.d.).

Bangladesh (figure 2) is surrounded by India in its West, North, and East, while on its south is the Bay of Bengal, the largest bay in the world (NGS, 2013, MoFA, n.d.). Bangladesh is part of the Ganges-Brahmaputra-Meghna (GBM) Delta, where the high population density and fertile soil brought livelihood opportunities, while flooding, erosion, cyclones, salinisation, waterlogging, etc. brought challenges to the socio-economic position of the country (Rahman, 2020).

Figure 2, Bangladesh map (Picture by geology.com, n.d.)

Bangladesh has a rising literacy rate, but still, a quarter of its population is illiterate. According to UNESCO Institute for Statistics (UIS) (2018), in 2018, for Bangladesh's population aged 15 years and older, the literacy rate is 73.19% (male: 76.67%, female: 71.18%), while in 2007, the literacy rate is only 46.66%.

In the Bangladesh education system, class 0-8 is the primary education level (The Daily Star, 2016). After class 5's study, students are able to perform reading and writing tasks in daily life (Annaduzzaman, 2020). Secondary School Certificate (SSC) and Higher Secondary Certificate (HSC) are the certifications for class 10 and 12 students. After the SSC and HSC level, students could continue university study (Infos-arena, 2020).

There is a higher literacy rate with Bangladeshi young people. For the population aged 15-24, the literacy rate is 93.3%, while for the elderly generation aged above 65, the literacy level is 40.12% (UIS, 2018). **There is a lower literacy rate in Bangladeshi rural areas compared to urban areas.** In 2017, the literacy rate of the population aged 15 years and older in the rural area is 66.1%, while in the urban areas, this rate increased to 81.1% (BBoS 2018). In 2020, up to 61.4% of its population will live in rural areas (UN, 2018).

The country still faces vast poverty problems and severe problems with their drinking water. 21.8% of its population lives below the national poverty line in 2018 (ADB, 2020). In 2017, only 55.4% of Bangladeshi people have access to safely managed drinking water service (ADB, 2020). **This problem is caused by chemical contamination in the groundwater.**

Groundwater contamination in Bangladesh

Groundwater contamination in Bangladesh
In the 1970s, Bangladesh installed groundwater tube-wells (figure 3) to supply groundwater to its people to avoid the possibility of drinking bacterially contaminated surface water. However, after installing the tube-wells, people found the groundwater may contain chemical contaminations like arsenic, manganese, iron, etc. In coastal areas, the water is also highly saline.

The chemical contaminations in the groundwater can cause health and/or taste issues to the local households. Iron contamination is no hazard to health, but may lower the acceptability of drinking water by affecting its taste and appearance (WHO, 2017). Several experiments suggested that soluble manganese is associated with adverse effects on learning in children (WHO, 2017). High-salinity water might associate with the occurrence of hypertension while bringing a taste that would lower the acceptability of the water (WHO, 2017).

The most severe chemical contamination in the groundwater is arsenic contamination, Smith (2000, 78) described the arsenic contamination of Bangladeshi groundwater as the "largest poisoning of a population in history" in the World Health Organization's Bulletin. Arsenic does not affect the taste, smell, and appearance of the water. However, chronic arsenic exposure causes severe health issues, including dermal lesions, damage to the nervous system, and cancer in the lung, skin & bladder (WHO, 2017).

The health of Bangladeshi people got severely affected by groundwater contamination for decades. **To reduce the result of drinking contaminated groundwater, the people in Bangladesh desire safe drinking water options.**

Figure 3, Bangladeshi child pumping water from a private tube well. (Picture by A. Mink, 2018)

1.2 Piped water supply system

Piped water supply (PWS) systems were installed in Bangladeshi rural and peri-urban areas to provide safe water to households by removing groundwater contamination and bacterial contaminations at the central level, and they also meet the desire of households to have running water in their house.

The PWS system operates in the following way. The groundwater is first pumped to the surface and goes through a filtration system to remove chemical contaminations, if present. The cleaned water is stored in a water tower until it is supplied to the households through pipelines. Figure 4 is a visual that demonstrates an example of the PWS system.

Hundreds of PWS systems that supply safe drinking water to hundreds or even thousands of households are installed in Bangladeshi rural areas and peri-urban areas. There are big-scale, medium-scale, and small-scale piped water (SPWS) systems. The SPWS systems are easier to manage as they only supply water to around 100 households.

There are different governing systems of the PWS system. Either a sponsor and an entrepreneur set up the system, and the entrepreneur takes over. Or DPHE installs the system, maintains it for a couple of years, and then the local government or a local NGO takes over. Or an NGO installs the system and maintains it themselves or hands it over to the local government. In most cases, the households connected to the PWS system need to pay an instalment fee and pay monthly for their water usage; they pay either a fixed tariff or for their actual water use. Each system usually has 1-4 operators responsible for the daily operation, some maintenance work, and collecting water fees. Local mechanics are hired for bigger maintenance work and for bigger systems often an accountant is hired for collecting payments.

2,2 SIDKO filter

2,1 Sand filter

The filtration of PWS system might consists of a sand filter to remove iron and dirt, and a SIDKO filter to remove arsenic contamination.

4, Pipeline

The water will supply to the customer through pipelines.

The groundwater is first pumped to the ground surface from tube wells that are already checked for an approved arsenic level.

1, Main pipe supply and ground water pump

The cleaned water will be stored in the water tower until it is supplied to the customer.

3, Water tower

Lastly, households receive water from the tap.

6, Tap

Some households may use households water storage to storage water as the PWS system usually have Intermittent water supply.

5, Households water storage

Figure 4, Example of a PWS system

1.3 Problem definition

The PWS system is an ideal solution to benefit the Bangladeshi households with their desired running tap water, treated on a central level. However, in practice, there are some malfunctions and issues that may cause the system to provide contaminated or insufficient water to households with PWS systems. Some of the contamination risks are shown in Figure 5.

These malfunctions and issues lower the households' trust in PWS systems, resulting in the pipeline water being used for many other purposes, except for drinking. As the tube-wells are still available for the households and the households trust that water better, they continue to use the contaminated groundwater from their hand-pumps as their drinking water. To keep providing safe water to the households, the PWS system needs monitoring and timely maintenance to solve those malfunctions and issues. However, there are some problems that lead to insufficient monitoring and a daly of maintenance work.

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1) **The PWS system lacks sufficient water quality tests for monitoring the system.** Regular testing is generally the task of DPHE, who does not have sufficient resources for regular water quality testing at all PWS systems. Thereby, they conduct laboratory tests, which are expensive and can only be done at specific laboratories in the country.

2) **The households lack engagement in the operation, monitoring, and maintenance of the PWS system.** They are not informed about the operation and maintenance of the PWS system. Their drinking water is not tested regularly and they are not informed about the outcomes. They also do not demand data or knowledge if they are too busy or lack knowledge of the system and of drinking water quality in general.

3) **The PWS systems often lack an efficient monitoring model and operation & maintenance process.** Different factors lead to this problem, including lack of budget, lack of testing, lack of knowledge of the system as well as lack of trust in the local operator and the system's water quality.

The PWS system needs to have proper operation & maintenance and regular monitoring, to supply safe water to Bangladeshi households, and, by that means, restoring the households' trust with the pipeline water and switching the households from drinking contaminated groundwater to drinking safe pipeline water.

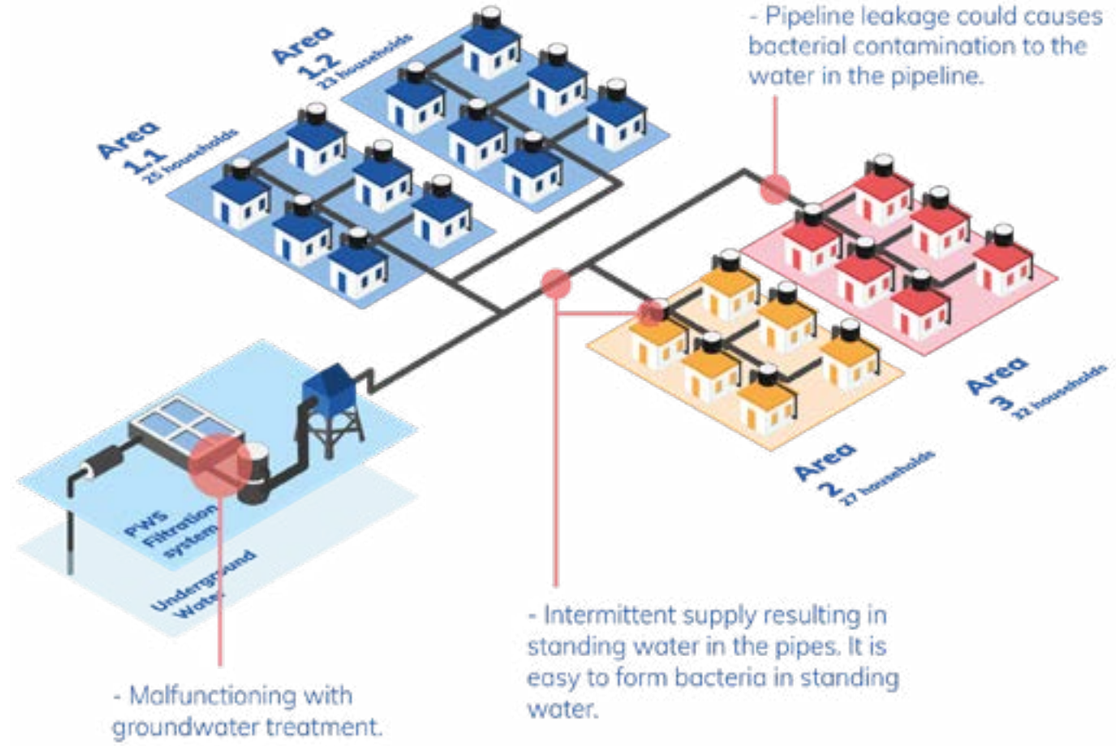


Figure 5, Malfunctions and Issues with PWS system

1.4 Solutions: DELTAP project and TAPP-BDP project

DELTAP project

The DELTAP project (2016-2020) is an NWO (Dutch Research Council) funded research project aiming to reduce arsenic contaminant exposure of drinking water for households in India and Bangladesh. The DELTAP project introduced Mobile Crowd Participation (MCP) approach as one of the solutions to solve the 3 main problems of the monitoring and operation & maintenance of the PWS system. MCP is the engagement and participation of end-users through smartphone applications.

MCP (figure 6) is derived by dr. ir. Doris van Halem from 'Mobile Crowd Sensing / Sourcing (MCS)' which means data collection from a large number of mobile sensing devices such as smartphones. Compared to MCS, MCP not only collects data but also shares data from the database to the local stakeholders, and stimulates information sharing between all stakeholders. MCP engages local stakeholders to participate in the monitoring of the PWS system by building an interactive channel through which local households receive water quality information, can request servicing, can pay their water bills, can interact with each other, can upload water quality test results, and request for water quality testing.

MCP could help with the monitoring of the PWS system. Local PWS system operators could use MCP in combination with water quality field tests to provide low-cost monitoring and to assist in operation and maintenance for the PWS system (Mink et. al., 2019). Furthermore, MCP helps to organise customer service. MCP could provide local households access to receive water quality information, knowledge of water quality, service, payment and a water communication channel. Thereby, it can stimulate the local households to engage and participate in the monitoring and operation & maintenance of their own PWS system.

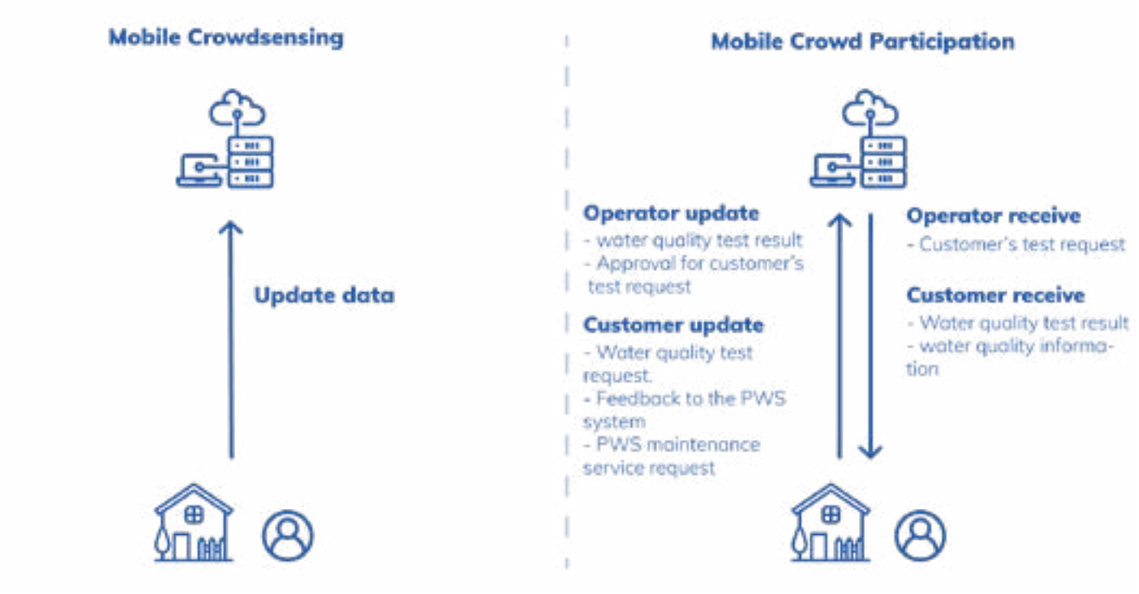


Figure 6, Mobile Crowdsensing and Mobile Crowd Participation

A mock-up smartphone application for MCP in PWS projects has been developed. It is a water supply application called TAPP.

TAPP-BDP project

TAPP-BDP project is also an NWO-funded project, aiming at the full design and programming of the TAPP application. It is a follow-up project of the DELTAP project. Based on the DELTAP research, TAPPs functions have been finalised to include service delivery, an educational package, interaction, payment, and water quality testing (Mink, 2020, -a). Within the TAPP-BDP project two smartphone apps will be developed; one for the opertor and one for the consumer, as well as a web-based admin panel connected to a server. TAPP-BDP will also help launch the TAPP application to the Bangladeshi market to enable efficient monitoring and maintenance of the PWS system.

Before launching in the Bangladeshi market and testing in the field, the TAPP application prototype requires design and development which is the responsibility of the TAPP development team.

TAPP development team

There are different organizations involved in the design and development of the TAPP app. The Environment and Population Research Centre (EPRC) is a multi-disciplinary research, education, training, networking non-government, and not-for-profit organization in Bangladesh, established in 1998 (EPRC, n.d.). EPRC is the leading institution of the TAPP-BDP project and coordinates collaboration with TU Delft and local partners (MAX Foundation, Dhaka University, HYSAWA) (TAPP-BDP group. 2019).

From EPRC, Prof. Engr. Bilqis Amin Hoque is the project leader of the TAPP project. Mr. Sohel Ahmed is the project officer. From TU Delft, Dr. ir. Doris van Halem is the project lead of the DELTAP and TAPP-BDP project, Dr. ir. J.C Diehl is the supervisor of the designing of the TAPP application. Dr. ir. Annemarie Mink joined the project as a postdoctoral researcher and design lead.

Nayantara Thomas, a Design for Interaction master student from TU Delft, joined the team for her MSc graduation project at the faculty of Industrial Design Engineering, responsible for designing the water knowledge part of the TAPP app. Maruf Hossain works in the TAPP team as an external programmer responsible for the app and database programming.

This MSc graduation project will further design and develop the water quality part of the TAPP app, aiming at solving the problems with the monitoring and maintenance of the PWS system using the MCP method. The water quality monitoring part of the TAPP app could assist the local stakeholders in engaging in the monitoring of the PWS in the following way: 1, Measure chemical contamination concentration with a smartphone camera in combination with inexpensive strip test kits, 2, record the field test result and send the water quality information to the database, the opertor and the households. 3, Enable households to engage in the monitoring of the PWS system by requesting water quality tests and receiving test results.

1.5 Design question & research sub-question

For designing the TAPP app to improve the monitoring and maintenance of the PWS system, 3 design questions are raised. For each design question, research sub-questions are initiated to assist in addressing the design questions. Design questions & research sub-questions:

1, In which ways can a digital intervention assist the local operator in testing water quality and in monitoring the water supply system?
- What difficulties would a local operator have with testing water quality with TAPP?
- What should be done in order to ensure the reliability of the test result?
- In which way would they love to interact with smartphone applications?

2, In which ways can a smartphone app enable households to engage in the monitoring, operation, and maintenance process of their own piped water supply systems?
- What information do they want to share & receive via the smartphone?
- In which way would they love to obtain information related to water quality?

3, How would a monitoring model and maintenance process work for the PWS system after implementing the TAPP application and field test methods?
- What are the key characteristics of a monitoring and maintenance model for piped water supply systems, which is based on mobile crowd participation?
- How to maintain the PWS system according to the PWS status?

These design questions and research sub-questions will guide the research and design work of this MSc graduation project presented in this thesis.

1.6 Design process

Bangladesh PWS systems and their problems in monitoring and maintenance are introduced in chapter 1. The Current water quality research methods and the future water quality research methods suggested by the DELTAP project will be presented in chapter 2, followed by an analysis of strip tests and other field test methods, together with the AKVO technology in chapter 3. Chapter 4 focuses on researching the impact of Bangladeshi households' literacy level and their smartphone usage on the development of a smartphone application.

After the research phase, three design tasks and the design requirements for design questions one & two are concluded in chapter 5, based on the research in the previous chapters. Design guidelines for smartphone application design are presented in Appendix D. Chapter 6-8 comprises the design phase. Chapter 6 presents the first ideation of the TAPP operator application, and the TAPP customer application is presented. The ideas are evaluated, and the chosen ideas are developed into concepts. The application concepts are evaluated and iterated in chapter 7. The final design of the TAPP applications addresses design questions 1 & 2. In chapter 8, a new PWS system's monitoring model and maintenance process is designed to answer design question 3.

Chapter 9 concludes the project and gives some future recommendations for developing the TAPP application and the monitoring & maintaining model of the PWS system.

Figure 7 visualises the design process and the structure of the report. The project consists of two phases: the research phase (chapter 2-4) and the design phase (chapter 6-8).

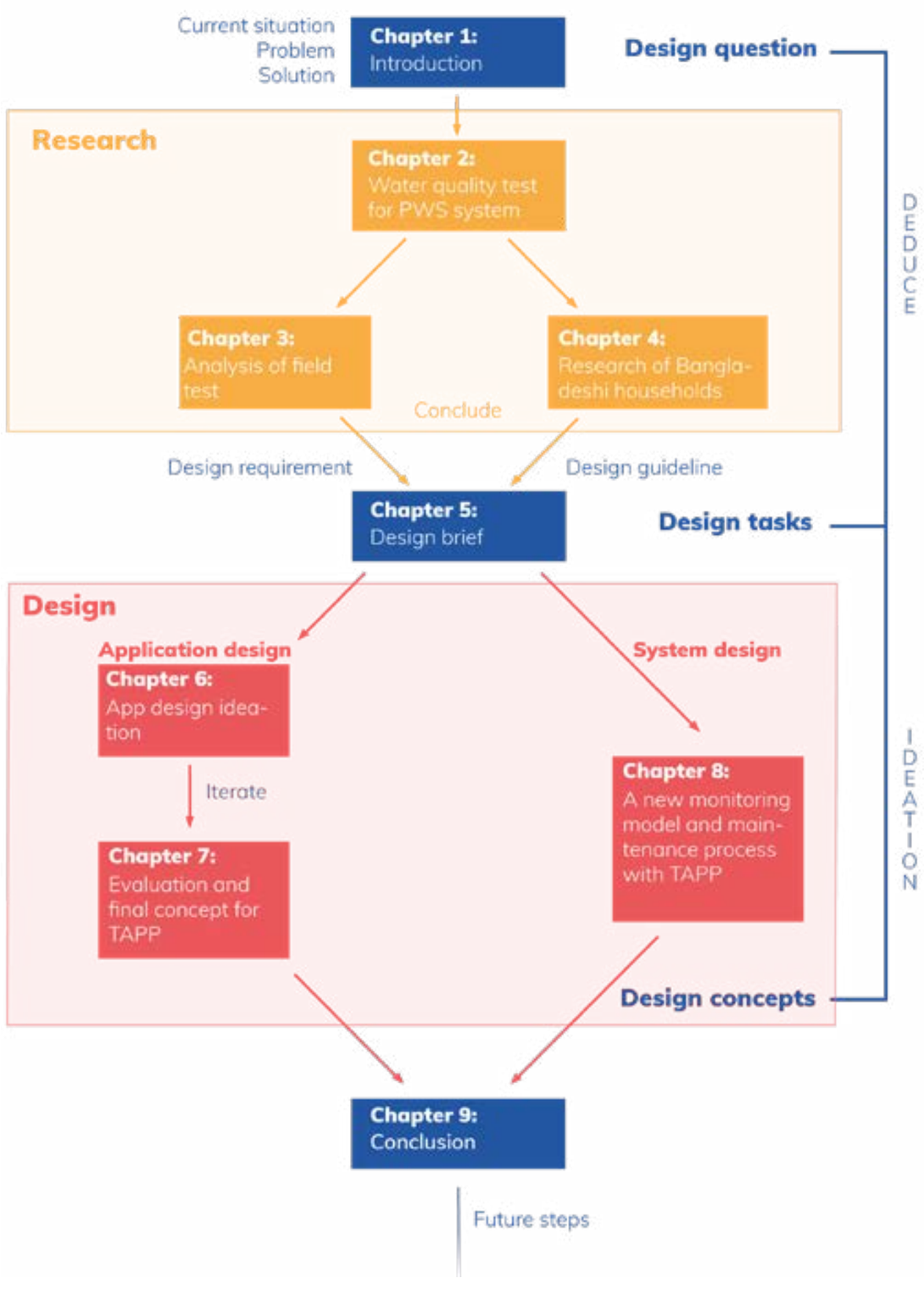


Figure 7, design process and the structure of the report.

Summary on chapter 1

Chapter 1 introduced Bangladesh and its groundwater contamination problem. The PWS systems were built in Bangladesh to remove chemical contaminants and provide safe drinking water. However, there are still problems with the PWS system. The DELTAP project and TAPP project are working on solving these problems. One of their methods is using an application called TAPP. This project will design the water quality part of TAPP. The design question and the design process is presented at the end of chapter 1.

Next step

Aiming at solving the monitoring problem with Bangladesh PWS systems, the current water quality test methods will be analysed. After that, a new test plan given by the TAPP project group is introduced.

Chapter 2
Water quality test for PWS system

In the Bangladeshi PWS system, water quality testing is currently not sufficiently executed for monitoring its water quality. Therefore, a new plan of supporting water quality testing was created by the DELTAP project team. In this new plan, chemical strip tests and AKVO technology are used to give a low-cost, quick, and reliable indication of the chemical contamination in the sample water.

This chapter will provide an introduction to the status quo of the water quality test methods in Bangladesh, together with an introduction of chemical strip tests and AKVO technology

2.1 Current water quality test in Bangladesh

There are two water quality test methods that are used in Bangladesh now, water quality lab tests that are done in the laboratories by using advanced equipment and water quality field tests which are done by the testers at the field with portable test kits.

Water quality laboratory test

The water quality laboratory tests (lab tests) are quantitative test methods to research the water quality. It gives an accurate result to indicate the quantity of the substance in sample water, using different lab testing equipment.

In the DPHE laboratory, Atomic Absorption Spectrophotometer (AAS) is used to test the most chemical contaminations, including Iron, Manganese, Arsenic, etc. AAS (figure 8) detects substances in sample water by applying characteristic wavelengths of electromagnetic radiation from a light source (TFC, n.d.). The AAS determines the quantity of only one element at a time and can provide complete results for each sample in minutes (UseScience, n.d.-a). Bacteriological 'colony count' can be performed to detect bacteria contaminations and also Most Probable Number(MPN) tests, which make use of incubators and/or UV Light.

Water quality tests give a relatively accurate indication of sample water quality. But in practice, there are limitations to arranging lab tests. Firstly, lab tests are effort-costly as there are only 14 labs in in Bangladesh. The water sample needs to be collected and shipped to the testing lab to arrange a lab test. However, the DPHE, which is responsible for the water quality tests, does not have sufficient resources to arrange enough lab tests for all water supply systems.

Secondly, the accuracy of lab tests comes at a high cost. The cost of using AAS to test chemical contaminations at the DPHE lab is 3-4.5 euro (300-450 BDT) per contaminant. This cost does not include the cost of sampling, which involves water containers, time and transportation. A lab test at commercial labs can cost 60 - 100 euros (6000 – 10,000 BDT) per test per parameter. Insufficient budget brings another difficulty to arrange sufficient lab tests. Due to the high cost, and required human effort, lab tests are not arranged regularly to determine the water quality of PWS systems.

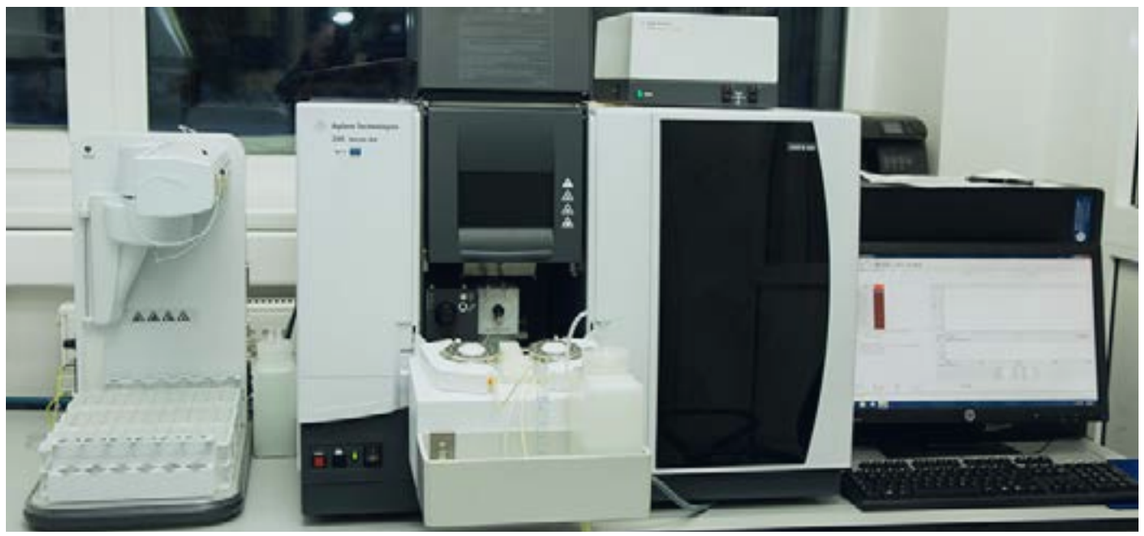


Figure 8, An Atomic Absorption Spectrophotometer instrument (Picture by UseScience, n.d.)

Water quality field test

To investigate water quality in the field, also water quality field tests can be used. These tests are executed by trained testers with test kits for different parameters. Field tests are semi-quantitative tests that do not measure the precise quantity of a substance but give an estimation of the range of the detected substance's presence (Sekisui, 2019). Field tests are more prone to human errors, including misuse, test accidents, and inaccurate interpretation of test results, which influences the accuracy of the test result. Currently, most NGOs in Bangladesh use field test kits (mostly strip tests or colour disk kits), hand-held digital instruments (such as multi-meters), and different bacteriological test kits (for presence/absence, most probable number, or colony count) to test water quality in the field.

Field test kits

NGOs working in Bangladesh, such as UNICEF, MAX Foundation and HYSAWA are using field test kits to test for chemical contaminations (Figure 9). Sometimes NGOs organize water quality test campaigns. But testers need proper training before executing field tests with field test kits. Also Due to constraints in time and budget, field testing is not performed regularly by NGOs.

Another type of field test is the strip test. This test is for most parameters cheaper to execute, available in smaller quantities (therefore requiring less capital investment to start testing), and easy to use (less training required). A more detailed explanation of the strip test is provided in chapter 2.2.

Multi-meter test

A multi-meter can measure pH, temperature, turbidity, electrical conductivity, etc (figure 10). The electrical conductivity and turbidity give an indication of the salinity and dirt in the water. Testing pH and temperature of the sample water is always an essential step for field tests, as they might influence the outcome. After the first calibration, to test a particular parameter, the tester first dips the multi-meter's sensor into the sample water and then presses the button for that parameter. After receiving a stabilised test result on the screen, the tester records the test result manually.

Figure 9, HACH field test kit for iron. (Picture by HACH, n.d.)

Figure 10, Testing sample water with a multi-meter. (Picture by opticsandlab, n.d.)

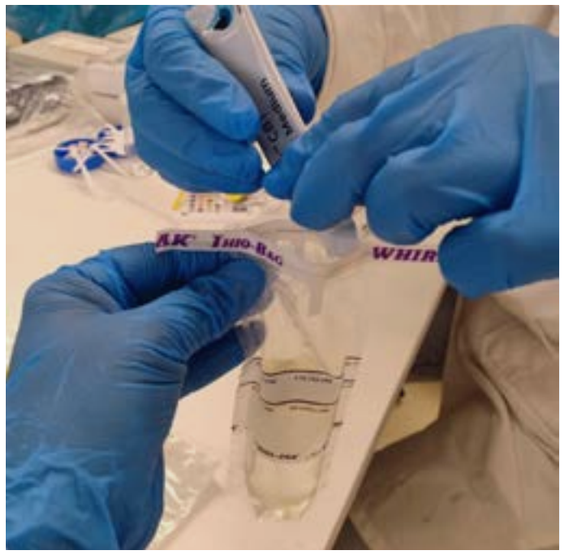


Figure 11, Execurting bacterialogical field tests

Bacteriological test

The bacteriological field test is mainly used to determine the presence/absence (P/A) or the Most Probable Number (MPN) of the bacteria in the sample water (figure 11). Bacteriological tests give an important indication of the sanitation of the sample water and the PWS system. Chlorine inactivates bacteria and protects the water from bacterial re-contamination (WHO, n.d.). Usually, the bacteriological field test will first test the free and total chlorine in the sample water. If there is no chlorine in the water, the water is not protected from bacterial contamination. The tester will test the E.Coli in water with bacteriological field test kits to provide an indication for its bacterial contamination, as E.Coli is perceived as a good indicator for signalling faecal pollution of water (WHO & UNICEF, 2012).

Comparison of lab tests and field tests

In comparison, field tests are semi-quantitative tests that cost less time, money, and human effort than lab tests. On the other hand, lab tests are quantitative tests, costing more money and human effort, but providing accurate results. Table 1 shows a comparison of testing chemical contaminations with field tests and laboratory tests.

	Field test	laboratory test
Test methods	Field test kit	Atomic absorption spectrophotometry (AAS)
Type of test	**Semi-quantitative test** estimate the quantity	**Quantitative test** measure the precise quantity
Accuracy	Give reliable result, need to avoid tester's human error	Give the most accurate result
Cost of time	15-45 min	3-5 days for shipping 1-2 min testing
Cost of money	0,5-3 Euro (50-300 BDT) per parameter per test	3-4.5 eurp (300-450 BDT) per parameter per test + shipping cost and sample container cost
Skill	Needs adequate skills	Needs professional skills

Table 1, Comparison between field tests and lab tests with testing chemical contaminations.

2.2 Field test and TAPP: methods for monitoring PWS system

The DELTAP project planned to introduce chemical strip tests in combination with the TAPP application as field test methods to test the chemical contamination with the PWS system, as the strip test is an easy to conduct chemical test which can be combined with a specific smartphone application technology from the Dutch company AKVO that provides an objective reading result for the strip test (for details on the AKVO technology see chapter 3.1). In this chapter the strip test will be further explained.

Chemical strip tests

Compared to field test kits, the strip test kits would be more fit for testing chemical contaminations in the Bangladeshi field as they are easier to learn and can be purchased in smaller quantities. More operators with sufficient training could execute chemical strip tests and give a relatively accurate water quality test result to monitor the PWS system. The Chemical strip test kits could test the existence of different chemical parameters in sample water. It gives a reliable indication of the sample water's chemical contamination level within a 3-20 min' test.

A strip test kit usually consists of containers, reagents, manual, and strips with a patch (figure 12, 13).

Compared to colour disc test kits, the strip test kit would be more fit for testing chemical contaminations in the Bangladeshi field as they are easier to learn and can be purchased in smaller quantities. This would also mean that operators of PWS systems can be trained to execute this chemical strip tests which opens up the possibility for regular monitoring. Thereby, these strip testsprovide a range for the level of contamination, quite similar to the colour disc method.

Figure 12, Chemical strip test kit((Picture by Macherey-Nagel, n.d.)

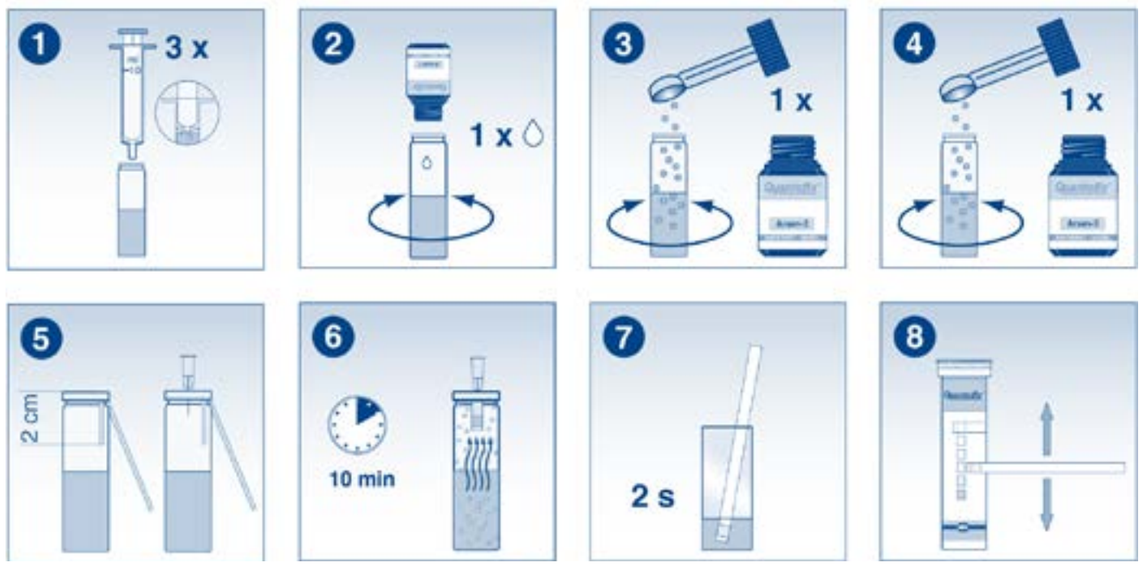


Figure 13, A visual guidance of the Quantofix Arsenic 10 test kit

The chemical strip test is usually performed by dipping a strip into the sample, sometimes after adding some reagents, and then comparing the discolouration of the patch with the provided colour scale on the strip bottle to find a reading. Figure 14 shows the process of executing a HACH IRON test. A video of testing with HACH iron strip test kit can be found at: https://www.youtube.com/watch?v=hpTLaqdCzAQ&t=23s.

Figure 14, steps of doing HACH IRON test

bacteriological tests

There are many different bacteriological tests, ranging from Presence / Absence (P/A) testing, Most Probable Number (MPN), and Colony Count (CC). P/A testing only results in determining whether certain bacteria are present or absent, and not about the quantity. MPN testing results in a semi-quantitative analysis of bacterial contamination but often requires UV Light and / or incubation of the sample. It also requires a certain amount of training. CC testing gives an accurate count of the bacterial contamination, often of different bacteria simultaneously, and requires incubation / UV light / cold storage of the test, costly equipment, and extensive training and hygienic working circumstances.

When setting the following requirements, only a limited amount of tests remain:
- PWS operator should be able to execute the test with a limited amount of training
- The possibilities for contamination of the sample should be limited
- No costly equipment should be required
- Cold storage is no option
- Cost should be as low as possible

These are the H2S P/A test, The CHROMagar P/A test, the Whirlpak MPN test of mWater, the Compartmentalized Bag MPN-test of Aquagenx, and the compact dry E.Coli CC test and Charm Sciences Peelplate. The MPN tests are the most expensive but easiest to conduct in field circumstances. The Compact Dry EC plate is much cheaper but requires more training, hygienic circumstances, and specialized equipment. P/A tests are relatively cheap and can provide a good indication.

As most PWS systems in Bangladesh use chlorination to remove microbial contamination, the easiest option is to use a chlorine strip test to see if sufficient chlorine is left in the water to prevent bacteria from growing. This test is quicker than a P/A test. If insufficient chlorine is left, an MPN test might come in useful if the further specification of the number of bacteria is required to adjust the chlorination dosing.

TAPP

Besides introducing chemical strip tests, the DELTAP project will also introduce the TAPP application to assist water quality field tests as the TAPP application could improve the accuracy of the strip test results and manage field test results.

TAPP assists in managing test data by collecting field test results and information with a survey. It also enables collecting photos of the test strip together with the colour scale to back up the original test result for checking. Moreover, it introduces distant monitoring by DPHE, NGOs and other organizations, as the strip test results and the back-up picture will be uploaded to a database.

