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LOTUS

LOW-COST INNOVATIVE TECHNOLOGY FOR WATER QUALITY MONITORING
AND WATER RESOURCES MANAGEMENT FOR URBAN AND RURAL WATER SYSTEMS IN INDIA

Co-Creation Workshops Results

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Abstract

This report highlights the methodology and results co-creation workshop is to understand the needs of the final users, in order to ensure that LOTUS solution matches the market needs, and to co-create features of an "ideal sensor" together with them, taking into account the social foundations, regional characteristics and the network building aspect.

Four co-creation workshops took place in three cities of India in December 2019. The co-creation workshops enable to co-define the specifications of the LOTUS sensors together with the final users of the solution.

Keywords

Co-creation, workshop, final users, participatory methodology, stakeholder engagement

Disclaimer

LOTUS has been financed with support from the European Commission and the Indian Government, Ministry of Science and Technology.

The LOTUS Project

LOTUS is a project funded by DG Environment under the European Union Horizon 2020 Research and Innovation Programme and by the Indian Government. It brings together EU and Indian prominent organisations with the aim to co-create, co-design and co-develop innovative robust affordable low-cost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban area.

The LOTUS solution is based on an innovative sensor and includes tailor-made decision support to exploit the capabilities of the sensor as well as a specific approach to co-creation. LOTUS aims to be co-designed and co-produced in India, and have a wide, diverse and lasting impact for the water sector in India due to intense collaborations with commercial and academic partners in India.

Based on the low-cost sensor platform, solutions for the early detection of water quality problems, decision support for countermeasures and optimal management of drinking and irrigation water systems, tailored on the functionalities of the new sensor, will be developed and integrated with the existing monitoring and control systems.

This sensor will be deployed in five different use cases: in a water-network, on groundwater, in irrigation, in an algae-based wastewater treatment plant and in water tankers. The packaging of the sensor, as well as the online and offline software tools will be tailored for each of the use cases. These last will enable to test the sensors and improve them iteratively.

The project is based on co-creation, co-design and co-production between the different partners. Therefore, an important stakeholder engagement process will be implemented during the project lifetime and involve relevant stakeholders, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water. Broad outreach activities will take place both in India and in Europe, therefore contributing to LOTUS impact maximisation.

The further development and exploitation (beyond the project) of the novel sensor platform will be done in cooperation with the Indian partners. This will create a level playing field for European and Indian industries and SMEs working in the water quality area.

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1 Overview of co-creation workshops

1.1 Aim and objectives

Co-creation is one of the forms of collaborative innovation: it defines the collaborative development of new values together with the users, most often the stakeholders. Ideas and concepts are shared and discussed together enabling the work or product to be developed jointly.

Co-creation and co-development do not happen instantly. It requires a significant amount of investment and, as with any relationship, trust is integral for each party to know that their investment will not be wasted. Studies have shown that trust influences knowledge transfer in research partnerships as it reduces the fear of opportunistic behaviour and ultimately increases the willingness to share information (Plewa et al, 2013; Steinmo 2015). However, building relationships with trust requires frequent communication (de Wit-de Vries et al, 2018).

The specificity of co-creation process in the LOTUS project is that it is organised *simultaneously* at three levels:

- **Level 1: co-creation within the consortium**. Starting from the available technologies with low technological maturity level, for example the sensing technology developed by Ecole Polytechnique (France), visualisation methods and tools developed by University of Exeter (UK) or optimisation tools developed by Technical University of Dortmund (Germany), the European and Indian partners from academia and industry work together to co-develop the initial concept and features of a future low cost solution adapted to Indian conditions.
- **Level 2: co-creation with end users**. This is business to business co-creation with representatives of technical users of LOTUS technologies: water utility (Guwahati), irrigation firm (Jalgaon) and tanker provider (Eureka Forbes). It takes place during the technical workshops in India in December 2019 conducted by the technical partners of LOTUS.
- **Level 3**: **co-creation with final users**. This is B2C co-creation with users of end users, called here **final users**: population (for drinking water), farmers (for irrigation water). This concept notes describes specifically co-creation workshops organised with the final users.

The objective of the co-creation workshop is to understand the needs of the final users, in order to ensure that LOTUS solution matches the market needs, and to co-create features of an “ideal sensor” together with them, taking into account the social foundations, regional characteristics and the network building aspect. Operational scenarios for stakeholders’ engagement have been discussed.

The overarching goal was to create a shared vision on water quality solutions, and to provide co-specifications for the technical requirements that will be prepared in WP6.

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The participatory approach (small group method/World Café method) has been used to create a space where everyone has the chance to speak. Information was collected in different ways including personal brainstorming, quiet reflection and group discussions.

The workshop aimed at retrieving the information around five main topics:

- How the users use water now? What are the current practices?
- What do final users need, in terms of water quality (and quantity)?
- What additional functions do they want/need from the system (system functionality)?
- How do they want to interact with the solution (user interaction)?
- How much are they ready to pay, and what is the most desirable arrangement, e.g. monthly payment, or purchase of a sensor (business model)?

Summary of the workshops includes expectation baseline, co-specification of the requirements around the use cases; definition of priorities from the final-user perspective; co-definition of success criteria for the use cases, and operational scenario.

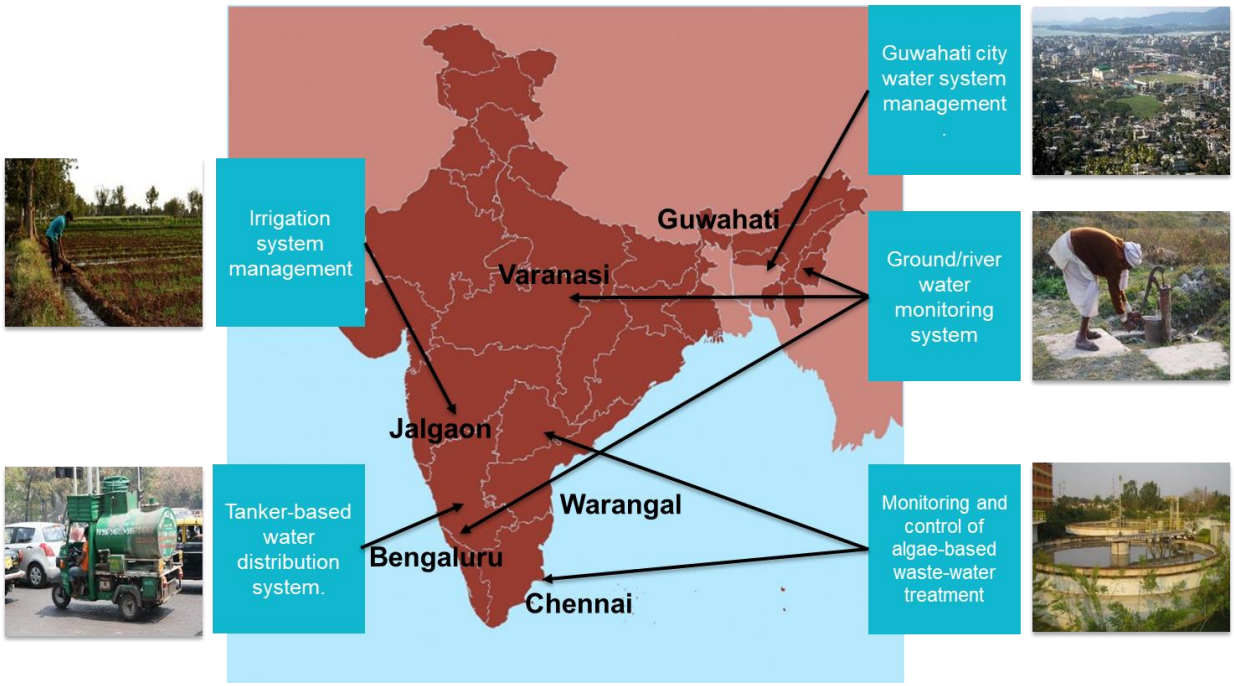

Figure 1 Location of five LOTUS use cases, including three cases where co-creation workshops took place (Guwahati, Jalgaon and Bengaluru)

The four co-creation workshops were conducted in three out of five LOTUS use cases (Fig. 1): Guwahati, Jalgaon and Bengaluru. These case studies have been chosen based on three criteria (Eisenhardt, 1989): (1) *variety*, as they are very different from each other therefore a good way to test the solutions in contrasting environments with different local needs, with regard to drinking water (Guwahati workshop), groundwater (Guwahati workshop), irrigation water (Jalgaon workshop) and tanker-based water (Bengaluru workshop); (2) *comparability*, as the water quality solutions are in the centre of preoccupation in all these cases/locations in India, and (3) *availability* of a local

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partner to organise and host the co-creation workshops. The content of the workshops is adapted to each use case.

1.2Workshop logistics

The co-creation workshops (Layer 3 of LOTUS co-creation) took place in India in November-December 2019 (Month 11-12) of the LOTUS project.

They took place in three cities, corresponding to four different use cases of LOTUS:

Table 1 Schedule for the workshops

Date	Place
29/11/2019	Guwahati co-creation workshop: drinking water
30/11/2019	Guwahati co-creation workshop: groundwater
03/12/2019	Jalgaon co-creation workshop: irrigation water
07/12/2019	Bengaluru co-creation workshop: tanker-based water

Each workshop lasted for approximately half a day.

The technical workshops (Layer 2 of LOTUS co-creation) were conducted during the same week. Both types of workshops were necessary for the user's requirements.

