

**Assisting stakeholders in data-scarce settings: citizen science as a tool to
assess intermittent water supply systems in developing countries**

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A thesis submitted for the degree of Doctor of Philosophy

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2021

Statement of originality

I hereby declare that this submission is my own work. Any contribution made to this thesis is explicitly acknowledged.

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Abstract

The lack of data on the operation and failures of urban water supply infrastructure in low-income countries prevents planners from fully understanding the water supply system, leading to an absence of evidence-based water management policies. It also prevents end-users from making informed decisions about their water use. The aim of the PhD was to assist stakeholders – at all levels – in making decisions regarding intermittent water systems, where there is a current absence of data.

The research investigated using citizen science as a tool and methodology to generate data in Kathmandu, Nepal, as a case study where water intermittency is widespread. The tool took the form of a bespoke smartphone application, developed by engaging closely with water consumers, which allowed households to communicate their location and patterns of water supply intermittency in real-time. A remote method for collecting and communicating water quality information was also included.

Because this research presents a novel approach to monitoring water supply in low-income settings, an important component of its contributions to knowledge lies in establishing the tool's feasibility and reproducibility. This was done using a mixed-methods approach, including validation of the methodology and the collected data by geographic cluster analysis, and by gathering qualitative feedback from key stakeholders. To ensure that the method would be applicable in environments with different water intermittency profiles,

demographics, and socio-economic conditions, an effort was made to engage with citizens and stakeholders across the city of Kathmandu.

The research found that the method is applicable across different users and can provide useful data and information to water utilities under a range of intermittency scenarios, leading to both improved water supply management and customer relations. An important impact arising from the research is that the Kathmandu water utility subsequently adopted the approach as part of its business strategy.

Acknowledgements

This thesis is dedicated to my father, who passed away before he could see this accomplishment.

My sincere gratitude goes to my supervisors, Professor Michael Templeton, for his unrelenting support, guidance and words of encouragement and Dr Christian Onof for his precious help with statistical methods and his unwavering confidence in me.

The work presented in this thesis is my own, with the exception of the coding of the smartphone application which was conducted by Imperial College London final-year undergraduate student Richard Glass, under my direction. Thank you for your efforts to make my vision come true. Thank you also to Imperial College London final-year undergraduate student Lewis Momen for his assistance with the fieldwork associated with the pilot phase of this research.

I wish to acknowledge Prof Sabitri Tripathi, for her help in securing the local contacts and meetings needed to carry out this research, as well as her insights on Nepalese culture. Her assistance in reaching the community people, and then in translating my words to them with such enthusiasm was invaluable. Students of the Nepal Engineering College also assisted with the citizen science volunteer training and on-site translation, for which I am grateful.

Thank you to Prof Stephane Bressan for giving me the opportunity to carry out a part of my research at the National University of Singapore which inspired the statistical work on Truth-Finding Algorithms and allowed me to collaborate with the brilliant Dr Olivia Jensen. Thanks to her for sharing her experience and providing helpful guidance during the stakeholder engagement.

My studentship was funded by UK Engineering and Physical Sciences Research Council (EPSRC) via the Centre of Doctoral Training in Sustainable Civil Engineering (grant reference EP/L0168261) and the research was supported by the EIT Climate-KIC program.

This research was approved by the Imperial College Science Engineering Technology Research Ethics Committee (SETREC reference 18IC4470).

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Glossary

ADB	Asian Development Bank
API	Application Programming Interface
AWS	Amazon Web Services
<i>E. coli</i> or EC	Escherichia coli
3G or 4G	3 rd Generation or 4 th Generation
GIS	Geographic Information System
IBNET	International Benchmarking Network
ICT	Information Communication Technology
ID	Identifier
iOS	iPhone Operating System
IP	Internet Protocol
IT	Information Technology
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
IWS	Intermittent Water Systems
JICA	Japan International Cooperation Agency
JVS	Global Water Partnership Nepal
KUKL	Kathmandu Upatyaka Khanepani Limited (water-management company, Nepal)
KVWSMB	Kathmandu Valley Water Supply Management Board
MLD	Million Litres per Day
MWSP	Melamchi Water Supply Project