Using TAPP could also improve the accuracy of the field test result. First, TAPP could provide guidance to the field tester during field tests to execute the test correctly. Secondly, TAPP will use a strip reading technology developed by a Dutch company, AKVO, to give an objective reading result to the strip with smartphone camera and an AKVO reference card (figure 15). An objective reading result of the test strip could validate the tester's subjective reading result, which might slightly vary by different testers. Testers could also use the objective reading result as a reference when they decide on the final test result. Lastly, this function is specially designed for dealing with different situations in the field. More detailed information on the AKVO technology is provided in chapter 3.1.

Figure 15, Give objective reading results (Picture by AKVO n.d.)

A plan for testing chemical contamination

To conclude, the DELFTAP project decided to use chemical strip tests together with multi-meter tests and bacteriological tests to involve more PWS system operators in doing water quality tests, enabling regular water quality testing and efficient monitoring to the PWS system. TAPP applications will assist water quality field tests in three ways, 1, guiding test procedure, 2, collecting test data. 3, Give objective strip reading results.

Different chemical strip test kits have been selected by Annemarie after validating the accuracy of the strip test result. The function of assisting water quality field test is in the water quality monitoring part of the TAPP, which will be designed in this project. More research about field test procedures and the AKVO technology is arranged to find insights for designing the TAPP application. This research is shown in chapter 3.

Summary on chapter 2

In chapter 2, the current water quality methods in Bangladeshi is introduced. These methods include water quality laboratory tests and water quality field tests. One reason the current field test has not been done regularly is that it is difficult to learn by more people.

To enable more water quality field tests and regular monitoring of the PWS system. The DELFTAP project team decided to introduce water quality strip tests, which are easy to learn as chemical contamination field test methods. The DELTAP project team also plans to use TAPP to manage test data and improve the accuracy of the test result.

Next step

To design the water quality monitoring part of the TAPP, an analysis of the field test and the AKVO technology will be done and shown in chapter 3.

Chapter 3
Analysis of field test

After having a basic understanding of the water quality test methods, this chapter will further research testers' experience and difficulties with performing field tests and using AKVO technology.

The goal of analysing the field test kits and the AKVO technology is to address the research-sub question for design question 1, What difficulties would a local operator have with testing water quality with TAPP?

3.1 Analysis of AKVO technology

The AKVO technology will be implemented in the TAPP application to give an objective reading result of the test strip with the following steps.

1, Calibrate the smart phone camera with AKVO reference card.
2, Execute the test
3, Use the smartphone camera and the AKVO reference card to read the strip, get an objective reading result.
4, Submit the result.

Figure 16 shows how AKVO technology helps the testers execute the test by reading test strips, collecting, and uploading test data. The objective reading result given by AKVO technology has been proved to be accurate in most lighting conditions (van Oorschot, 2017). On the other hand, according to Mink (2020), AKVO technology may bring the following difficulties to the test process in some cases.

The AKVO technology has difficulties with reading test strips in unideal lighting conditions.
When the lighting conditions are not ideal (too sunny, too cloudy, or when the dusk sets in), the test strip reading is difficult, and the app sometimes even fails to give a result. This difficulty might also influence the objective reading result. Suppose it takes too long to calibrate or read results in an unideal lighting condition, in that case, the discolouration on the patch might change, thus influencing the objective reading result given by the application. It is therefore best to perform the tests between dawn and dusk and to perform the task in the shade between 12pm and 2pm - when the sun is at her highest point.

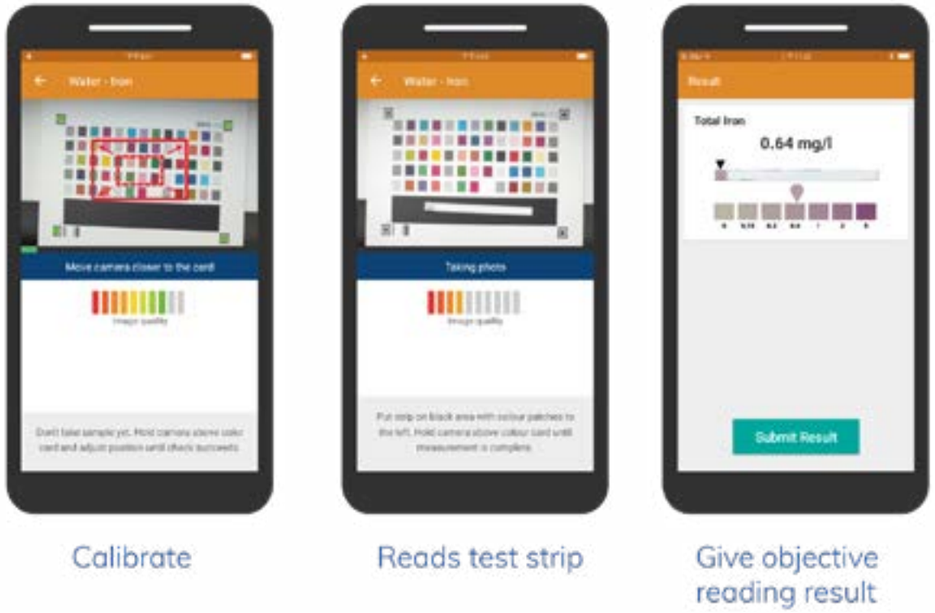


Figure 16, AKVO technology with giving objective reading results.

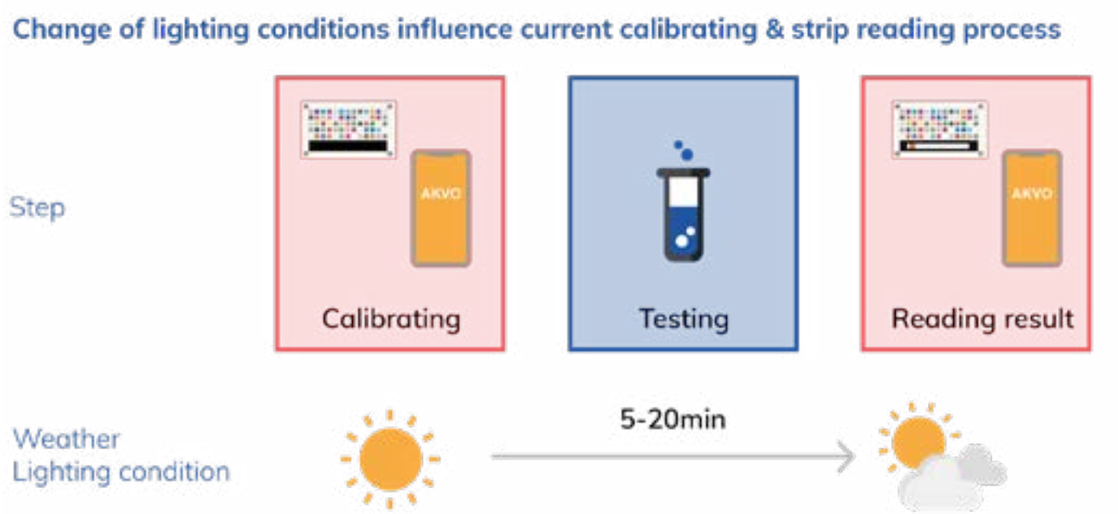


Figure 17, A scenario of how lighting conditions might change during the test and influence the application calibration & reading test strip.

Current app calibrating process might influence the reading result

Currently, the tester will first calibrate the smartphone camera with the reference card, then executes the test and reads the test strip. However, a strip test can take up to 20 minutes, and if the lighting conditions change during the strip test execution. (Figure 17). Different lighting conditions during the calibrating and reading influence the objective reading result.

The TAPP development team decided to change the order of the calibration step to minimize the change of lighting conditions during calibration and reading strip. When using TAPP, testers will first execute the test, then calibrate the camera and read the test result (Figure 18). The calibration and reading steps should not take longer than 5 minutes, in order for the patch not to dry out and change colour (van Oorschot, 2017).

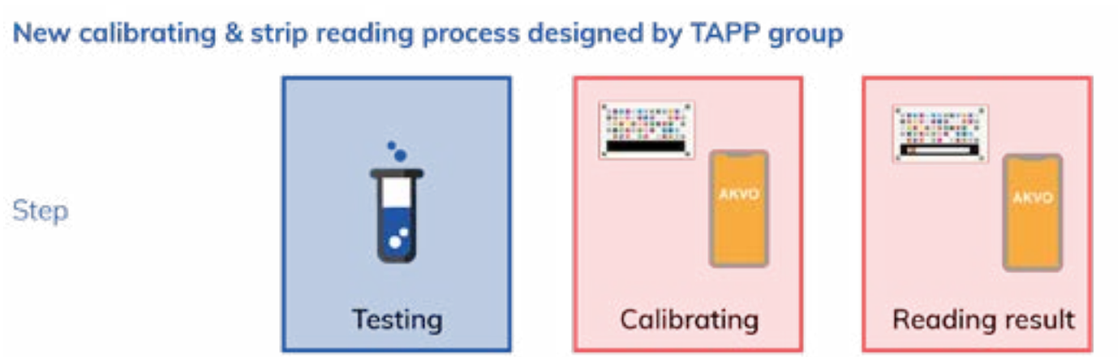


Figure 18, New calibrating & reading process designed by TAPP development team.

Figure 19, Nayantara & Cheng doing bacteriological tests (Picture by A. Mink, 2020).

3.2 Evaluation of test kit

To understand the process of doing water quality field tests, to find difficulties and challenges with the field tests process, the TAPP design team (Annemarie, Nayantara, and Cheng) experienced the test kits used in the Bangladeshi field at the water Laboratory, TU Delft, faculty of Civil Engineering and Geosciences.

Research methods

The following test kits will be used in Bangladesh, for the TAPP project:

1, Multi-meter test:
- EZ-9908 TDS/PH/EC/Temperature 4 in 1multimeter.

2, Bacteriological test:
- E.Coli Compartmentalized Bag Test(CBT) EC+TC MPN kit from AquagenX.
- PathoGel test kits from Charm Science.
- Compact EC dry plate.

3, Chemical strip test:
- QUANTOFIX® Arsenic 10 from Macherey-Nagel.
- The SenSafe Manganese test strips
- HACH iron strip test kits with AKVO technology
- HACH chlorine strip test kits.

Annemarie, who has done different water quality field tests for around 2000 times, shows the visual guidance to Cheng and Nayantara and guides them to execute water quality tests (Figure 19). Cheng has executed the HACH iron strip test with AKVO technology 2-3 times. Nayantara has almost no experience with field tests. During each test, they could speak out loud about their test experience. After each test, there is a small discussion about each field test.

The experience and analysis of the different tests took 5 hours. After the testing, Annmarie incubated the bacteriological tests to get the result after 48 hours.

Guidance on how to execute field tests could be found at **Appendix A**.

Result

The team found several difficulties with executing the different tests, which are summarized in figure 20, and further explained below.

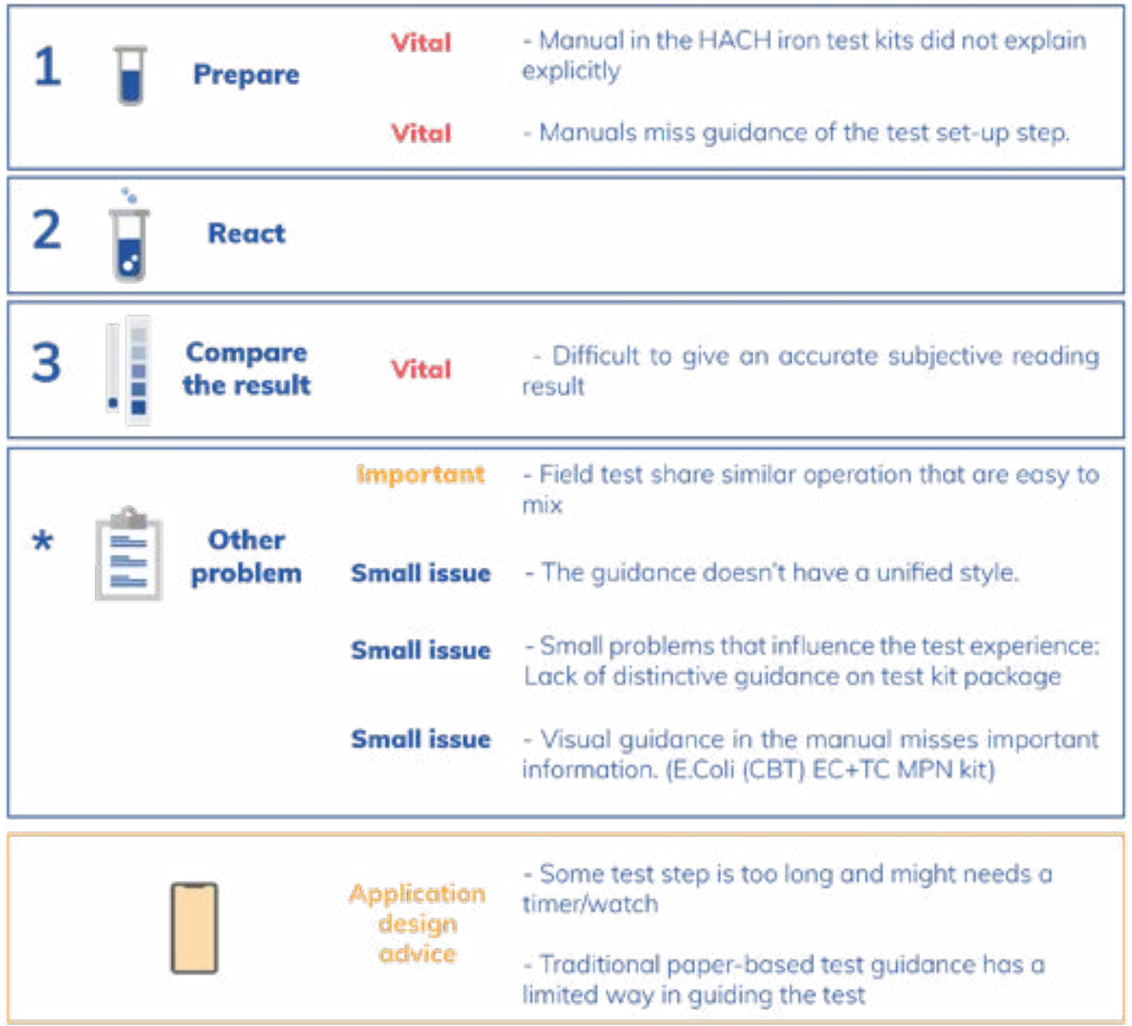


Figure 20, Difficulties with executing the field test.

These difficulties include

Vital problem: Manual in the HACH iron test kits did not explain explicitly.

The HACH iron test kits have unclear explanations to indicate the required amount of water (Figure 21). The guidance states "fill half of the vial," however, the guidance does not give a clear explanation about half of which part of the vial. And the vial also does not contain a fill indication. Such guidance would make testers misunderstand the test process and therefore bring vital mistakes to the test results.

Figure 21, Ambiguity during the test caused by an unexplicit guidance.

Vital problem: Manuals miss guidance of the test set-up step

Most test guidance misses proper guidance of the field test set-up, such as cleaning the kit properly in the field before and after the test. Missing these steps may have a vital influence on the test result. The test guidance in the TAPP application should include these steps.

Vital problem: It is difficult to give an accurate subjective reading result

Sometimes, the tester has to estimate the test result when the patch's colour falls between two colour blocks on the colour scale. It is very likely to give an inaccurate result when testers estimate the test result. According to Mink (2020), different testers give different subjective reading results to the same test strip since people interpret colours differently. Therefore, subjective reading result of the strip based on visual interpretation vary slightly per tester.

Important problem: Field test share similar operation that are easy to mix

The field tests share similar test procedures. This does make it easier to learn different field test kits (figure 22). On the other hand, similar test procedures also increase the chance of mixing up steps and making mistakes.

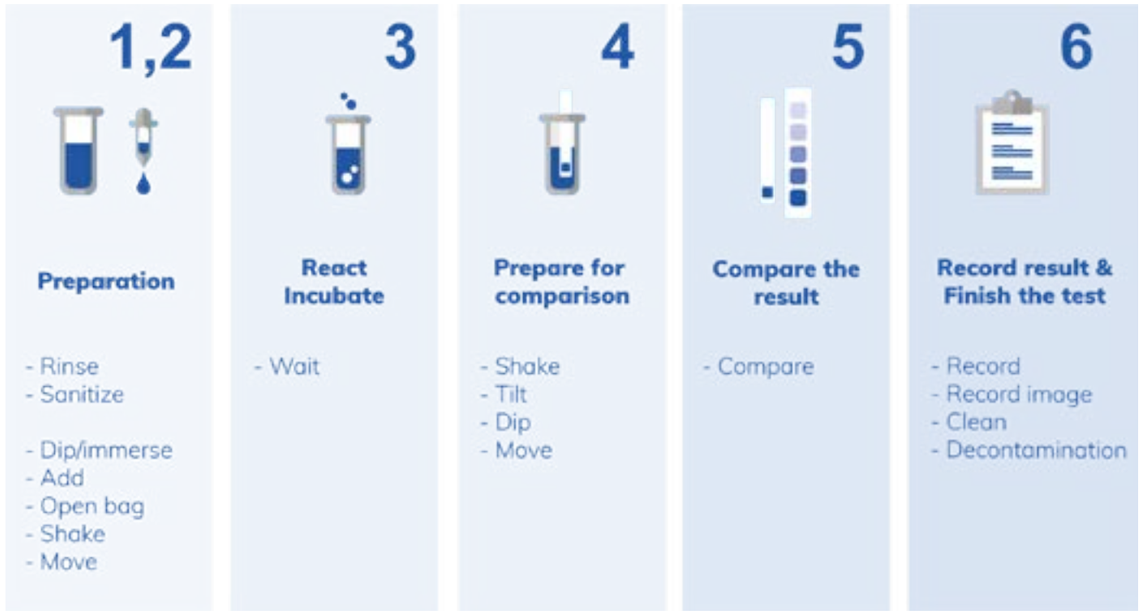


Figure 22, Common steps and operations with water quality field test

Small problems that influence the test experience: Visual guidance in the manual misses important information.
The visual guidance of the E.Coli (CBT) EC+TC MPN kit from AquagenX miss some information (figure 23). The testers have to recap the detailed text guidance, making the recalling process less efficient and tedious.

Small problems that influence the test experience: Lack of distinctive guidance on test kit package
There is a lack of guidance with the packages of test kits. The SenSafe Manganese strip test kits have multiple strips (figure 24). A lack of distinctive visual guidance on the kit package adds difficulties when the testers need to recognise different strips.

Figure 24, SenSafe Manganese strip tests kit

Small problems that influence the experience: The guidance does not have a unified style.
The test kits from different suppliers may have different names and visualisation for the same items and operation. Also, different visual styles summarise test steps with different logic. The tester has to understand and get used to different visual styles when they go over the test guidance. Figure 25 shows different visual styles to visualise the test step ("wait XX minute"). These different visual styles might add inconvenience while reading test guidance.

Figure 25, Different visualisation styles about "waiting for a certain time"

Advice on application design: Some test step is too long and might needs a timer/watch
A timer or a watch is needed to measure the time in some test steps that take a relatively long time, such as "Dip strip #3 for 30 * seconds, pull out, wait 3 minutes for the colour to develop". According to Annemarie, if testers only have one smartphone, they have to switch between smartphone timer and test applications in the field.

Adding a timer in the application would improve the test experience. However, only if the timer can be stopped in between. Experiences in the field demonstrated that if a mistake is being made in between and the tester has to wait for the timer to finish first, this leads to time loss and frustration.

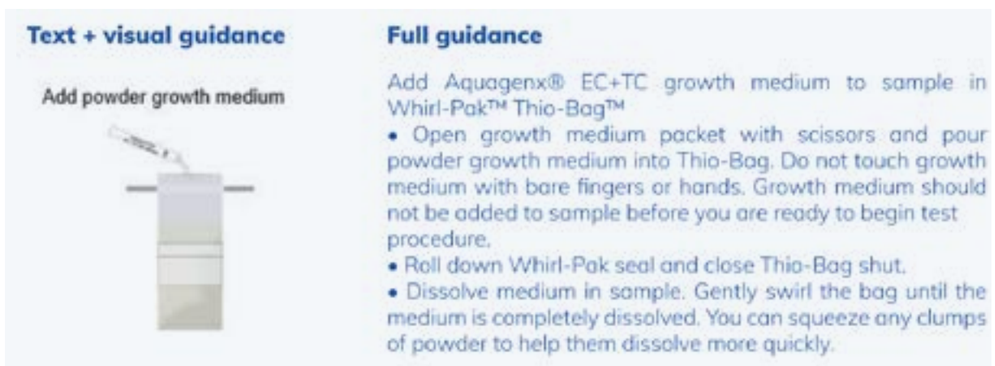


Figure 23, A visual guidance of one step of the Aquagenx® EC+TC P/A test that misses vital information.

Advice on application design: Traditional paper-based test guidance has a limited way in guiding the test
Traditionally, the test guidance is printed on a paper with text and sometimes with visuals. However, there are other methods to deliver guidance, such as audio, video, animation, virtual reality, etc.

Discussion
The test is done at a laboratory in TU Delft. However, doing a field test in the field may bring different experiences than doing field tests in a laboratory. The insights about how the field test is done in the field are mainly concluded from the DELTAP team's experiences in conducting research in Bihar, India and Bangladesh. To research the tester's experience in the field, more research is needed.

Conclusion
Currently, there are several difficulties with performing field tests and using applications to assist field tests. Most difficulties with performing field tests are caused by the design of the test guidance. These difficulties can negatively influence the tester's testing experience and even bring mistakes to the test result, influencing the reliability of the test results.
The test guidance and test process need to be redesigned to solve these difficulties. In chapter 5, the design requirements for a redesign based on the results found during the evaluation of the field test kits are provided.

3.3 Local experience with water quality field test

Using water quality field strip tests seems an ideal way to research the water quality of different PWS systems. However, how would water quality field testing work in Bangladesh with local households?

Research methods
In 2017, the DELTAP research team and A.N. College Patna, India, arranged 60 Indian rural households in seven villages in Bihar to learn how to perform HACH iron strip test with AKVO caddisfly and AKVO flow. AKVO caddisfly is a smartphone app that uses AKVO technology to record objective test results. AKVO flow uses surveys to manage test data. The households performed the test every day for 6 days in a row and were then re-visited to execute the test again while being video-recorded. Their vital mistakes that would influence the test result are recorded and being analysed.

Figure 26, Local households perform strip test with smartphone app. (Picture by A. Mink, 2017).

Result

As the test result shows, the surveyed Indian households have difficulties with performing chemical strip tests in combination with the AKVO application. They made some vital mistakes that influence the accuracy and submission of the test result (figure 27)

With using AKVO applications, most mistakes happened at:

- starting the survey.
- saving & submitting test results.

When local households execute the water quality test with the strip test kits, most problems took place when they:

- Rinsing the sample vial.
- Performing the test steps with correct actions (the amount of time, the amount of water).
- Performing the steps that may easily get missed.

Conclusion

Based on these mistakes, the design of the app can help the local households in Bangladesh to avoid those mistakes made by the Indian local households. The TAPP app should provide water quality surveys that are easy to start and save. Also, TAPP should provide Bangladeshi households with high-quality guidance that could help them diminish or even avoid those vital mistakes made by Indian households.

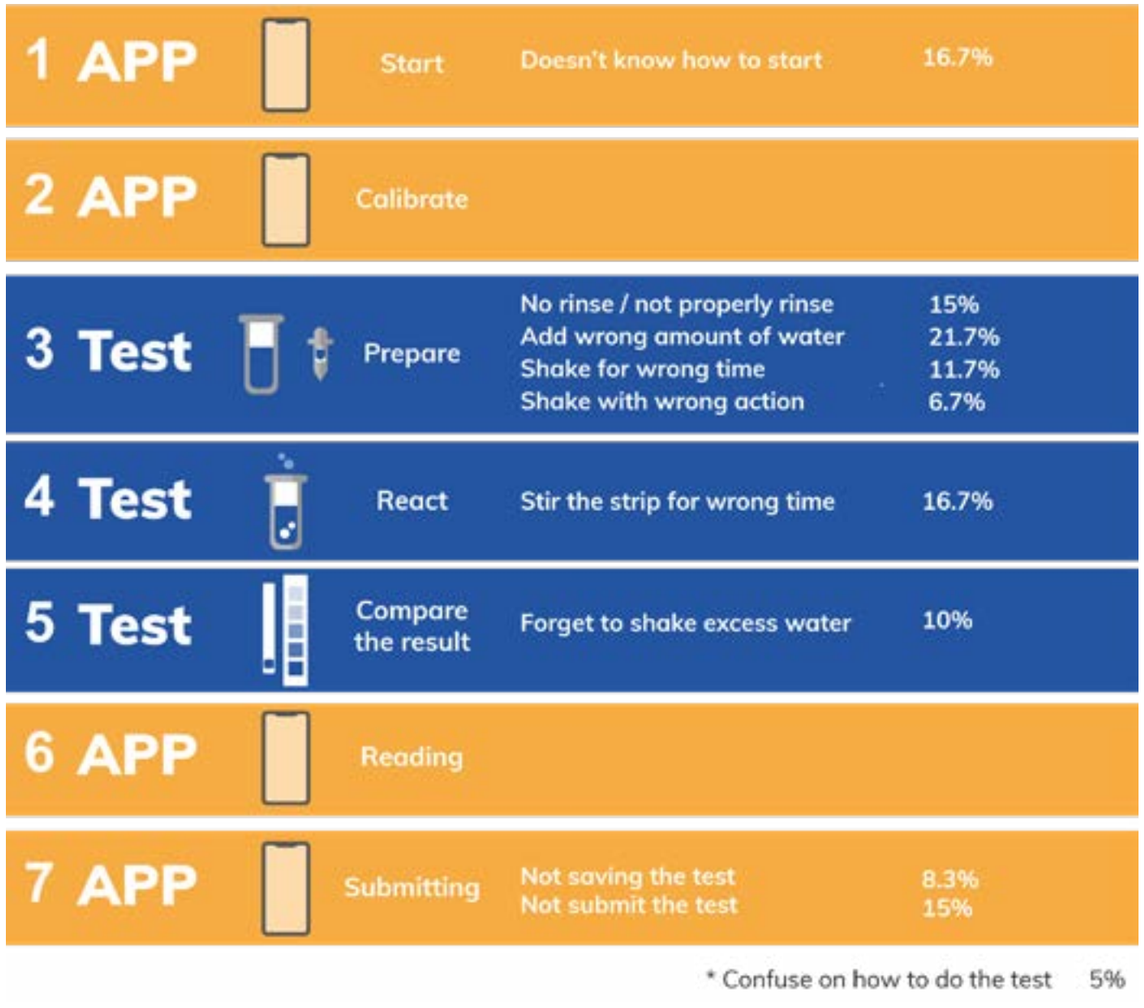


Figure 27, Overview of the households' vital mistake during a water quality test.

3.4 Expert interview

To get insights into how the test guidance in the TAPP app should be designed, interviews with the expert water quality field tester are arranged to understand how experienced field testers feel about the existing test guidance and which difficulties they experience when executing field tests in the field.

Six field test experts participated in the expert interview. Three testers are TU Delft, CiTG students who executed around 100 strip tests in Bangladesh in 10 days in 2018. They have experience with using HACH Iron strip test and QUANTOFIX® Arsenic 10 strip test from Macherey-Nagel.The other three field test experts are from AN College, Patna, India. In April 2017, they executed approximately 200 strip tests in Bihar, India. They have experience with using HACH Iron strip test and QUANTOFIX® Phosphate strip test from Macherey-Nagel

The research questions for the expert interview were:

What difficulties did the testers experience while executing the water quality field strip tests?
How would the testers use the guidance before the test?

Method

Influenced by the covid-19, all the interview is done online through Skype. Interview questions are created before the interview. During the interview, the testers will first describe the test procedure without going over the guidance to see which parts are easy to forget. Then different questions are asked to the participants.

All the interview questions can be found at **Appendix B.**

Result

By interviewing tester's test experience and the difficulties they had during water quality field tests, these insights are found:

- Testers usually put more effort on memorising the detailed informations in the guidance

There are two kinds of information in the test guidance, operational information and detailed information. Operational information refers to information that guides the tester on how to operate the test kits. Detailed information is the detailed requirement of a test step. The detailed information in guidance might include:

The amount of water
The amount of time interval
The amount of reagent
The types of reagent

Figure 28 shows an example of a field test guidance consisting of operational information and detailed information. This detailed information is relatively easy to forget and mix up compared to operational information. When testers learn or memorise the field test process, they would put more effort on memorising the detailed information in the test guidance.

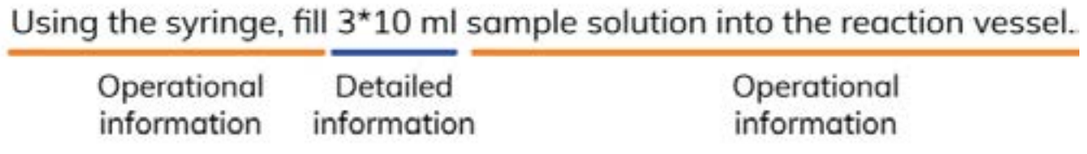


Figure 28, Test step of QUANTOFIX® Arsenic 10 kit

- Testers have various needs when memorising test process

From the interview, different memorising methods the testers would use to memorise the test process are concluded. They are: learning, recapping, and recalling. Learning means gaining the skills of executing field tests by seeing or experiencing a field test. Recap is briefly going over a few points the testers forget. Recall refers to going over the field test guidance carefully to bring back the memory about the test process when the testers forget most of the test process. Testers have various needs with different memorising methods. The design of the app should fit the user's needs for learning, recapping, and recalling.

During the interview, a video on guiding the HACH iron test is shown to the testers. It is a 2:30 min video with text subtitles. In the video, a narrator explains the test process and performs the HACH iron test. The participants compared the video guidance with the guidance they used before (text guidance or text + visual guidance). The testers felt that the video is an efficient medium of teaching testers with no experience since the video clearly shows the test processes and details. However, after learning the test, the testers desire a quick and easy way to go over the test process and grab information before the field test. They would choose a text and visual guidance for recapping and recalling.

- Field tests face lots of uncertainties

During the field test, most mistakes that influence test results happen due to the uncertainties in the field, such as a sudden strong wind or dust falling into the vial accidentally. It is quite challenging to avoid these accidents, and these problems are not easy to solve with designing a better guidance.

Conclusion

During the expert interviews, the main finding is that there are different phases in the learning curve of the test process which support the tester to memorise the test process. To conclude the expert interview result, a learning & forgetting curve is made to visualize the process of learning and memorising the field test steps. Three personas are created to summarise how testers memorise / recap the test steps differently.

- *Learning & forgetting curve for field tester*

The learning & forgetting curve (figure 29) is concluded from the tester's answers about how they learn and forget the field test process. It visualises the process of how the tester's memory on the test process declined over time and retained with conducting tests and reviewing guidance.

At the beginning, testers with no experience would learn the test process by a training, consisting of watching professionals performing field tests and then experiencing the kits themselves. Once they learn the field test process, they will remember the test if they execute the field test frequently. The testers' memory on the test process declines without any testing or reviewing the guidance. After a few days, if they are not confident with remembering a few parts of the test process, they will recap the parts they forget.

After 1-2 months without doing any field test or reviewing field test guidance, they might forget most of the test process and not be able to directly start the field test. Before performing the field test, testers need a careful recall of the test process by reading the test guidance.

The learning & forgetting curve summarises the way testers learn and forget the test process. There might be slight differences between people in how they learn and forget a test, but the learning & forgetting curve could conclude most cases.

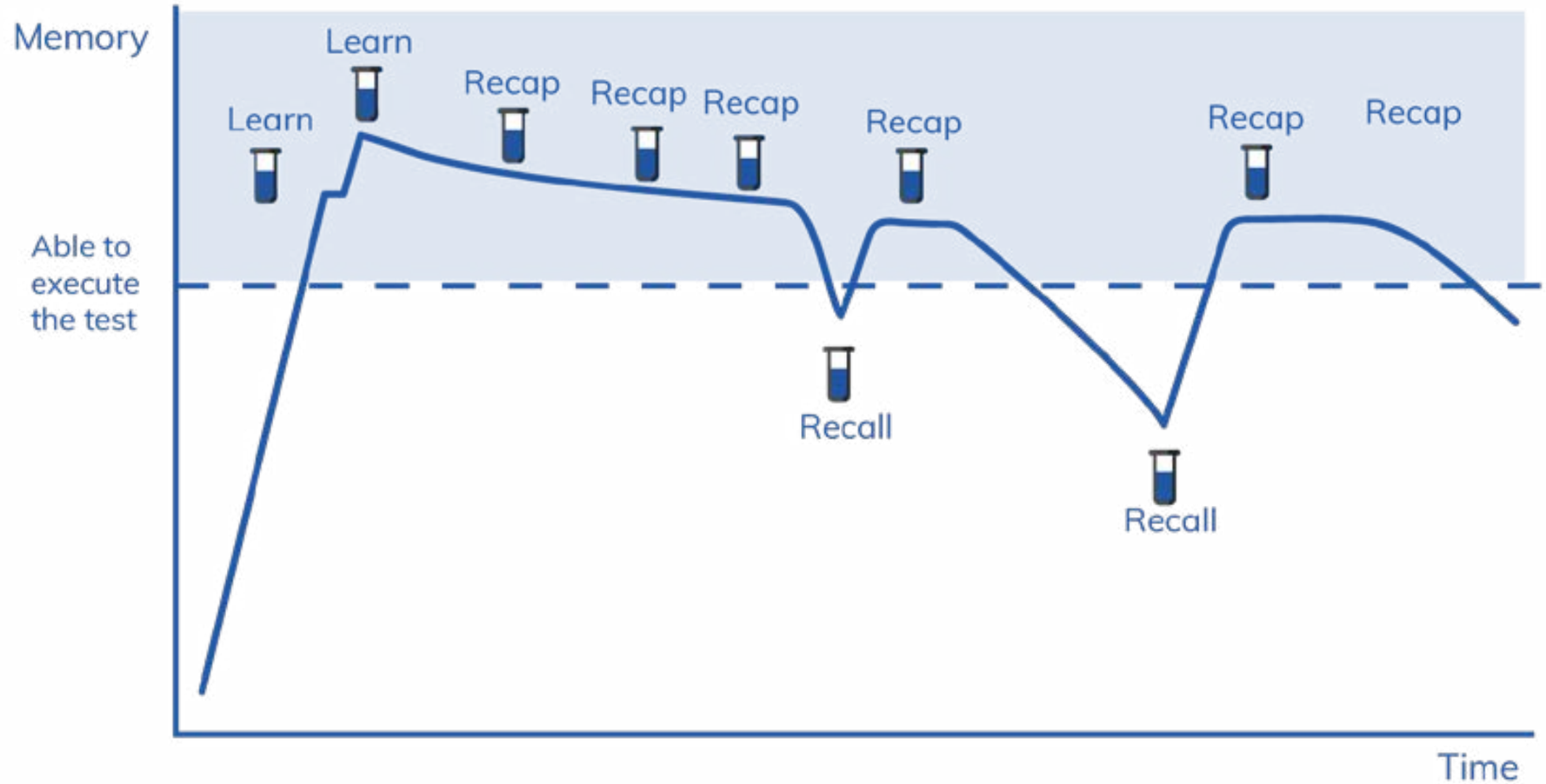


Figure 29, the learning & forgetting curve of remembering a water quality test.

User persona

Testers recall and recap the test guidance differently before the test. Three personas are created based on the tester's recap & recall habits to summarise different recap and recall processes.

Persona 1:

Alex (figure 30) has an average memory of both the test operation and the test details. He did not have confidence in executing the test without recapping the test process before the field test. He will recap both the operational information and the detailed information in the guidance carefully before a field test. Four out of six field testers recap test procedure as Alex.

Persona 2:

George (figure 31) could quickly remember the test steps and details. However, he also forgets it fast. After 2-3 days without doing any water quality tests, George might forget most of the test process. To start the testing, he needs to recap the test guidance and memorise the test steps carefully. If he does water quality tests continuously, he could test without recap the test process. One out of six field testers recap test procedure as George.

Persona 3:

John (Figure 32) is good at remembering the test operations. However, he has difficulty memorising the details of the steps. Therefore, he will quickly recap the detailed information in the guidance before he starts a field test. One out of six field testers recap test procedure as John.

Due to the limited sample size of the expert interview, the personas also represent user groups with small sample size. During conversation with Annemarie, she mentioned some testers are over-confidence and tend to skip guidance and make mistakes. But all the interview participants have not made this kind of mistake. To validate the current personas and add more types of persona, more research about the Bangladesh operators' recapping and recalling habits needs to be done.

The test guidance design should fit the recap & recall habits of different testers and provide the information differently to fulfil various recapping & recalling needs.