1.2.1 Participants

The co-creation workshops included on average 20 participants and involved the following:

- Final users: users of LOTUS use case providers
- Use case "owners" (e.g. Jain Irrigation in Jalgaon)
- at least one technical (academic or industrial) LOTUS partner involved in the use case
- moderators (joint EU and Indian team)

Table 2 Participants in the workshops

	Guwahati city water system management	Guwahati ground water management	Jalgaon irrigation system management	Bengaluru tanker-based water distribution system
Moderators: co-creation process	Partha J Das (Aaranyak),	Partha J Das (Aaranyak),	Svetlana Klessova (INNO)	Caroline Guillet (INNO) & Kate

	Svetlana Klessova (INNO) & Kate Baker (UNEXE)	Svetlana Klessova (INNO)		Baker (UNEXE) supported by Ms Monika Makhwana (IITB social science)
Technical partner (contributors to moderation)	Senthilmurugan Subbiah (IIT Guwahati)	Senthilmurugan Subbiah (IIT Guwahati)	Sebastian Engell (TUDO) Yannik-Noel Misz (TUDO)	Florian Benz (Autarcon)
Co-moderators: Use case owner	Just Paani	Senthilmurugan Subbiah (IITG)	Abhijit Bhaskar Joshi Sachin Siddharam Patil (Jain Irrigation)	Sankar (Eureka Forbes) James (JustPaani)
Final users	Population	Population	Farmers	Population

1.2.2 Discussion topics for the workshop

The workshop were based on four main pillars, including user interaction, system functionality, and business model. Questions for discussion during the workshop were based around these topics:

- Current practices in terms of water quality, concerns, needs
  - How do people use the water (drinking, washing laundry, cooking, gardening…)?
  - How do issues around water quality impact them? / Do they have an alternative water supply?
  - What is the main water source (well, tankers, rivers…)?
  - If water quality could be guaranteed, how would this change people' lives? Do you worry about getting sick from the water?
- User interaction
  - If final users have direct access to the solution (i.e. can they hold it), how do they want the information to be provided (screen attached to the sensor, mobile app, software…)
  - If final users do not have direct access to the sensors, how do they want the information to be provided? How to build their trust?
- System functionality
  - What level of water quality do final user want (drinkable? Suitable for irrigation? Safe for babies?)
  - What extra information is crucial for them (pH? Salinity? Free from bacteria?)
  - What level of information do they need rough indicator vs number, global information versus parameter by parameter, periodicity of use)?
- Business model & costs
  - How much do they currently pay to reach this level of quality?
  - How much are they ready to pay extra for guaranteed/better quality water?

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- Are they ready to perform maintenance and renew their consumable? How often?

As this workshop aims to understand the final users, it is important to create an opportunity and space for them to share their stories and challenges on the topic of water quality. Workshops therefore were an opportunity for the final users to share their successes and challenges of water quality; and for them to ask their own questions to the LOTUS project and the end users. This strong emphasis on knowledge exchange is key as it enables relationships to build and trust to develop. People are more likely to share openly and honestly if they feel comfortable and safe; good level of trust was achieved through the Indian LOTUS partners who invites participants at the workshops.

For each workshop, the LOTUS team has developed a rich set of questions. They must be understood as support for the moderators and were used depending on the workshop needs.

It was important to collect information on format and price during the co-creation process. The LOTUS team wanted to understand the user, and to work with them, to ensure their needs are met with the LOTUS technology.

1.2.3 Facilitation of the workshop

Workshops were co-facilitated by Indian and European partners (with variations depending on the use case). The European team (Inno and the University of Exeter) co-designed the workshops with the Indian partners (TISS, IITG, Aaranyak, JustPaani, Jain) providing the structure for the workshop.

Table 3 Schedule of the workshops

Timings	Activity
	Arrival & tea - Sign attendance sheet + ethics form (support from Indian partner to ensure people understand content) - Gift distribution
30 mins	**Introductions** - Official opening by a local leader (decision left to use case owners) (5 min) - Brief overview of the workshop (use case owners) - Presentation of the moderators (few words to introduce) - Roundtable introduction & icebreaker (who they are, what they do and why interested in participating in the workshop / share a memory or dream about water, - phrases)
10 mins	**LOTUS simplified presentation** (European partners + a few words from the use case owner)
1 hr 15mins	**Brief presentation of the workshop methodology** **Small-group facilitation format**
30 mins	**Tea break**
1hr 15mins	**Feedback to the larger group** - Participants will be invited to share their results to the larger group - One local participant per group will provide feedback for its table - Cost of water (discussing the business model) - Discussions

10 mins **Next steps**

- Immediate next steps
- Lotus Development (what information can we provide about the development of the solution?)

1.2.4 Methodology

Facilitation is a structured conversational process for knowledge sharing in which groups of people (5-8 people) discussed the four main pillars (described in full above) which included current practices of water quality, concerns, and needs; user interaction; system functionality; and business model and costs.

Each table had two moderators (one EU, one Indian) who ensured everyone had the chance to speak and take notes on large pieces of paper with questions printed on it using either markers or sticky notes

To facilitate the discussions, each table had a printed sheet which represented three levels of information:

- What is the current situation;
- What is the wished situation;
- How would it translate in terms of technical requirements.

The printed A1 sheet worked as a visual support for the questions of the moderators. Participants were encouraged to write their ideas on sticky notes and stick them on the printed A1 Sheet. This enabled to gather data while structuring the reflexion (from what is the current situation to the final LOTUS solution).

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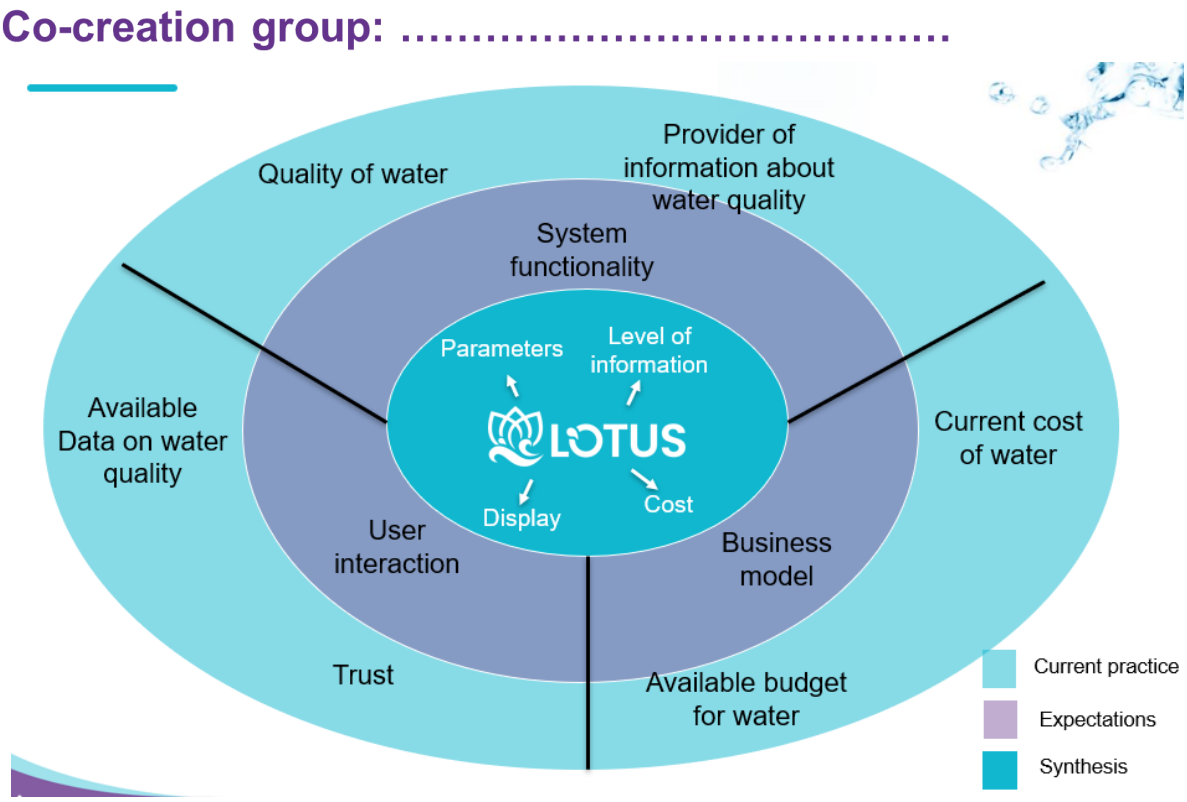

Figure 2 Printed visual to facilitate the workshop

Each 15 minute, the moderator moved onto the next set of questions. Each group remained with the same moderators during the whole workshop. This enabled to build upon what had already been said and ensured that everybody had a chance to speak.

Each group presented its results at the end of the session. The goal of this feedback session was to create consensus amongst participants on the desired features of LOTUS.

1.2.5 Formalities

The logistics of the workshops were organised by the Indian partners. Indian partners invited local personalities (politicians, businessmen) to open the workshop to raise the profile of the LOTUS project. Time was scheduled for coffee and lunch to enable networking and informal conversations to occur increasing the usefulness of the day for participants.

Language and translation

The language of the workshop was adapted to the participants. If the addressed community did not use English as primary language, Indian partners worked as translators to best convey the participant's ideas.

When the workshop is conducted in English, translation was provided for the participants who were not comfortable with English. It was essential that all voices were heard. Special attention was given to listening to them.

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1.2.6 Delivering information about LOTUS project

People participated in the workshop due to interest in the project and its outcomes. It was therefore necessary to provide information about LOTUS project. The information communicated about the project aimed not to raise unrealistic expectations (for instance, "thanks to LOTUS, you will be able to drink water directly from the tap" shall not be used) nor hinder the co-creation process (i.e. be too precise on the specifications for instance).

LOTUS presentation was given at the beginning of the workshop. Then the workshop focussed on the participants and their needs. At the end, moderators re-explained briefly about LOTUS and explained how the LOTUS team would use the workshop results.

Information about the LOTUS project aimed to be both basic and neutral. The text was adapted to each use case. For example:

- *LOTUS is a project co-funded by the EC and DST. It aims at developing low-cost solutions to monitor water quality in India. LOTUS aims at developing a low-cost sensor which monitors precisely the quality of water and offers real-time information which is used to better manage and control water systems.*
- *LOTUS is developed by a consortium of European and Indian partners:*
    - *Introduction of the local facilitator*
    - *Introduction of the European partners that are present (no need to go over the 21 partners)*
- *LOTUS is developed in Europe and India in partnership. Your city has been chosen for testing the solution.*
- *LOTUS is a four-year project which started in 2019 and will continue until 2023. We are one year in the project. At this stage, the solutions are still being conceived. This workshop will support their conception. The sensors will be deployed in mid-2020 on the field for trial.*

1.3 Post workshop visits

To validate the information gathered during the workshop and to ensure that we have a good understanding of the final user needs, we organised field visits and engaged directly with local people (with the support of translators/community members). Logistically, this was done in Bengaluru.

The field visits enabled LOTUS European team to better grasp the reality of the final users. During field visits, we were able to continue to listen and to validate information. Topics included:

- How do they use the water (drinking, washing laundry, cooking, gardening…)?
- How do issues around water quality impact them? / Do they have an alternative water supply?
- What is the main water source (well, tankers, rivers…)?
- If water quality could be guaranteed, how would this change their lives?

2 Guwahati city water system management

2.1 Aim of the workshop

This co-creation workshop aims to understand the current practice of water use in the home and how the LOTUS solution could help increase trust in knowing the water quality from the tap. It is particularly important to take into consideration that the people are not used to drinking tap water. An important aspect of the workshop was therefore to understand the interaction of people with tap water. Then, the workshop focussed on how the LOTUS solution could match final users' needs in terms of information, quality, functionality, and price.

2.2 Background

Guwahati is the largest city in the state of Assam. It is located in the North-East of the country. The city has developed along the Brahmaputra river banks. The city is expanding along three corridors which radiates from the urban core, located on the riverbanks. Guwahati is one of the fastest growing cities in India with an estimated 2.8 million residents by 2025.

The city takes water mainly from the Brahmaputra river. Groundwater contributes almost nil to the main city water supply. The raw water from the river is treated and supplied through the pipelines. There are around 12 water treatment plants located in the Guwahati Municipal Corporation (GMC) area. The total installed capacity of these WTPs is 96 MLD. The total supply of water, in addition to the treated water, is 103 MLD of which 90 MLD is provided by the GMC.

According to the census of India (Census, 2011), the population of Guwahati is around 0.96 million, the total demand of water is about 160 MLD (considering CPHEEO guideline of 150 LPCD for the city). This shows there is a sharp demand-supply gap for drinking water supply in the city.

In addition, Guwahati also faces a problem of irregularity in water supply, with sharp seasonal variation. Further, the quality of water is a concern in the city, particularly during the monsoon season. In general, the water has high turbidity levels, especially during the monsoon season as the water carries a large amount of silt. Therefore, the settlement process takes longer than usual (GMC, 2006). During the floods, polluted water enters into the water distribution pipes through the cracks and holes in the old pipes which reduces the water quality further. The intermittent water supply also does not help with the water quality.

Water supply in the region is managed by the public health and engineering department (PHED). In the municipality areas of the city it is also managed by the GMC, and in the surrounding areas the Assam Urban Water Supply and Sewerage Board jointly supplies water. It needs to be noted, not

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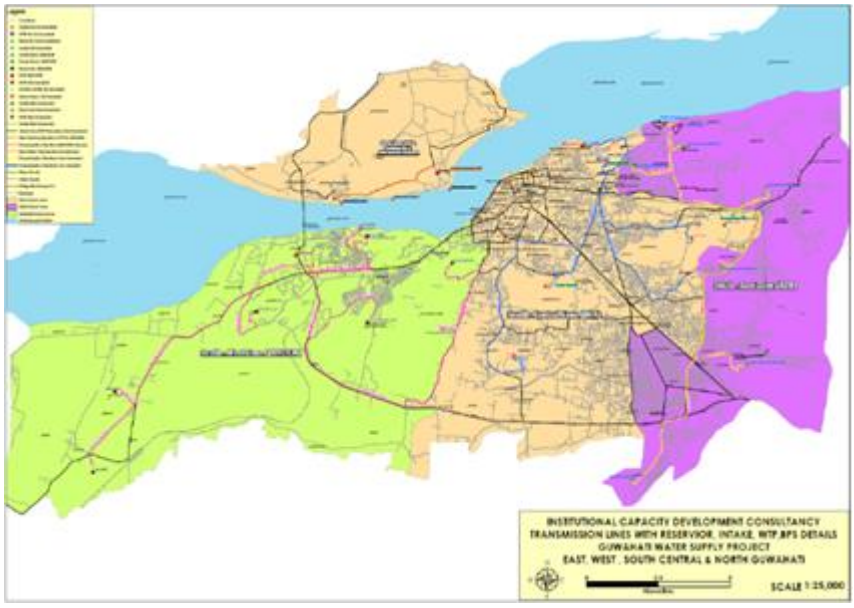
every resident of the city has access to piped water and the use case focusses on households which have access to the water distribution network.

The Guwahati Water Distribution Network is managed by the Guwahati Metropolitan Drinking Water & Sewerage Board (Guwahati Jal Board), established in 2011 to *"promote uninterrupted, hygienic, piped drinking water and encourage a hygienic environment in the Guwahati Metropolitan Area (GMA)"*.



The water distribution network is divided in four zones:

- South Central zone, which covers Guwahati urban core and the southern corridor;
- The South-West zone;
- The South-East zone;
- and the North zone (on the other side of the Brahmaputra river).

The project will first address water quality in the Southern Central zone of the city. This city gathers rather wealthy and educated people. It will then be extended to all other three zones.

Currently, water supply facilities cater to less than 30% of the population, for about 1-2 hours per day. Guwahati Jal Board is building a system which will enable a 24/7 water distribution.

Regarding water quality, most of the plants and pipelines have outlived their designed life period. As a consequence, they are more prone to leakages and introduction of exterior contaminants, notably when flooding. The intermittent distribution is aggravating the water quality as low levels of water enable mud to enter the pipes. Entering a 24/7 distribution system should enable to avoid such source of contaminants.

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2.3 LOTUS Project in Guwahati water distribution system

Guwahati JalBoard aims to run water 24/7 in the pipes of the Central South Area. This is a huge improvement towards the current situation. Running water constantly in the pipes will highly contribute to increase its quality, avoid the infiltration of sediment and other contaminants carried by rains.

Concomitantly to the modernisation of its infrastructure, Guwahati Jalboard, will install the LOTUS solution in the water distribution system. Together with the IT platform, this will enable the water provider to obtain real-time information about the quality of water. It is important to manage the expectations of participants and to underline here that LOTUS is not responsible for the modernisation of the infrastructure, hence cannot provide details about this part of the programme. LOTUS is very much the water quality monitoring system. It is a research and development project, which is currently under development and may need to be iterated before to become a final product.

Knowing about the quality of water, will enable to apply the right water treatment to the water to make it drinkable. If the water is currently infected, the information is available and reliable. As a result, the adequate awareness campaign can be run toward consumers.

2.4 Information about participants

The people that will be benefiting from this project are middle/upper class people who are well educated. They live in the South West zone, the most developed part of the city, connected to the city centre. They speak English and the second official language of the region, Assamese. Hinduism is the main religion in Guwahati city with 85 % and Islam is second with approximately 12 % following it.

They are aware of the water quality issues and have the finances to find other ways to have water in the home, for example by purchasing bottled water. Even with new technology, they may be sceptical over drinking water from the taps due to the possibility of contamination and the risks of water borne diseases.

2.5 Questions for the workshop

Introducing LOTUS

Basic information

- *LOTUS is a project co-funded by the EC and DST. It aims at developing low-cost solutions to improve water quality in India. LOTUS aims at developing a low-cost sensor which monitors precisely the quality of water and offers real-time information which is used to improve the management and control of water systems.*
- *LOTUS is developed by a consortium of European and Indian partners:*

- *Introduction of the local facilitator*
- *Introduction of the European partners that are present (no need to go over the 21 partners)*

- *LOTUS is developed in Europe and India in partnership. Your city has been chosen for testing the solution.*
- *LOTUS is a four-year project which started in 2019 and will continue until 2023. We are one year in the project. At this stage, the solution is still being conceived. This workshop will support their conception. The sensors and associated system will be deployed mid 2020 on the field for trial.*

Information about the use case

Guwahati JalBoard will install LOTUS sensors directly in the water pipes, in several strategic locations. This will enable to monitor the quality of the water 24/7 in real time.

1. **Current practices on water quality**

Drinking water:

- Where does the water that you currently drink come from?
- What are current water supply issues (source wise) in the city? Please specify if there are seasonal issue in supply of water, if yes, specify the nature of issue?
- How does residents deal with problems related to water supply?
- How do you know it is safe?
- What are key common water quality issues with respect to pipe water supply in the city?
- If you know it is not safe, do you apply a complementary treatment?
- How much you pay for the water?
- How satisfied are you with the current pipe water supply management in the city?
- Are there frequent water quality problems? Do you report them to the Jal Board?
- Does the amount of drinking water/ground water from your source vary depending on season?

Other sources of water:

- What are other water sources? How often do you use supply from other sources? Does water supply from sources vary depending upon usage? How accessible of these sources? Does getting water from other sources cost to you, if yes, how much? How would you make sure that the supply from other sources is safe for drinking purpose?
- Would having water quality information be helpful? How would it change how you use water in everyday life?
- What do you know about the quality of tap water?
- If Jal Board will provide water supply and quality information on real time (advance basis), how helpful this would be for you?