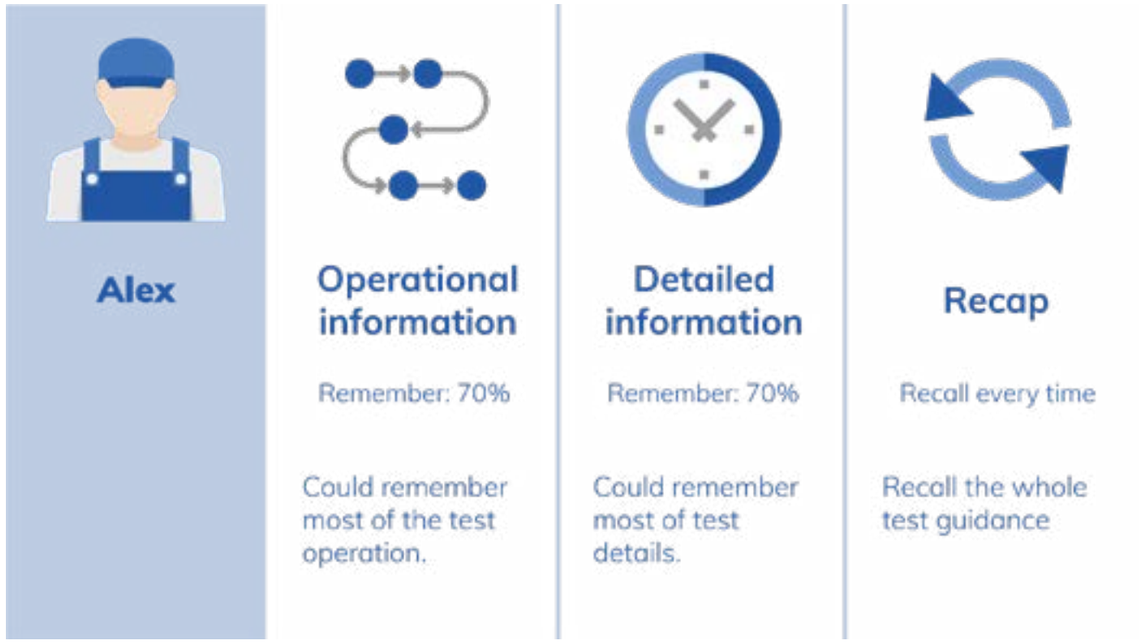


Figure 30, persona type 1: Alex

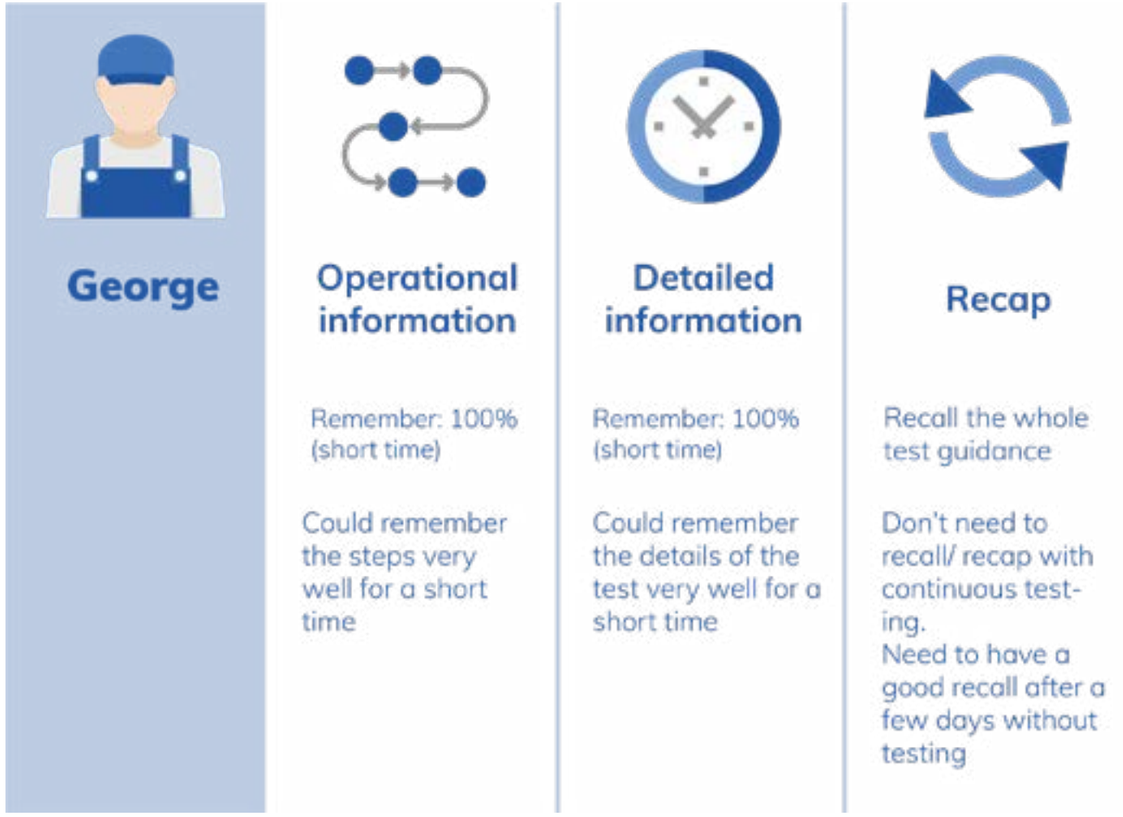


Figure 31, persona type 2: George

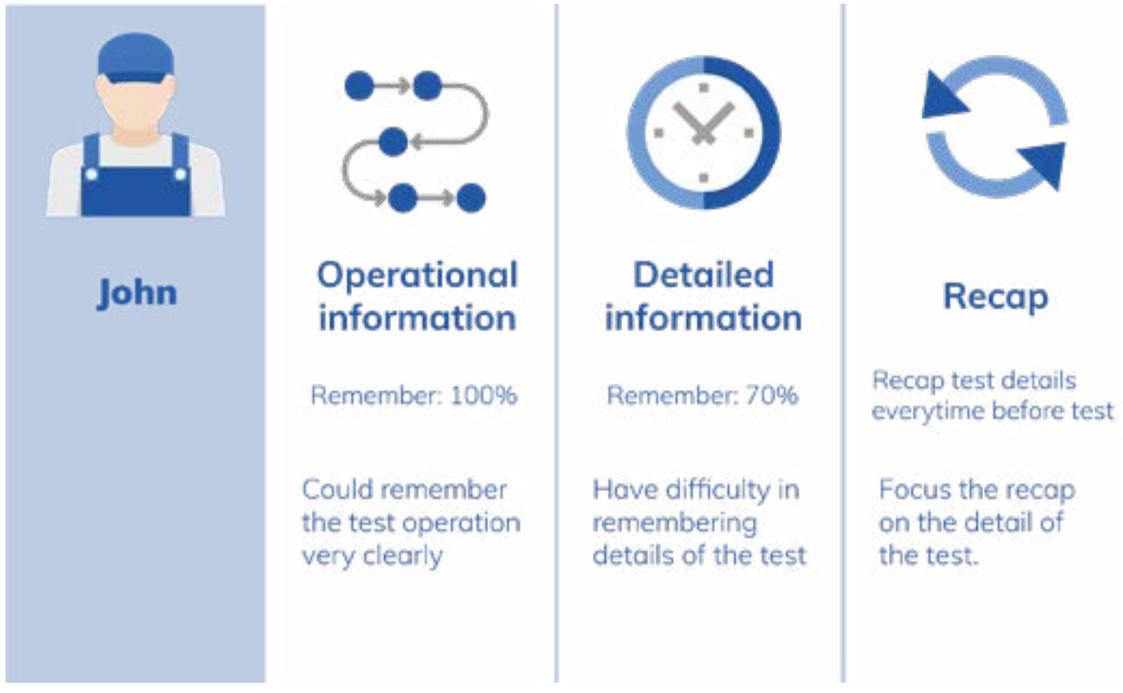


Figure 32, persona type 3: John

Summary on chapter 3

Chapter 3 first analysed the AKVO technology that helps to objectively read test strips in the field and to store the data in a database. Then, an evaluation of the test kits is performed and explained. More insights are concluded from previous research of local Indian households' test performance and expert interviews of experienced field testers.

A learning and forgetting curve and three personas were created to conclude how testers learn and memorise the test procedure. Some design requirements based on the information in this chapter can be found in chapter 5.

Next step

After this analysis of the tests, test technology and test behaviour, the research will now focus on investigating Bangladeshi households to discover how the TAPP application should be designed and how to build a communication channel for Bangladesh households to participate in the monitoring of the PWS.

Chapter 4
Reserch of bangladeshi households

To implement the Mobile Crowd Participation (MCP) method for the TAPP-BDP project, a smartphone application will be designed in this project. Chapter 4 will focus on the research with the three different project areas of implementation for the prototype app, along with Bangladeshi households' smartphone usage to conclude the list of design requirements for the application design.

4.1 Baseline survey: Target areas context

There are hundreds of PWS systems in Bangladesh. Different PWS systems from Faridpur (peri-urban area), Bagerhat (rural area), and Kurigram (peri-urban area) are chosen as the target areas for the development and testing of the first version of TAPP. After implementation in these three target areas, the TAPP will be iterated and then implemented in other Bangladeshi areas.

Methods

In order to start the TAPP project and understand the target users from those three areas, a baseline survey researching the households' daily water usage, mobile phone ownership and usage, and the attitude towards the TAPP project is conducted by EPRC (2019). The participants of the baseline survey are users of different PWS systems. There are 88 participants from Faridpur, 40 participants from Bagerhat, and 82 participants from Kurigram. The survey result was analysed in order to find perspectives for further research.

Result

By analysing the baseline survey results, the following insights were found. Due to the limited sample size, the findings from the baseline survey are still hypotheses. Research with a larger sample number is required to validate these hypotheses.

Households's eductionl level

There is a difference between the educational level and the literacy level between the three target areas(*Figure 33*). People's literacy level is usually linked to their educational level since receiving systematic learning at school is one of the main methods to improve literacy. The baseline survey results show that in Kurigram, 22% of the participants are illiterate (only educated to write their signature), and 3.6% of participants are semi-literate (their education level is below class 5). While in the other two areas, the percentage of illiterates is 6.8% (Faridpur) and 5% (Bagerhat), and of the participants, no-one turned out to be semi-literate .

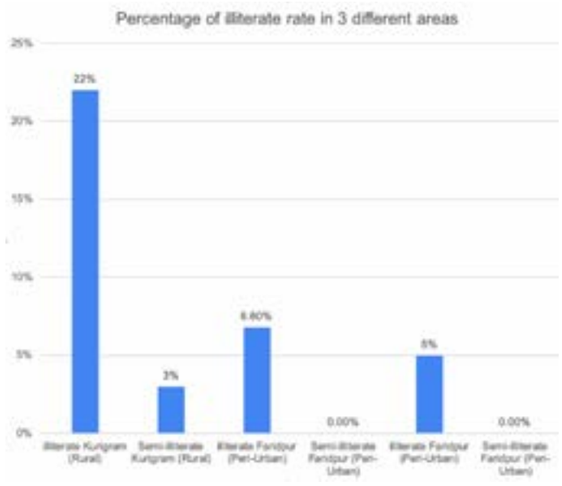


Figure 33, Percentage of illiterates and semi-literates in the 3 different project areas

Educational level seems to affect people's income. Figure 34 shows in Bagerhat, people with lower educational levels are more likely to have lower average incomes than those who receive higher education. The other 2 regions also show the same pattern.

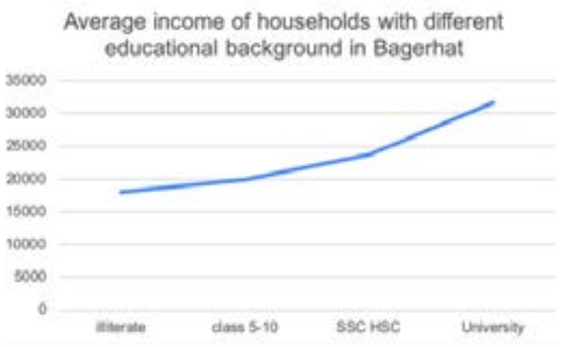


Figure 34, The average income of households with different educational background in Bagerhat

Households's Mobile Phone usage

There is a difference in households' smartphone ownership in different areas. Smartphone ownership in Kurigram (48%) is lower than in Bagerhat (70%) and Faridpur (77.3%). One factor influencing smartphone ownership might be average income, which is lower in Kurigram than in the other areas. The households' educational level might be another factor that restricts their access to smartphones. Within the same region, households with low literacy levels are less likely to own a smartphone (figure 35).

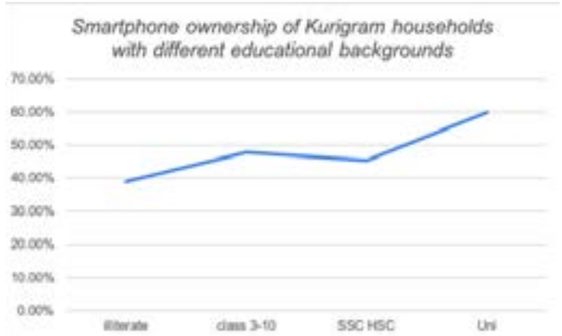


Figure 35, Smartphone ownership of Kurigram households with different educational backgrounds

Some smartphone users in Bangladesh sometimes do not know and use applications, only call and receive messages. In Kurigram, about 62% of smartphone users know smartphone applications, and smartphone users with higher education levels are more likely to know applications (figure 36).

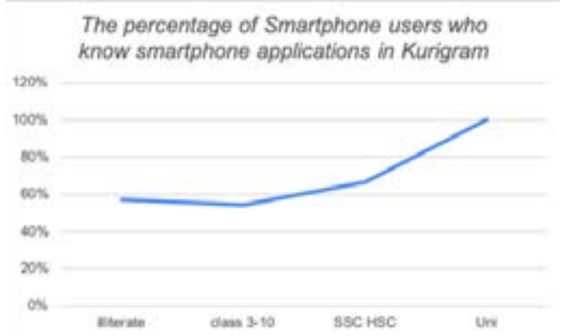


Figure 36, the percentage of Smartphone users who know smartphone applications in Kurigram.

For households who own smartphones, the households would always share the smartphone. However, smartphones tend to be mainly used by men. For instance, in Bagerhat, 78.5% of smartphones are mainly used by men, and only 14.2% of smartphones are mainly used by women. 7.1% of smartphones are shared within households.

In Bagerhat and Faridpur, 37.5% and 32.5% of participants would like to use a mobile application to do water quality tests, get test results and price. It is the user's second favourite function out of seven functions (1, Pay 2, Test result / price. 3, Contact with supplier. 4, Contact for complain. 5, Product price service charge. 6, Health tip. 7, Awareness) related to water safety and water management.

Discussion

By analysing the baseline survey of the three target areas, some insights about how educational level probably influences literacy level, income, smartphone usage, and application usage are found. However, in practice, households' smartphone and application usage might be influenced together by several other factors as well, such as job, income, family circumstances, etc.

Due to the small sample size, the insights still need to be validated with further research

Conclusion

To conclude, the baseline survey provided information on the households' educational level, income, smartphone usage, and their knowledge about applications. *Table 2* shows a summary of the baseline survey result.

There is a need for a mobile phone app that could help the users to do water quality tests and get water quality results. However, households with a low educational level may lack access and experience with using smartphones and smartphone applications, bringing challenges to the design and the implementation of the TAPP app.

To design an application for the target area, Bangladesh rural area, the household's educational level needs to be considered. Further research of households with low education level is required before designing the application.

	Faridpur	Bagerhat	Kurigram
Literacy level	literate: around 93.2%	literate: around 95%	literate: around 74.4%
Average income	26636	25625	18548.78
Smartphone users	77.3%	70%	48%
Smartphone users who knows app	57.3%	67.9%	61.5%

Table 2, summary of the baseline survey result.

4.2 Literature review

Bangladesh households in rural areas are more likely to have a low educational level, bringing challenges to the design of the application. A literature review is done to further study how households' educational levels influence their daily lives and smartphone usage.

Methods

People with less school training are referred to as functionally illiterate since they have difficulty being functionally successful in society due to the lack of sufficient reading, writing, and calculating skills (van Linden, 2008).

They might fail in some everyday tasks, such as reading news, filling in forms, using ATMs, etc. The functionally illiterate may also have difficulty in using ICT devices as they have low digital literacy and insufficient cognitive skills and sociological skills in using ICT (Eshet, 2004).

The below presented literature review aims to investigate functionally illiterate households by studying how their daily lives and ICT usage get influenced by being functionally illiterate. The findings from the literature review will be used to conclude the design guidelines presented in chapter 5, which guide the TAPP app design.

Result

Influence on daily life

Being functionally illiterate, households with low education level got largely influenced in their daily life regarding the following aspects:

The households' poorly developed reading and writing skills significantly influence their capacity to temporarily memorize verbal serial-order information (Smalle et al., 2019). By comparing the literate group and illiterate group's performance on verbal and visual learning tasks, Smalle (2019)'s research shows that short-term memory on verbal serial-order information is influenced by literacy level. Azizi (2013)'s study also indicates that the illiterate group performs less on memorizing verbal information, compared to a literate group.

Functional illiterate groups have lower cognitive processing speed and have difficulty in dividing attention and keeping focus. The result of illiterate & literate groups' performance on the Rey Complex Figure Task (Rey, 1941, as cited in van Linden, 2008) indicates that the illiterate group's cognitive processing speed is lower than the speed of the literate respondents (van Linden, 2008). The literacy level affects brain organization to efficiently perceive both written symbols and spoken language (Dehaene, 2015). The result between the illiterate & literate group's attention tests shows that the illiterate group is less capable of keeping their focus and dividing their attention to two separate tasks (van Linden, 2008).

The illiterate have the same self-efficacy as the literate group. Self-efficacy refers to a person's belief about their capability of doing certain tasks. Utilizing a self-efficacy scale, Van Linden (2008) found that, though the illiterate group feels anxious about using technology, the illiterate group has the same self-efficacy level in general as the literate group.

Illiterate might have difficulty understanding abstract ideas and items. Poor language skills and a lack of educational experience makes the illiterate have an unorganized mental hierarchic structure to understand and represent the world (Katre, 2006; Kulakov et al., 2002). According to Katre's research (2006) an unorganized mental structure might make that illiterate people differently interpret abstract images, since they had difficulties with getting an overall summary of items and ideas.

Influence on ICT usage
By doing literature reviews, some insights about what difficulties the functionally illiterate might have when they use ICT devices are found. These difficulties include:

Functionally illiterate groups have difficulty in learning ICT devices. Medhi (2010,-a) found among 56 participants, that Illiterate groups from India perform worse than literate groups on both specific learning tasks and learning from similar tasks. Familiarity with ICT devices help the illiterate group to feel comfortable and confident in learning to use new ICT or complex machines (Medhi, 2010-b). A lack of access and acquaintance with smartphones and smartphone apps makes it more challenging for the illiterate group to learn a new application.

Functionally illiterate groups have difficulty navigating through apps. Low literacy level has shown to have a negative influence on people's spatial orientation skills (Matute et al., 2012; van Linden, 2008). These less-developed navigation skills also make them have difficulty navigating through the website and interface (Neerincx et al., 2001). Illiterate users understand linear navigation structure where different screens are accessed sequentially better since the research of Medhi (2010-a) illustrates that illiterates understand the linear structure like the pages of a book.

Discussion
The literature review comprised published research to study how the functionally illiterate group's daily lives and ICT usage is influenced by their low educational level. However, the literature review only provides general conclusions. More research is needed to better understand the households' ICT usage habits and daily lives. The study should focus on what ICT device/application they are familiar with and what ICT device they would feel easy to use.

Conclusion
To conclude, the functionally illiterate group has weak short-term serial memory skills and lower cognitive speed. They might have difficulties in keeping their focus and understanding abstract ideas and images. The functional illiterate also may have problems with learning new applications and navigating through the application. A detailed research about their smartphone usage should be executed, which is presented in the next chapter, chapter 4.3.

4.3 Telephone interview

After the literature review about understanding the effect of low literacy levels on people's daily lives and ICT usage, a telephone survey was developed by the TAPP design teamto obtain a better understanding of the local households, their daily water usage, ICT usage, and their understanding of the PWS system they use. The interview aimed at finding guidelines for the TAPP application design.

Methods
The TAPP design team (Annemarie, Nayantara, and I) initiated the interview questions to research the TAPP target users. The following five aspects were investigated: 1) Background information, 2) information & communication, 3) drinking water & water safety, 4) PWS system usage, 5) technology usage. The full list of interview questions is included in Appendix B.

The interview aimed to answer the following research questions for this project:

Information & Communication
How can information about water quality be communicated through an app to rural communities in Bangladesh?
How can water quality testing procedures be communicated to operators of the PWS systems through an app?

Drinking water & Water safety
What does water safety mean to Bangladesh people who live in rural areas? What do they care the most about related to water safety?

Technology
What are the difficulties of Bangladeshi piped water users in using ICT? What factors may influence them to learn and use ICT devices?

The interview was revised and translated into Bengali, then Mr. Sohel Ahmed from EPRC conducted the interviews. Influenced by the lockdown policy responding to Covid-19 in Bangladesh, the interview could not be done in the field. Mr. Sohel conducted telephone interviews instead of face to face interviews.

8 participants aged 27-55 from the Faridpur area were recruited for the telephone interview. The participants include smartphone users and non-smartphone users with different educational backgrounds (from class 8 to master's degree). 6 out of 8 participants own a smartphone, and 5 out of 6 smartphone users have regular internet connection and use smartphone applications.

The full interview question (English) is included in **Appendix C**.

Result
The following key insights are concluded from the interview outcomes.

Participants desire water quality tests and test results. 6 out of 8 participants did not have their water supply tested before. 1 out of the 2 participants who have had their water quality tested has not received the water quality test result. 7 out of 8 participants indicated to desire regular water quality tests and test results.

Participants desire trustworthy information related to drinking water quality. Households would love to receive more information about their drinking water quality. They demand contamination information regarding their drinking water, such as whether it is safe to drink and how their drinking water gets contaminated. Participants would also like to receive more information about the consequences of drinking polluted water, affordable water purification methods, and safer drinking water sources. Participants will trust information if the data comes from trustworthy sources, such as water suppliers and pourashava (Municipality in Bangladesh).

Households would share information related to water quality. 7 out of 8 participants have shared the condition of their drinking water within their community. 7 of them would like to share unfavourable water conditions to find whether community members have the same issues, including bad quality drinking water, bad smell and dirt in the water.

Participants desire a 'light' app. Since participants do not connect with Wi-Fi but only use limited internet data packages (1GB-5GB per mount), and have no place to store their phone data, the households care most about internet data usage and the space an app occupies when choosing smartphone applications. The participants desire a 'light' app that does not occupy too much storage space and consumes fewer internet data.

Facebook, Google, Messenger, Imo, and YouTube are the participants' favourite smartphone apps. These apps enable local households to communicate with family and friends as well as search for more information, and enjoying entertainment. **Participants choose YouTube, Imo, Google play store, and SHAREit as easy-to-use applications.** These apps are easy to use because users could use these app's functions to make a difficult task in life more manageable. Also, these applications have easy interactions that the households could understand.

Discussion

The telephone interviews provided important insights into how households use smartphone applications and how households desire water quality information. However, influenced by the covid-19, the sample size is relatively small. In total, eight participants joined the telephone interview, and only five of them have used smartphone applications before. It would be valuable if more interviews and group sessions were executed, to research more local households, validate the findings, and provide more insights. Moreover, the participants can have provided socially desirable answers about desiring the TAPP app, to please EPRC, as EPRC works in this area a long time already. Finally, the interviews were conducted in parts, as the attention span and available time was often only 20-30 minutes. This can have influenced the answers of the participants.

Conclusion

The telephone interviews show households' requirements for water quality tests and test results. Bangladeshi households seem to love to receive more water quality information, including how to purify water, how to choose water sources and the consequences of drinking polluted water. The interview results also show the households' smartphone application usage and what kind of TAPP app interaction the households would like. Based on the research result from the literature review & telephone interview, design guidelines are concluded to guide the application design.

These design guidelines are shown in **Appendix D.**

Summary on chapter 4

In chapter 4, the target users are first studied by analysing the baseline survey result provided by EPRC. The baseline survey results show that households' educational level might influence their smartphone usage and knowledge of smartphone applications. A literature review is done to study how functionally illiterate households daily lives and smartphone usage are influenced by their low literacy level. A telephone interview further investigated the Bangladeshi households' smartphone usage and the desired water related information they would like to receive. App design guidelines are concluded from the research results and conclude this chapter on user research.

Next step

In the next chapter, design tasks and design requirements for the in chapter 1 specified design tasks one & two will be presented. Three experience objectives the guide the experience deisn are initiated from the sights of the literature review.

Chapter 5
Design Brief

In the previous chapters, the research is about water quality tests, testers' testing experience, and Bangladeshi local households. In this chapter, the design brief is deduced from the research result. The design brief made up of three design tasks that describe the work needs to be done to address the design questions, design requirements explaining design tasks with detailed requirements, and three experience objectives guides the experience design of the Applications.

5.1 Design task

Three design tasks are deduced from the three design questions and the research results, outlining the design that will be done in the later chapters.

Design task one

Design task one aims at answering design question one, creating a smartphone app for the local Bangladeshi operators to monitor the PWS system.

Design the water quality monitoring part of TAPP to assist local operators in executing water quality field tests. The app will provide test guidance to testers and collect & upload data of water quality tests.

Design task two

Design task two will address design question two, implementing the mobile crowd participation and the TAPP to invite the local households to engage in the monitoring of the PWS system.

With the TAPP application, build a communication channel for the local households to engage in the monitoring process by requesting water quality tests, receiving test results, and related information.

Design task three

Design task three tries to answer design question 3 by designing the PWS system's monitoring and maintenance process.

Using water quality tests and the TAPP application to design a standard monitoring model for the PWS system and design a standard maintenance process for the continuous maintenance improvement of the PWS system.

5.2 Design Requirement

Design requirements are concluded from the wants and needs of the customers, the local Bangladeshi households, and PWS operators. The design requirement further explains all the requirements for the design works. The final design should meet the design requirements.

Requirements for TAPP-BDP

There will be three different versions of TAPP applications for operators, customers, and staff based on different purposes.

The TAPP operator and customer application are android applications. The operator uses the TAPP operator app to manage, connect with the users, monitor water quality, arrange water quality tests, and receive water quality information. The customer uses the TAPP customer app to connect with the operator, finish online payment, request water quality, and receive water quality information. The TAPP application for staff is a web application that will be used to manage the database.

This project is designing the water quality monitoring part of the TAPP operator's app will help the operators to

- **Scheduled water quality tests** (design task 1)
- **execute water quality field test and manage test result**(design task 1)
- **Receive result after tests** (design task 2)
- **Approve customer's water quality test request** (design task 2)

The water quality monitoring part of TAPP customer's app will help the local households to

- **Request a water quality test** (design task 2)
- **Receive test result** (design task 2)

Design a light app.
Bangladesh households have limited internet packages every month, and they may also have limited phone storage. The application should be a lite app that does not occupy much storage and does not use much internet.

The design requirement for design task 1

The design requirement for design task 1 is concluded from the needs of the Bangladesh local operator. These needs are the research result of Chapter 2.3, Low literacy user's experience with field tests, and chapter 4, Tester's UX of field tests.

The app should provide test guidance to fit the tester's various needs for memorising the test process. Testers have various needs for memorizing test steps in different conditions (learning, recalling, recapping). The design of the guidance should fit their various needs for memorising test steps.

The app provides video for the testers' learning process. When testers first learn how to execute a strip test, they would take a long time to learn the test process with comprehensive guidance about the test process.

The app provides visual and text guidance for the test steps' recalling and recapping process. When recalling and recapping the test guidance, the test would desire a quick way to go over the test operations and test details. The app will use visual and text guidance to meet the need to recap and recall quickly.

Redesign the process of camera calibration & reading strip test results. The tester will calibrate the camera and read the strip after the water quality test to avoid the change of lighting conditions during the water quality test.

Add a timer for some test steps.
Provide a timer to the testers when they need to measure the time-interval during some tests.

The design requirement for design task 2

The design requirement for design task 2 is initiated from Bangladeshi local households' needs from chapter 3,3, telephone interview.

The households should be able to request water quality tests with minimal interaction. A function of request water quality test will be added to the water quality monitoring part of the TAPP app to meet the user's desire to have their drinking water tested.

The households should receive water quality test results that are easy to understand. After the water quality test, the water quality test results and their drinking water quality will be shared with the households. Moreover, households should be able to understand the test result easily.

Provide household knowledge/information about water contaminants. The households desire the knowledge of water pollution information so that the water quality monitoring part will link to the education part (designed by Nayantara Thomas). According to the telephone interview result, the households desire knowledge and information related to purifying water, choosing a safer drinking water source, and possible health issues of drinking polluted water.

Design a consistent visual language for field test guidance

A consistent visual language for translating text guidance into visuals to explain field test procedures will be created. The visual guidance should conclude tests from different suppliers with one consistent visual style to make test guidance more easy-to-learn. Using this consistent visual language, EPRC should be able to visualise test procedures for more test kits in the future easily.

The visual guidance should explicitly explain test steps to avoid giving ambiguous instructions that would lead to the tester's misoperation. The visual guidance should also include guidance for all necessary steps.

Based on the analysis of the test kits and research result of the tester's testing performance and experience, the first ideation of the consistent visual language is created and then evaluated and iterated.

Figure 37, final designof the consistent visual language

The 1st-ideation, evaluation and the final design of the consistent visual language will be shown in **Appendix E.**

5.3 Experience objectives

There are three experience objectives concluded from the research result. These experience objectives explained the experience that the target users intended to receive using the application and its related service.

Structured
Structured is an experience the users have when they understand how to navigate through the app and are conscious about how they interact with the app (figure 38).

Medhi(2010,-a) finds that illiterate users are quicker to understand linear navigation. The four easy to use applications chosen by the telephone interview participants also have a linear navigation structure for their primary functions(Youtube--Play video/search video; Play store: search and downloads applications; Facebook: seeing post; Imo: chatting with friends.) The app design will use a linear navigation structure to make the app have a clear structure, especially for low-literacy users.

For Bangladeshi users, feeling structured is like navigating through a book. They can know where they are with a page number, and they can also navigate through the book with page numbers.

Figure 38, Experience objective - structured

Instinctive
Instinctive means users can react or behave naturally without much thinking. Most low literacy users have a lower cognitive speed of processing information.
The application should be easy to understand so that low literacy users can understand the app instinctively.

The users feel instinctive when they have less difficulty understanding the application content and have no/little obstacles interacting with the application.

The app will have good usability and have the interactions that Bangladeshi households think is easy to use, to make the user feel instinctive when using the app,

Figure 39 shows a vision for being instinctive. It is the visual guidance in Japanese train station platforms that tells the passenger how they should move. The visual provides passengers with information that could be understood naturally and instinctively.

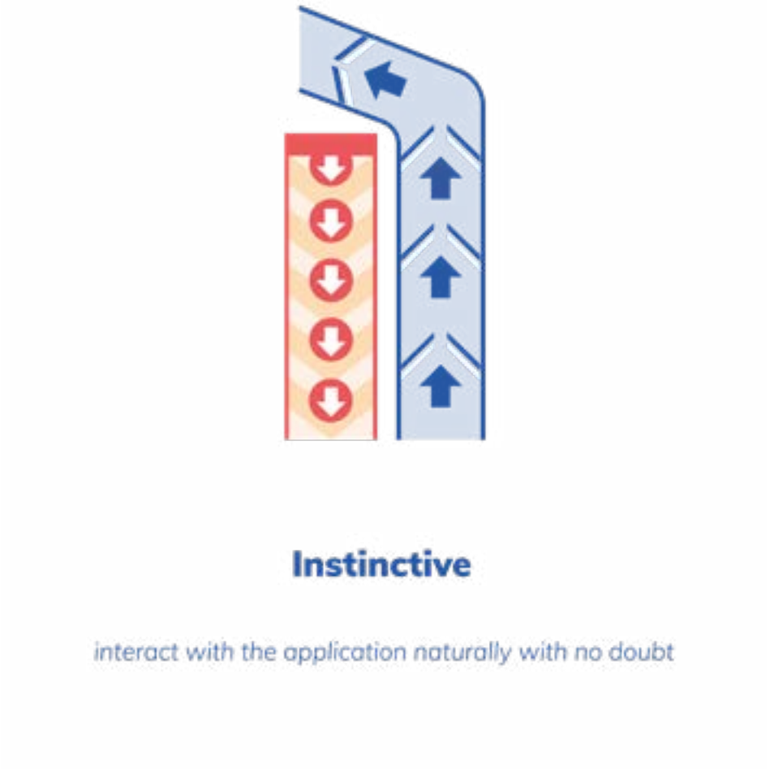


Figure 39, Experience objective - Instinct

Achieved

Achieved means that users enjoy the process of exploring something difficult and accomplish some meaningful challenges (figure 40). The app will only bring support to users in an unnoticed way in necessary cases, just like parents bring protection to the children learning to ride a bike.

The application will let the user explore the application and accomplish the challenges, learning to use an application by themselves. The users could improve their abilities, gain confidence in using ICT, and feel achieved while using the app.

TAPP could also make users feel achieved besides using the app. when the operator and households contribute to the PWS system's monitoring and maintenance process with TAPP.

Conclusion

The three design guidelines guide the design of the application differently. The app design will follow this guideline to fit the target user's habit and preference.

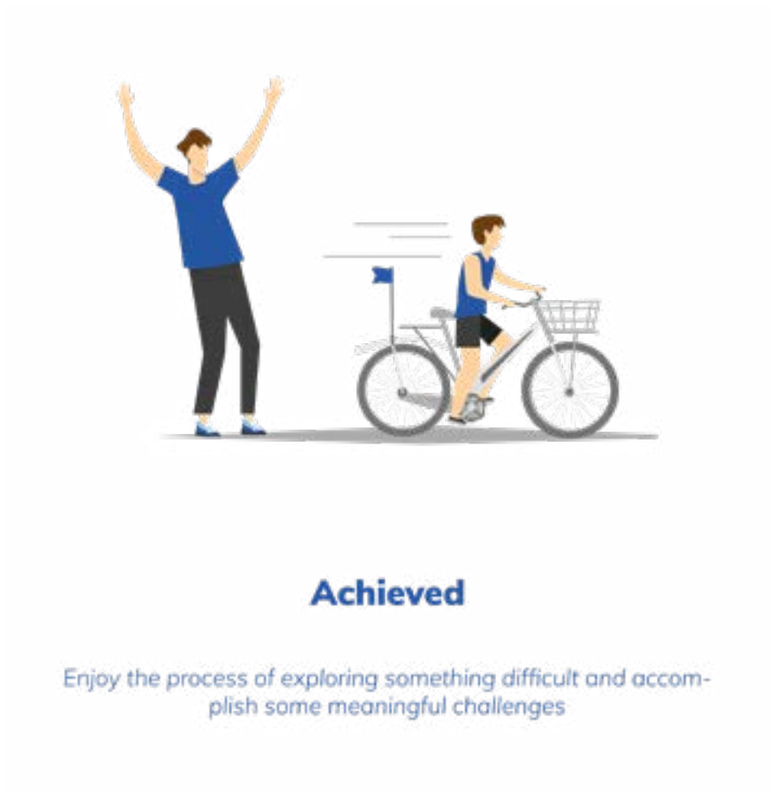


Figure 40, Experience objective - Achieved

Summary: chapter 5

In chapter 5, three design tasks and the design requirements for design tasks one and two are concluded from the previous research. Three experience objectives explained the target experience that would be brought to users by using the TAPP application.

Next step

The project will turn into the design phase In the following chapters. The design will follow the design requirement (chapter 5) and design guidelines(appendix D). The design & evaluation of design tasks one & two will be shown in chapter 6 & 7, and the concept for design task 3 will be shown in chapter 8.

Chapter 6
App design ideation

This chapter presents the first concept of the design task 1, assisting the local operator in executing water quality tests, collecting & uploading the water quality test results. This chapter also shows the 1st ideation of design task 2, using the TAPP application to let the households engage in monitoring the PWS system by requesting water quality tests and receiving water quality test results.

In this chapter, the redesigned test process will be discussed. The design of the water quality test function of the TAPP operator application is shown. After that, the service of requesting water quality tests is designed, the TAPP customer application is designed.

6.1 Field test process: testing with TAPP

In order to complete design task one, design the water quality monitoring part of TAPP to assist local operators in executing water quality field tests, a process of test water quality with TAPP is created internally with Annemarie Mink and Annaduzzaman Kajol, aiming at improving the accuracy of the test result. Figure 41 shows an overview of the new test process.

In the redesigned test process, there are 5 different stages of ding water test with TAPP. The water quality test function of the TAPP operator application will be created based on the redesign test process,

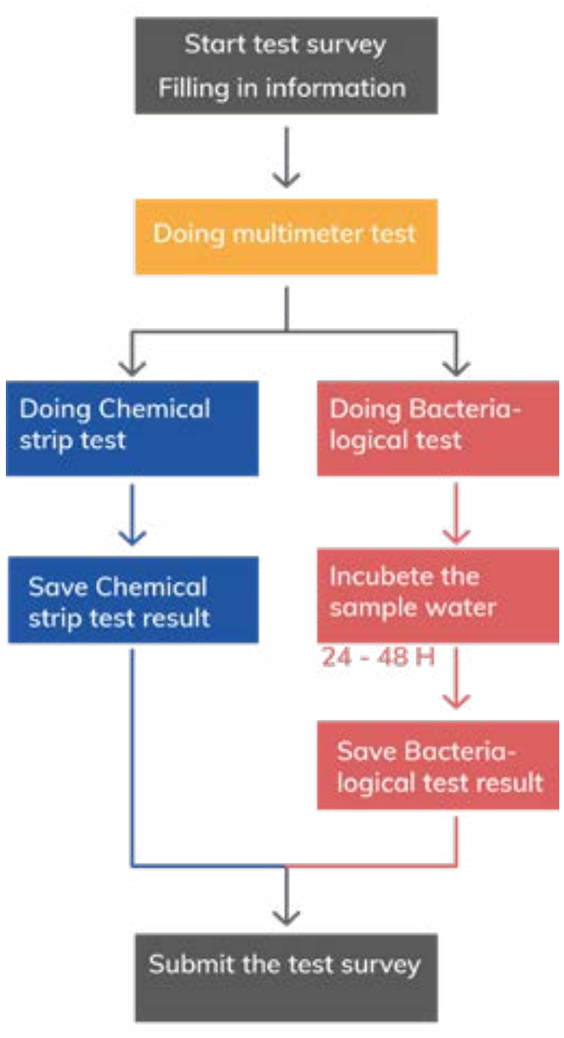


Figure 41, overview of the new test process.