2. **What are your water quality needs and wishes (understand needs about the LOTUS solution, system functionality)**

- What would make you trust the water quality?
  - What do you know about the quality of your tap water? What do you know about contamination risks?
  - If you were told it had a high water quality, would you drink it without treatment?

- Would you trust data given by the water provider or do you need to see the information yourself? (side comment: it is possible to see it yourself if the water provider operates the sensors? The question is broad, for the future)

- Which information is useful?
  - What information would be helpful to you? (for example, fluoride)
  - Would you want to know detailed information, or do you just want to know that the water is safe to drink? (quantified information vs. good)?
  - How often do you need to check water quality information?
  - Do you have any means available to you to test the quality of water yourself?
  - If not, would like to have an efficient instrument to check water quality yourself?

3. **How do you want to interact with the sensor (user interaction)**

- How would you like to receive the information?
  - Do you need a display of information? Where can the display be located?
  - Do you want information displayed through an app that can be accessed from your mobile or computer? Or would a screen by the tap? Non-digital information?
  - What information do you need (good vs multi parameters)?
  - How often do you want to check the quality of the water?
- How does this information affect you?
  - If the sensor indicates that the water is of low quality, what will you do? Do you have an alternative water supply?

4. **How do you want to acquire the solution? (Business model)**

Moderators will make sure to ask the question in a culturally appropriate manner.

- What is the current price of water?
  - How much do you pay for water per month (all water / drinking water)?
  - How much do you spend currently on monitoring the water quality?
- Can it change? Under what conditions?
  - Would you be ready to pay more for higher quality water? Or should it be a free service from the City?

5. **Discussing the cost of clean water (Business model) in plenary**
   - Would you be ready to pay more for higher quality water?
   - What price would you be ready to pay for a portable sensor? Would you prefer to rent or buy it?
   - Would you be ready to spend money on sensor? Would this increase the amount of money you are currently spending on monitoring water quality?

2.6 Results of the workshop

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The workshop took place during the afternoon of the 27th November at IIT Guwahati.

2.6.1 System functionality

2.6.1.1 Current situation about water quality

Most people in Guwahati get their water from groundwater by creating their own borewell. This means that apart from installation and the energy cost to pump out the water, the water is free. However, there are concerns over the quality of the groundwater as there is iron, arsenic and fluoride contamination. This is why the government are creating a centralized system. However, at the moment only a small part of the city is connected to the main surface water distribution network and people do not trust the water with complementary treatments always being used. The most common being filtration and boiling of water.

2.6.1.2 Current provider of information about water quality

Most attendees of the workshop do not test the quality of the water. Instead they always filter the water using in-house methods. Even if they if they were told that the water was of high quality, they would add further treatment. When asked if they would trust the information given by a water provider, the response was it would depend on where the information is coming from and they would want to see the data / behind any classification system. They noted there is more trust in the private sector compared to government.

2.6.1.3 Desired system functionality

There are a range of water quality parameters that were mentioned during the workshop that are of concern to people. This included:

- Ph
- chloride,
- Total Dissolved Solids

- Vital minerals that are often taken out during the filtration process
- Bacteria

2.6.2 User interaction

2.6.2.1 Available data on water quality

As explained above, there is very little trust in the government's piped water supply and no current method for communities to check the water quality. Instead people always add complementary treatment.

2.6.2.2 Trust

Attendees at the workshop said there is no trust in piped water. Even if they are told that the water has been treated, there was concern that the water could become contaminated from the treatment plant to the house. People were concerned that the piped water supply would become contaminated by the wastewater pipes; however, there are no wastewater pipes. There is a general concern with drinking surface water because people know there are no wastewater treatment facilities with waste water going directly into the river. People therefore don't want to drink river water.

People are also concerned that there is no accountability. If a concern is reported there is often no response. There is no trust in Jalaboard. Some days the water is clean but at other times it is dry or dirty. There is no consistency.

2.6.2.3 Desired user interaction

There were a range of suggestions about how to interact with the sensor. It was discussed that a public display of the ground water quality would help increase transparency and trust in the government's main system. A public display near to where people gather would help increase transparency and trust in the water supply. There are 31 municipal wards so it could be displayed in 3 or 4 places. It could also be displayed on public water taps. Staged information on water quality would be helpful; for example, a colour coded system from 'good' to 'bad'. It would also be helpful if there was useful information about how to make the water clean. For example, adding a statement such as 'safe to drink after boiling/filtering/ treatment'. A mobile app would enable anyone to log in and check the water quality.

An SMS message to be sent when the water quality has declined and it's unsafe to drink the water.

2.6.3 Business model

Piped water household connection is 8,500 rupees plus a meter for the water you use. On average, 1 litre = 0.08 rupee. It was generally agreed that people would be willing to pay more for their water if there was information about its quality. However, it was also recognised that many people in the city

are not in the financial situation to be able to pay for this information. The price of the sensor needs to standardised and controlled.

It was suggested that the information about water quality could be used to help build trust in the water sector. A Reward system for companies who supply water of high quality for a period of time. Also fines for companies when water quality is bad. This would help to build trust. It was also suggested that water could be free for the lower strata of people but then chargeable beyond a reasonable quantity.

During dry periods people may use tankers which cost on average 250 rupees for 1,000 liters.

2.7 Synthesis for LOTUS sensor

System functionality	User interaction	Business model
• Parameters: "Must have" Parameters: Turbidity, bacterial contamination • Sensor used to increase trust in piped water supply	• SMS alert • App with staged information • Public display	• The government/ water utilities would use the sensor • People would pay for information but hard to quantify the amount

3 Guwahati groundwater management

3.1 Aim

The aim of this workshop is to understand how people perceive the quality of their water source and how the LOTUS solution can be designed to increase awareness of water quality. This was done in two ways:

- Firstly, there is a need for reliable information (by using the LOTUS solutions) so the public know when it is safe to drink the water
- Second, there is a need to educate the population on the risk of contaminated water. For instance, people believe that rains recharge the phreatic tables and clean the water whereas, on the contrary it increases water pollution. Educating the community is not the purpose of the workshop, but the LOTUS team will collaborate to this aim by showing that water quality can be measured by a scientific device. LOTUS will therefore support the education of local communities.

3.2 Background

Only 30% of the population of Guwahati have access to piped-water supply (Das and Goswami, 2013) and the existing facilities have outreached design life and running below the capacity of Water Treatment Plants (JnNURM, 2006). However, the area is abundant of groundwater at a shallow depth of 2-4 m, which encourages people to use dug wells, hand pumps or bore wells (Das and Goswami, 2013). Several researchers, however, have expressed concerns towards groundwater quality regarding iron, fluoride, nitrate and arsenic contaminations in various regions of Assam (Chakrabarty and Sarma, 2011; Chetia et al., 2011).

As per WHO guidelines, arsenic in drinking water should be below 10 mg/L (WHO, 2008) and as per the Indian standards the desirable limit is 10 mg/L and permissible limit is 50 mg/L (BIS 10500, 2012). It is well documented that high levels of arsenic exposure cause chronic health effects which include cancer, skin pigmentation, skin lesions, respiratory, neurological and haematological effects in human (Ahmad and Bhattacharya, 2019; Sogbanmu et al., 2019). As per WHO guidelines and BIS permissible limits, fluoride in drinking water should be below 1.5 mg/L (WHO, 2008). The major health problems caused by excessive fluoride are dental fluorosis, skeletal fluorosis, and deformation of bones in children as well as adults (Marya et al., 2014).

In response to the poor water quality; the Ministry of Urban Development of the Government of India has initiated various projects to improve the situation. Yet many of these water supply schemes fail in terms of public acceptance. This is primarily due to lack of public awareness, transparency on water tariff policy, and angst of water privatisation. A recent study by Das et al (2019) has found that the public perception on groundwater quality was far away from reality, only 3-4% of people being

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aware of contamination and the rationale for public opposition were more of public misconception. Public awareness on groundwater quality and its adverse health effects were found to be the most influencing factors affecting public willingness to procure (maximum amount an individual is willing to sacrifice to pay for a good) improved from 58 to 74% after creating awareness.

Monitoring water quality will enable people to know if the water quality is high enough to drink. When there is heavy rain, people think that the groundwater is recharged, increasing the water quality. In reality, it causes water to move underground and can cause arsenic leaching. A system is required to monitor and tell people if the water is safe to drink. Currently, the ground water quality data is collected manually, for a few parameters such as temperature, level and total dissolved solids (TSD). Samples are collected by the Central Water Commission. It is monitoring water quality at 531 key locations covering all the major river basins of India, including Guwahati. Data is stored by the Public Health Department and is accessible for all.

3.3 LOTUS solution for monitoring ground water quality

Unlike the water distribution system, sensors will not be placed in the phreatic table or in the wells. They will be used by technicians to measure water quality. The information collected will enable to map the movement of water in the table and anticipate and inform about pollutions.

3.4 Information about participants

Guwahati is the largest city in the north-eastern state of Assam. It is one of the fastest growing cities in India. It is a major riverine port city and one of the fastest growing cities in India. Many communities will not know there are issues with the groundwater quality and not know the dangers of drinking water contaminated with fluoride and arsenic. Most of the people attending will have houses with hand pumps followed by tube wells and dug wells. It is important not to scare the attendees with water quality information. They will speak a mix of English and the second official language of the region, Assamese. Hinduism is the main religion in Guwahati city with 85 % and Islam is second with approximately 12 % following it.