Based on the redesigned test process, the TAPP operation app water quality test part is created in presented in chapter 6.2

Start

Before the water quality test, the TAPP will remind the operator of executing the water quality test with mobile phone notification. After arriving at the test location, the tester starts the water quality test survey in the TAPP application and fills in basic information.

Multi-meter test

The tester will use the multi-meter to test the PH, Temperature, EC, Etc, and type in the test result in the survey

Chemical strip test

The operators will execute the strip test with guidance on the TAPP application. After the test, operators first compare the test strip with a colour scale to give a subjective reading result. The TAPP application will collect the subjective reading result and a picture of the test strip together with the colour scale. The tester will then use the TAPP and the AKVO reference card to calibrate the camera and use the TAPP to give an objective reading result. Then the tester will save the test results for this strip test.

The tester needs to execute the strip test two or three times until they get two similar test results, trying to avoid having a test result from human error. The tester types the final test result in the TAPP application, based on the two similar subjective reading results, using the objective reading results as reference and validation.

Bacteriological test

If there is insufficient Chlorine, the tester will collect the sample water with bacteriological test kits, guided by the TAPP application. The tester will set the incubation time (24-48 hours) with TAPP to receive a reminder after the incubation period. Afterward, the tester will receive a reminder from TAPP, reminding the testers to determine the test result and upload the result on TAPP.

Submit

After filling in all the information, uploading all the test results and data, the tester will submit the survey.

6.2 Application design: Water quality test

With the redesigned field test process and the consistent visual language, prototypes of the TAPP operator's part are created. A low-fidelity prototype is used for internal discussion (figure 42). The low-fidelity prototype is discussed with Bilqis and Annemarie, who have abundant field test experience, to iterate the application function. The app design is also discussed with the programmer to see whether designs are technically possible.

After the discussion of the low-fidelity prototype, a high-fidelity prototype is designed guided by the design guideline. Some app components are created for the application design.

The application design components including buttons, cons are shown in **Appendix F.**

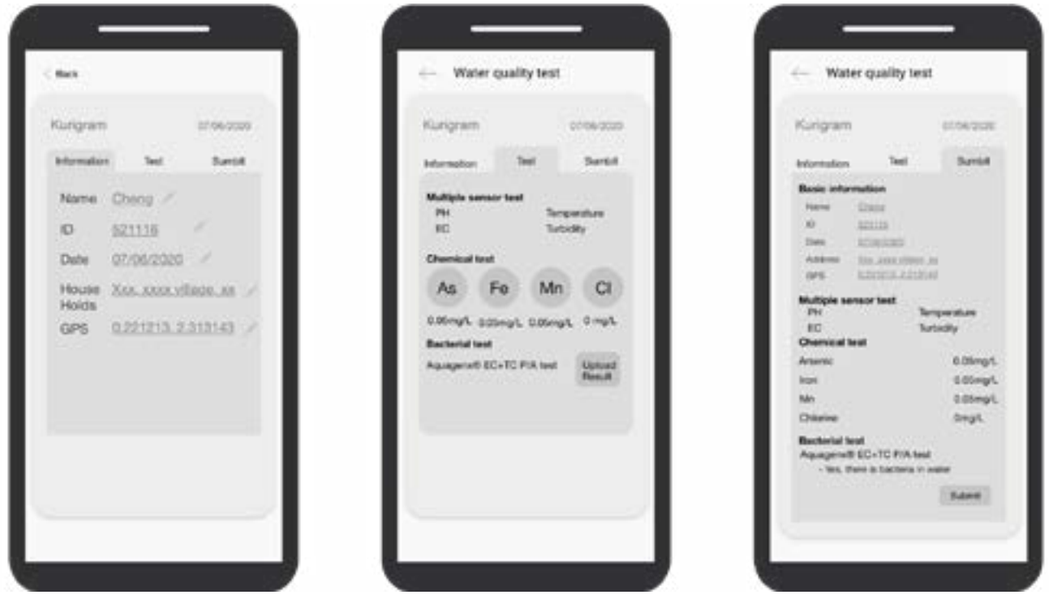


Figure 42, low-fidelity prototype of TAPP

The TAPP operator application works in the following way. Before the test, TAPP will notify the tester about the upcoming test. TAPP will provide a survey to guide the tester to collect basic test information and test results(figure 43). After collecting all the datas, the tester will submit the survey, and upload the data to the cloud.

Figure 43, TAPP water quality test survey

There are guidances to guide the chemical strip tests and bacteriological tests (figure 44). A text & visual guide provides a step-by-step guide to the tester. A video tutorial teaches testers who need detailed guidance. The app also provides a timer for the steps that need to measure the time-interval .

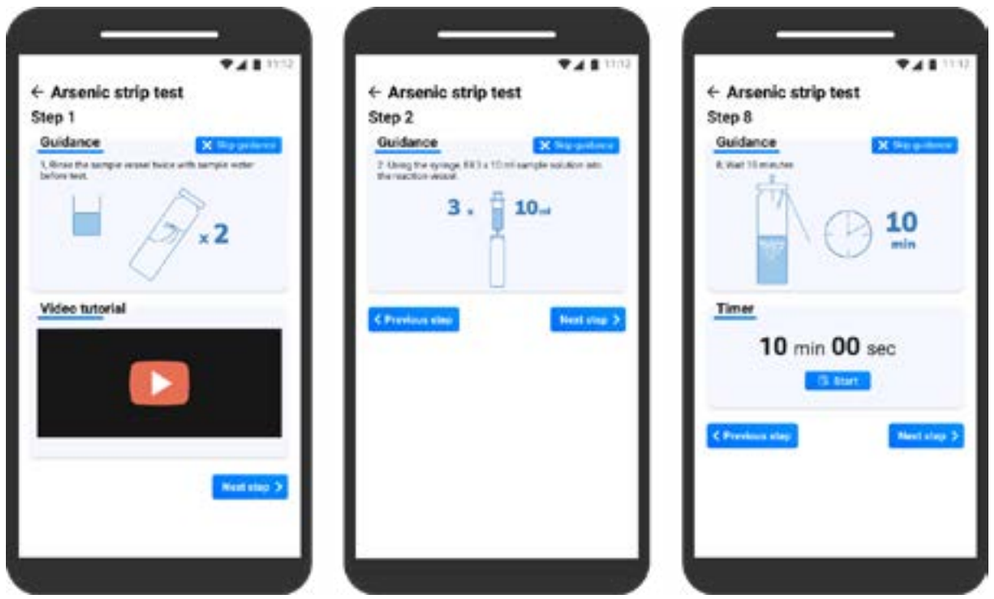


Figure 44, TAPP's water quality field test guidance.

At the end of each test, the TAPP will help testers to manage the test results (figure 45). The testers first read the test strip and upload a subjective reading result. Then they use the TAPP to give an objective reading result. If the tester receives two similar subjective test results, they will type in the result as the final test result.

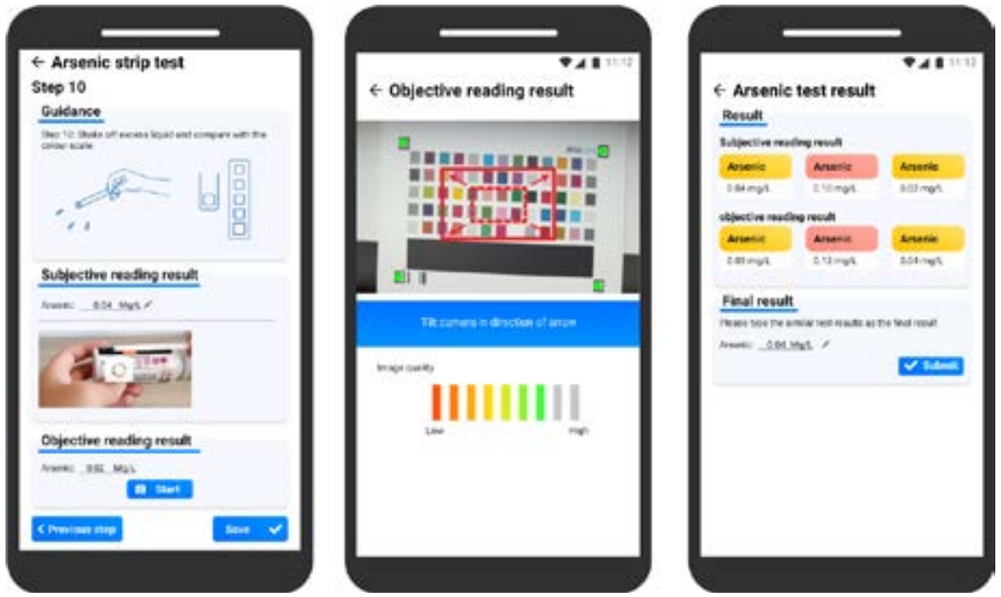


Figure 45, TAPP collecting test result

TAPP will provide guidance and assistance to the execution of the bacteriological test if needed (figure 46). Testers could receive bacteriological test guidance from TAPP and use the TAPP to set alarm for the incubation period. After the incubation period, the tester types in the test result and saves the data.

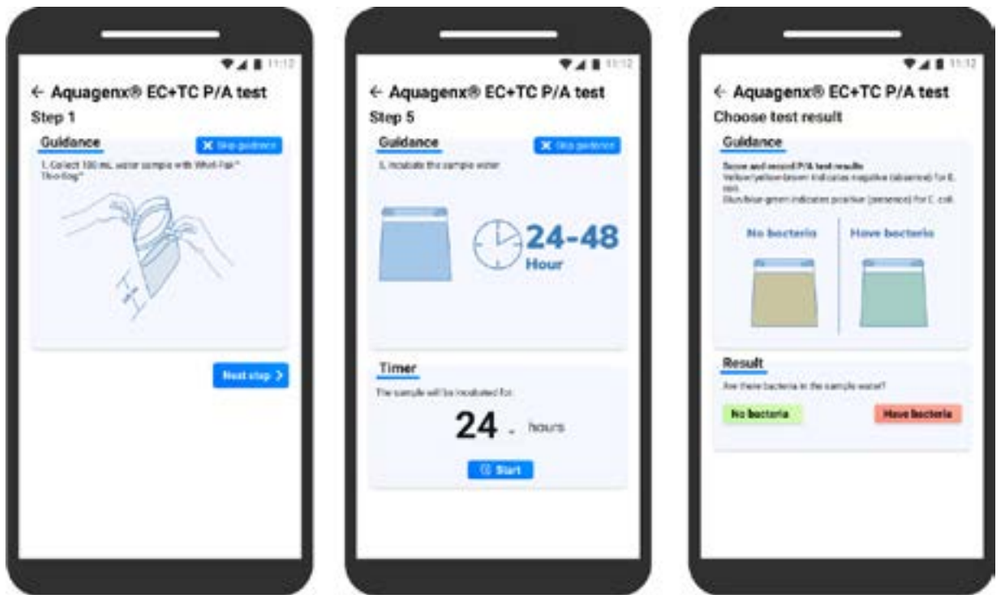


Figure 46, TAPP guiding the execution of bacteriological tests.

6.3 Service design: Managing households' water quality field test

According to the telephone survey result, Bangladeshi households desire more water quality tests and test results. A service is designed to enable the households to use the TAPP to request water quality tests and receive water quality test results. **This service is intended for design task two,** building a communication channel for households to engage in the monitoring of the PWS system.

Figure 46 shows the service blueprint of the service, managing households' water quality tests. The service blueprint shows how households interact with the operator and how NGO staff support the service. In the service blueprint, there are four different stages of arranging a household's water quality test.

The first stage is to request a water quality test, in which the households will use the TAPP customer application to fill and upload a request form. The second stage is to confirm the test request. The operator will receive the customer's water quality test request with the TAPP operator application. After calling the customer to confirm the test request, the operator will approve the request. The customer will then receive a confirmation of their test request and sometimes together with a payment request if they choose to pay the test fee online. The third stage is the executing of the water quality test. On the day of the water quality test, the operator will visit the households and execute water quality tests with the TAPP operator application. The final stage is sharing the test result. The NGO staff will check the water quality test result and share the test result with the households.

After designing this service, the TAPP customer and operator application that supports the service will be created based on this service blueprint. **The app design is presented in chapter 6.4 & 6.5.**

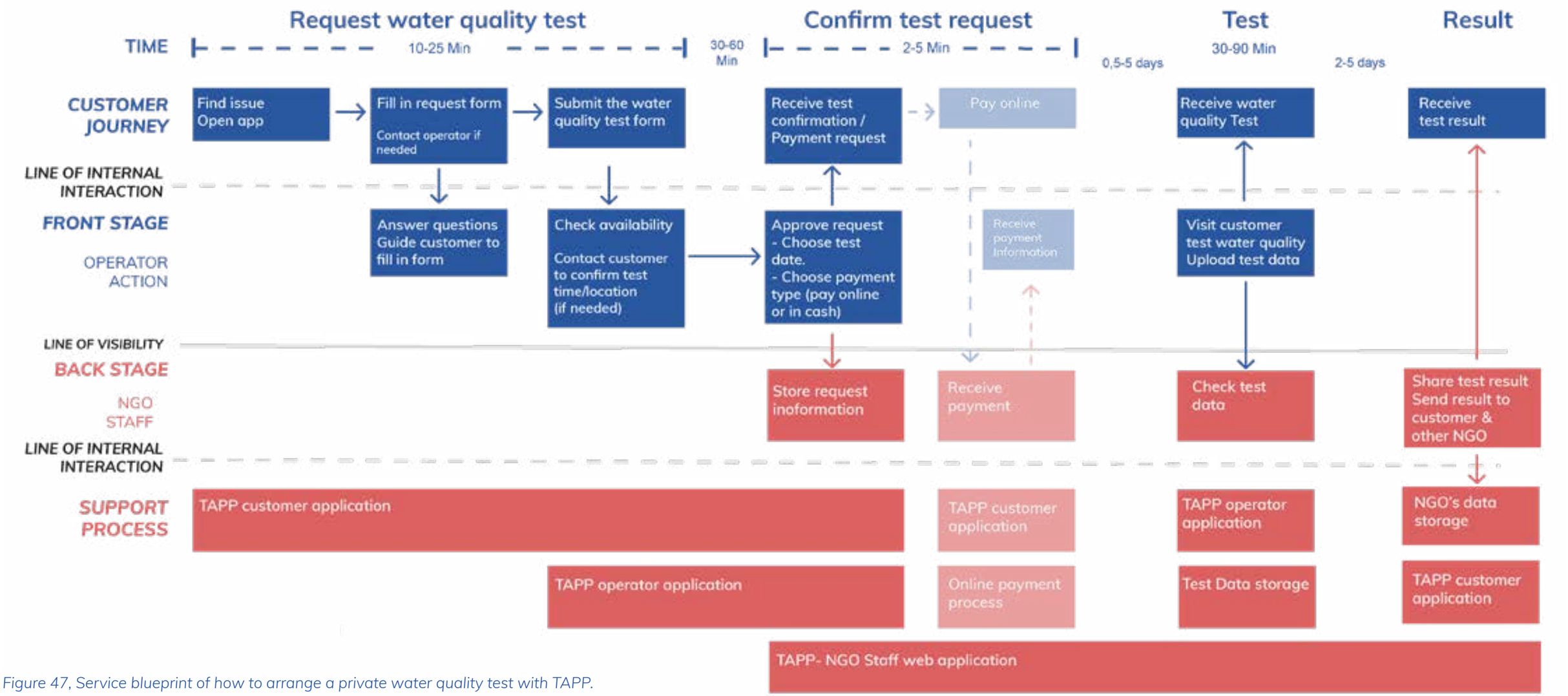


Figure 47, Service blueprint of how to arrange a private water quality test with TAPP.

6.4 Application design: arranging a water quality test

TAPP applications play a significant role in building a communication channel for households and operators by enabling households to request water quality tests with TAPP customer applications and assist the operator in approving a water quality test request with TAPP operator applications.

TAPP customer app

The household will use the TAPP customer application to request a water quality test to their PWS system tap or private hand pump. Suppose the household does not know which parameter should be tested. In that case, they could call the operator or go to the drinking water knowledge part designed by Nayantara Thomas to check the information of each parameter.

Figure 48 shows a basic flow of how customers request water quality tests with TAPP customer applications. The households could add new water quality field tests request from the water quality monitoring page of TAPP.

When a customer fills in the request form, the system will prefill the form with the customer's basic information collected when the households registered in the TAPP. The households need to choose types of water supply they want to test. Then, the households need to select the parameters they want to test and submit the request. The test request will be sent to the operator, waiting for their approval.

TAPP operator app

Figure 49 shows the TAPP operator app when approving households water quality test requests. The operators will receive notification of approving the customer's test request. The operator will call the households to confirm the information and choose the test's time and payment methods since Bangladesh mobile phone users are more used to communicating with calls. After the operator approves the test request, the households could receive a notification that tells them their water quality test has been approved.

Figure 48, Requesting water quality test with TAPP customer application.

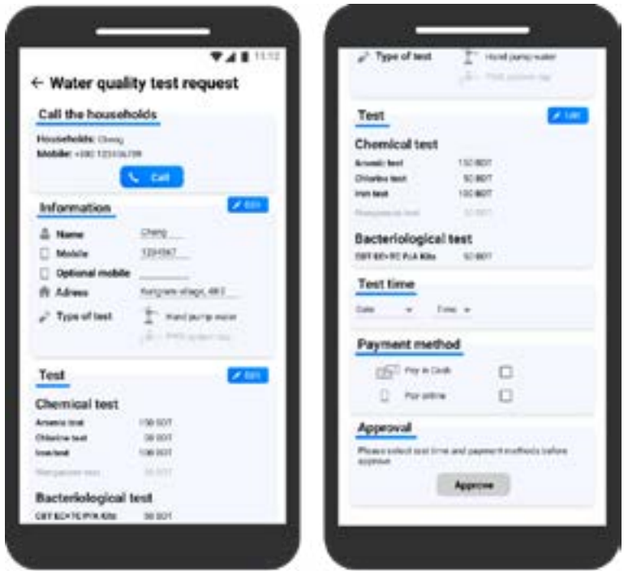


Figure 49, TAPP operator application

6.5 Application design: receiving water quality test results

After operators have done the water quality test, the NGO staff will check the water quality test result and send them to the households. In the customer's TAPP application, there is a list of households' private water quality test results and a list of water quality test results of the water tower(Figure 50). In the list, Some cards show the basic test information and the water quality with icons of each test.

Figure 51 shows a detailed test results page where the customer could find more information about the concentration level with each parameter and advice on using the sample water. Each rectangle represents one parameter. The rectangle's length shows the quantity of the substance in the water while the color of the rectangle indicates whether this quantity in water is safe, at-risk, or dangerous. At the end of the test result, there is advice related to the sample water. This part will link to the drinking water knowledge part of TAPP designed by Nayantara Thomas (2020).

To find problems with the design concept, the TAPP prototypes are tested in chapter 7. After the test, the design is iterated and finalised. The final design is also shown in chapter 7.

Engage in the monitoring process with SMS

Since there are still some non-smartphone and non-smartphone application users in Bangladesh, Annamarie and Maruf created a function for non-smartphone users. These users could also participate in the monitoring process and receive test results by sending SMS messages.

Figure 50, Private water quality test list

Figure 51, Water quality test result.

Summary of chapter 6

Chapter 6 presented the design of the water quality monitoring part of the TAPP operator application and customer application. The application design concept of the following functions are made,

1, Operators executing water quality test with TAPP
2, Customer requesting water quality
3, Operators approving water quality test request
4, Customers receiving water quality test results.

Next step

In chapter 6, the basic function of the water quality monitoring part of TAPP customer app and operator app is presented. The next step is evaluate the concept and make final designs based on the evaluation result.

Chapter 7
Evaluation and final concept for TAPP

In chapter 6, the design of the application has been created. This chapter will focus on testing the application with the user to find insights about how to iterate the application. After the testing, a final design of the TAPP is made after iteration.

7.1 App evaluation

Methods
The application 1st-ideation prototype is created in Figma and used for the evaluation of the design. The TAPP customer application and the TAPP operator application are tested separately with the following tasks.

TAPP customer application:
- Check the water quality test result for the water tower.
Test whether the user could find water quality test results from the home page, test whether they could understand the information about water quality.

- **Request a new water quality test**
Test whether the user knows how to add a new water quality test request and edit the request.

- Check the water quality test result of their private pump.
Test how the user finds the list of all the private water quality tests and distinguish the date and types of water supply with the water quality test.

TAPP operator application:
- Approve customer's water quality test request
Research the tester's performance on approving test requests, calling operators, and editing their households' requests.

- Doing water quality strip test with TAPP
Test whether the tester could start a water quality test with TAPP and decide then final result accordingly.

- Doing a bacteriological test with TAPP
Test whether the tester could set the timer for the incubation period with TAPP and successfully save&subimit test results. One day before the test, the participants who will perform the water quality strip test will watch tutorial videos to learn how to execute water quality strip tests. Before the application testing, the PWS system and the water quality tests are explained to the participants if they are not familiar with the Bangladeshi drinking water treatment & monitoring methods.

Two scenarios for PWS system customers and PWS system operators are created for the participants to finish the tasks. During the test, the participants will speak out their feedback, which will be recorded and analysed. How the participants complete each step in different tasks will be recorded to find usability issues. After each test, there are few questions for participants to answer, aiming at collecting the evaluation result related to application usability and application experience objectives.

Question after the evaluation
Usability:
Do you feel the application is easy to use? (Likert scale, 0-7)
Do you feel the application is easy to learn? (Likert scale, 0-7)

Research target experience:
Clear-structured:
Do you feel easy navigating through the application? (Likert scale, 0-7)

Instinctive:
Can you understand the information about drinking water quality easily? (Likert scale, 0-7)
Do you feel they can understand the application function easily?

Achievement:
Do you think they learn something new by using the application? (Likert scale, 0-7)
As PWS system operators, do you think you have contributed to monitoring the PWS system by using the TAPP? (Likert scale, 0-7)
As PWS system customers, do you think you have contributed to monitoring their drinking water quality? (Likert scale, 0-7)

Guidance design
Do you think the guidance is easy to recognize? (Likert scale, 0-7)

Participants
Eight participants are recruited for the application evaluation. Of the 8 participants, two Bangladesh local field testers are recruited to test the application with skype. Three UX testers are also participants in the testing and have done the expert review of the concept.

Two participants did the testing offline and did water quality tests with the TAPP application and strip test (figure 52).

Six users did the water quality test online with skype meetings. Their test process and interaction with the application is recorded to find usability issues.

A detailed test plan is initiated and presented in **Appendix G.**

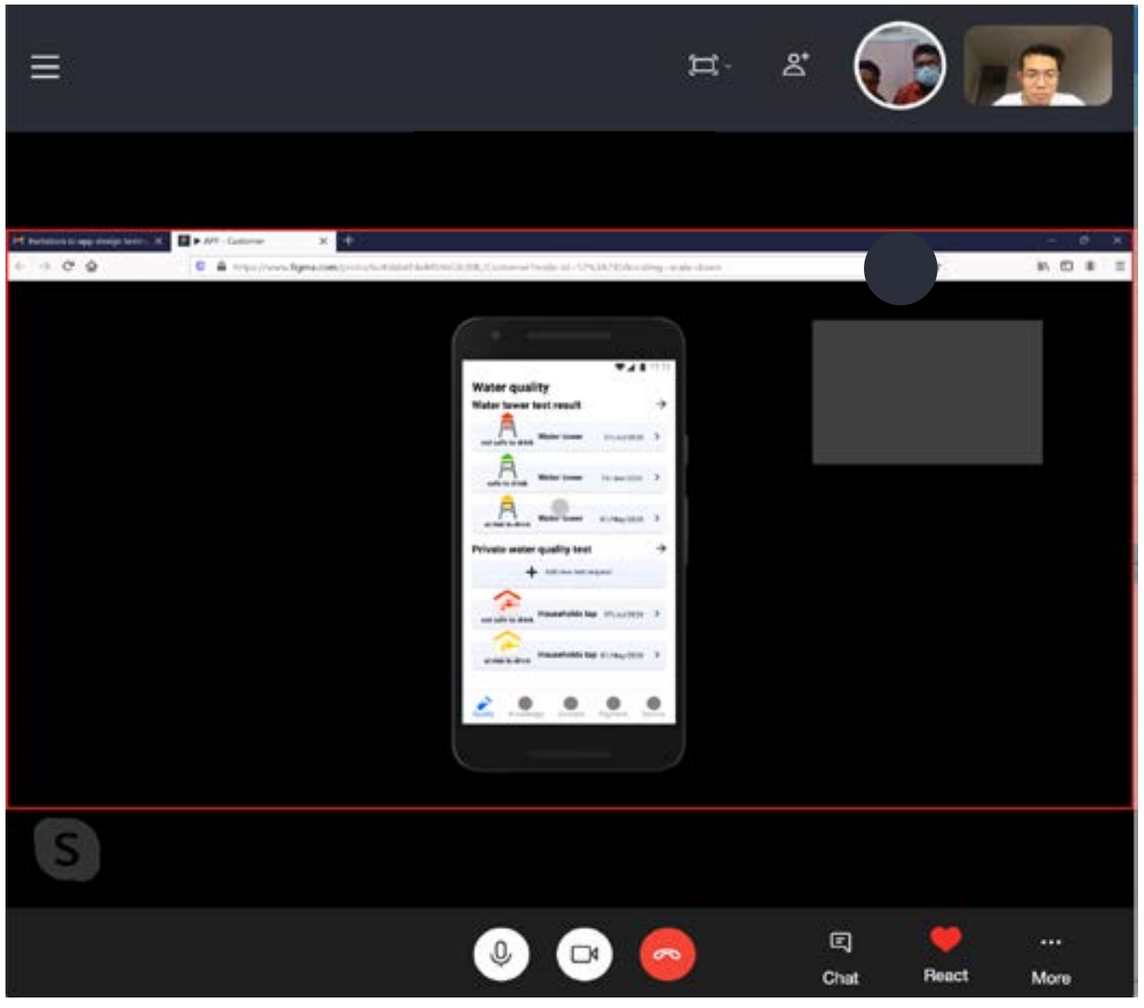


Figure 52, testing TAPP with Bangladeshi participants

Result

After the application testing, the data is collected and analysed to find usability issues and how the application achieves the experience objectives. The main findings after analysing the test result is presented in this chapter.

Customer application:

Task completion

In general, the participants could succeed with task 1,2 (check the water quality test result for the water tower, request a new water quality test.). There are only two difficulties with finishing task 1,2. First, 2 out of 8 participants have difficulties with recognizing the function of the cards. Second, 3 out of 8 participants forgot to select the types of water supplies.

There are critical usability issues with finishing task 3, as 6 out of 8 participants failed by finding the list of the private water quality test results. This usability issue needs to be solved with the final design. An overview of task completion is presented in figure 53.

Figure 54 shows the usability issues with the app interface.

The test result is presented in **Appendix H**.

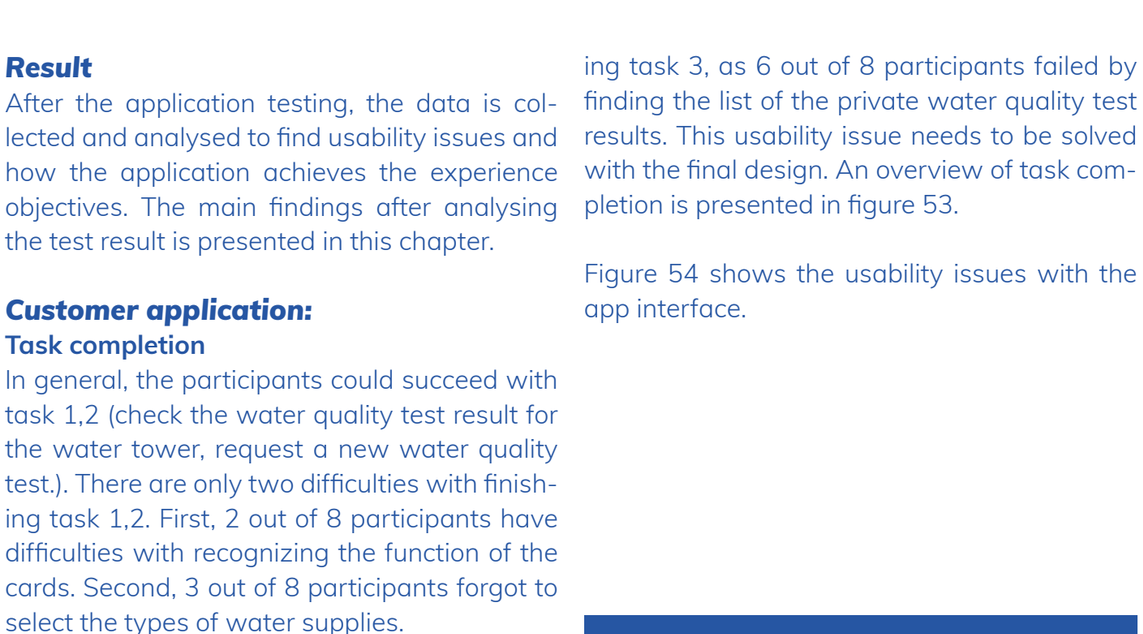


Figure 53, usability issues with the TAPP customer app interface,

Figure 54, Overview of user's task completion of TAPP application for customer

Objective experience evaluation

Figure 55 shows the average score of each question after the application testing. The TAPP customer application performs well with showing users water quality information that users could instinctively understand. Also, the customer app is doing good at helping users feel achieved by contributing to monitoring their drinking water.

For the 1st time user, the TAPP customer application is not very easy to use mainly because the participants could not find the list of the private water quality test results, and felt confused with the navigation of finding the list of test results. Users are not aware that there is a list of more test results with The current UI. However, the participants felt that the application is easy to learn. Once they have learned the application, they can finish the task easily. With the TAPP customer application, the user did not feel they had learned many new things as they felt would learn water quality information with other parts of the application or by other information sources.

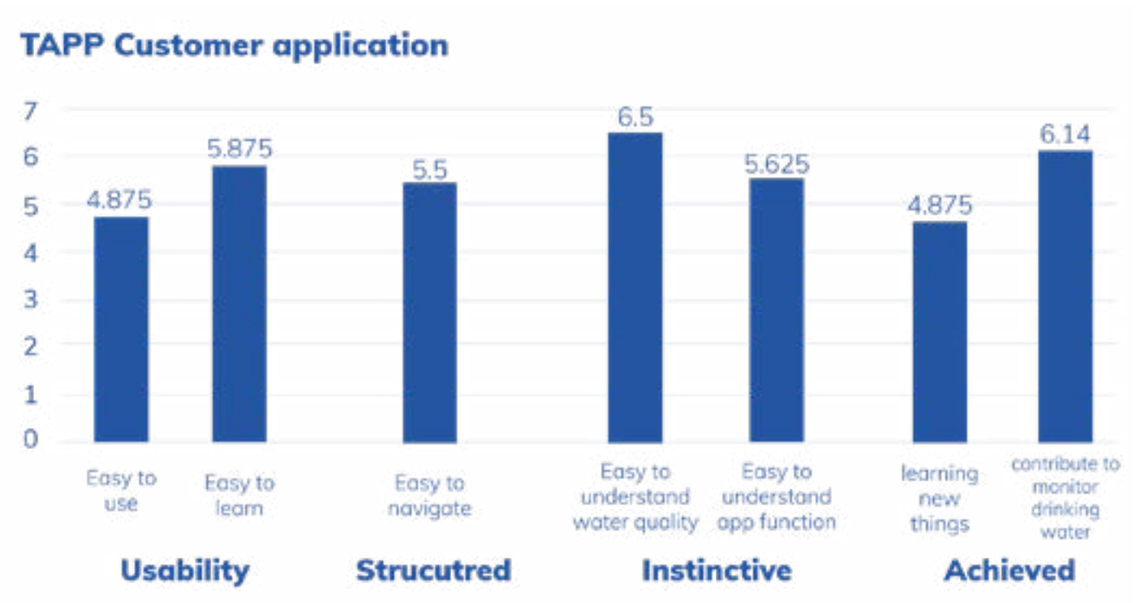


Figure 55, average score of the question after testing TAPP customer app.

Operator application

Task completion

In general, the participants felt the operator apIn general, the participants felt the operator application is easy to use. Most participants have no difficulty with approving water quality test requests and executing bacteriological tests. The two biggest problems happened when starting chemical strip tests and filling in water quality test results. Two Bangladesh participants have difficulty with starting the chemical strip test for the first time. After the chemical strip test, the process of filling in the water quality test result is too complicated, and some inappropriate icons make this process even more difficult. The user interface of filling test results after the test needs iteration.

During one test, the smartphone camera could not give the objective test result with the AKVO technology, and the user failed to save the test result. Currently, the user could not save the test result without an objective reading result. This technical defect would lead to critical issues with saving test results. The test process needs to have a small iteration.

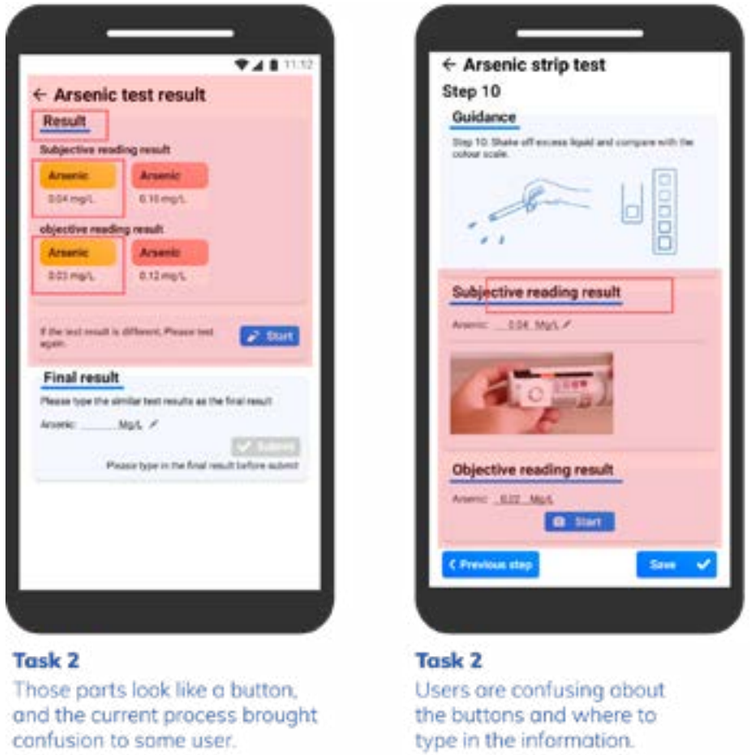


Figure 56, average score of the questionnaire question.

An overview of the task completion of the operator application is presented in figure 57.

figure 57, Overview of user's task completion of TAPP application for operator

Objective experience evaluation

Generally, the operator application receives better feedback than the customer application because the functions with the operator application use linear navigation that makes the app function and navigation more structured. However, the operator application shares the same navigation structure as the TAPP customer application that makes finding the list of all the test requests and test results difficult. The user test did not test that part since the customer application already tested how that navigation structure works. The home page of the operator application still needs to be improved.

The operator application performs well at giving guidance and showing an application function that the user understands instinctively. The participants felt that they contributed a lot to monitor the PWS system by using TAPP. However, they think that using the TAPP operator application did not learn new things as TAPP's function is to help the operator recap the information they already learned.

Figure 58 shows the average score of each question after the opertor application testing.

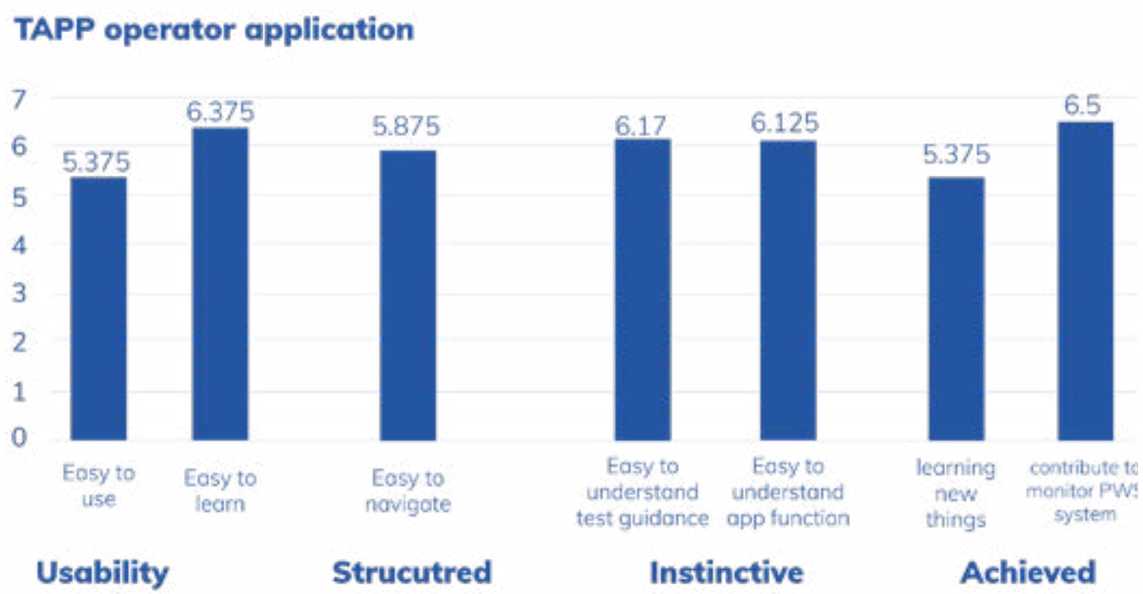


Figure 58, average score of the question after testing TAPP operator appliction

Discussion

The application test gave some feedback for iterating the application. However, influenced by the lockdown policy with the COVID-19, two testers did not participate in testing the operator's water quality testing part as they have not seen or used the strip test before and lack knowledge about executing strip test. Furthermore, only two participants test the water quality offline, and other participants only go through the application. More application tests are needed to test whether the PWS system operator could follow the guidance to perform water quality tests and whether operators felt confident with the accuracy of the final result.