3.5 Questions for the workshop

Introducing LOTUS

Basic information

- *LOTUS is a project co-funded by the EC and DST. It aims at developing a solution to improve water quality in India. LOTUS aims at developing a sensor which monitors precisely the quality of water and offers real-time information which is used to improve the management and control of water systems.*

- *LOTUS is developed by a consortium of European and Indian partners:*
  - *Introduction of the local facilitator*
  - *Introduction of the European partners that are present (no need to go over the 21 partners)*
- *LOTUS is developed in Europe and India in partnership. Your city has been chosen for testing the solution.*
- *LOTUS is a four-year project which started in 2019 and will continue until 2023. We are one year in the project. At this stage, the solution is still being conceived. This workshop will support their conception. The sensors will be deployed in 2021 on the field for trial.*

1. Current practices on water quality

- Do you prefer ground water or surface water? Why?
- How do you access groundwater for the drinking purpose? (by hand pump, open wells of bore wells?)
- Do you fully or partly depend upon groundwater use for drinking? What are your other sources, if partly?
- Are you aware about the quality of the ground water? What do you know about it?
- Do you know what are the risks of contamination of groundwater supply?
- Do you use a domestic sand filter (mostly for iron) or do you use advanced filtering (for arsenic etc)?
- How frequently do you think you are affected by diseases due to water contamination? (if "yes" => do you mix this ground water with some other sources?
- Does the amount of ground water from your sources vary depending on season? Do your wells go dry?
- If the quality is bad, what do you do? How do you improve the quality if it is bad? Do you take care about quality improvement yourself, or do you depend on other options (external agency), if yes, who?

2. Provider of information about water quality

- How do you know that accessing groundwater is safe in your area? How you get the information?
- How do you trust this knowledge about ground water quality in your area?
- Do you check the reliability of the information? Cross-check?

3. Current cost of water

- How much the ground water cost you? (one time instalment cost or buying from the tanker? if own pump, no cost except installation)?
- Does the cost of supplied (tanker) ground water change according to the demand or season? (for example, if pumping more in dry season, more electricity?
- Will you be happy to have official information from the government about water quality and recommended treatment technologies? And if this government information is certified by the credible third party is needed, is it more acceptable?

4. Available budget for water

- Do you think supplied ground water is expensive? (it will be tanker water)

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- Has the cost increased over time?
- Would you spend more on supplied ground water if you knew it was clean?

5. Trust

- Do you have any concerns that the water may not be safe to drink? (Note: almost no water in India is safe to drink without treatment, e.g. boiling it.)
- How this doubt shall be removed?
- If you use the borewell, do you check it sometimes for quality? If yes, how often?
- Do you know that there are private labs in Guwahati which are doing free quality check of water samples and give you reports? (mobile clinic on Sunday, people come with bottle of sample and get reports...)
- If it is not safe, do you have a way to treat it? (Note: almost no water in India is safe to drink without treatment, e.g. boiling; but the question is not about boiling)

6. Future data on water quality

- How having water quality information be helpful for you?
- What would you like about your water quality (NB: ask about priorities in case of multiple parameters). (arsenic and fluoride are the most common)
- Would you like to be told that your water quality is bad? What do you do then, if you know that your water quality is bad? (NB: most rural people prefer not to know unless there are alternative safe sources nearly)

7. System functionality

- What improvement you want in ground water quality, with the knowledge that you have?
- What information would be like to have? parameters?
- Would detailed you want this information that ground water is safe to drink (quantified information vs. safe/unsafe)?
- Would public display with water quality index be helpful?
- How often do you want to check ground water quality information?
- What would make you trust the water quality?

8. User Interaction

- How would you like to receive the information?
- Do you want information displayed through an app that can be accessed from your mobile or computer? Or SMS?
- How does this information affect you?
- If the information indicates that the ground water is of low quality, what will you do?

3.6 Results of the workshop

The workshop took place during the afternoon of the 27th November at IIT Guwahati.


Fig X Photos of the workshop at IIT Guwahati

3.6.1.1 Current situation about water quality

Most people in Guwahati get their water from groundwater by creating their own borewell. This means that apart from installation, the water is free. However, there are concerns over the quality of the groundwater as there is iron, arsenic and fluoride contamination. In a recent study by Das et al (2019) groundwater samples from household borewells exceed WHO guidelines; Iron by 55%, Fluoride by 12% and Arsenic by 9%. The public perception does not reflect these figures with Das et al (2019) finding only 3- 4% people being aware of contamination issues after interviewing 1,500 households.

The workshops found that educated people (but not water experts) never trust the water and if economically possible add treatment after pumping out the water using a filtration process. However, filtration systems that are used in the home are not able to remove arsenic and fluoride. The less general educated people are not aware of any contamination issues, generally if the water is clear with no smell then they are okay to drink it. Very few people, no matter the socio-economic status test the water quality. When there are issues with groundwater, such as lowering of the water table during the dry season (Dec-Feb) they use water tankers.

3.6.1.2 Desired system functionality

Presently, there is little information about the water quality of the groundwater in Guwahati. The LOTUS sensor will assist in collecting data and increasing knowledge. People want to know if the water is safe or not. If they are told the ground water is contaminated, they would use the water for a different purpose, washing instead of cooking or drinking for instance. The important parameters are:

- Fluoride
- Arsenic
- Iron

However, Jal Board said they have to be careful how they communicate groundwater quality to the public as it may cause panic if they have no other water supply options. Many households are not yet connected to the centralized surface water system, and people may not be able to afford tanker

water. The long term plan for the city is to have a centralized water distribution network; with the information on the poor groundwater quality being used to encourage people to switch from ground water to the centralized system.

3.6.2 User interaction

3.6.2.1 Available data on water quality

As explained above, although there are concerns about groundwater quality there is little or no information. There is also currently no way of the public easily testing the water. Participants in the workshop noted that if there was more information about the groundwater this would give them power to complain and create change. However, there was also discussion about what people would do with the information if there were no other water sources. It could create panic within communities.

3.6.2.2 Trust

Trust is an important issue when discussing water quality. People need to trust the water is clean for them to drink it. From the workshop there seems to be a lack of trust with the government and this was a reason why they are happy to have their own borewells; they have control over the water. Trust is something that takes a long time to build and the LOTUS water sensors could be used to give people evidence of the water quality.

An idea of creating a nexus between government and private companies was raised. Private companies are usually trusted in India as they have built trust with their customers over time, but the government needs to be included to create standards.

3.6.2.3 Desired user interaction

It was discussed that a public display of the ground water quality would increase transparency but would only be helpful in areas where there is the option to be connected to the government's main system otherwise it would cause panic. A colour coded system similar to air quality was suggested as a good way to display information. In addition, an SMS message to be sent when the water quality has with more information available. A mobile app would be helpful so anyone can log in and check the water quality. Attendees mentioned that it would be helpful if advice can with the information. For example, 'Safe after boiling/filtering'

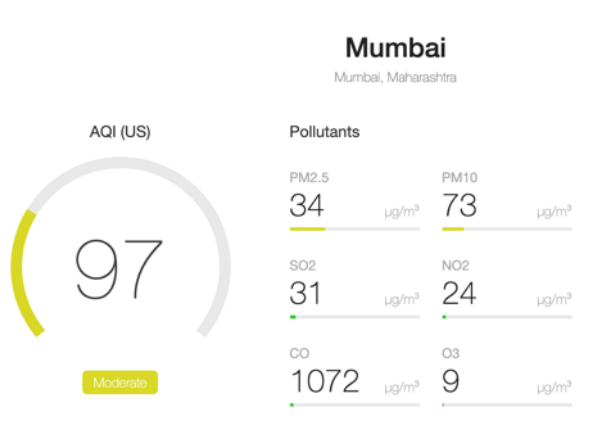

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Figure X Example of an air quality display from air-quality.com and a public display board

3.6.3 Business model

In Guwahati's groundwater the main water pollutants (Fluoride, Arsenic, and Iron) can only be treated on a large scale and is an expensive process. Therefore, it can only happen on a large scale, for example for groundwater municipal supply. In the workshop middle class people said they would pay more to know the water is clean but it is not helpful if they are unable able to clean the groundwater. In this sense, it was decided that the sensor would probably be more helpful if was used to educate communities of the dangers of drinking polluted groundwater and encourage them to sign up to the government water supply. This would only work if these communities can access the government water supply scheme and if they can afford it. Piped water household connection is 8,500 rupees and then there is a meter for the water you use. This would not be accessible for many people in Guwahati.

3.7 Synthesis for LOTUS sensor

System functionality	User interaction	Business model
• Parameters: "Must have" Parameters: Fluoride, Arsenic, and Iron • Sensor to be used to encourage people to sign up to the government water supply	• SMS alerts • Public display (alternative water supply is required otherwise will cause panic)	• The government/ water utilities would use the sensor • A nexus between government & private

4 Bengaluru tanker-based water distribution system

4.1 Aim

The aim of the workshop is to understand how the final users (communities in Bengaluru) feel about the water tankers being fitted with LOTUS solution and an automatic chlorination system. The aim was to understand the following:

- What is the level of trust in the water quality from the tankers?
- How can the LOTUS solutions help improve the transparency and trust in the water quality?
- What level of water quality do people expect?
- How do they want to receive this information?

4.2 Background

The founders of Bengaluru in the 1600s, created an irrigation system that would supply the city with water. The streams formed at the top of valleys that surrounded the city, these were dammed into man-made lakes by constructing bunds. Each of these lakes would then harvest rainwater from its catchments and the surplus would flow downstream, spilling into the next lake in the cascade via storm water drains or raja kaluves. The bodies of water would in turn serve the needs of the population. Bengaluru was known as the “city of lakes”. This system survived through to the 1970s, when there were still 285 lakes in the city, making it self-sufficient in its water needs. Today, however, there are just 194 lakes left, and the large majority of them are sewage-fed. The rest have been lost to encroachments – by the Bangalore Development Authority, private real estate developers and illegal builders – to cater to the booming housing needs of a city of 10 million. According to studies by the IISc, rapid urbanisation and expansion between 1973 and 2016 caused a 1005% increase in paved surfaces and decline of 88% in the city’s vegetation, while water bodies declined by 85% between 2000 and 2014.

Today, piped water supply systems cater only to central Bengaluru, while the outskirts rely on alternatives including domestic bore wells or private water tankers, tapping into and depleting deep groundwater aquifers. These services are typically used by the urban poor, but operated on a for-profit basis, which means they actually come at higher costs than the heavily subsidised centralised water supply system. The growing use of groundwater is linked with the private business of water tankers. There are more than 120 water tanker companies in the city, with more than 3000 vehicles in the city reaches (Raj, 2013).

There have been calls to introduce tariffs for the water tankers due to private water tankers charging exorbitant rates during the summer months. The Bangalore Water Supply and Sewerage Board

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(SWSSB) and the Bruhat Bengaluru Mahanagara Palike (BBMP) plan to set the price to be similar to what the BWSSB charges for its tankers. The BWSSB water tanker with 16,000 litres costs Rs 540 but the private suppliers allegedly have been charging three to four times that price. There have also been calls for officials to check the source of the water used by private tankers with reports that the tankers have been using residential borewells to supply water to commercial places at higher rates.

There have been reports that the quality of water from the tankers can vary. A study from 2016 showed that some water samples from tankers samples in Mumbai had microbiological contamination. Monitoring the tanker water quality using LOTUS technology will enable the final users to know if the water is of good enough quality to drink. However, the LOTUS team is aware that the water tankers are not the only solution to the water quality, nor water quantity crisis that is impacting Bengaluru. Instead, the LOTUS team acknowledges that approaches which combine local knowledge and communities have helped to restore public wells and clean up the Bengaluru lakes which are more sustainable sources of water.

4.3 LOTUS solution in the tankers

LOTUS solution will be deployed in 1-2 tanker of the JustPaani company. An Onsite Chlorine Generation system will be installed at an existing borewell/water filling station. The chlorine will be dosed during water filling into the tanker at the required rate. The Lotus sensor will enable to monitor the water quality in the trucks. Sensors will be linked to an automatic chlorine dosing system attached to the tanker, which will ensure pathogen free water conditions, as soon as the required residual chlorine level in the water is not met anymore.

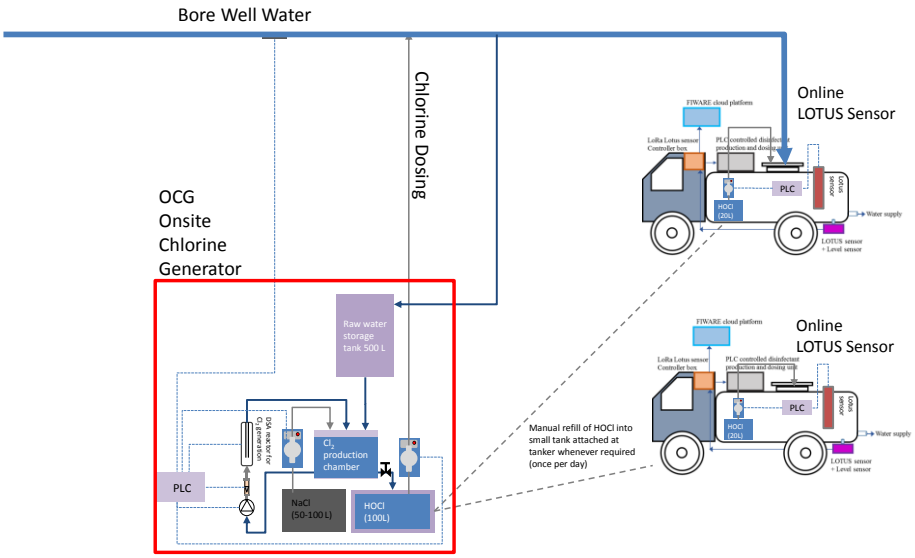

Figure 3 Scheme for tanker-based water quality assurance

4.4 Information about participants

Bengaluru has a population that is multi-ethnic, multi-religious, and of cosmopolitan character. Kannada is the official language of Bengaluru spoken by 46%, Tamil spoken by 14%, Telugu spoken by 14%, Urdu spoken by 12%, Hindi spoken by 5%. However, English is also widely spoken. Many communities have to use water-tankers in the summer dry months and there are also some communities that solely rely on water tankers. People from all low-socio economic backgrounds use water tankers in summer. In winter, more people can tap directly from groundwater sources, suing private pumps of borewells.

There have been news reports over the water quality issues. People from higher socio-economic background retreat the water but people may not have the ability to find other ways to access clean water. Even if they knew the water was contaminated, they would be in a limited position to gain access to clean water (i.e they do not have the finances to purchase bottled water).

In Bengaluru, participants to the workshops were the customers of JustPaani, a start-up that proposes an application to better follow-up the water delivery system. They invited their most important customers, i.e. people directing companies, who recharge their buildings using tankers. Majority of the participants are people from banking, educational institutions, Hotels, software companies etc and use Water tankers on a regular basis, especially in summer. Some of the institutions use tanker water 365 days in a year.

4.5 Questions for the workshop

Introducing LOTUS

Basic information

- *LOTUS is a project co-funded by the EC and DST. It aims at developing low-cost solutions to improve water quality in India. LOTUS aims at developing a solution which monitors precisely the quality of water and offers real-time information which is used to improve the management and control of water systems. Specifically for Bengaluru case,* LOTUS aims at a solution that provides water of guaranteed quality.
- *LOTUS is developed by a consortium of European and Indian partners:*
  - *Introduction of the local facilitator*
  - *Introduction of the European partners that are present (no need to go over the 21 partners)*
- *LOTUS is developed in Europe and India in partnership. Your city has been chosen for testing the solution.*
- *LOTUS is a four-year project which started in 2019 and will continue until 2023. We are one year in the project. At this stage, the solution is still being conceived. This workshop will support their conception. The solution will be deployed in mid 2020 on the field for trial.*
- *Autarcon is a German SME. They will couple the LOTUS solution with an onsite chlorine generation system installed at a filling a station and a chlorine dosing system, installed directly within the trucks to ensure that the water distributed is free of contamination.*

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1. **Current practices on water quality**

Drinking water:

- Where do you normally access your drinking water?
- What are current water supply issues (source wise) in the city? Please specify if there are seasonal issue in supply of water, if yes, specify the nature of issue?
- How do residents deal with problems related to water supply?
- How often do you use water tankers?
- Do the people use tanker water for the drinking or cooking purpose?
- How do you know from where the tankers have sourced the water? Is it important for you to know this?
- How easy/difficult to access tanker water in your area?
- How much is the cost of water that tanker water supplier charges from you? Does the tanker water supplier give any guarantee (information) regarding quality of water?
- Does the rate of tanker water changes according to the demand or season?
- Do you have any concerns that the water may not be safe?
- If you know it is not safe, do you have a way to treat it? (*Note: of course boiling is always a way to kill bacteria! Other ways?)*

Other sources of water:

- What are your other water sources? Does your water source vary depending on usage?
- What do you know about the quality of your tap water?
- Would having water quality information be helpful? How would it change the way you use water in everyday life?

2. **What are your water quality needs and wishes (understand needs about the LOTUS solution, system functionality)**

- What would make you trust the water quality?
    - What do you know about the quality of your drinking water? What do you know about contamination risks?
    - If you were told it had a high water quality, would you drink it? Treated or untreated?
    - Would you trust data given by the water provider or do you need to see the information yourself? (*Note: To see the information does not mean that you can control that it is correct)*
- Which information is useful?
    - What information would be helpful to you? About which parameters? Would you want to know detailed information or do you just want to know that the water is safe to drink? (quantified information vs. good)? *(Note: may be distinguished: safe to consume or safe to drink without treatment).*
- How often do you need to check water quality information?

3. **How do you want to interact with the solution (user interaction)**

- How would you like to receive the information?
    - Do you need a display of information? Where can the display be located?

- Do you want information displayed through an app that can be accessed from your mobile or computer? Or would a screen by the tap? Non-digital information?

- How does this information affect you?
  - If the solution indicates that the water is of low quality, what will you do? Do you have an alternative water supply?

4. **How do you want to benefit from the solution (i.e clean water from the tanker)? (Business model)**

- What is the current price of water?
  - How much do you pay for water per month (all water / drinking water)?
  - How much do you spend currently on monitoring the water quality?
  - Would you be ready to pay more for higher quality water from the tankers? How much more?
  - Should there be differentiated tankers: one for drinkable water and one that refills the house tank for other purpose (cleaning, gardening...)?

5. **Discussing the cost of clean water (Business model) in plenary (Note:** There are two types of questions, on the quality of the water, what one would pay for higher quality and reliability, and on the potential of the sensor for home usage).

- If LOTUS would provide a portable sensor you could use at home, what price would you be ready to pay for a portable sensor? Would you prefer to rent or buy it?
- Would you be ready to spend money on sensor? Would this increase the amount of money you are currently spending on monitoring water quality?

4.6 Results of the workshop

The workshop took place at the Radisson Blu hotel of Bengaluru on December 7, 2019.

"In summer, there is a lake that sets on fire under the combination of heat and high levels of pollution" (quote from a participant)

Figure 4 Bengaluru workshop participants

Figure 5 Workshop in action in in Bengaluru

4.6.1 System functionality

4.6.1.1 Current situation about water quality

In Bengaluru, **the issue of water quality is entangled with the issue of water quantity**. Water is scarce and most water in households comes from water tankers. Bengaluru undergoes water shortages because the demand exceeds the available resources. This is particularly true in summer. Demand for water tanker explodes as individual groundwater sources usually dry up. As a participant explained "Digging wells have become a gamble game".

As a result, people dig deeper and deeper to find water. In many cases, people do not find water.

Tankers are supposed to refill from groundwater, considered as clean. In practice, they also refill from surface water when groundwater is too scarce or mix the two sources of water within the same tank. In Bengaluru, surface water is more contaminated than groundwater.