Also, only 2 Bangladeshi people who are experienced with ICT devices participated in the application testing. Further testing with Bangladeshi households and PWS system operator is needed to find usability issues with the application.

Another limitation is that only the water quality monitoring part of TAPP is developed and tested with the participants this time. For the PWS system customer application, the participants also desired drinking water knowledge, which is the project of Nayantara Thomas and was not implemented in the prototype. When testing with bangladeshi households, the two parts should be tested together to see how different parts of the TAPP application work together to help the households finish the three tasks.

Conclusion

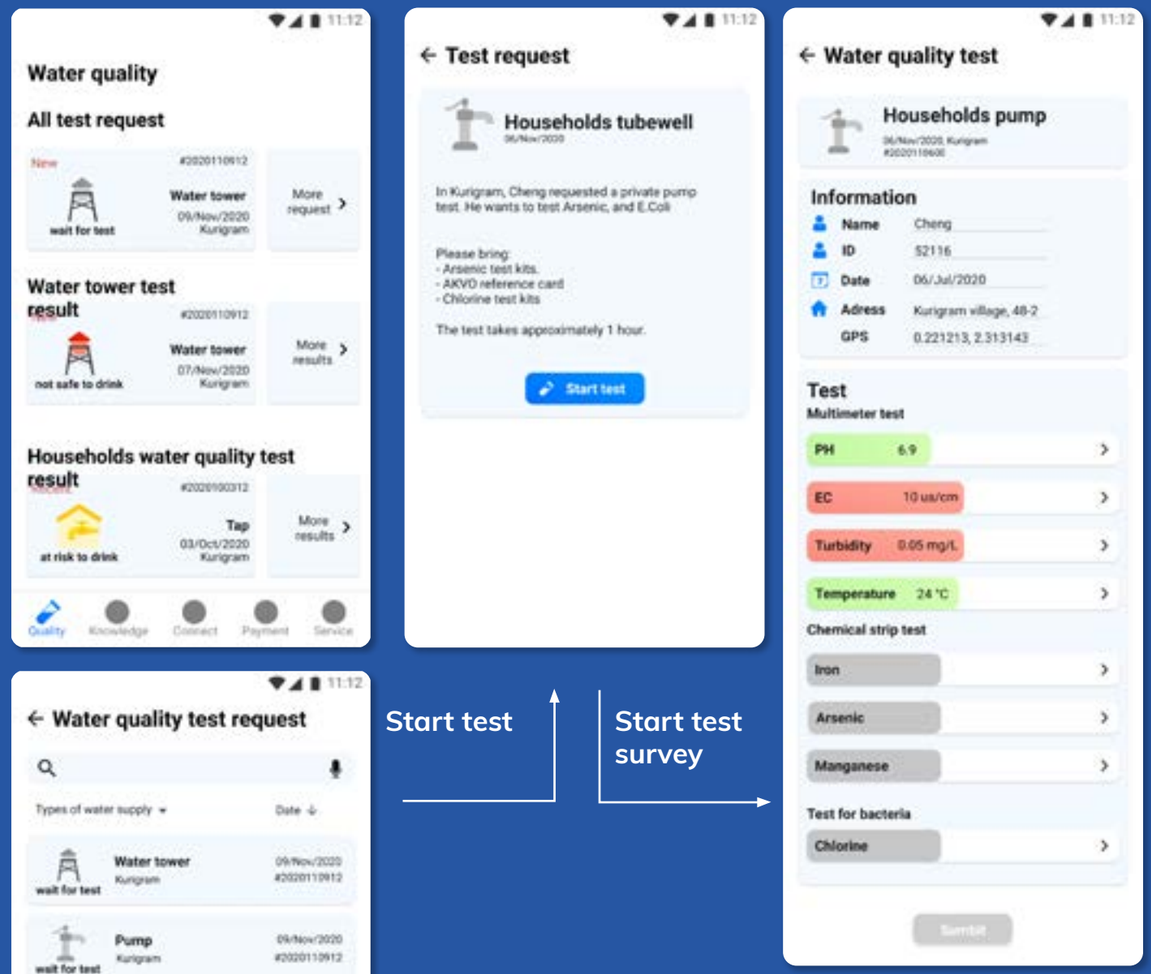
In general, both applications are easy to use. The users could finish the task without any tutorial when they use the application for the first time, except for finding the list of water quality test results with the TAPP customer application. There are also little difficulties with starting the chemical strip test and filling in the test result of the chemical strip test with the TAPP operator application.

Interaction of the app design will be made according to the problems found with the application testing. The app function of finding the list of the water quality test needs the most redesign to make the navigation more clear. Some minor changes to the application will be made to improve the consistency of the application and make the application function easier to recognize. The final concept of the project is created after the iteration of the application.

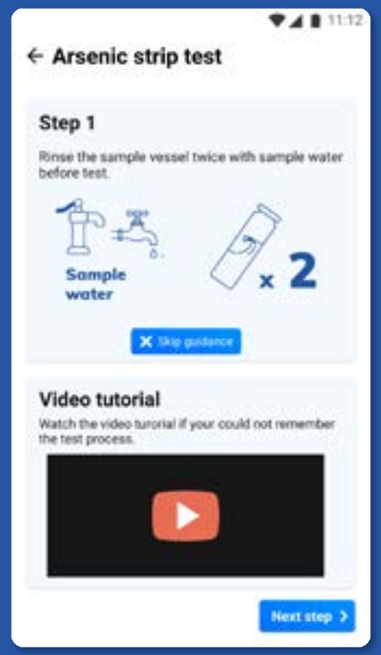
7.2 Final concept

Design task 1: test water quality with TAPP operator application

The operators can find all the water quality test requests that need to be done at the homepage of the water quality monitoring part of TAPP. The operator can start the test once they bring all the needed test kits when they are in the field. The operator will first check and edit the information about the test. Then they will type in the multimeter test result with TAPP.

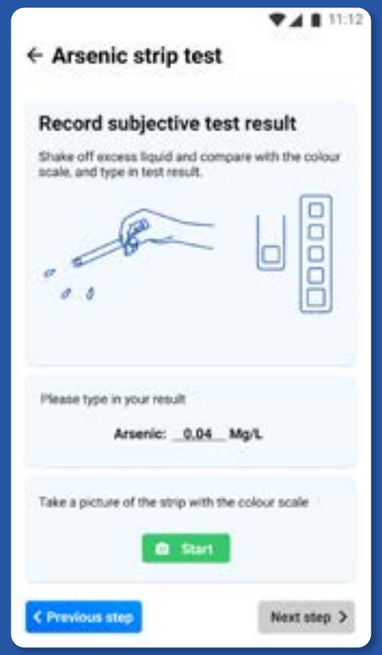


The operator will then perform chemical strip tests with TAPP. During the test, text & visual guidance will be shown to the operator, and there is also a timer to help the operator measure the time intervals. At the first step of each strip test, there is an online video tutorial for the operators if they are not familiar with the test process. On the other hand, if the operators are familiar with the test process, they could skip step-by-step guidance but watch simplified guidance instead.



Strip test guidance

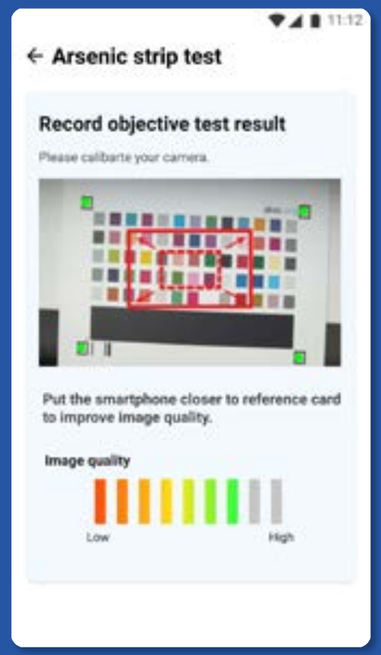
Strip test timer



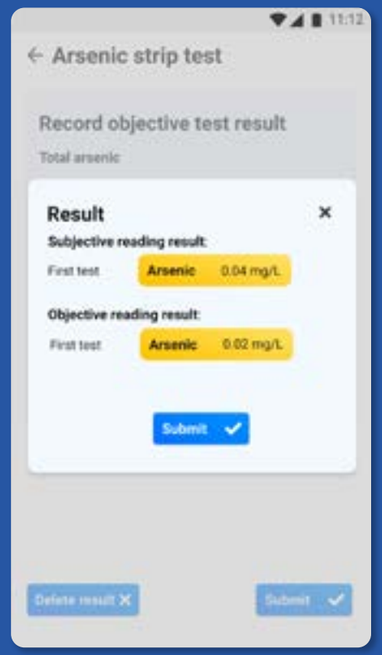
Give subjective reading result

After the test, the operator will fill in the subjective reading result of the test strip with TAPP. Then they will use the smartphone camera and the AKVO reference card to give an objective reading result of the test strip.

Give objective reading result

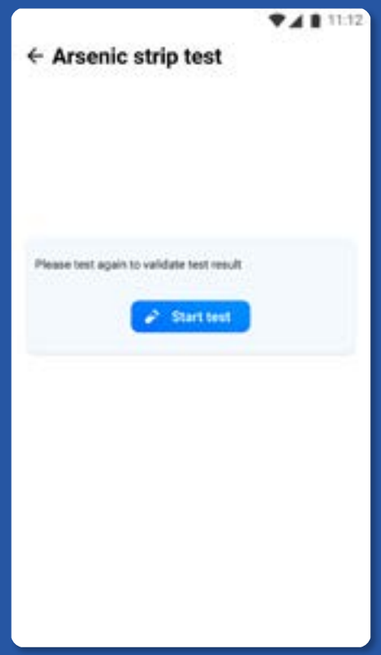


reading objective reading result

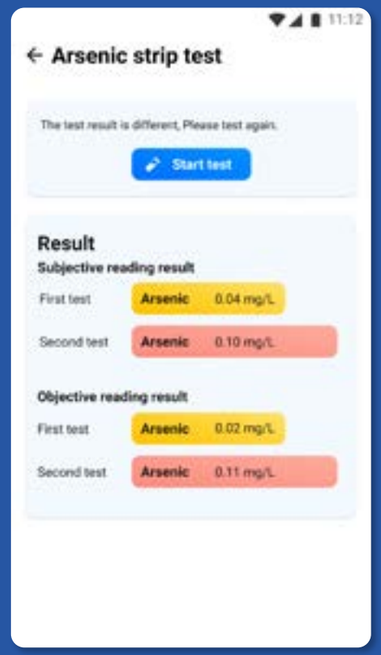


submit final result

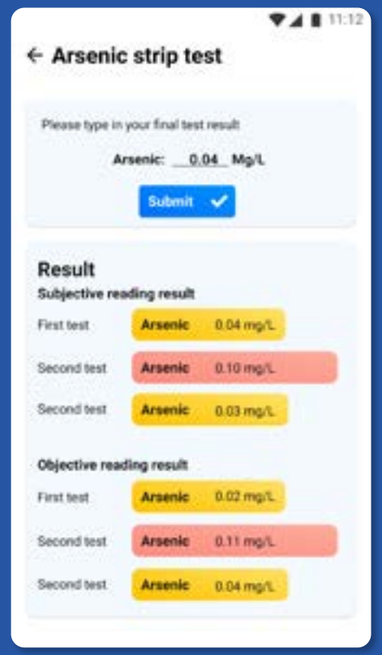
The testers will perform the test multiple times to validate the test result. The TAPP will check the test result given by the testers to decide whether they need to perform the test again. Once the tester got two similar test results, the TAPP will ask the testers to give a final test result.



1st time test result

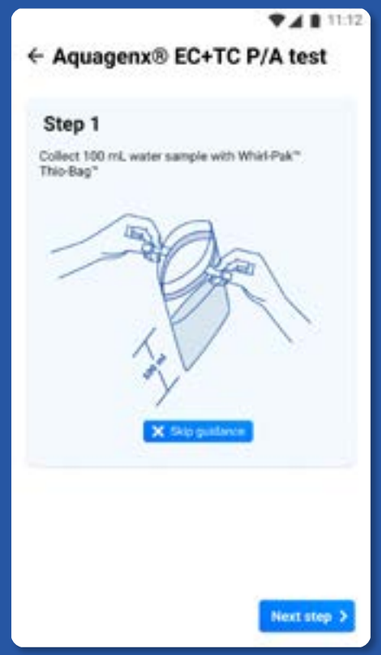


2nd time test result



3rd time test result

TAPP will also assist the testers to do bacteriological field tests, providing guidance, and sending reminders after the incubation period. After incubating the sample, the TAPP will collect the bacteriological test result.



Bacteriological test guidance

Bacteriological test timer

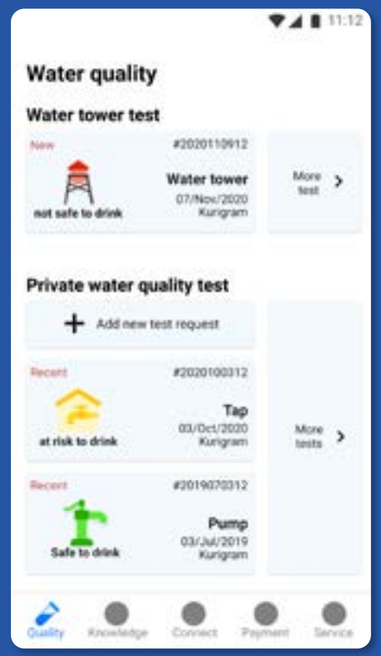
Decide bacteriological test result

Design task 2: test water quality with TAPP operator application

Households: TAPP customer application

Receive water quality test result

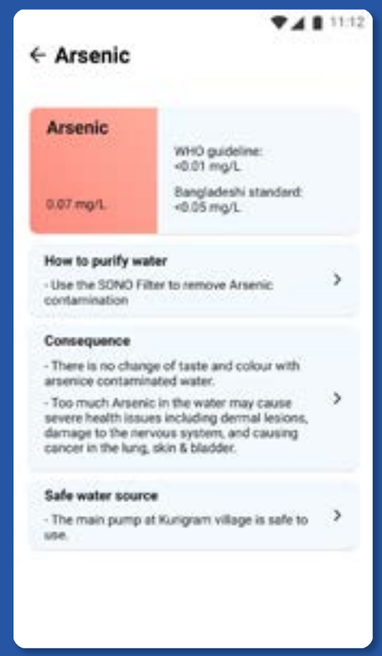
After each water quality test, the result will be uploaded to the database and shared with the households after the NGO staff accept the test result. The customer can check their latest test result on the home page of the water quality monitoring part. The test result page will show the overall water quality of the water supply, whether it is safe to drink. The test result page will also show the test result of each parameter.



Go to test result list

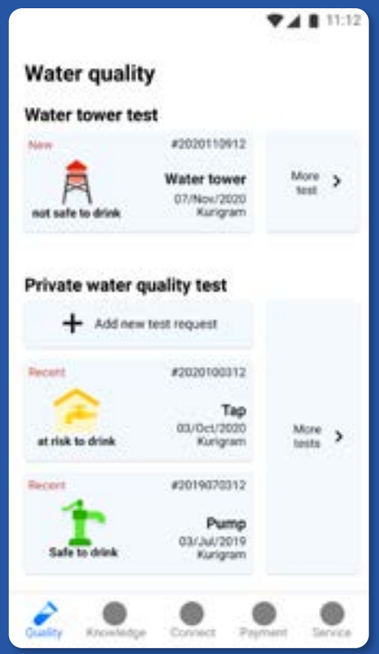
Test result

Check detailed contamination

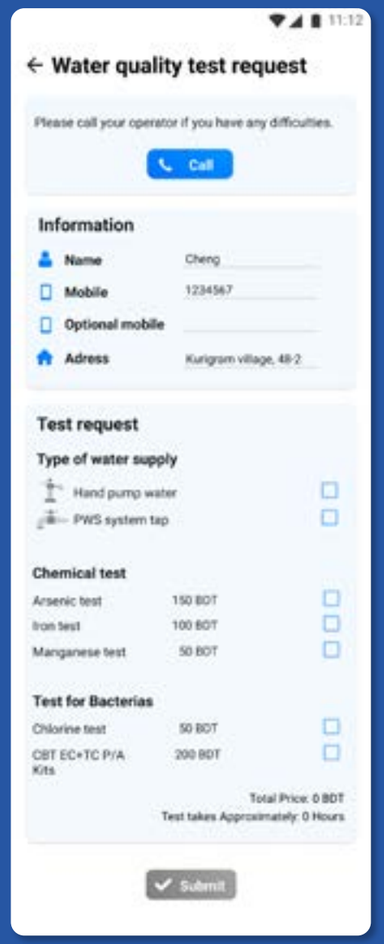


Requesting water quality test

The households could use the TAPP customer application to add a new water quality test request. In the test request form, they will select the type of water supply and the parameters they would like to test. If they have any difficulties filling in the form, they could use TAPP to call the operator for help. The request form will show how much the test would cost and how long the water quality test would last. After submitting the form, they will receive confirmation and wait for the operator's approval.



Go to test request page



Summary of chapter 7

In chapter 7, the first ideation of the application is evaluated with 8 participants to find usability issues that influence the user's experience with the application. The application is iterated based on the usability issues and participants' feedback. The final design of the TAPP customer application and TAPP operator application is presented at the end of chapter 7.

Next step

Researching the water quality and involving the households in the water quality monitoring is only the first step of monitoring and maintaining the PWS system. A new monitoring model and maintenance process of the PWS system is needed to monitor and maintain the PWS function properly. In the next chapter, the current governance system and the TAPP application function is first analysed. Based on the analysis result, a new monitoring model and maintenance process is designed.

Chapter 8
A monitoring model and maintenance process designed for PWS system

In the previous chapters, the water quality monitoring part of the TAPP application has been designed. However, executing the water quality test and communicating the water quality test result is only the first step of the monitoring and maintenance. After the water quality test, the operator and water service provider needs to decide system status/ issues and maintain the system correspondingly. Currently, there is a lack of an efficient monitoring model and maintenance process with the PWS system. Implementing the TAPP application brought an opportunity to build a new monitoring model and set a standard maintenance process.

In this chapter, a work frame is introduced to analyse the monitoring, and maintenance system of the PWS system after the implementation of the TAPP application. Then a new monitoring model and a maintenance process will be designed based on that system.

8.1 Work system

Different activities and stakeholders are involved in governing the PWS system. Together, these activities and stakeholders make up a system to operate, monitor, and maintain the PWS system. Before designing the monitoring model and the maintenance process, an analysis of the PWS system governing scenario is desired.

The work system designed by Alter (2002) is a method for summarising and analysing a system. Figure 59 shows the framework of Alter's working syste methods.

There are nine elements in the framework, and the four basic elements consist of a work system (Participants, Information, Technologies, Business process). The rest elements fill out the situation of the system. The arrows in the frame show the alignment of the different elements and how elements influence each other. (Alter, S. 2002.).

In this work frame, the Business process is the work performed in this work system; Participants are the People who work for the system; Information will be used or created during the work process; Technology represents the tools and techniques used by the participants.

Customers are the users who interact with the Product & service; Product & service are the productions of the system. Environment, Strategies, Infrastructure are additional elements that influence the work system. The Environment is the condition that the system is in, including cultural environment, organizational environment, etc. Strategies of organizations, firms, or countries will influence the performance of the work system. Infrastructure is any resource that the system may rely on.

The work frame is used to analyse the governance system of the PWS system after the implementation of the TAPP application.

The analysis result of the governance system of PWS system is shown in **Appendix I.**

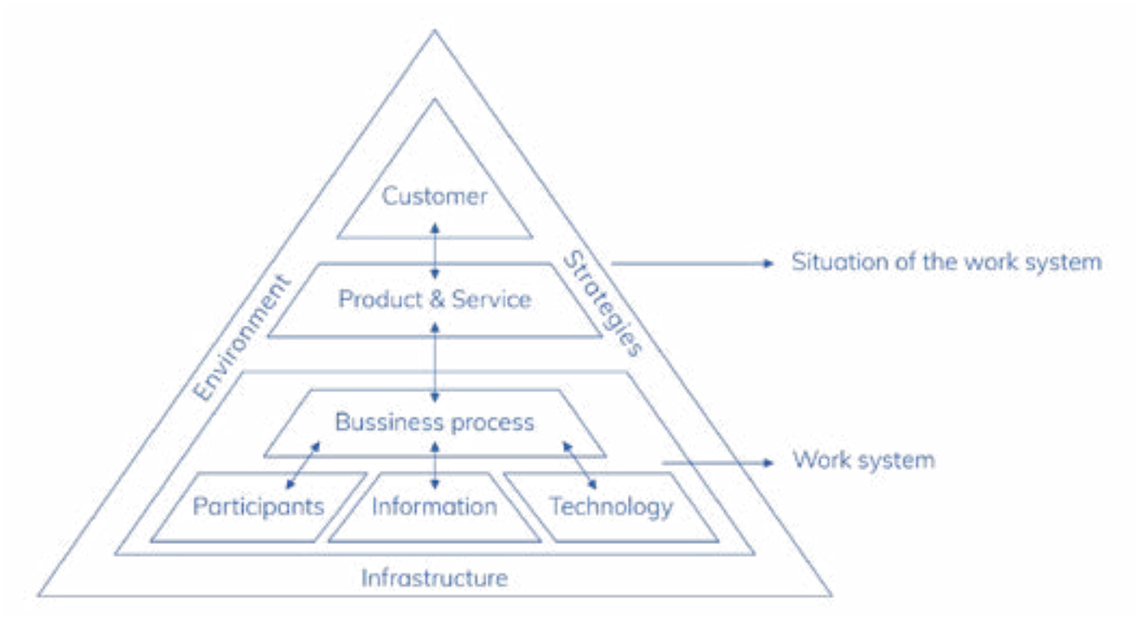


Figure 59, The work system framework (Alter, 2002)

8. 2 Water quality field test plan

The DELTAP project team is researching a way to use different field test methods to research water quality of the PWS system at low cost. Local operators of the PWS system will be trained to execute three types of field tests at different places in a PWS system to monitor the system function, detect system issues. Figure 60 shows an overview of where different field tests will be used to research water qualities in an ideal scenario.

Multi-meter tests are tested to give the result of the water's temperature, PH, turbidity, and electrical conductivity at every field test.

Field tests for bacterias are done to research the bacteria contamination at the main water tower, household tap, and the household's water storage unit. The tester first uses strip tests to research whether there is sufficient chlorine in the sample water, if there is sufficient chlorine in the sample water, then the sample water is protected with Chlorine. And then execute bacteriological tests to determine the presence or absence of E.Coli if needed. Ideally, the bacteria test will be done once every week to research bacterial contamination.

Chemical strip tests are done at the in-flow and out-flow of the PWS system's filtration system to test the quantity of chemical substance in water and determine the status of the filtration system. The chemical strip test should be done once every month to research the chemical contamination with the PWS system.

These tests will be used to research the water quality and monitor the PWS system's function.

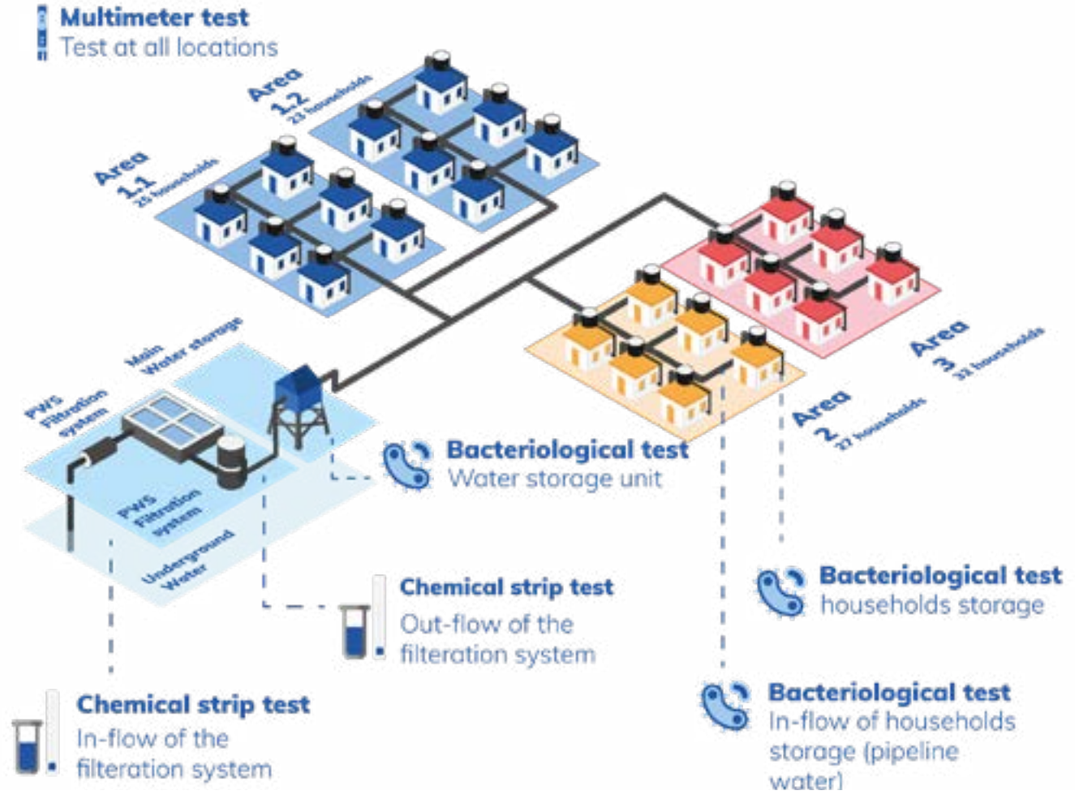


Figure 60, overview of field tests pln for the PWS system

8.3 Design of the Monitoring model & maintenance process

With the TAPP app implementation, there will be more water quality tests, enabling a regular monitor of the PWS system. To guide the operators and service providers to execute water quality tests to monitor the PWS system's function and condition efficiently, maintain the PWS system in light of the result of monitoring, a monitoring model and a maintenance process is designed. This monitoring model and maintenance process is the outcome of design task three.

There are three steps for the monitoring and maintenance of the PWS system:

The water quality test step, which aims to research the water quality by doing water quality tests for regular monitoring or responding to households' test requests and feedback;

The conclusion step, during which the operators and service providers use the water quality test results to conclude the condition, issues, and problems of the PWS system;

The repair & maintenance step where water service providers or local governments arrange repair and maintenance to solve the problems and issues founded in the previous steps. The water quality test step and conclusion step will be guided with the monitoring model, and the repair & maintenance step will follow the design of the maintenance process. Figure 61 shows an example for the monitoring model and maintenance process of the PWS system.

With the PWS system, there are three different monitoring & maintenance missions.

Monitor & maintain the filtration system with its function of cleaning groundwater.

Monitor & maintain the main water tower & pipeline water with bacterial contamination problems.

Monitor model and maintenance process households storage unit with bacteria contamination

The concept of how to monitor and maintain the system is designed based on the analysis result of the PWS system's governance system.

Three monitoring models and maintenance processes design of the PWS system are presented in **Appendix J.**

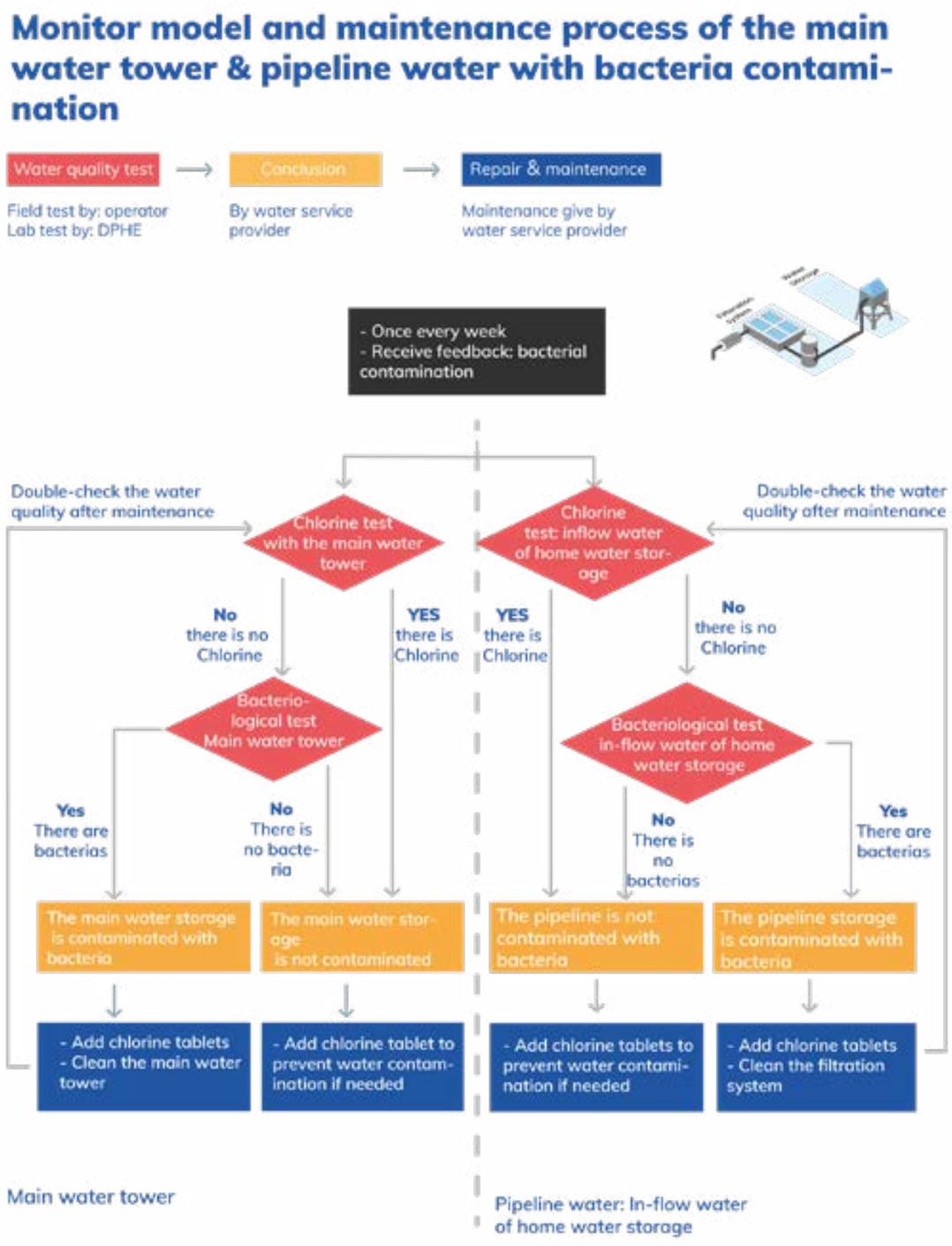


Figure 61, example for the monitoring model and maintenance process of the PWS system.

Summary of chapter 8

In chapter 8, the current governance system of the PWS system is analysed with a method called the working frame. Aiming to guide the monitoring and maintenance of the PWS system, a new water quality field test plan and three monitoring model and maintenance processes of the PWS system are created based on the current governance system and the TAPP application functions.

Next step

After creating the TAPP application and related monitoring model and maintenance system, the project is finished. Next, conclusions on the project with a reflection on the project process and a recommendation for future work are made.

Chapter 9
Conclusion

In the previous chapter, the final concept of the TAPP was created after the test of the first ideation. A monitoring model and maintenance process for the PWS system is also created to improve the efficiency of maintaining the PWS system using TAPP.

This chapter will conclude the design process and the limitation during the design, followed by a reflection of the project process and a recommendation for the future design of the TAPP-BDP application.

9.1 Summary of the design

The project first started with three Bangladeshi PWS systems' monitoring and maintenance problems. They are
- Insufficient water quality tests
- A lack of households' participation with the monitoring and maintenance of the PWS system,
- Lack of an efficient monitoring model and maintenance system for the PWS system.

Water quality field test and TAPP applications are introduced to the Bangladeshi field to enable regular water quality tests done by the PWS local operators. The TAPP operator application has been designed based on the analysis of the current strip test and the AKVO technology, which could help to improve the accuracy of the strip test by reading strip test results. The TAPP operator application could help the local PWS system operators to do water quality strip tests and give a reliable result of the water quality.

After researching the households' communication needs and smartphone usage, the TAPP customer application is designed to enable the households to participate in the monitoring and maintenance of the PWS system by requesting water quality tests and receiving water quality test results.

The TAPP application has been created and iterated after testing. The final concept of the TAPP application is shown in chapter 7.

After having the water quality test methods and TAPP application, a monitoring model and maintenance system utilizing the water quality test and the TAPP application is created and presented in Chapter 8.

To conclude, the project designed two smartphone applications: TAPP operator application and TAPP customer application, together with a new monitoring model and maintenance process for the PWS system. These outcomes solve the three design questions in chapter 1.

9.2 Reflection on the project

Influenced by the Covid-19, doing field research in Bangladesh is not possible. Therefore, the research and test of the project are done remotely by skype or calling local households. This restriction limits the connection with the target user and the efficiency of research.

Also, since the strip test is not introduced to the Bangladesh field yet. The research result is not come from the PWS system operator who are going to do the strip test in the future. More testing needs to be done after creating the first version of the TAPP.

Doing water quality tests request high budgets. However, currently, there is a lack of budget for maintaining the PWS system. The monitoring model and maintenance process did not fully consider the current budget but designed under an ideal situation where the budget is enough. The design of the monitoring model and maintenance process will be implemented and tested after the stakeholders have enough budget.

9.3 Recommendation for TAPP-BDP project

Due to the time limit, the project did not design animation guidance with consistent visual language. The design team could use consistent visual language to design moving guidance and test how that would work.

When designing the video tutorial for the test, the requirement should also be the same as designing the visual guidance, clearly showing each step and highlight test details.

TAPP is an application with lots of different functions, including water quality tests, knowledge about drinking water, service, and payment. These parts are designed separately by three different designers with three different styles. The final TAPP application will combine three different application design concepts. When combining these parts, the style and interactions should be consistent and guarantee good application usability.

The TAPP project group needs to consider how to prompt water quality tests and TAPP applications to the target users. Currently, there is no systematic monitoring and maintenance of the PWS system. Arranging water quality tests is a new concept to the Bangladesh households and operators. The TAPP project group needs first to tell the households what the water quality test is and how each type of water quality test works with monitoring the water quality before introducing the TAPP application to the user to arrange water quality tests. Designing ways to prompt water quality tests could be another master graduate project.

The TAPP and chemical strip test is not yet introduced to the monitoring process of the PWS system. In the current PWS system, there is not an efficient monitoring and maintenance system yet due to many reasons, including insufficient budget. To make the TAPP application work as the original plan, the monitoring, and maintenance system should be built together with the implementation of the TAPP. The DELTAP project should consider how to build a simple monitoring system with the current budget and test the TAPP application works.

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Appendix

Appendix A Manual for field kits

Multimeter test

There are different multimeters on the market, they are quite similar and would have similar operation.

Typical steps of executing a sensor test:
1,Remove the protective cap from the meter.
2, Clean the electrode with distilled water and dry it.
3, Press the power button.
4, Insert the meter upright in the solution to the brim and stir gently.
5, Press the C / F key to switch between Celsius and Fahrenheit
6, Press the PH / EC button to switch between PH and EC.
7, Rinse with water after use and press the power button.
8, Store the meter upright with the storage liquid in the protective cap.

Chemical strip test

1.1 Iron test

To quickly test the iron contamination in the groundwater in the field, the researcher of EPRC currently uses an iron test tool kit to get accurate results with simple steps. The strip test kit is HACH Iron test strip,0-5 mg/L. It consists of a strip with a strip, a vial, a reagent, and a colour scale on the strip bottle.

Figure 62, the iron test tool kit.

The tester need to follow the steps in order to correctly conduct the iron test and read the test result.
1, Rinse sample vial with tap water after each use.

2, Fill sample vial HALF FULL with sample water.
3, Open one foil packet and add powder contents to vial.
4, Cap vial and shake rapidly for 5 seconds.
5. Dip a test strip into sample vial and rapidly move back and forth underwater for 15 seconds.
6. Remove and shake excess water from test strip.
7. Immediately compare test pad to colour chart and record results. Estimate result if colour on test pad falls between two colour blocks.
8, Rinse sample vial with tap water after each use.

More information of HACH iron test kit at
https://www.hach.com/iron-test-strips-total-dissolved-iron-0-5-mg-l/product?id=7640211605

1.2 Arsenic test

For the arsenic test, the test chosen for the DELTAP Project is the QUANTOFIX® Arsenic 10 from Macherey-Nagel.

Figure 63, the QUANTOFIX® Arsenic 10 kit from Macherey-Nagel

To determine the quantity of arsenic in the water, the testers use the test kit according to the following steps:

1. Using the syringe, fill 3 x 10 ml sample solution into the reaction vessel.

After adding each of the following reagents, shake gently for about 2 secs:
2. 1 drop of Arsenic-1

3. 1 measuring spoon of Arsenic-2
4. 1 measuring spoon of Arsenic-3

5. Immediately afterwards bend the test strip with the test field about 2 cm deep into the reaction vessel and then fit the lid.
6. To vent the reaction vessel, pierce the lid with the needle and leave the needle in the lid.
7. Wait 10 minutes.
8. Afterwards dip the test strip with the test field into distilled water for two seconds.
9. Shake off excess liquid and compare with the colour scale.
Figure 64 shows the visual guidance of the *Quantofix Arsenic 10 test kit.*

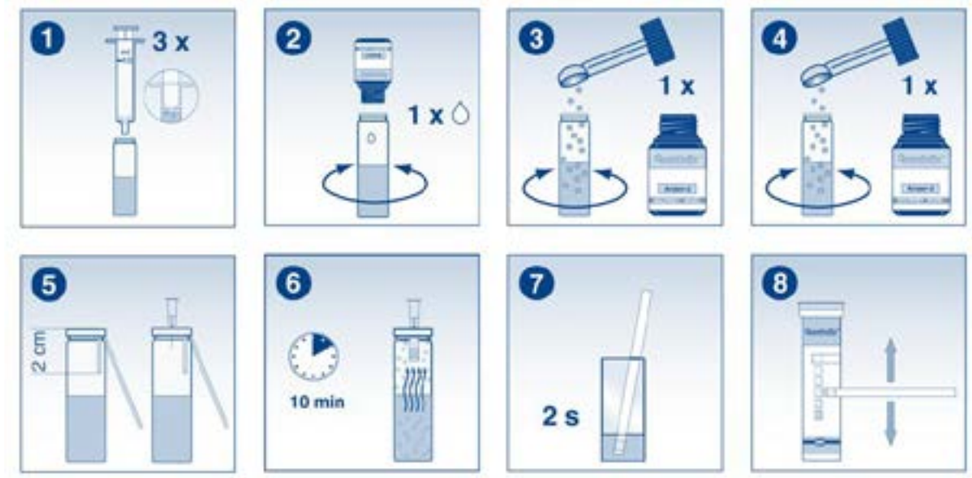


Figure 64, The manual of the ***Quantofix Arsenic 10 test kit.***

More information of the QUANTOFIX® Arsenic 10 kit at
https://www.mn-net.com/semi-quantitative-test-strips-quantofix-arsenic-10-91334

1.3 Manganese test

The manganese test is the SenSafe Manganese test strips.

Figure 18, the SenSafe Manganese test strips kit.

Steps to test:
1. Collect water into a vial ,
2. dip test strip #1 for 20 seconds, discard.
3. dip test strip #2 for 20 seconds, discard.
4. Dip strip #3 for 30 * seconds, pull out, wait 3 minutes for colour to develop,
5. Match colour chart.

* Because the temperature of the tested water can affect the results, please adjust dip time according to the following table. Step #3 above assumes warm water of 75 degrees Fahrenheit (24 C). If you water sample temperature is different, adjust dip time of strip #3 accordingly:

Temperature C / F	Dip time, Seconds
0 / 32	120
5 / 41	90
9 / 48	75
13 / 55	60
18 / 64	45
21 / 70	36
24 / 75	30
28 / 82	25
32 / 90	22
36 / 97	21
40 / 104	20

More information about the SenSafe Manganese test strips at
https://sensafe.com/sensafe-manganese/

1.4 Free and total chlorine test

The free and total chlorine is to test whether the water is free from bacterial contamination and has the ability to avoid recontamination from bacteria. The strip kit used for this project is the HACH chlorine strip tests.

There is no visual guidance with the HACH chlorine strip test, only a text guidance on the test strip bottle.

1, Dip the strip into water and move back and forth for 30 seconds(or hold pads under water stream for 10 seconds).
2, Compare the TOTAL CHLORINE and FREE CHLORINE pads to the colour chart above. Estimate if the colour on the test pad fails between two colour blocks.

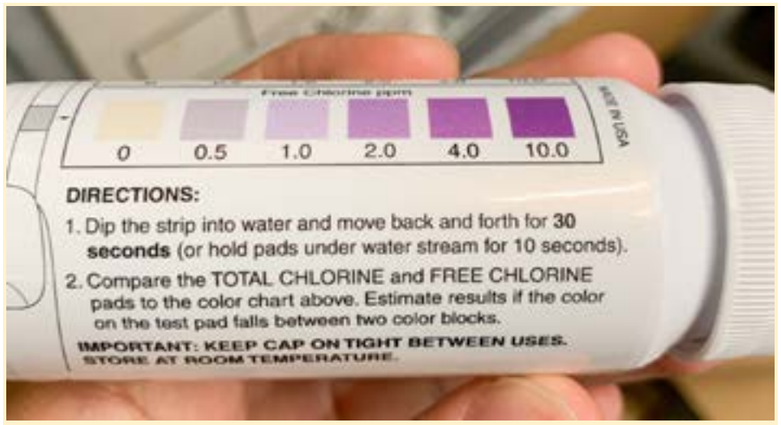


Figure 65, text guidance on the strip bottle of HACH chlorine strip test.

More information about the HACH chlorine strip test at
https://www.hach.com/free-total-chlorine-test-strips-0-10-mg-l/product?id=7640211603

2. Bacteriological test

The E.Coli test is to test the bacterial contamination with the water. The test used is the Aquagenx® CBT EC+TC Presence/Absence (P/A) kit and the H2S strip test of the Water Health Laboratories India.

2.1 Aquagenx® CBT EC+TC Presence/Absence (P/A) kit and

The test needs Whirl-Pak™ Thio-Bag™, growth medium, incubator and UV light. Gloves are also desired to avoid contaminating the sample.

Steps:

1. Sanitize the work area with disinfectant cleaning solution, paper towels or wipes.
2. Collect 100 mL water sample with Whirl-Pak™ Thio-Bag™
3. Add Aquagenx® EC+TC growth medium to sample in Whirl-Pak™ Thio-Bag™
4. Incubating the sample
5. Score and record P/A test results
6. Decontaminate sample

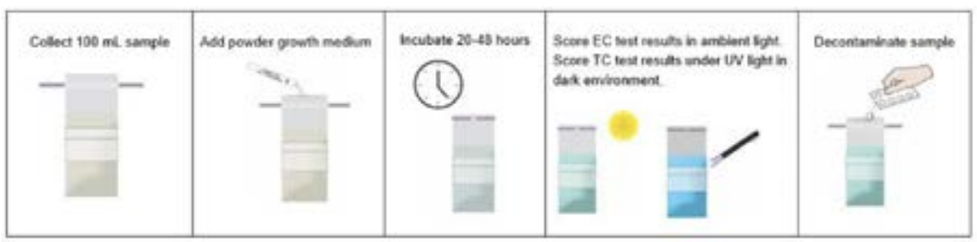


Figure 66, Visual of the E.Coli P/A test procedure.

Compared to strip tests, the E.Coli test takes longer time since the sample needs to be incubated. Also, there is more requirement to pay attention during the test. The tester needs to be very precise to not contaminate the sample with outside bacteria. And there are more rules for incubating temperature and period. Therefore, more guidance is needed for conducting the E.Coli test.

How to Interpret Color-Change Test Results

Color in Thio-Bag	Yellow/Yellow Brown in ambient light and does not fluoresce blue under UV light	Yellow/Yellow Brown that ... fluoresces blue under UV light	Blue/Blue Green in ambient light	Blue/Blue Green that ... fluoresces blue under UV light
E. coli	Negative	Negative	Positive	Positive
Total Coliforms	Negative	Positive	Positive	Positive

Figure 67, How to interpret the E.Coli test result.

To count the Most Probable Number of the E.Coli, the test steps are:

1, Sanitize the work area with disinfectant cleaning solution, paper towels or wipes.
2, Collect 100 mL water sample with Whirl-Pak™ Thio-Bag™
3, Add Aquagenx® EC+TC growth medium to sample in Whirl-Pak™ Thio-Bag™
4, Pour sample with dissolved medium from Thio-Bag into Aquagenx Compartment Bag
5, Seal compartment bag shut
6, Incubation Period and Temperatures
7, Score and record MPN test results
8, Decontaminate sample

More information about the Aquagenx® CBT EC+TC P/A Kits and CBT EC+TC MPN Kits at
https://www.aquagenx.com/cbt-ectc/

2.2 H2S strip test of the Water Health Laboratories India

The H2S strip test is an easy and cheap way to test the absence and presence of the E.Coli in the sample water.

Test instructions

1. Fill the water to be tested up to 'FILL LINE' and replace the cap.		
2. Keep at room temperature (preferably 250 - 370C) for the specified time below		
Temperature Range Average	Incubation Period	
30 - 350 C	24 Hours	
25 - 300 C	24 - 36 Hours	
20 - 250 C	36 - 48 Hours	
15 - 200 C	48 - 60 Hours	
3. Observe for the change in colour of the medium.		
4. a) If the content turns black, water is not fit for drinking. Refer to adjacent picture.		
b) If the content turns into any color other than black, it indicates that water is free of bacteriological contamination.		
5. Add few drops of some disinfectant (i.e. dettol, phenyl etc.) and discard.		

Figure 21, How to test the E.Coli in the water with the H2S strip test.

More information about the H2S strip test at
https://www.indiawaterportal.org/articles/h2s-strip-test-water-quality-testing-kit-bacteriological-contamination

Appendix B Interview question

Interview questions,

Which area have you visited? When.

If you are testing a household's private water pump. What will you do during the whole test?
Which test have you done in the field?

How many times have you done these tests? How frequent will you do the test?

Which of those tests you feel is the most difficult one, why?

What did you do when you first learned to do these tests? Did you immediately remember every step and details after your learning?

After you fully learn the test, you have confidence in doing the test. Will you read the guidance/ manual before your test?

If yes, what will you do? Which part will you read the most and read most carefully?

Will you feel you can't remember how to do the test if you haven't done it or read the guide of a certain time? If yes, which part or step would you feel is the most easy to forget?

After how long times of no practice with the test would you feel I need to look at the manual before the test?

If yes, which part will you focus on reading when you recall the test?

Do you have any experience with making mistakes during the test? Do you want to share some stories that you still remembered?

Do you have any special techniques when you try to remember a test or try to remember a step?

Have you used the AKVO service before?
If yes.

How do you think AKVO service helped you during the test?

What will you do with the test guidance that AKVO caddisfly gives you?

Do you still remember some stories that there is any difficulty with using the AKVO service?

Are you satisfied with the AKVO app? Why?

Appendix C Telephone interview question

PART 1

General information:

GOAL - Establish an idea of the context and personal situation of the participant

	District / Union / Upazilla / Ward / Village	
	Gender of participant	F/M
Nr.	Question	Question type
1	What is your name?	Short answer
2	What is your age?	Short answer
3	What is your religious belief?	Short answer
4	What is your educational level?	Short answer
5	household composition: Who lives in your house? - Gender and Age	Open answer Long explanation not required.(an indication for age is also okay)
6	What is your occupation?	Short answer
7	What is the monthly income of your household?	Number - can be an estimate
8	What is the monthly expenditure of your household?	Number - can be an estimate
9	Who makes the decisions in your household with regards to: - Financial decisions - Drinking water	Short answer / Open
10	Who makes the decisions for your community?	Open Can have multiple answers/ based on participants perception

Technology:

GOAL - Establish an idea about the experience and use of technology by the participants.

Research question / sub-research question

Nayantara: *What is the existing scenario around smartphone usage amongst the community members?*
Cheng: *What are difficulties of Bangladeshi piped water users in using ICT? What factors may influence them to learn and use ICT?*
Annemarie: *Are Bangladeshi piped water users able and willing to pay their water bills through their smartphones?*
Are Bangladeshi piped water users able and willing to interact with their operator and community members through their smartphones?

Nr.	Question	Question type
11	Which electronic devices do you use in your daily life?	Open
12	Do you own any of these: - Television - Button Phone - Water pump - Radio - Computer/Laptop - Tablet/iPad - Smart Phone	Y/N
If they don't have smartphone:		
13	Did you face any difficulty in learning to use these electronic devices?	Y/N (From the Devices listed above)
14	If yes, which devices did you face difficulties with and what were these difficulties?	Open
15	Have you ever used a smartphone?	Y/N
16	Does anyone in your household own a smartphone? Who?	Open - Gender and age of person who owns one
If they have a smartphone:		
17	Does anyone else in your household own a smartphone? What is their gender and age?	Short Answer
18a	Did you face any difficulty in learning to use your smartphone?	Y/N
18b	If yes, what were the difficulties?	Open
19	How frequent do you have internet access on your smartphone?	Short answer
20	Do you have apps on your smartphone?	Short Answer - Prompt with apps like facebook, whatsapp etc.
21a	Do you use it alone or do you require any help from others to use the smartphone app?	Short Answer
21b	If you require help in what part do you need help with?	Open
22a	What smartphone app / function is your favourite to use? Name 2 to 3.	Open
22b	And why?	
23a	What smartphone app / function do you think is easy to use? Name 2 to 3.	Open
23b	And why?	
24	What do you do with your / a smartphone? - Calling - Messaging - Searching information - Taking photographs - Watching videos - Listening to songs - Playing games - For educational purposes - Making payments - Other (please describe)	Y/N
25	What are the three things that you do the most with your smartphone?	Short Answer
26a	If you receive water information from an app on your phone, would you trust it?	Y/N
26b	Why/ why not?	Open
27a	Do you think it will be helpful if you can submit your queries or complaints about the piped water system to the water supplier(s) via a smartphone app?	Y/N
27b	Why/ why not?	Open
28a	Do you think it will be helpful if you can submit your queries or complaints about the water supply to other community members via a smartphone app?	Y/N
28b	Why/ why not?	Open
29	From the following list, what are the three most important aspects for you in the current apps that you use:	Rank - If possible mix the sequence of options in each

	- How it looks - How much internet data it uses - How well you understand the information given in the app - How easy it is to learn to use the app - The space the app occupies on your phone	interview

Information/Communication:

GOAL - **Establish an idea of the preferred modes and means to communicate information.**

Research question / sub-research question

Nayantara: *How can information on water safety be communicated through an app to rural communities in Bangladesh?*
Cheng: *How can information on water quality be communicated through an app to rural communities in Bangladesh?*
How can water quality testing procedures be communicated through an app to operators of water supply systems in Bangladesh?
Annemarie: *How can information be communicated through an app to rural communities in Bangladesh?*

Nr.	Question	Question type
30	If you require information or advice, how do you get that? From who / where?	Open Channels + people they get information from (detailed way)
31	From who or where do you currently receive information about drinking water?	Open
32a	Would you like to know more about pollutants in your drinking water?	Y/N
32b	And Why?	Open
33a	Would you like to know about the consequences of drinking polluted water?	Y/N
33b	And Why?	Open
34	Would you like to receive information about which water sources are safe to drink in your community?	Y/N
35	Would you like to know about ways to collect and store your water to ensure it remains suitable to drink?	Y/N
36	Is there any other information you would like to receive regarding your drinking water?	Open
37	From who and via which medium(how) would you like to receive this information?	Open
38a	Have you ever shared information on the condition of your drinking water within your community?	Y/N
38b	If yes: what was the information and why and how did you share it?	Open
39	Do you ever share information with groups of people in your community?	Y/N
40	How do you share the information amongst the group?	Open
41	Choose the top three of the following types of media which you prefer to receive information on your smartphone? - Text - Photograph/picture - Bar chart - Symbol (Like on a smartphone) - Drawing - Audio - Video	Short answer- Describe list to participant
42	Would you prefer to know: a. if your water is safe to drink or not b. exactly how much of which pollutants are in your drinking water and how much is safe for your health c. Both of the above	Option - describe options to participant

Part 1 estimated time : 21 minutes

PART 2

Drinking water / Water safety:

GOAL - Establish an idea of the current drinking water situation and awareness of water quality and water safety

Research question / sub-research question

Nayantara : *What types of information needs to be provided to build awareness on water safety for the communities in Bangladesh?*
Cheng: *What does water safety mean to you? What do you care the most about related to water safety?*
Annemarie: *What is the existing knowledge of the community members regarding water quality?*
What are the preferences and desires of the community members regarding their drinking water?

Nr.	Question	Question type
43	Can you explain your activities with regards to using water during a full day?	Open - Ask from Morning to evening so participant can organise their thoughts in a timeline
44	From which source do you collect your drinking water? Multiple answers possible. - Private tubewell - Community tubewell - Shared tubewell - Private dug well - Community dug well - Shared dug well - Private Piped water supply - Community tap point - Spring water - River/lake water - Rain water - Bottled water - Other	Option
45	Why do you use this water for drinking purposes?	Open
46	What is your most preferred source for drinking water?	Open
47	Why is this the most preferred source of water for you?	Open
48	From where do you collect your drinking water and how long does it take you to get there?	Open
49	What do you use to carry the drinking water to the house?	Open - Ask the method of collection in terms of containers used.
50	Who collects the most water for your household?	Short answer - *This concerns all water collection, not only drinking water*
51	Who collects the drinking water in your household?	Short Answer
52	Do you store drinking water in your house? if so where and how?	Open
53	Do you cap the drinking water you store in the house?	Y/N
54	If you are thirsty, how do you fill your glass of water?	Open - Participant should Describe the method of filling
55	Do you know what ways your water can get contaminated during collection, storage and use?	Open
56	Can you name any health issues that can be caused from drinking water?	Open - View of the participant (Need to take down their perception)
57	Have you done anything to prevent these health issues?	Open
58	Have you done anything to treat your drinking water?	Open
59	Can you name any contaminants in the drinking water that might endanger your health?	Short answer
60	Please rank the top three: My drinking water should: - Be cheap - Be safe to drink - Taste good - Take little time to collect - Take little physical effort to collect - Always be available	Ranking
61	What are the reasons you would trust your water for drinking purposes?	Open
62	Has your drinking water ever been tested?	Y/N
63	If yes: by whom and was the result shared with you?	Open
64	If no: why not?	Open
65	Would you like your water to be regularly tested to ensure it is safe to drink? Why / why not?	Open

Piped Water System:

GOAL- Establish the existing beliefs and practices towards the Piped water supply system.

Research question / sub-research question

Nayantara : *What are the perceived uncertainties towards the PWS system?*
Annemarie: *What are the preferences and desires of the community members regarding their piped water supply system?*

Nr.	Question	Question type
66	Do you have a connection to the piped water supply system?	Y/N
67	Do you have a private or shared connection?	Short answer
68		
If yes, then:		
69	Why do you have the piped water supply connection?	Open
70	How do you pay your water bill for your piped connection?	Open
71a	Do you trust piped water for drinking purposes?	Y/N
71b	Why / why not?	Open
72a	Are you regularly in touch with the piped water system operator(s)?	Y/N
72b	Why / why not?	Open
73	What are the current problems you face with the piped water system?	Open
74	What actions do you take when you experience these problems?	Open
75a	Are you satisfied or dissatisfied with the piped water supply system?	Short answer
76b	Why?	Open
If no, then:		
77	Why don't you have piped water supply connection	Open
78a	Would you like to have a connection to the piped water supply system?	Y/N
78b	Why/ Why not?	Open

Part 2 estimated time = 16 minutes
Total estimated time for part 1 and 2 = 37 minutes

Appendix D design guideline

The design guidelines are deduced from the literature review and the telephone interview result to guide the application design. The design guideline includes application design guidelines and communication guidelines that fit the Bangladeshi context and the Bangladeshi user's requirements.

Application design guideline:

- The app should have good accessibility and usability
  The interface design of the app would follow accessibility and heuristic guidelines, such as Web Content Accessibility Guidelines (WCAG) 2.1(W3C, 2018), Nielsen's 10 Usability Heuristics for User Interface Design (Nielsen, 1995).

- The application should have interactions similar to the apps that Bangladeshi users are familiar with
  The TAPP interaction design should be similar to the applications that the Bangladeshi households are familiar with to assist target users to learn the app.

  Four applications are mentioned by the telephone interview participants as easy-to-use applications. They are Youtube, Google Play Store, Facebook, and Imo. The TAPP will use similar UI design components as those applications. These UI design components include:

  - Bottom navigation (Figure 68) has been used in Youtube and Play Store, allowing movement between screens at the same level of hierarchy. (Material design, n.d.-a).

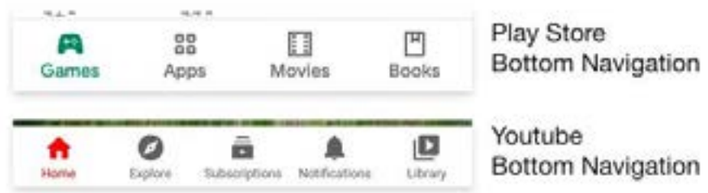


Figure 68, Application design component--- Bottom navigation

The TAPP will use bottom navigation for moving between primary destinations.

- Tabs (figure 69) are also used for navigation between groups of related content and at the same level of the hierarchy. (Material design, n.d.-b). Facebook and Imo use top tabs as their primary navigation, Youtube and Play Store use tabs as secondary navigation.

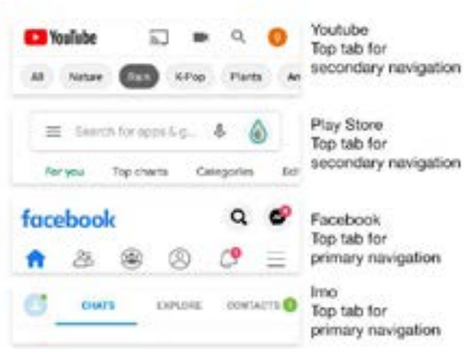


Figure 69, Application design component--- Tabs

The TAPP will use a top tab for lateral navigation when bottom navigation is not capable, allowing users to move between screens at the same level of hierarchy.

- The card (Figure 70) is used in the four easy-to-use applications for containing contents and actions of a single subject.

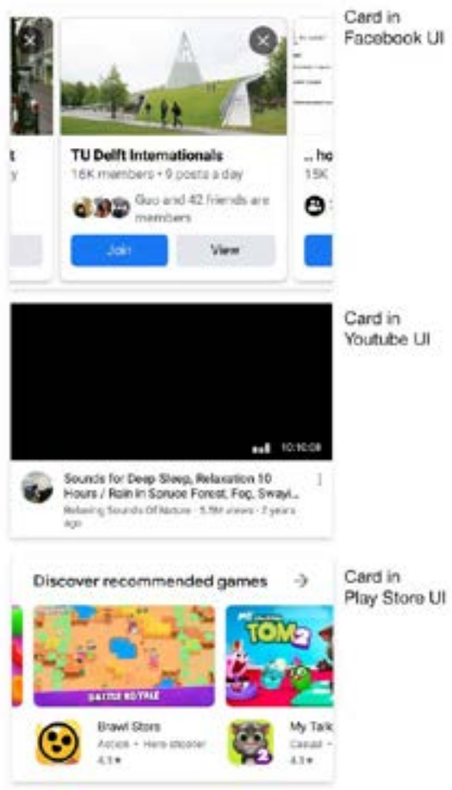


Figure 70, Application design component--- Card

TAPP will use cards to organize content, such as water quality test requests and water quality test results.

- The Top bar displays information and actions relating to the current screen. Figure 71 shows different top bar design in four easy-to-use applications. These app top bars show actions(searching, calling, reverse navigation, Etc.), and information (title).

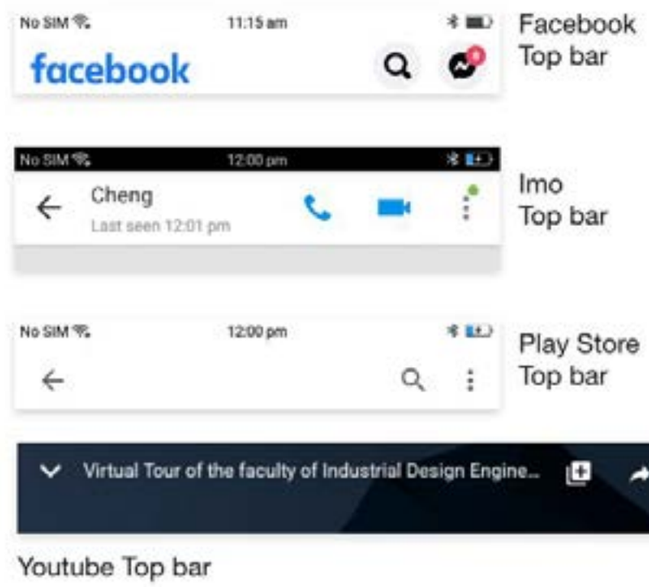


Figure 71, Application design component--- Top bar

The water quality part of the TAPP will use a top bar for display information about the current page and for Reverse navigation.

- Dividers (Figure 72) are often used for dividing contents into different sections to make the user interface more organised.

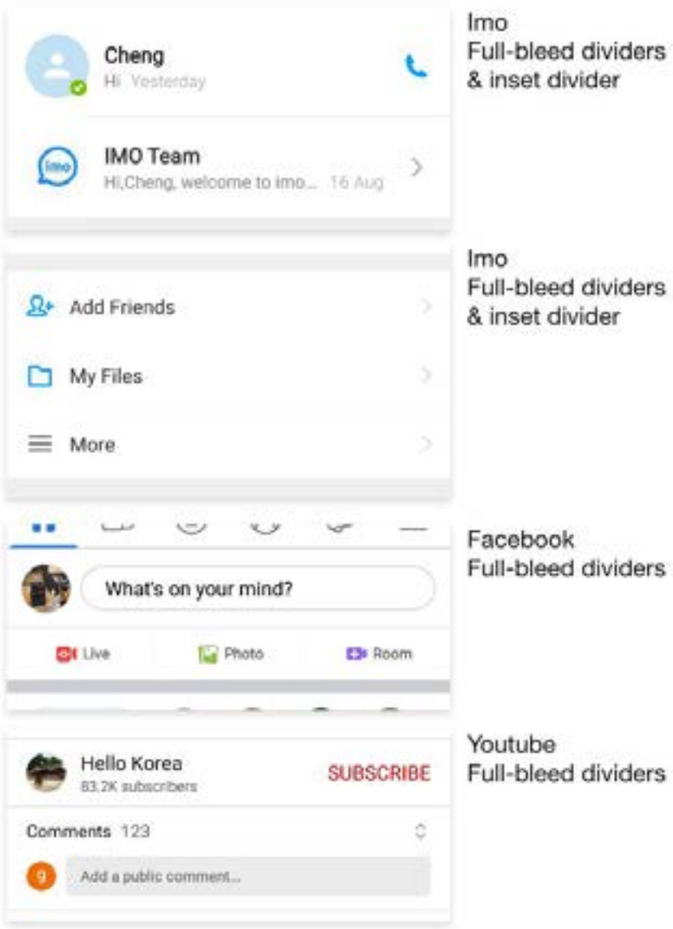


Figure 72, Application design component--- Divider

The TAPP app will use dividers similar to the dividers showing above.

Five UI design components from the easy-to-use applications are analysed. These UI design components included Bottom Navigation, Tabs, Cards, Top bar, Dividers. The TAPP app design will use these components to provide navigation, organise information, and actions. The design of these fundamental elements will have similar interactions to the four easy-to-use apps to lower the user's difficulty of learning to the TAPP application.

Communication Guideline

Communication guidelines are concluded from the literature review to guide how the application efficiently delivers information to Bangladesh local households and operators.

- Use minimal text

  According to Medhi(2010)'s research on designing ICT for functionally illiterate users, the text in the app should be short and explicit with less decorative words to make the text easy to understand for the potential semi-illiterate user. The app could use the minimal text for the user to understand the information, learn the app, and navigate through the app (Medhi, 2010).

- Use icons/graphics that is less abstract to explain ideas

  Using icons and graphics is a useful and efficient way to deliver information since visuals are usually interpreted similarly even when users speak different languages. The icons could also serve as a landmark for illiterate or semi-literate users to learn to use the app and navigate through the app.

  When designing the icons and graphics, the design should avoid making ambiguous graphics to help the user clearly understand the image without misunderstanding.

The design guideline will be used to guide the design of the consistent visual language and the design of the application.

Appendix E Consistent visual language design

First ideation

In chapter 5, an opportunity for test guidance is concluded from the research of the test experience. A consistent visual language for test guidance will be designed to let the tester receive better guidance with TAPP during the test process

Visual style

Before designing the visual language, the visual style is first decided. Based on the communication guideline in chapter 6.2, the visual language should have a realistic visual style. There are two ways to make the visual style realistic. The first way is using photographs of the test process to guide the tester; the other way is creating realistic pictograms and icons to represent test kits and test processes.

The main differences of using pictogram and photographs are:

- It is easier to create pictograms with a consistent visual style.
- It is easy to highlight important elements with a pictogram visual guidance to show detailed information and test difficulties, thus enabling testers to grab important information easily.
- Local operators will receive sufficient training before going to do field tests. They will be able to understand the pictogram after training.

The design team decided to design pictograms to visualise the test process, but not using photographs

Two different design styles are chosen for the design of the pictogram. Linear design (figure 73) uses lines to outline an item, and it is widely used in Bangladesh applications, including (bKash, popular mobile financial application; My Gov, application for Bangladesh government; Etc.

Figure 73 Bangladesh apps with linear visuals.

Flat design is a minimalist design style that uses flat two-dimensional shapes with a bright colour to visualise physical things. It is getting more popular in the interface design.

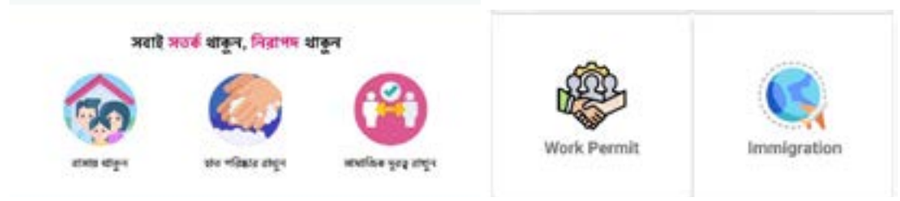


Figure 74 Bangladesh apps with flat visuals.

The consistent visual language is first designed with both linear design and flat design. After the first ideation, there is a comparison of how these two visual styles guide water quality tests in chapter 9.

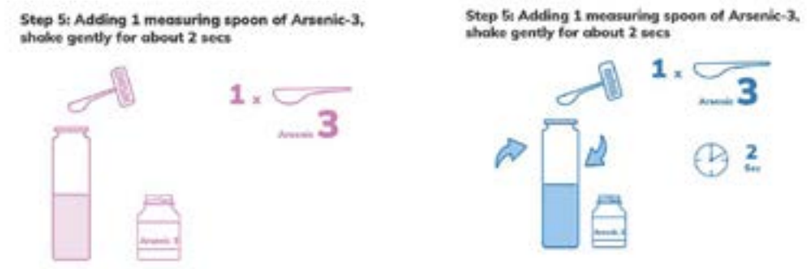


Figure 75, First ideation of consistent visual language in Linear design style (pink and blue)

Figure 76, First ideation of consistent visual language in flat design style

There are two different colours for the linear visual design, pink and blue. Pink is used in some Bangladeshi apps, while blue is also a popular colour used by Facebook and Imo. In some countries(for example, India), blue is the colour that represents clean water.

Design

The design of the consistent visual language includes
1. visuals of the test kits
2. How to combine visuals of different test kits to summarize the information in the guidance into visuals.

Visual for test kits:

The visual language realistically depicts the items in the kits (figure 77).

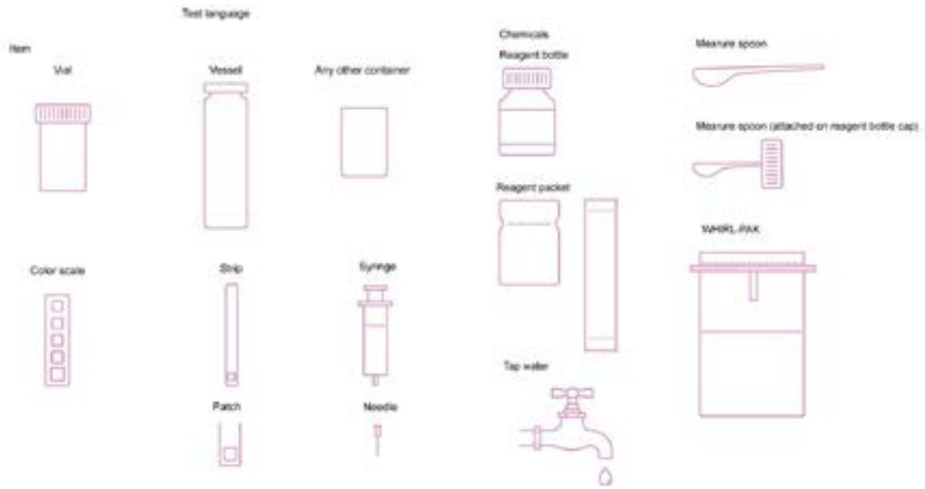


Figure 77 Test items in visual test language.

There are several visuals designed for the same item. These visuals are tested in chapter 9 to research which visual is more welcomed by the users.

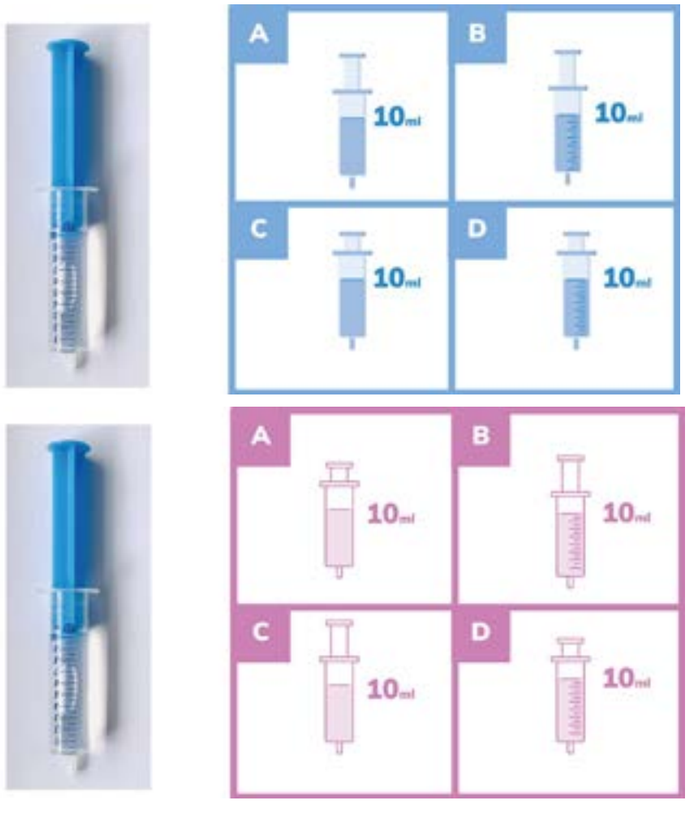


Figure 78, different visuals for the syringe.

Operational information

There are two ways to visualize the operational information in the guidance. For some steps, there will be a visible change with the test kits, such as “open the vial” “fill the vessel.” The visual of these operations should show the result of the operation, how the test kit gets changed.

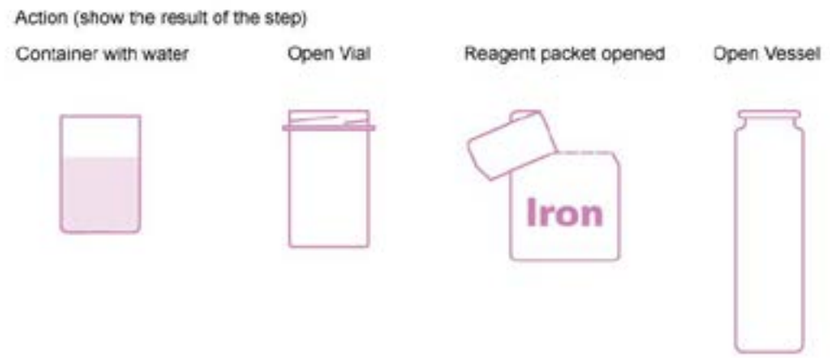


Figure 79 Operational information in the visual test language

Some operational information focuses on showing a particular movement, such as “shake the vial.” “compare the strip with the colour scale.” Or there is hardly any change with the test kit after the operation, such as “rinse the vial.” In these situations, the operational information visual will focus on showing the process, how the testers would perform.