Tanker water is used mainly for non-drinking purposes. For drinkable water, people who can afford it choose bottled water. Also, tanker water is re-treated before to be used or drinking and cooking. People use reverse osmosis (RO) to clean the water or UV. RO is a costly process that requires a lot of

energy. Only 30% of the water that is treated remains. RO has limits: if the water comes from a source that is too highly polluted, it is not enough to make the water pure and safe

4.6.1.2 Current provider of information about water quality

Water tankers are not organised by the government in Bengaluru. It is led by entrepreneurs who refill and resell the water to customers.

Figure 6 Florian Benz (Autarcon) in front of a JustPaani truck

Figure 7 The LOTUS team in front of the refilling station

Therefore, it is for now impossible to track the water source and guarantee its quality. The government also has a tanker system but does not provide information about the water source either.

Tanker drivers are obliged by Law to run tests on the water they sell. Tests are run once per month. Users do not believe these tests and usually run independent tests.

4.6.1.3 Desired system functionality

People are interested in whether the water is safe or not. If they were told the water is contaminated, they would accept the tanker but use the water for a different purpose, gardening instead of cooking for instance.

Here are the wished parameters from the users expressed during the Bengaluru workshop:

- Total dissolved solids (TDS)
- Color
- pH
- Nitrates
- Chlorides
- Heavy metals (Lead, mercury…)
- Hardness
- Turbidity
- Bacterial contamination (E-Coli)

Water does not need to be drinkable as most tanker water is used for purpose other than drinking. Knowing about potential bacterial contamination is important.

Users have would like to receive three types of information:

- Information about the quality of the water
- Information about the quantity delivered by the tankers
- Information about the time of filling and the source

4.6.2 User interaction

4.6.2.1 Available data on water quality

As explained above, there is little or no information about water quality. Participants in the Bengaluru workshop pledged for more advanced research in Bengaluru to know about the water quality (database, mapping of the ground water sources and the evolution of contaminations).

Tanker companies are indeed required by Law to run tests once per month, but the test results are not trusted. Bengaluru participants, who are important water customers buying a lot of water from tankers to fill schools, hotels…) usually run their own test afterwards.

4.6.2.2 Trust

Trust is at heart of the water quality issue. **Trust is low on tanker water system**. Also, it depends on the vendors rather than source. Therefore, a rating system is needed. Sometimes, even municipal tankers are sent back due to unacceptable water quality. The main parameters from the consumer side is colour and odour. Consumers are generally unknown about the source of water.

There is a need to build trust. If the water was certified by credible actors, users would trust the water quality. A certification from a corrupt free organisation such as the Bureau of Indian standards can be trusted. Private companies are usually trusted in India as well, because they have built trust with their customers over time.

4.6.2.3 Desired user interaction

Users are not so interested in a complex mobile application. Instead they would like to have **SMS notifications** indicating the amount, the quality and the source of the water received. If they are informed the water is of low quality, they can decide to use for a purpose that does not need clean water. Also, they can decide to change vendor if the water is repeatedly of low quality.

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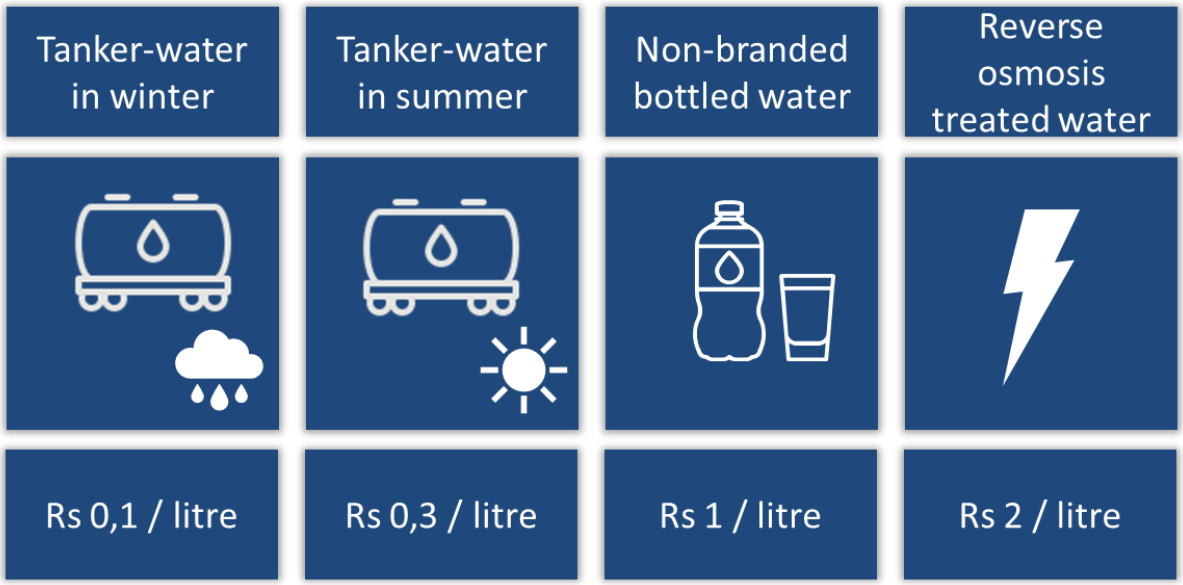
4.6.3 Business model

4.6.3.1 Current cost of water

The current price for tanker water of uncertain quality is Rs. 600 for 6000 litres (Rs. 0.1 per litre), in winter. In summer, prices rise, due to higher scarcity and higher demand. During summer, quality is a least concern, with quantity becoming more important. People buy tanker water at the inflated price of Rs 2000 per 6000 litres. The price of treated water is much higher: Rs 2 for R/O water and Rs 1 for non-branded bottled water.



4.6.3.2 Available budget to increase water quality

In Bengaluru, the issue of water quality is hindered by the urge to have water, notably in period of scarcity. Budget could be increased for water quality in winter when prices are low but not in summer, when households are not guaranteed to have water at all. In period of scarcity, middle class people rely on the municipal water supply. They buy tankers in group and use the water conservatively.

4.6.3.3 Information for the business model

In order to fix the price, customers need to know how often the tankers are cleaned. They must be drained and chlorinated daily and the inside must be made of stainless steel.

The increased cost must be compensated by the savings done on local treatments, such as UV or RO. Savings can also be done on the cost of re-testing the water (Rs 700 per test).

Bengaluru participants agreed on a 5% price increase for water.

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4.7 Synthesis for LOTUS sensor

System functionality	User interaction	Business model
Information about: • quality of the water • quantity delivered by the tankers • time of filling the source	SMS notifications on tankers delivery	Increased cost must be compensated by savings: • On the re-treatment of water • On the cost of testing

5 Jalgaon irrigation system management

5.1 Aim

The aim of the workshop is to introduce LOTUS solution to farmers and find out their interest in terms of sensor parameters, displaying the data and other needs related to the irrigation and fertigation machines, in order to create a tailored and well-accepted product.

5.2 Background

The State of Maharashtra is the second most cultivated state of India with 19.8 million hectare (mha) of land cultivated, accounting for 12% of India's crop area, according to the FAO. A total of 5.12 mha, representing 26% of the state's crop area is irrigated, using two different techniques: canal irrigation and groundwater irrigation. Before the 1960s, prior to the Green Revolution, farmers used surface water (creating tankas, zings, ahars and johads), instead of groundwater. Recent studies have suggested that these traditional approaches of community-based rainwater harvesting may have the capacity to reduce demands on groundwater and help prevent droughts in the future (Agarwal, 2000).

However, until these traditional approaches become more popular, groundwater is the most common type of irrigation, using wells, but due to high demand they are under stress. The groundwater level in India has declined by 61% between 2007 and 2017, with 89% of the extracted water being used for irrigation, according to the Central Ground Water Board (CGWB) Fifth Minor Irrigation Census. There are strong links between cash cropping, the failure of borewells and overwhelming debts in the semi-arid regions of the State of Maharashtra. Farmers are encouraged to use groundwater as the crops have twice the crop water productivity of those that rely on surface-water alone. This is largely because the resource allows farmers greater control over when to irrigate their fields and how much water to use each time (World Bank, 2012).

Farmers use the groundwater and mix with fertilizers to enhance the crops. Currently, Jain Irrigation offers farmers an automatic solution which enables them to inject the right amount of fertilizer in the irrigation water using just two parameters. The parameters are pH and electrical conductivity (EC). EC is used to monitor the salinity. Water that is too salty is not good for crops and hinders their development. Besides, fertilizers increase the salinity of the water. As a result, when the salinity of the water is high it is unnecessary, and counterproductive, to inject a lot of fertilizers. Monitoring electrical conductivity helps farmers to inject the adequate amount of fertilizers.

At the moment, the farmers use fertilizer induction machines. There are several variants of these machines. Farmers calibrate the machines themselves, by indicating the EC level and pH. Fertilizers

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proportion are given as an input and the machine can calculate the right amount of fertilizers. Along EC and pH, nitrogen, phosphorus, and potassium are useful parameters in fertigation.

In drip irrigation, there is a risk of clogging in the irrigation systems. This causes breakdown and additional cost.

5.3 LOTUS in irrigation

LOTUS sensors are planned to be integrated directly to the fertigation machine, enabling them to inject the perfect amount of fertilizers in real-time and to monitor the quality of the water and to prevent clogging. LOTUS sensors have multi parameters and would optimise the use of fertilizers in irrigation. LOTUS can help farmers monitor the amount of fertilizers which are put in the soil. Chlorine is a useful parameter as it is toxic to plants. Carbonates and bicarbonates can inform the farmers about clogging risks. Currently Jain Irrigation has a pool of 400-500-middle income farmers who uses these fertigation machines.

Moreover, LOTUS has the goal to optimise the use of water from different sources where surface water is used for irrigation.