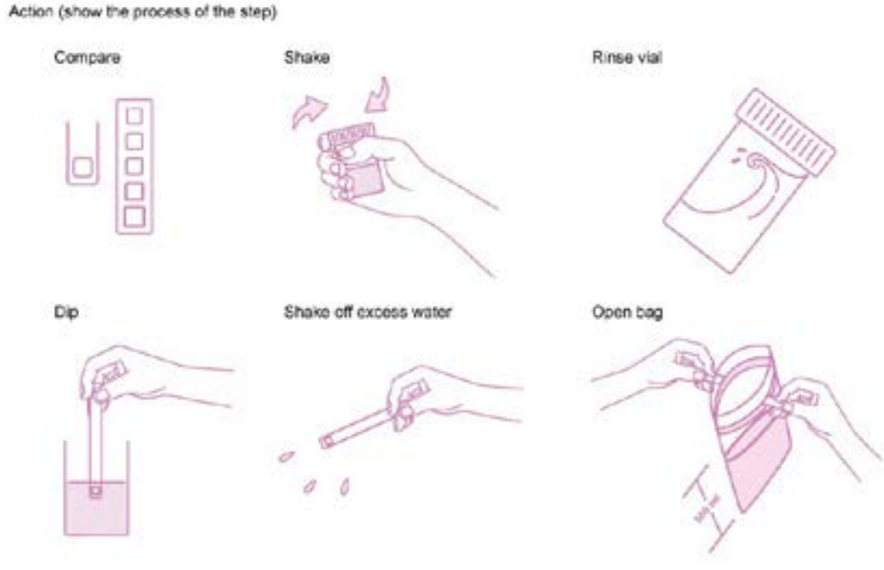


Figure 80 Test action 2 in the visual test language

Detailed information

Detailed information is highlighted in the test guidance to help the testers to grab the test details quickly.

Type and amount of reagent

The test guidance will clearly show the amount of reagent and the type the reagent on the top right corner of each visual guidance (figure 81).

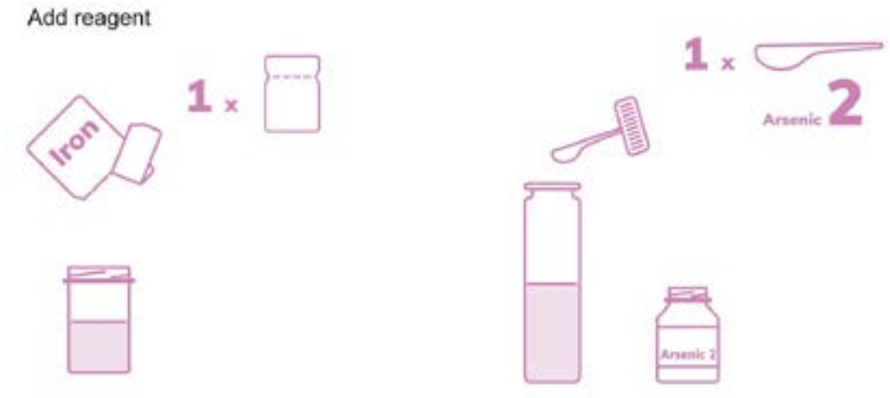


Figure 81 Detailed information (type and amount of reagent) in the visual test language

Amount of water

Figure 82 and 83 shows two ways of showing the amount of water. Some guidance shows the amount of water with a portion of the container (Half of the vial). The guidance should realistically visualise the shape of the container and clearly show how to measure water with the container to avoid giving ambiguous guidance.

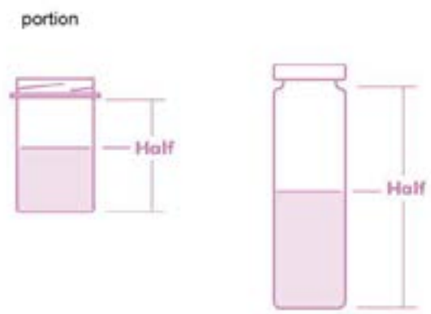


Figure 82 Detailed information (amount of water) in the visual test language

The visual will show the amount of water in milliliter on the right side of the visual gandance. and highlighted the number.

Figure 83 Detailed information (amount of water) in the visual test language

The amount of time

The visual guidance will show a clock to tell the user that these visuals are related to the amount of time. The test guidance will show the amount of time with the number and its measurement unit(usually in minutes and seconds). The visual focus highlights the time and makes the unit of time smaller. Since the difference between minutes and seconds are quite big, so the tester can choose the right unit of time for the steps that they are familiar with.

Figure 84 Test details(amount of time) in the visual test language

The visual language

Figure 85 is an example of the visual guidance of a test step design with the consistent visual language.

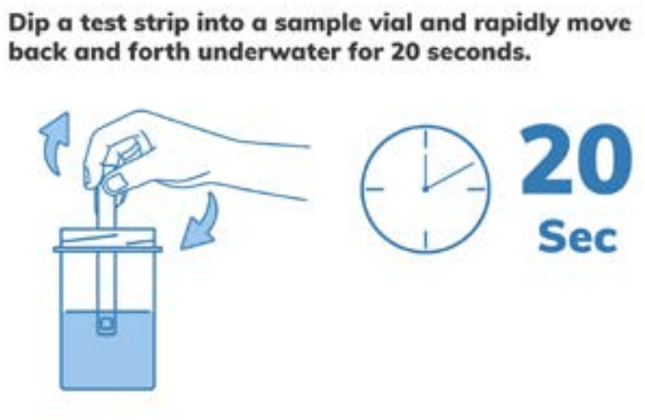


Figure 85, Visual guidance of strip test

Text guidance, operational information guidance, detailed information guidance together make up visual guidance. The text guidance is explaining how to perform the step. On the right part of the visual is the visual of the operational information, visualising how to perform the test. On the left side of the visual is the visual of the detailed information in the test guidance.

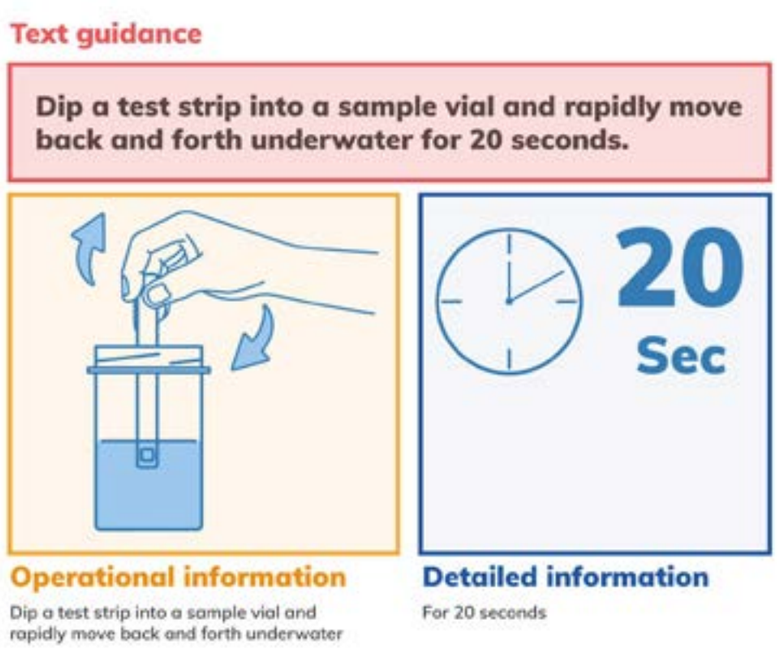


Figure 86, Visual guidance of strip test

The visual guidance designed with the consistent language will meet the tester's various needs in memorising the test process. For recapping the test process, the test could go over the detailed information on the right side of the test visual. The testers could recall or learn the test process by reading through the text guidance and checking the visuals of the operational information.

The evaluation of the consistent visual language will be evaluated with Bangladeshi NGO staff, Bangladeshi non-smartphone users, previous field testers, and people with less/no strip test experience, aiming to evaluate the style and design of the visual language with both current strip tester and potential testers.

After the evaluations, the consistent visual language will choose the visual style/visual design that is welcomed by most users. Some visuals that would cause confusions will be redesigned.

Iteration

The following visuals are iterated based on the evaluation result. The colour of the visual will use blue.

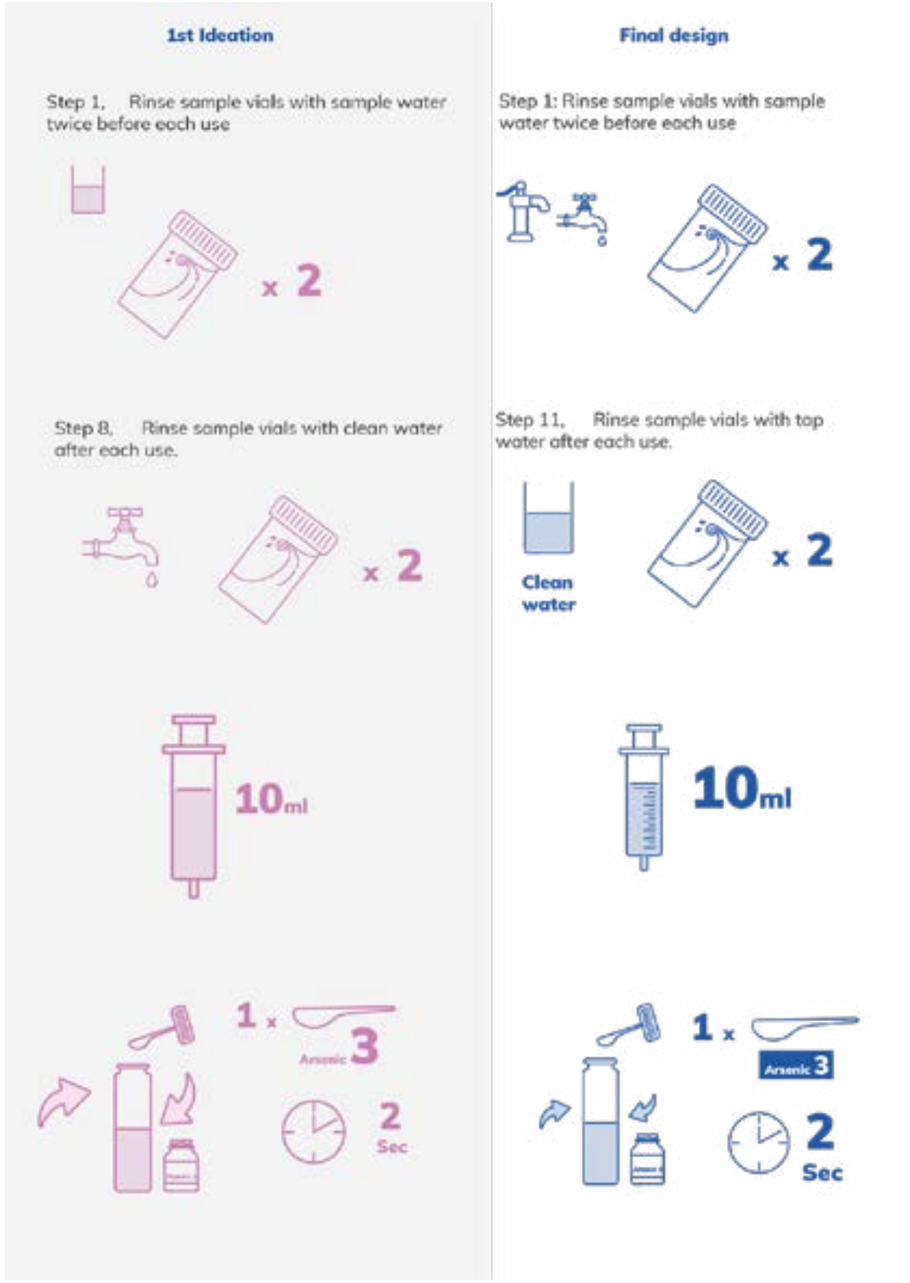


Figure 87: iteration of the consistent visual language

FInal design

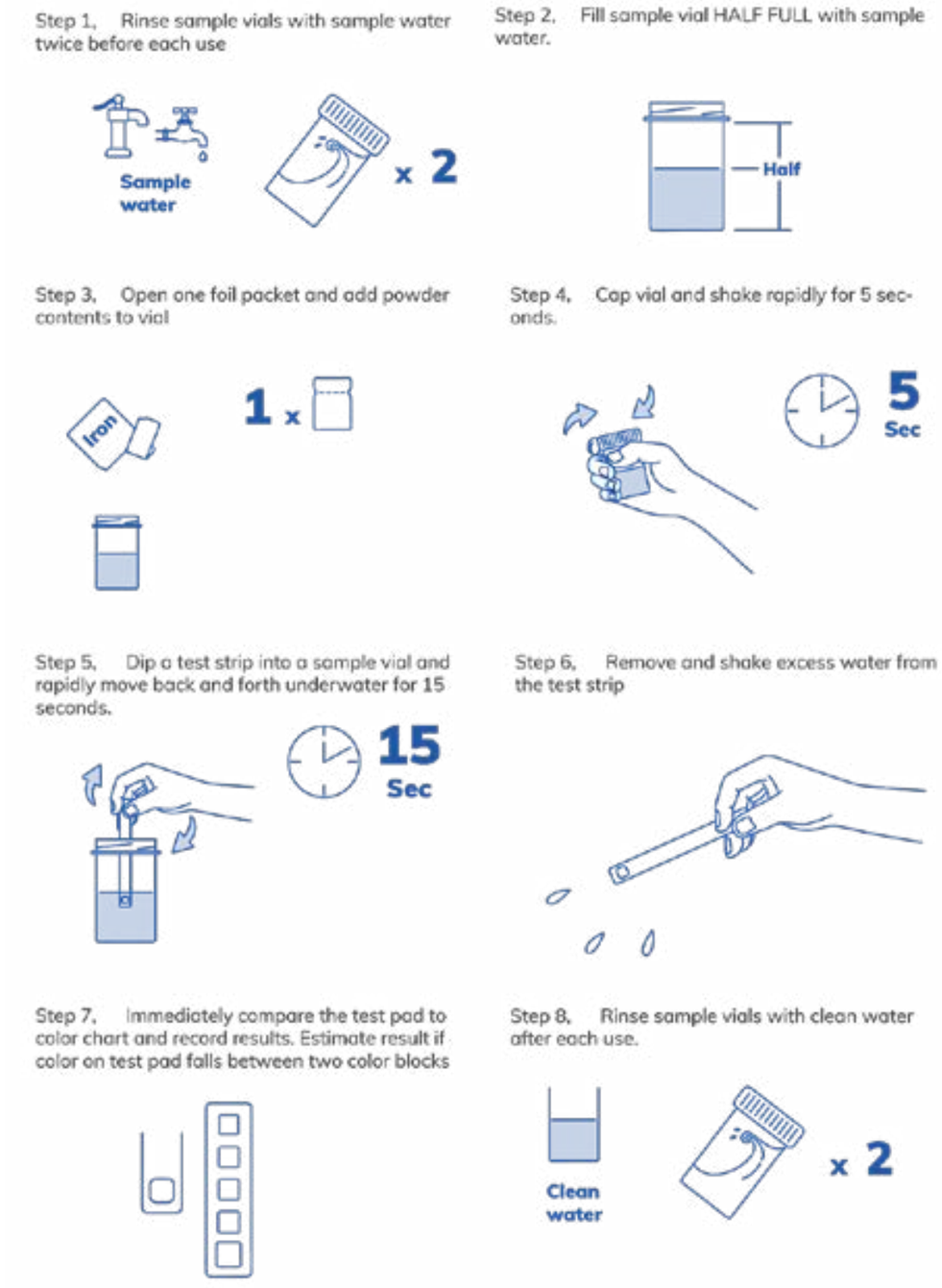


Figure 88: Final design of the consistent visual language

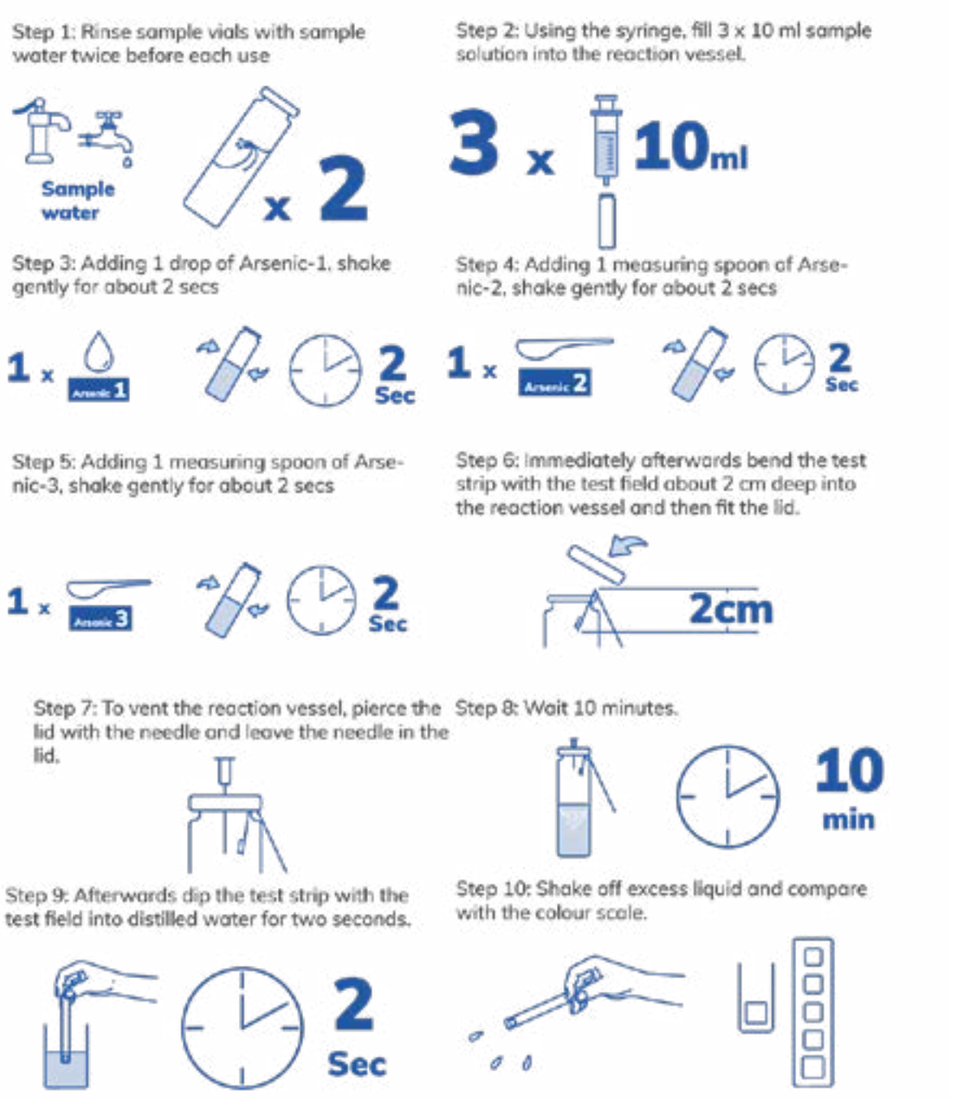


Figure 89: Final design of the consistent visual language (simplified guidance)

Appendix F Ideation of application component

Besides the visuals for test guidance, there are several application components that are designed based on the design guideline and design requirement. The TAPP is made up of these application components.

Different water source are visualised with icons(figure 90).

Figure 90, icon for different water sources.

For the same icon, different colours are used to show the test result(figure 91). According to DPHE (n.d.) green is used to show the water is safe to drink and red is showing the water is not safe to drink. Yellow means the water is at risk to drink, if the test result is above WHO guideline but lower than the Bangladesh standard. Gray means there is no test result yet, please wait for the test result.

Figure 91, different test results of households tap water.

Buttons in the application have icons and text to show the function of the button, aiming at guiding user with low literacy level to understand the application (figure 92).

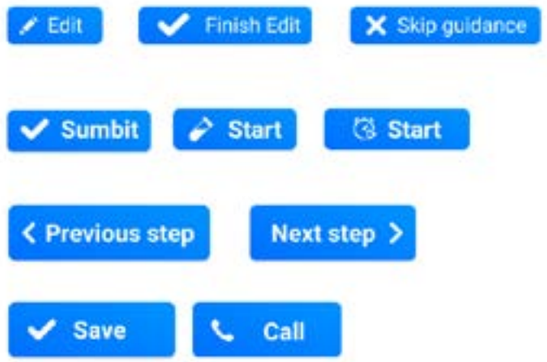


Figure 92, Application design component: Buttons for different application functions.

The design of the application component makes the application design easier. The application will use these components to show information and interactions.

Appendix G test plan

Test Plan:

Day 0:

- See the test video(iron test), or I will explain how to do the strip test(Arsenic test).

Day 1(test):

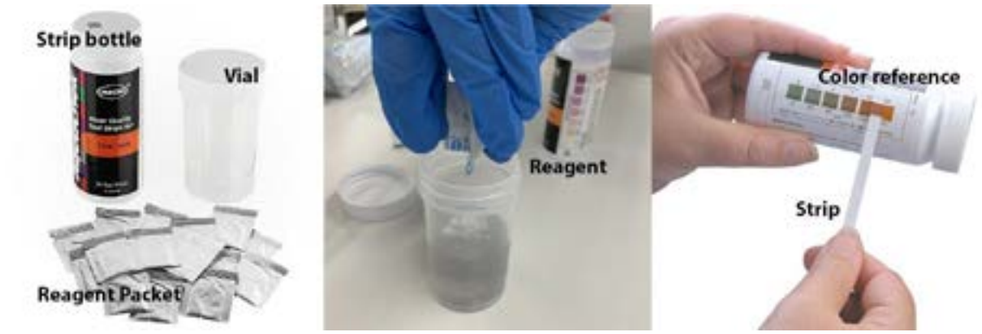
- First, explain: What is the PWS system. What is the water quality test?

Introduction:

In Bangladesh's rural area, piped water supply (PWS) is a good option to provide safe drinking water of good taste. In a PWS system, groundwater is pumped through a filtration system to remove Arsenic, Iron, Manganese, etc – if required. After treatment, the cleaned water is stored in a water tower until it is supplied to the customer with pipelines. There are operators responsible for the operating(switching on and off the system to supply water to the customer), cleaning and maintaining the PWS system.

To help the customer and operators to communicate, collect PWS system water information from the field, and share water quality information to the field, the TAPP-BDP application is designed, its function includes service delivery, education package, interaction, payment, and water quality monitoring.

To monitor the water quality throughout this system, water quality tests (including, strip tests and bacteriological tests) will be executed to test the water quality. Strip tests are an easy and quick way to test water quality in the field. It is, moreover, much cheaper than expensive lab testing. Strip test kits usually consist of a test strip with a chemical patch, a reference card, and reagent(s). It provides a semi-quantitative result of the water quality, which can be read by comparing the colour of the strip with the colour reference card.



There will be a subjective reading result given by the tester. And also an objective reading result, given by the TAPP application, by using the smartphone camera to read the test strip and the reference card. The operator will give a final result based on their own subjective reading result while using the objective reading result given by TAPP.

Sometimes, the test result is caused by accident and human error. To improve the reliability of the test result, the tester needs to do 2 or 3 times of water quality test, until they receive 2 similar water quality test results.

This project is aiming at designing the water quality monitoring part of the TAPP. The customer will use the TAPP to request a water quality test, and receive water quality information. The operator will approve the water quality test request and execute the water quality test guided by TAPP

This test is a usability and function test of the TAPP prototype. In this test you will first perform as a customer and later perform as a PWS system operator.

PWS system customer

In this task, you will perform two different roles in two different scenarios. The first role is a PWS system customer. You live in a family with 6 people, 3 kids, your husband/wife, and your parents (80 years old). There is a private pump that provides the groundwater to you. And you are also connected to the PWS system, with a pipeline and a tap, you have access to the water from the PWS system. You are responsible for arranging the drinking water for the whole family, you need to research/check which water source is safe to drink and share your findings with your family members.

Figure: on the left is your private hand pump, on the right is your tap that is connected to the PWS system.

Test scenario:

One day, there is a strange metal taste in your drinking water from the PWS system tap. You are wondering what is happening with the PWS system. There is no strange colour with tap water.

Task 1:
First, you decided to use TAPP to check the latest water quality information about the water in the PWS system water tower. You are concerning your drinking water quality, and want to find out the problem

You want to find what is the main contamination in the drinking water, and whether these contaminants cause the bad taste in your drinking water.

Task 2:
(It seems that last month, there is no contamination in the water from the water tower that could cause the current problem.)

You decided to use the TAPP to request a field test from the system operator to find out the problem with your PWS system tap. You have free time on Thursday afternoon and Friday morning to invite the operator to visit your house to do a water quality test. If you have difficulty with filling in the request form, please call the operator.

Task 3:
Now you have submitted your request, and the operator will come to your house to do the water quality test the day after tomorrow. You remember there was a water quality test of your household's private pump last year. You want to check the water quality test result of the groundwater from your pump. See whether the groundwater is safe to use as drinking water.

PWS system operator

Your second role is a PWS system operator of a Bangladeshi village. Every morning, you will switch on the system. And every night you switch off the system. During the daytime, you are responsible for monitoring and maintenance of the PWS system. For monitoring the water quality of the system, you need to execute water quality field tests and collect sample water and send it to the DPHE laboratory to do water quality laboratory tests.

Task 1:
A household from your system requested a water quality test, you want to approve the water quality test request and execute the water quality test for the households. Before approving the test result, you will call the households to confirm their test detail, test time, and their payment methods. After you confirm all the information, approve the drinking water quality test request.

Task 2:

It is time to do the regular water quality test for the drinking water in the water tower. Please start the test with TAPP.

For monitoring the water quality of the water tower, you need to test Arsenic(or iron) and check out whether there is bacterias in the water.

Task 3:
You will perform a water quality test for bacteria, you will start the bacteriological test with TAPP, follow guidance to collect samples and set a timer for the incubation period. After the incubation, you will type in the bacteriological test result with TAPP.

Question for evaluation

Task completion (count while participants perform the test)
Whether the user could use the application to finish all the tasks?
What difficulties do you have while using the application?

Question after the evaluation

The participants will answer these questions after using the TAPP customer app and TAPP operator app. The question answer is collected with questionnaire

Usability:
Do you feel the application is easy to use? (Likert scale, 0-7)
Do you feel the application is easy to learn? (Likert scale, 0-7)

Research target experience:
Clear-structured:
Do you feel easy navigating through the application? (Likert scale, 0-7)

Instinctive:
Can you understand the information about drinking water quality easily? (Likert scale, 0-7)
Do you feel they can understand the application function easily?

Achievement:
Do you think they learn something new by using the application? (Likert scale, 0-7)
As PWS system operators do you think they have contributed to the monitoring of the PWS system by using the TAPP? (Likert scale, 0-7)
As PWS system customers do you think they have contributed to the monitoring of their drinking water quality? (Likert scale, 0-7)

Guidance design
Do you think the guidance is easy to recognize?

Appendix H App evaluation result

Customer application
Task completion

Task 1: Check water quality test result of water tower

Task	Task compeletion	Usability issue
Find water tower information		Small problem
Find whether the water is contaminated		
Find the main con-tamination		

Task 2: Request water quality test

Task	Task compeletion	Usability issue
Find " Add new water quality test request"		Small problem
Select type of water suppply		Small problem
Submit the test request		

Task 3: Check water quality test result of private pump

Task	Task compeletion	Usability issue
Find the list of private water quality test		Critical problem
Find the latest pump test result		
Dicide whether this water is drinkable		

Figure 93: Task completion customer app

Question answers:

Usability(easy to use & learn)

Figure 94: Result: Customer app: easy to use and easy to learn

Experience objective:

Structured

Figure 95: Result: Customer app: easy to navigate

Experience objective: Instinctive

Figure 96: Result: Customer app: instinctive

Experience objective: Achieved:

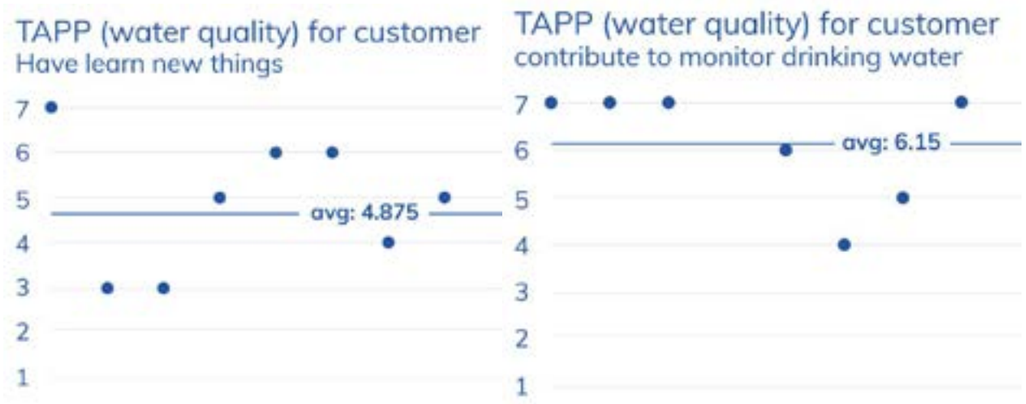


Figure 97: Result: Customer app: achieved

Operator application
Task completion

Figure 98: Customer app: Task completion

question results:

Usability(easy to use & learn):

Figure 99: Result: Customer app: Usability(easy to use & learn):

Structured

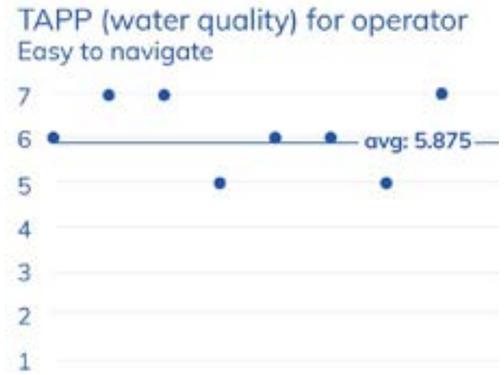


Figure 100: Result: Customer app: Structured

Instinctive

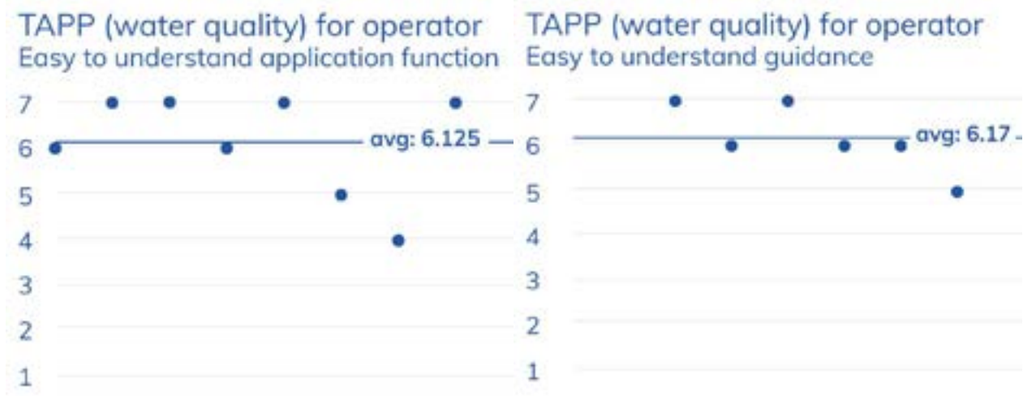


Figure 101: Result: Customer app: instinctive

Achieved

Figure 102: Result: Customer app: instinctive

Appendix I PWS system governance system

To better describe the work system elements, a method called work system snapshot is developed by Alter(2002). It could quickly summarize different elements in a work system.

The work system snapshot of the PWS system governance system is created based on a hypothesis scenario. In that scenario, the TAPP application has been successfully implemented in the Bangladesh field to assist the water service providers and the operators in the operation, monitoring, and maintenance work.

The work system snapshot is concluded based on discussions with Annamarie and the previous research on the water quality test and PWS systems in Bangladesh in chapter 1, 2.

Figure 103 is the work system snapshot that quickly summarises different elements of the PWS system governance system. The elements written in yellow are the elements that are not doing sufficiently in the current scenario; elements that are written in red are the elements that could be added after the implementation of the TAPP app.

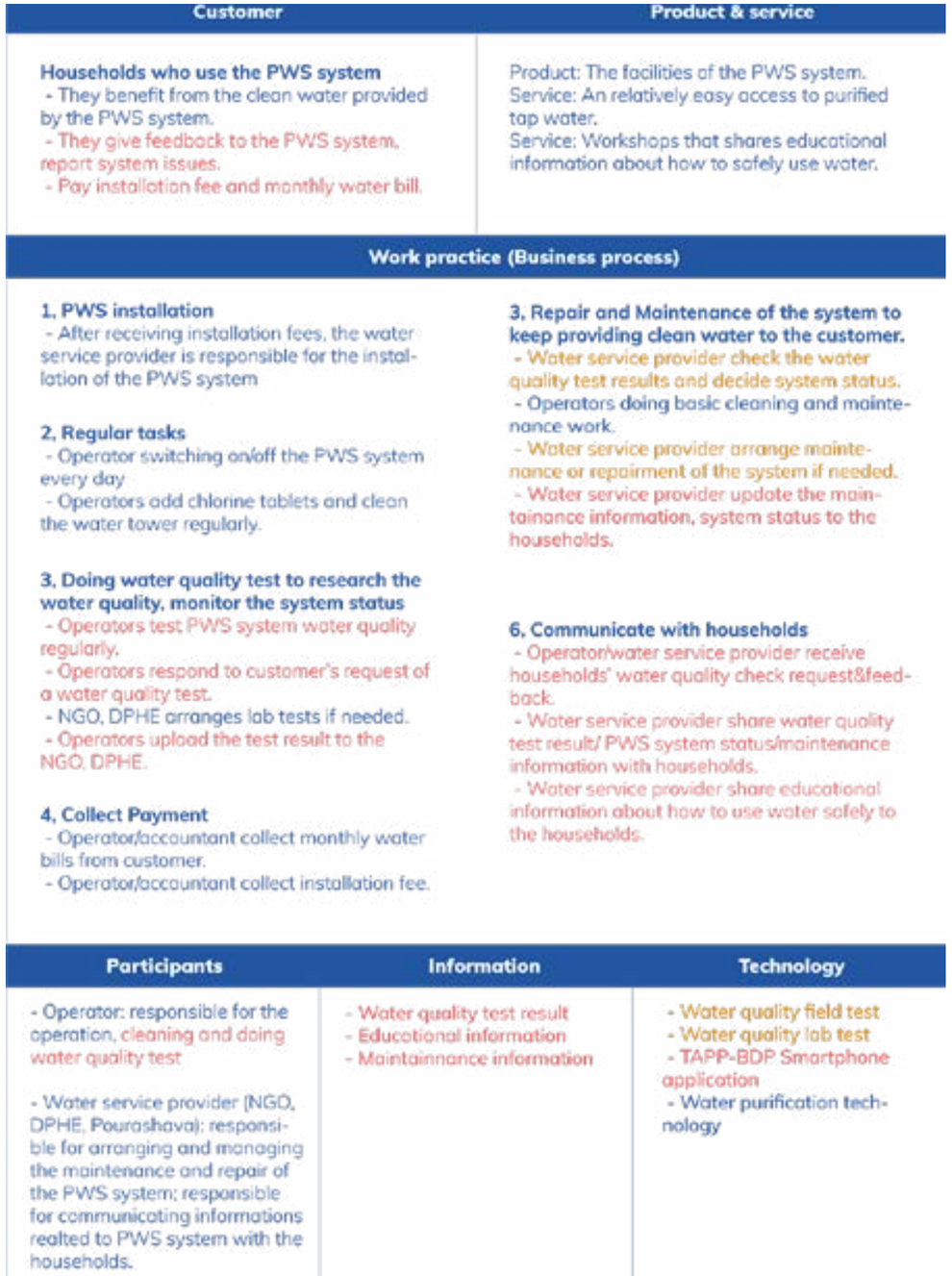


Figure 103 Work system snapshot of the governance system of the PWS system in Bangladesh.

Figure 104 shows the additional elements (Environment, Strategies, Infrastructure) of the PWS system's governance system.

Environment	Strategies	Infrastructure
Limitations in Bangladesh rural areas - has limited access to DPHE laboratories that are able to do a water quality lab test. - has limited resources with repair and maintaining the PWS system. **There are various situations / governing system with hundreds of PWS system.** Hundreds of PWS systems in Bangladesh governed by different stakeholders. **Households who connect to the PWS system, scattered around the village.** - A long pipeline that connects households with the PWS system has a greater possibility of having pipeline leakage.	Mobile crowd participation methods Quick response	TAPP-BDP design team Water quality test training group PWS system sponsor AKVO service PWS system building & professional maintenance team (External mechanics)

Figure 104 Additional elements that influence the monitor and maintenance system.

Before implementing the TAPP app, for the monitoring and maintenance job of PWS, the governance system of PWS maintenance is missing several elements. These missing elements include “an efficient monitoring process and maintenance process”, “participants---operator who executes water quality as a monitoring tool,” and “information-- water quality test information.” Figure 105 shows how the implementation of the TAPP app completes the current governance system’s missing elements with monitoring and maintaining the PWS system.