5.4 Information about participants

In Maharashtra, the official language is Marathi although different regions have their own dialects. English is applicable in urban areas. About 65% of the population works in agriculture. Most farmers are small-scale farmers producing mangoes, grapes, bananas, oranges, wheat, rice, sorghum, bajra (pearl millet) and beans, for their own needs and selling the surplus on markets. Middle and large-scale farmers produce peanuts, cotton, sugar cane, turmeric and tobacco, and also grapes and fruits.

The farmers that were present at the workshop are medium to large and successful farmers that specialise on certain crops: Banana, cotton, sugarcane, turmeric, grapes, onions. Their land is between 15-100 acres. Farmers have different situations regarding the sources of water. Many farmers use groundwater, some have several wells (up to 20). Some use river water or water from ponds where it is collected from the Monsoon rains.

5.5 Questions for the workshop

Introducing LOTUS

Basic information

- *LOTUS is a project co-funded by the EC and DST. It aims at developing low-cost solutions to improve water quality in India. LOTUS aims at developing a low-cost sensor which monitors precisely the quality of water and offers real-time information that is used to improve the management and control of water systems, among others irrigation systems.*
- *LOTUS is developed by a consortium of European and Indian partners:*
    - *Introduction of the local facilitator*

- *Introduction of the European partners that are present (no need to go over the 21 partners)*

- *LOTUS is developed in Europe and India in partnership. Your city has been chosen for testing the solution.*
- *LOTUS is a four-year project which started in 2019 and will continue until 2023. We are one year in the project. At this stage, the solution is still being conceived. This workshop will support their conception. The solution will be deployed in 2021 on the field for trial.*

1. Current practices on water quality

- Which information from the Jain fertilizing machines do you use in your daily work?
- Do you collect other information on the quality of the water? From which sources or devices? How often do you do this? (Note: the two questions are the other way to ask, how farmers do you normally monitor EC and pH, nitrogen, phosphorus, and potassium levels).
- Are you satisfied with the information about the water quality that you obtain? What should be improved?
- Do you have problems with clogging of the irrigation system?

2. What are your water quality needs and wishes (understand needs about the LOTUS solution, system functionality)

- What would make you trust the solution installed in the fertigation machine?
  - Would you trust data analysed by the machine or do you need to see the information yourself? (*Note: when the information is only provided via the fertilization machine, people have to trust it anyway. The question is about whether people would like to have a display on the machine).*
- Which information is useful for you?
  - What information would be helpful to you? (for example fluoride)
  - Do you want to see several parameters of the water
- How often do you want to check water quality information?
- Is avoidance of clogging an issue for you?

3. How do you want to interact with the solution (user interaction)

- How would you like to receive the information?
  - Do you need a display of information? Where can the display be located?
  - Do you want information displayed through an app that can be accessed from your mobile or computer?
  - Would you be interested in an advisory system for fertilizer content and water parameters for best fertilization levels?
  - Do you use water from different sources besides groundwater? Is the management of the flows from these sources of interest to you?
  - Are there other improvements of the irrigation system and its management that you are interested in?
  - How could the solution information be used otherwise?

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4. **How do you want to acquire the solution? (Business model)**

- What is the current price of a fertigation machine? (Note: to be asked from Jain).
- Would a fertigation machine enable you to do savings? (Note: farmers are all using them already; the question is rather about estimation of saving)
- How much more would you be ready to pay to increase savings on fertilizers for better control of fertigation and information on the water quality?

5. **Discussing the cost of clean water (Business model) in plenary**

- Would you be ready to pay more for higher quality water?
- What price would you be ready to pay for a portable sensor?
- Would you be ready to spend money on sensor? Would this increase the amount of money you are currently spending on monitoring water quality?

5.6Results of the workshop

The workshop took place in Jalgaon on December 3rd, 2019.

Figure 8 Participants of the Jalgaon workshop

Figure 9 Opening ceremony

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Figure 10 Workshop Setting

Figure 11 Moderation of the workshop by Prof. Sebastian Engell (TUDO)

5.6.1 System functionality

5.6.1.1 Background information

Crops cultivated by the workshop's participants require continuous irrigation outside the rainy season. Irrigation is combined with fertigation. All farmers use drip irrigation which is fostered by Jain Irrigation. The needs for fertilizers vary much with the plants and with their age. The farmers follow guidelines provided by Jain Irrigation to adjust the amount of fertilizer depending on the water quality. Fertilizer is added in liquid form to the irrigation water by pumps or suction. Most farmers use simple irrigation machines were all the settings are manually. In that regard, LOTUS presents an opportunity to upgrade their fertigation machine for more automation.

5.6.1.2 Current situation about water quality

Water quality is critical for the process: fertilizers are adjusted to the quality of water to maximise their efficiency.

Regarding water quality (water intake), there are three concerns:

- Depending on the water properties, clogging of the irrigation system is promoted (carbonates/ bi-carbonates, EC value, solids);
- Depending on the water properties, the efficiency of the fertilizer changes, especially dependent on pH;
- When surface water is taken in, there may be unwanted substances, e.g. pesticides from neighbouring farms.

Water quality-related problems increase in summer: When the water table is low and there are many carbonates and physical impurities increase. This leads to clogging the pipes. 30% farmers do quarterly flush to prevent clogging, 70% farmers do nothing, and changes pipes every 3 years For larger farms, monitoring of the pipes and dripper systems is labour-intensive and not done often. Some sectors may be under-irrigated for some time.

5.6.1.3 Current provider of information about water quality

Bore well water quality varies with season, even during the day in summers. Farmers check water quality, but often only once a year, and not for all sources.

5.6.1.4 Desired system functionality

Participants of the workshop expressed their wished parameters and prioritised them:

- **"Must have" parameters**: pH, EC
- **Highly desirable:** Sodium (Na)
- **Highly desirable:** Flow rate – but this does not have to be provided by the LOTUS sensor – it should be possible to connect additional sensors to the LOTUS box
- **Desirable**: Bi-carbonates, temperature, pressure (but value was discussed controversially), pesticides
- **Also asked for:** NPK, micronutrients. However, this is not needed when the total amount of fertilizer used is known, which is the case.

"Just measuring and having data is not useful" (quote from a participant)

It is critical for the farmers that **the sensor is located between the filter and the fertigation**. It will be used for an advisory system. There was a broad range of opinion regarding the **frequency of monitoring**: Data at high temporal resolution (1h) should be stored and provided for analysis.

5.6.2 User interaction

5.6.2.1 Available data on water quality

The amount of water that actually reaches the fields is not known. Irrigation is run for certain periods of time, but due to voltage variations and fouling, the amount varies. The amount of fertilizer that is fed is known because it is fed from a tank with a mixture of known volume and composition.

The farmers are interested in more precise guidelines on how much fertilizer to use when. It can lead to significant cost savings. The amount of sodium (Na) that goes to the fields is a strong concern as it may damage the soil. It is not known how the fertilizer interacts with the different soils. pH of the soil can vary a lot.

5.6.2.2 Trust

Trust was not an issue: participants have long-standing customer-relations with Jain Irrigation and trust their services.

5.6.2.3 Desired user interaction

Creating an advisory system for fertigation

The farmers expressed a strong wish of an **advisory system for fertigation**, that takes into account weather data, crop, soil properties.

Based on information, the advisory system computes the optimum amount of water and the amount and composition of fertilizer for a specific crop, soil (one out of a set of discrete classes, past weather, weather forecast, growth stage of the crop).

This also influences the need for cleaning, as some fertilizers **reduce the risk of clogging**. This should be independent of the use of **highly automated fertigation systems** because few farmers use them. There is a need to include data from soil moisture sensors in the longer term. In the long term, data could be correlated with satellite data.

Data display

There is a need to plan for two displays:

- One mobile display (on the phone / app);
- One display on the irrigation system, in local language.

Jain would like to provide only display via mobile phone. If there are problems with the system or with the water intake, alerts should be sent (SMS).

Transfer, storage and data analysis

Data should be transferred to a system for storage and analysis (Jain cloud and/or PC). Annotation of the data should be possible to help with the analysis. The system should plan for combination with further data to enable notably machine learning.

Maintenance

It is crucial that the LOTUS solution requires low maintenance effort. Maintenance should only occur once a year.

Important considerations

There are power cuts in the region, which sometimes hinder the irrigation process. The sensor will be used in an environment with availability of power and mobile connectivity

5.6.3 Business model

During the workshop, participants expressed different opinions of the acceptable cost: ranging from one-time investment up to 50k INR (600 €) (if many parameters are there) down to 90 euros.

There should be a monthly service fee for decision support (if specific enough).

Savings on the fertilizers is expected to pay for the investment.

There should be options of only measurements, advisory system, and full automation

Some farmers asked for the option to install and remove the sensor in different places (“mobile sensor”).

5.7 Synthesis for LOTUS sensor

System functionality	User interaction	Business model
• Parameters: "Must have" Parameters: pH, EC Highly desirable: Sodium • Sensor located between the filter and the fertigation • High temporal resolution of monitoring 	• Creating an advisory system for fertigation • Two data diplays • SMS alerts • Low maintenance (<1/ year) 	• Diverging opinion on prices: price should vary depending on options • Increased cost must be compensated by savings • Desirability of a "mobile sensor" 

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6 Next steps after the workshop

Communication activities with final users will be pursued after the workshops until the end of the project, through the use case owners. Importantly, validation workshops will be organised at the end of the project, to check the satisfaction of the users and review, if needed, the sensors, before its industrial roll-out.

After the workshop, the findings were firstly shared within the team, during the individual workshop meetings on Thursday Dec 5th morning, and, briefly, at the plenary meeting (Dec 5-6).

The workshop results will be communicated to the use case providers and to the Work Package 6 team (Senthil Subbiah and Sebastian Engell), to take into account in the user requirements.

It is also expected that the findings will be useful for the WP1 socio-economic study done by TISS

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