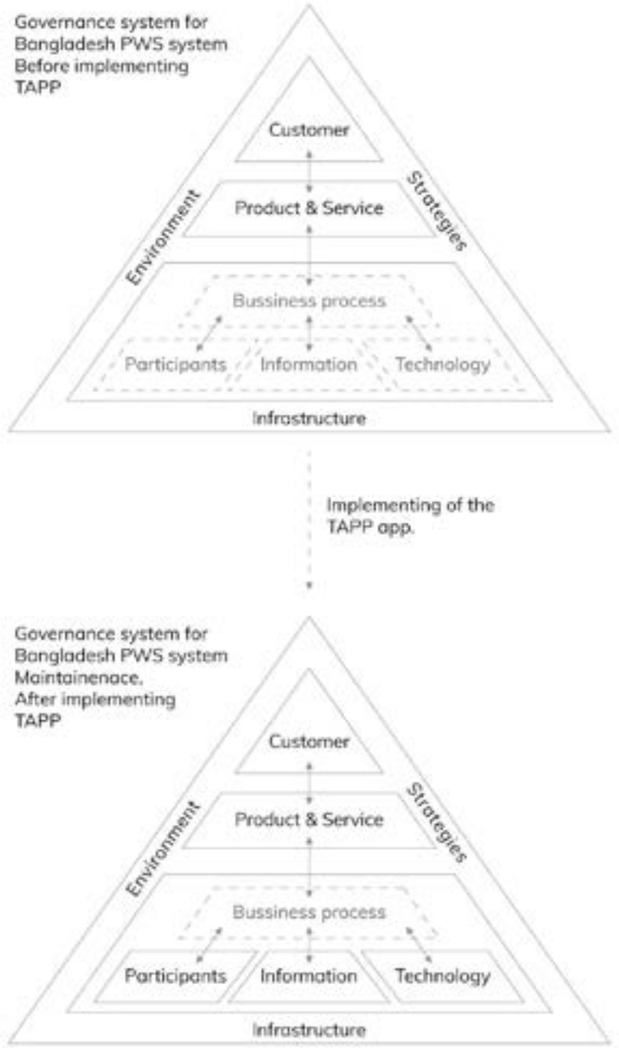


Figure 105, The change of the governance system after the implementation of the TAPP app.

With the implementation of the TAPP app in the future, the governance system is almost complete, however, a detailed business process to guide the monitoring and maintenance work is still missing. A design of a monitoring model and maintenance process is needed for the governing of the PWS system.

Appendix J Monitoring model & maintenance process

Monitoring model & maintenance process for filtration system's function

The PWS system filtration system can sometimes have a malfunction, causing the households to receive water with chemical contamination. A monitoring model and a maintenance process are designed to guide the monitor and maintenance of PWS system filters with its cleaning function, solve system issues, and provide safe water to households.

The first step to monitoring the filtration system's chemical contamination is doing water quality tests to its in-flow water and out-flow water. The chemical strip test will be done once every month, and lab tests will be done once every six months for regular testing & monitoring of the PWS system. The testers will arrange extra chemical lab tests to verify the strip test result, which shows chemical concentration level above the standard level, before making any conclusions and maintenance work.

After the water quality test, a conclusion of the system status is made from the water quality test result.

The water quality test result of the in-flow water will decide whether there are more contaminants in the groundwater and whether the water source is still safe to use. More contaminants mean the chemical concentration level is above the standard before, but now it is even greater; or the chemical concentration level is initially lower than the standard, but now it is above the standard, the groundwater has one more chemical contaminant.

The water quality test result of the out-flow water shows the filtration system's status, is it still functioning and working properly. There are four different system status based on the test result.

1. The filter is not capable of cleaning with the more contaminated groundwater.
   When the in-flow water is more contaminated, and the out-flow water also shows chemical contamination. The filter might still work, but the filter is not capable of removing the chemical contaminations anymore.
2. The filter is still working and capable of cleaning with the more contaminated groundwater.
   When the in-flow water is more contaminated, but the out-flow water shows no chemical contamination, the filter is still working and capable of removing chemical contaminations even if there is more contamination in groundwater.
3. The filter is not working.
   The in-flow water contamination remains the same, but there are chemical contaminants in the out-flow water. The filter is not working properly to remove chemical contaminations.
4. The filter is working properly.
   The in-flow water contamination remains the same, and there are no chemical contaminations with the out-flow water, so the filter is still working correctly.

According to the four different filtration system status, the following maintenance could be arranged by the service provider.

1. When the filter is not capable of cleaning with the more contaminated groundwater, the operators or service providers should contact DPHE to inform them of the geography change in the groundwater, They should also change a new filter to clean the more contaminated water or change to a new water source that the filter is still capable of cleaning chemical contamination.
2. When the filter is still working and capable of cleaning with the more contaminated groundwater,
   more contamination in the groundwater will influence the filtration system's life, as filters need to clean more chemical contamination. The water service provider longs to inform the DPHE of this geography change and calculate the filter's life again.
3. When the filter is not working, repair the filter or change a new filter, make the filter working correctly again.
4. When The filter is working properly, no repair is needed.

Figure 106 and 107 are an overview flow chart of the monitoring model and the maintenance process, which the testers and service providers could follow step by step to

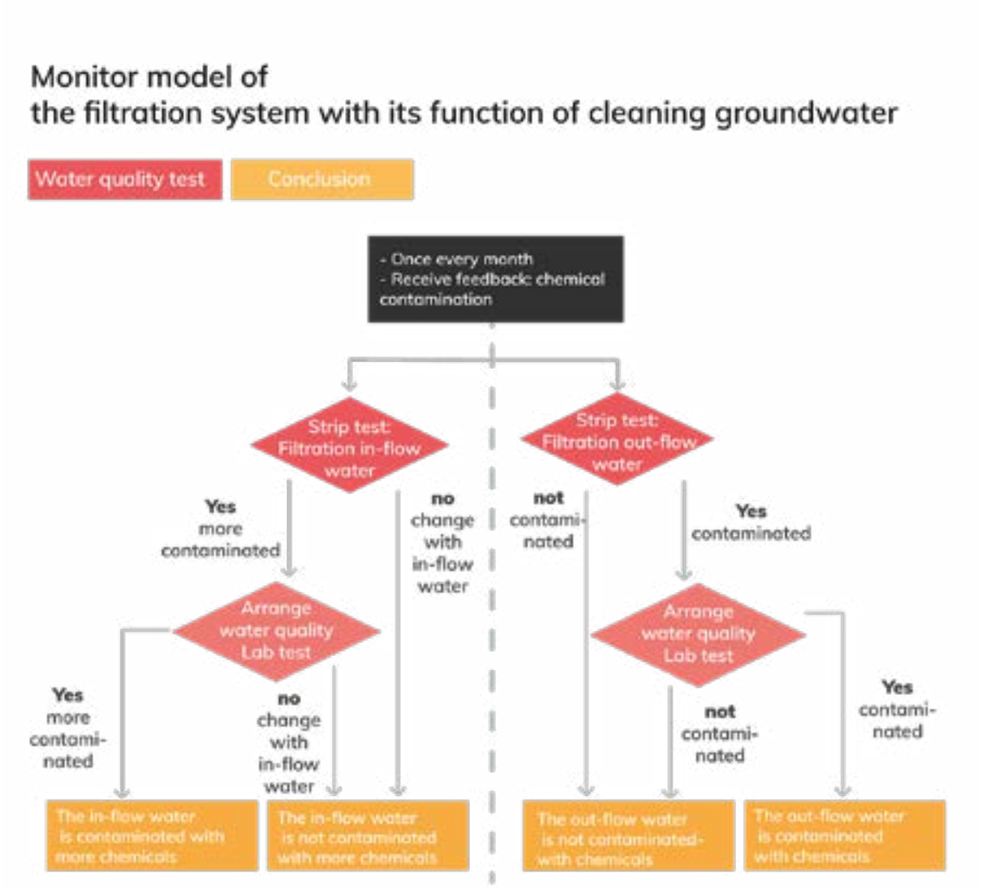


Figure 106 Flow chart: Monitoring model of guiding the monitoring work of the filtration system's function.

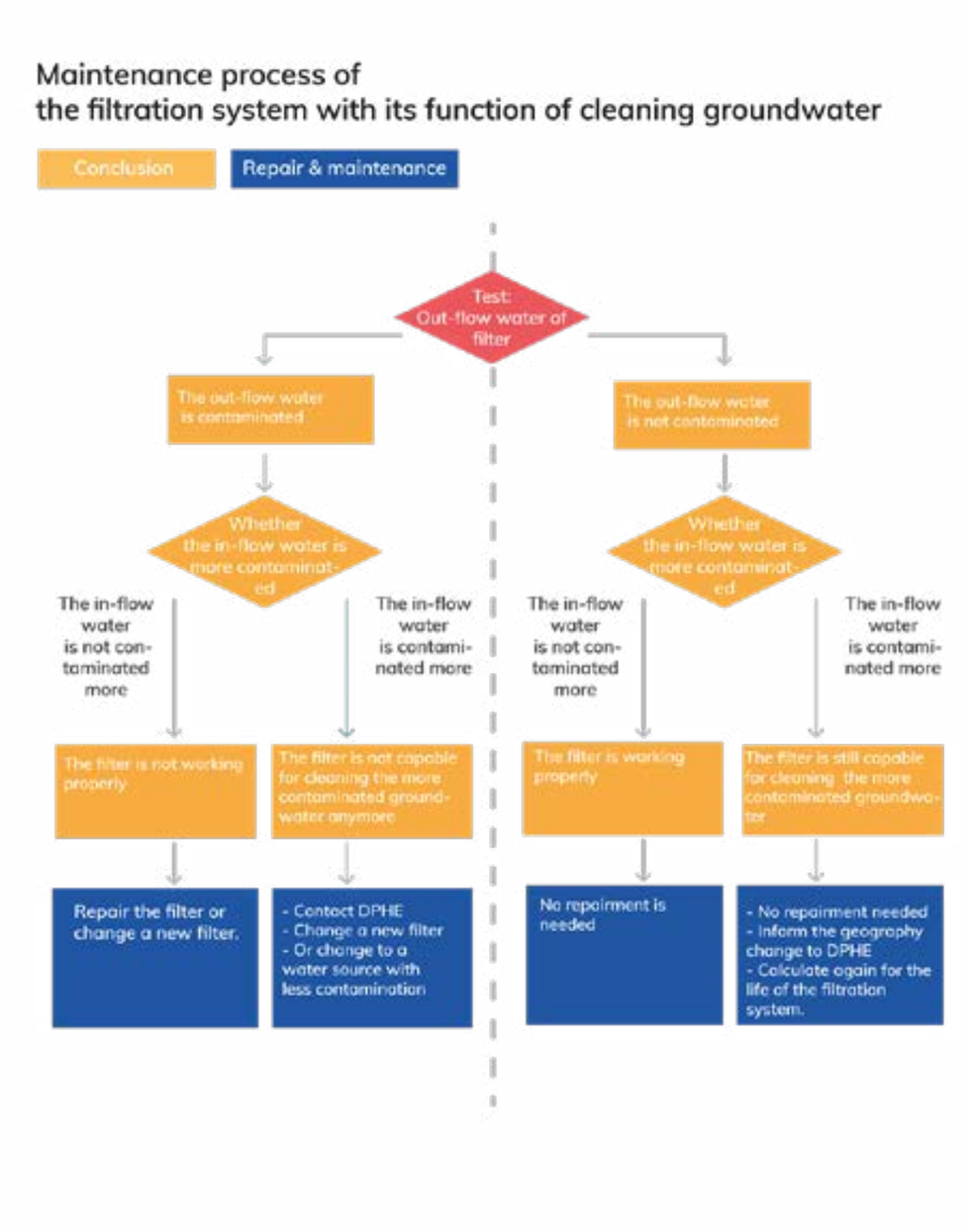


Figure 107, Flow chart: Maintenance process of guiding the maintenance work of the filtration system's function.

Monitoring model & maintenance process design for filtration system & main water tower with bacterial contamination problems.

Bacteria can contaminate the main water tower and pipeline, bringing bacterially contaminated water to each household. It is vital to have efficient monitoring and maintenance work to the main water tower and pipeline with bacterial contamination problems.

To monitor the main water tower and the pipeline, bacteriological tests are done by the testers once every week. The tester first executes the chlorine strip test to determine whether there is sufficient chlorine to protect the water from bacterial contamination. If there is insufficient chlorine in the water, the testers will execute the bacteriological field test to research bacteria's existence.

The water quality of the pipeline water could be used to detect the pipeline's contamination and draw the conclusion on pipeline status. From the water quality test result, four different pipeline status is concluded.

- Main water tower contaminated with bacteria:
  If the whole system (main water tower and the home water storage of different areas) shows bacterial contamination, the main water tower might be contaminated with bacteria, and the bacteria go through the pipeline to each household's water storage.

- Pipeline leakage at the main pipeline:
  If the main water tower is not contaminated, but all area's households' water storage shows bacterial contamination, there might be a pipeline leakage at the main pipeline.

- There is a pipeline leakage within this area:
  If the main water tower and other areas' households' water storage shows no bacterial contamination, only this area's households' water storage is contaminated, there might be a pipeline leakage within this area.

- There are no system issues:
  If the water tower and all households' water storage is not contaminated, then the water is free from bacterial contamination, and the system has no system issues.

After the water quality test, the tester concludes the main water tower's status from the test result. If there are bacterias in the sample water, the water towers are contaminated with bacteria.

Testers and operators could arrange maintenance work based on the conclusion of the water tower and pipeline status. These works include adding chlorine tablets, cleaning water storage, and fixing pipeline leakage.

Figure 108 & 109 shows a flow chart to summarize the design of the monitoring model & the maintenance process for monitoring and maintaining the main water tower and pipeline with bacterial contamination.

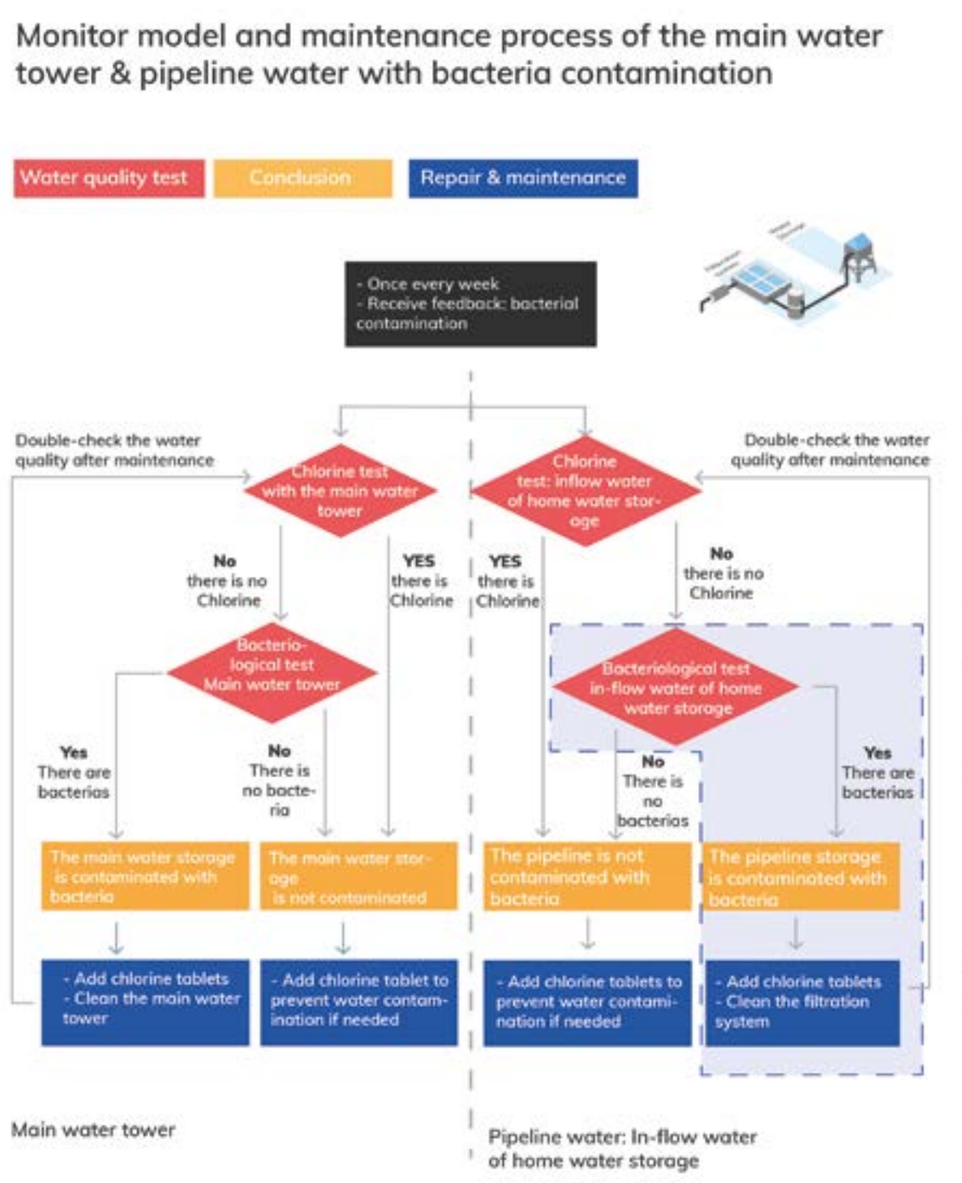


Figure 108, Flow chart of the monitoring model & maintenance process of the pipeline & main water tower with bacterial contaminations. (part 1)

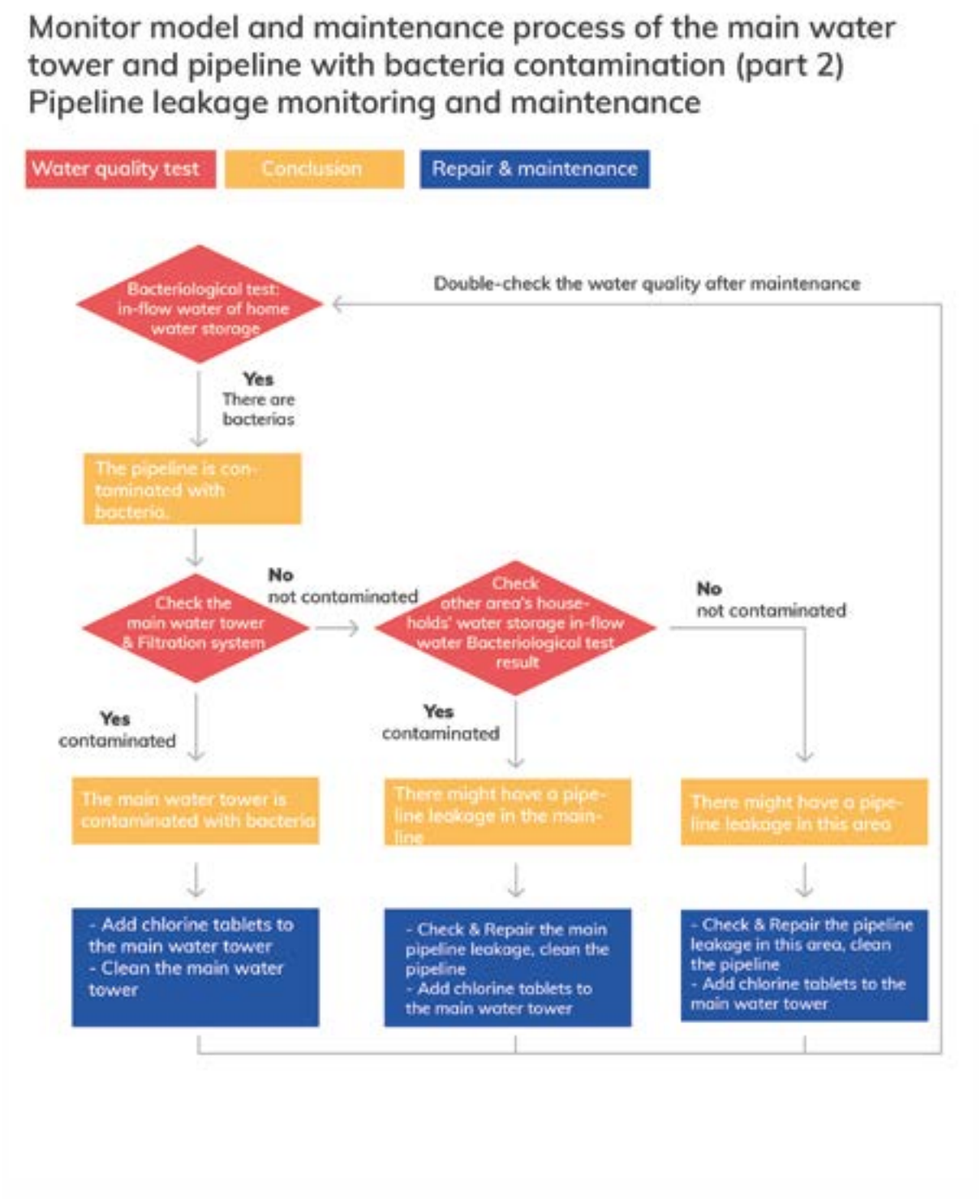


Figure 109, Flow chart of the monitoring model & maintenance process of the pipeline & main water tower with bacterial contaminations.(part 2)

Monitoring model & maintenance process design for the pipeline and households' water storage with bacterial contamination problems

The households' water storage and pipelines demand monitoring and maintenance as the bacteria forms with pipeline leakage and staying in the water storage for too long. A monitoring model and a maintenance process of households and pipelines are designed to guide the monitoring and maintenance work.

To monitor the bacterial contamination situation and the system status, the bacteriological test will be done once every week at the out-flow water of the households' home storage (households tap water).

The out-flow water's water quality determines the household's home storage unit's bacterial contamination status, which guides the operators and service providers' maintenance work. If there are bacterial contaminations or insufficient chlorine in the household's water storage, the operator could kill bacterias, maintain the water storage by adding chlorine tablets, and clean the water storage.

Figure 110 shows two flow charts to summarize the monitoring model and the maintenance process design for households water storage.

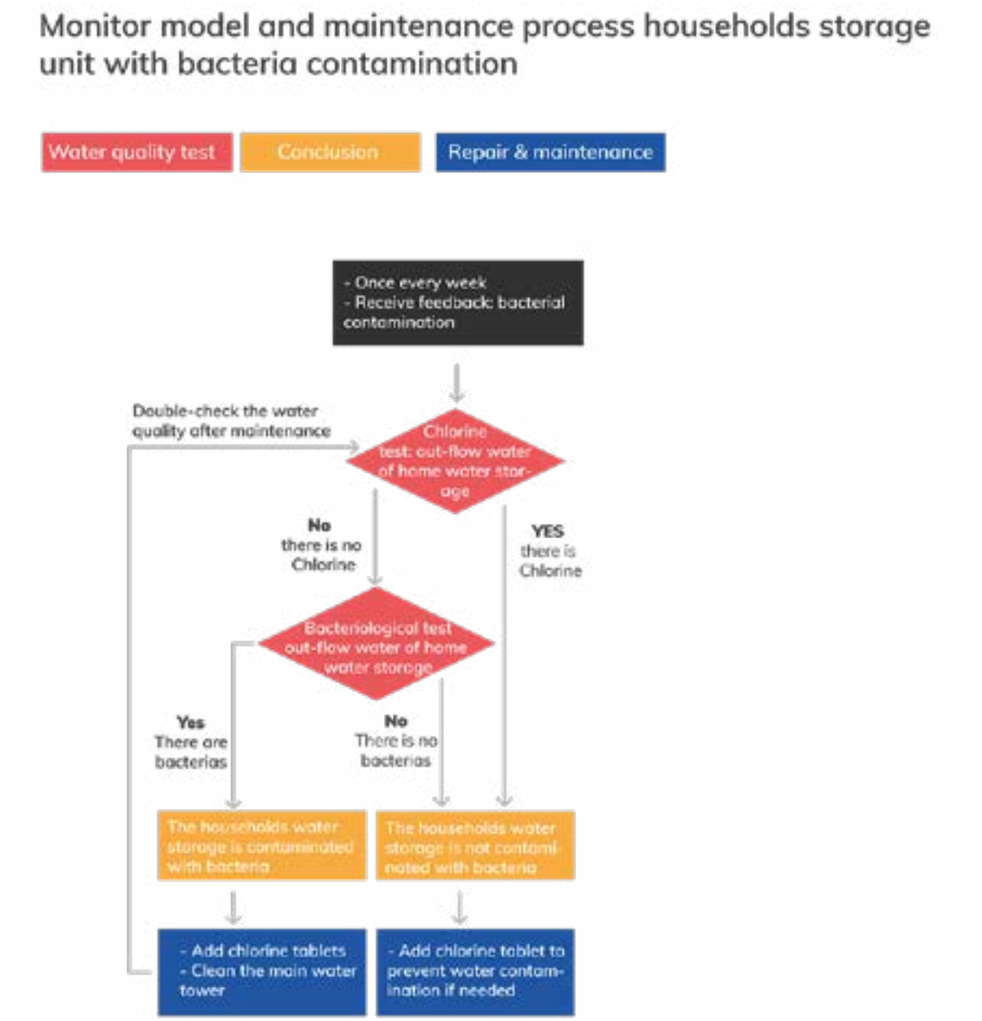


figure 110 Flow chart: check households bacteriological contamination

DESIGN FOR our future

TUDelft

Appendix K Graduation brief

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Cheng
initials: C given name: Guo
student number: 4795687
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): IPD | DfI | SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: Honours Programme Master
specialisation / annotation: Medisign | Tech. in Sustainable Design | Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Jan Carel Diehl dept. / section: SDE
** mentor: Gert Pasman dept. / section: HCD
2nd mentor: Annemarie mink
organisation: TU Delft Faculty Of Civil Engineering and Geosciences
city: Delft country: Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Jan Carel Diehl date - - signature

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

TU Delft

Personal Project Brief - IDE Master Graduation

A digital intervention to test drinking water quality in Bangladesh — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 25 - 03 - 2020 18 - 08 - 2020 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

In the 1970s, Bangladesh installed tube-wells to supply groundwater to communities to avoid people getting sick by drinking bacterially contaminated surface water. However, after installing groundwater tube-wells, they found the groundwater may get chemical contaminated with arsenic, manganese, iron - and in coastal areas the water is highly saline. In the following decade, Bangladesh people get severely affected by water contamination. Overexposure to these substances has health consequences. Chronic arsenic exposure, for example, causes severe health issues including skin lesions, damage to the nervous system and causing cancer in lung, skin & bladder. Due to the in-house storage of pumped water and hygiene issues in handling the water, the bacterial contamination still remained a problem.

For water safety, a piped water system is desirable, as it offers the opportunity for central treatment, operation, and maintenance. A piped system pumps up groundwater and filters it for the contaminants present in the water. After filtration, the cleaned water is stored in a water tank until it is supplied to the households with pipelines.

However, if the system is not properly operated and maintained, the malfunctioning of the system and filter might cause people to still suffer from chemically contaminated water. If the system is not properly cleaned and maintained, the water in the water tank and pipeline can become contaminated with bacteria like E.Coli. These may cause local households to lose their trust in the piped water system and stop using it for drinking water.

The mobile crowd participation(MCP) is an approach to help to research and monitor the PWS system, and it enables the local stakeholders to participate, learn, and provide feedback with a smartphone application. The prototype of the water supply app 'TAPP' has been developed. The functionalities of the TAPP include service delivery, education package, interaction payment, and water quality testing (with the function from AKVO Caddisfly application).

To make sure the users are using safe water, the water quality needs to be tested regularly. Chemical contaminants need to be tested at the in-flow and out-flow of the filter. Bacterial contaminants need to be tested in the tank and in the pipeline. Based on the water quality result, the caretakers will maintain and clean the PWS if needed. There is a tool kit with a test strip, reference card, reagent, and a smartphone application(AKVO Caddisfly) to help the caretakers of the PWS to test the water quality. The caretakers will receive guidelines from an application to properly conduct the water quality test, and the app will objective interpret the reference card and upload the result. The caretakers will monitor the PWS system with the result of the test while each household can also monitor their own water supply and the maintenance of the system. Also, various stakeholders (local Municipality, DPHE, NGOs) will then use the results of water quality tests to monitor the operation and maintenance of different PWS systems.

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introduction (continued): space for images

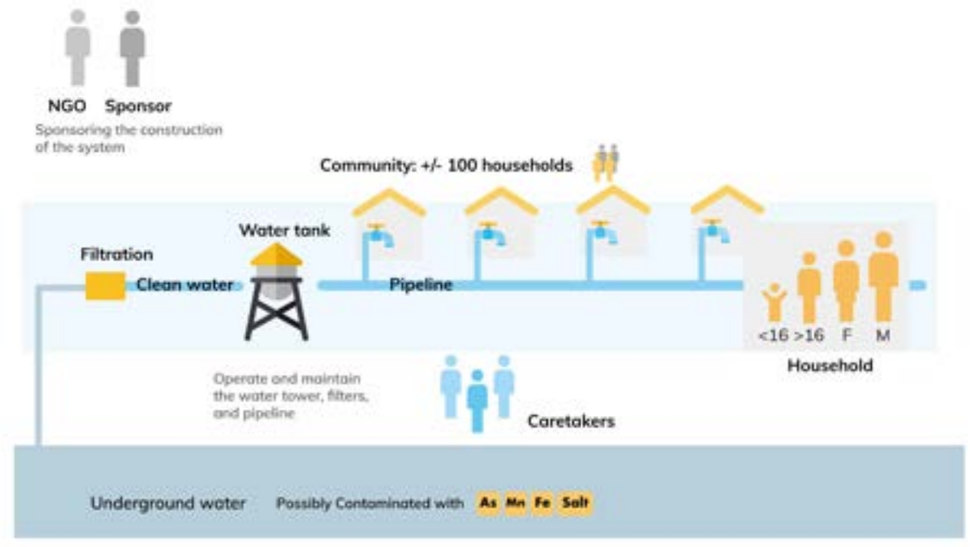


image / figure 1: System overview of the PWS system

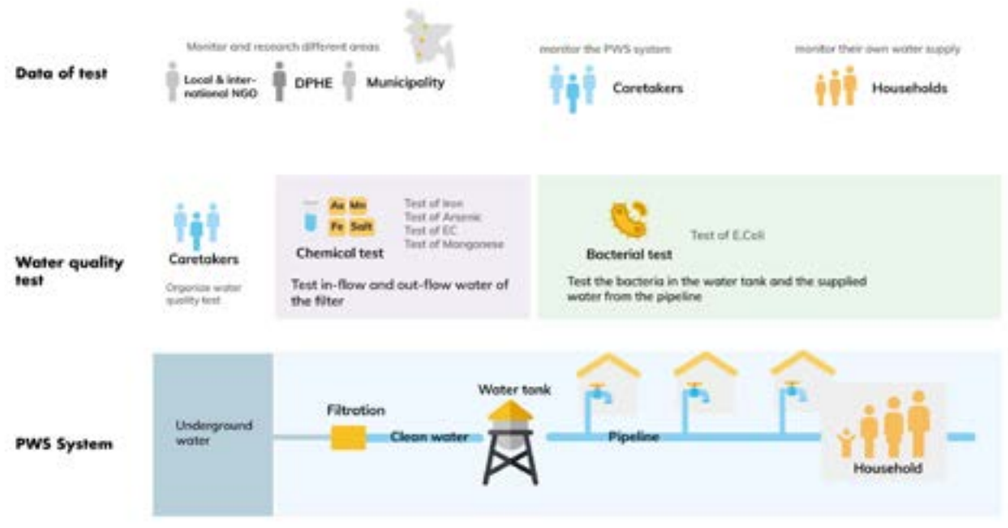


image / figure 2: The water quality testing system of the PWS system

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

To easily monitor the PWS in the Peri-urban area in Bangladesh, make sure it works properly to provide safe water to the community. A quick and affordable water quality test is desired.

Firstly, caretakers need an easy way to test water quality in the field. Take the arsenic test as an example, the caretakers need to take proper training and proper guidance, since the arsenic field test kit requires several precise steps and is potentially dangerous, as arsenic gas is formed during the test execution. Most of the application users would be illiterate and with the difficult manual of the current product, they have difficulty in completing the water quality test and get the result. The caretakers need to receive proper training and proper guidance with the app to conduct the water quality test.

Secondly, after testing the water quality, the data of the result of the water quality need to be collected and stored to help the caretakers to efficiently monitor and research the PWS system. By the implementation of the research and monitor system, the NGOs, DPHE, and the municipalities could get up to date data about the functioning of different PWS and the quality of the underground water of the whole area.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design a product-service combination design for water testing. The product is the water quality testing part of the TAPP application, aiming to properly guide the local caretakers to test the water quality and to collect and disseminate the results to the appropriate stakeholders. The service is to design the way the data of the water quality test collected and disseminated to help stakeholders to monitor the operation and maintenance of the PWS.

The solution to solve the above-mentioned problems is a product with a combined service to help the community in the Peri-urban area to test water quality and monitor the operation and maintenance of the PWS.

The product is the application that guides both the literate and illiterate caretakers to properly conduct different chemical and bacterial tests, read and upload the result of the water quality test. After conceptualization, testing, and iteration, the application will be developed and programmed by a Bangladesh professional programmer. After finalizing the final concept, the final design will be tested in Bangladesh with the local caretakers.

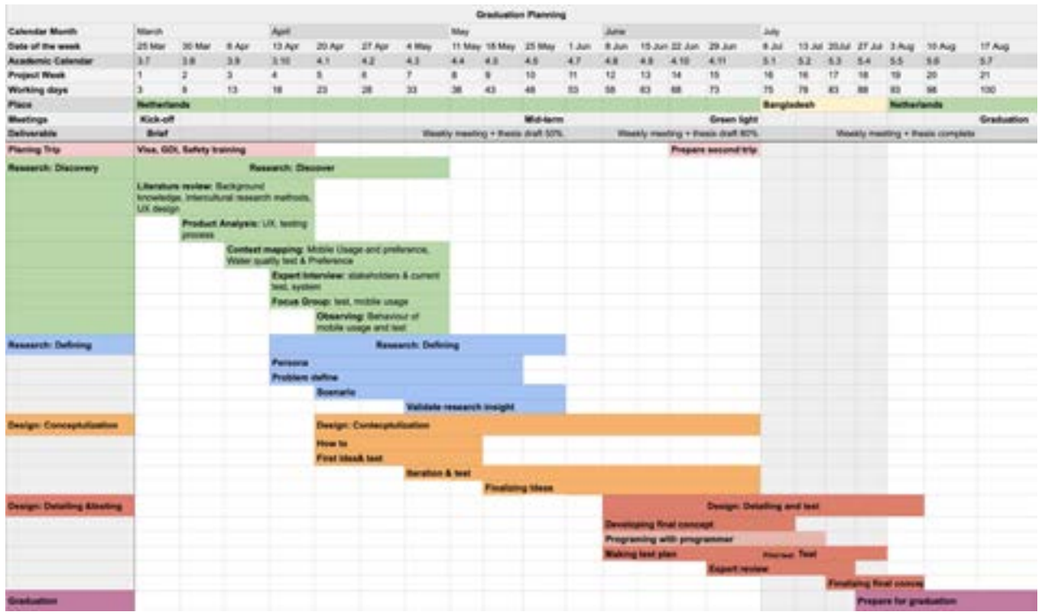
The service is to design the way different water quality test data collected and stored, and how different stakeholders (community, local caretaker, municipality, DPHE, and NGOs) could use the data to research and monitor the PWS.

In the long term, after the PWS receive proper monitoring and maintenance, the households would receive safe water from PWS and gradually build trust with PWS.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 25 - 3 - 2020 18 - 8 - 2020 end date



The project has 4 different phases in 20 weeks. There will be a trip to Bangladesh in July to test the final concept with the local caretakers if the coronavirus gets controlled at that time.

Week 1-7 (25 Mar - 4 May) Research: Discovery. This discovery phase starts with a literature review and product analysis to know the current context & situation in Bangladesh and the current water quality test product and APP. EPRC from Bangladesh will help to research to understand the context, user's usage and preference of mobile phone and water quality tests.

Week 4-10 (13 Apr- 25 May) Research: Defining. The second phase is about defining the current context after collecting data from the discovery phase, using Persona, Scenario, Problem define to make conclusions for the previous phase and get ready for the design phase. The research phase will end after the Mid-term in week 10.

Week 8-15 (11 May - 29 Jun) Design: Conceptualization. The conceptualization phase is the first design phase, aiming at developing concepts based on the previous findings. The conceptualization will have some sessions aiming at creating new concepts, tests, and iteration. A final concept will be the outcome of the conceptualization phase.

Week 13-19 (15 Jun- 3 Aug) Design: Detailing and testing. The final concept will be developed and tested during the last phase. The application will be programmed by a Bangladesh programmer and the test will take place in Bangladesh. After the final phase, the thesis will be finalized and the project will be concluded.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The projects located in Bangladesh and a very complicated context, this makes the design process more interesting and more challenging. It is also a very practical project since the app will be programmed and tested in Bangladesh and be implemented in the coming year. The works related to this graduation project consist of several key skills I developed during my master's study. Through this project, I will prove the abilities I learn in the past 3 semesters and further develop them by practicing them in the field.

1), With this project, I will first further practice my research skills acquired during the study at TU Delft. Such as context mapping tools, that help me to understand the context and empathize with the user. It is very challenging to go into another unfamiliar country and face a different context, language, and user. Therefore, the first 2 research phase in Bangladesh will be very challenging. Through this research process, my research skill will be further developed and gain more valuable experience with understanding complex context and users.

2), UX design skill will be the second skill that will get further developed during the project. During the past study, I have learned knowledge and skills related to UX design. These experiences will assist me to organize my design phase and design product. However, this is the first time I need to have the product programmed and test with the end-user. This part is challenging and will be a great opportunity to learn more about UX design and improve my ability.

3), With some design project, we sometimes designed a service related to the design. So I am always very interested in doing service design. With research and redesign the current service to monitor the PWS system, I intend to learn more about how to design a service. In the future career plan, I want to gradually change from UX designer to UX and Service designer. So by doing this project, I want to gain some service design knowledge and experience.

4), I am always interested in design for different cultures and doing design projects in a different country to gain an international perspective. By doing this project, I want to gain valuable experience with cross-cultural design and develop my research and design skills for that.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.