NA	Not Available
NDF	Nordic Development Fund
NGO	Non-Governmental Organization
Norad	Norwegian Agency for Development Cooperation
OPEC	Organization of the Petroleum Exporting Countries
Sida	Swedish International Development Cooperation Agency
U.I	User Interface
UK	United Kingdom
VDWVSC	Valley Drinking Water Victim's Struggle Committee
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

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1. Introduction and Literature Review

This literature review was designed through mind-mapping: keywords were chosen as starting points, and associations were mapped. Finally, connections were made between the associations, to create the storyline. The key words were citizen-science, water, supply, intermittency, and monitor. In the second instance, Google Scholar was used to search for relevant literature using the mapped words and phrases. The search began in September 2016 and ended in June 2021.

1.1 Intermittent Water Systems

Intermittent Water Systems (IWS) are piped water distribution networks that do not deliver water to customers continuously 24 hours per day. They are mostly supply-side driven, as a part of a reactive strategy to ration insufficient water resources (Vairavamoorthy, 2021). This means that the operator is in charge of deciding when, where and how much water is delivered by the system. A predictable IWS provides water per a rotational schedule and adopts the ‘some for all and not all for some’ approach to water distribution. The implication is that water supply is intentionally rationed with a well-established schedule, so that customers are able to access water on specified hours per day and plan accordingly (Lutaaya & Echelai, 2021). On the other hand, in an unreliable and/or irregular IWS there is no adherence to a schedule – even if a schedule may exist, it remains an approximation and water is often late, skipped without warning and does not last as long as planned (IWA Specialist Group on Intermittent Water Supply, 2020). In an irregular IWS, water is delivered at unknown intervals but consumers can rely on receiving a minimum water quantity in a unit time frame. This means that with the help of tanks and careful planning, customers can

simulate a continuous water supply for themselves (Galaiti et al., 2016). In an unreliable IWS, customers cannot be sure to receive water by a unit time frame and need to purchase additional sources of water to sustain themselves over long periods of non-delivery (Galaiti et al., 2016). Unfortunately, almost all IWS systems are unreliable (Mohan V & Abhijith GR, 2021). Within a city, households may experience different hours of supply due to network hydraulics, elevation, water demand, valve operations, and distance from the water treatment plant (de Marchis et al., 2011; Kumpel & Nelson, 2016; Totsuka et al., 2004). To make matters worse, the distribution is not only unreliable but inequitable, meaning that some people get more water than others (de Marchis et al., 2011).

To deal with untimely and insufficient water supply, consumers will spend time monitoring water availability and managing the collection process. In practice, this means that people will wait expectantly for the water to be supplied and store as much water as they can during supply hours, to overcome the unreliability of the network. Typically, consumers will not be satisfied to simply store what water they get – they develop strategies to acquire as much water as possible from the system, not realising that this will be to the detriment of others. Characteristically, this involves purchasing expensive pumps to draw more water from the network and investing in building water tanks to store it in (Lee & Schwab, 2005). As a result, customers collect more water than they would use with a continuously available supply (Ingeduld et al., 2008; Mohapatra et al., 2014). Clearly, this just-in-case versus just-on-time approach to consumption exacerbates the problem of water scarcity in the network, as well as the problem of inequity of supply (Totsuka et al., 2004). In the background, consumers who do not have the means to purchase these strategies are known to resort to installing illegal connections to the network, reducing the water provider's system knowledge and stretching the system way beyond its capacity.

Unfortunately, customers of an IWS also have to deal with inadequate water quality. All water supplied from intermittent networks is assumed to be contaminated because of the periodic intrusion of microbial contaminants (Charalambous & Laspidou, 2017; Mohan V & Abhijith GR, 2021; Mokssit et al., 2018). Regrettably, even if the water input into an intermittent system is potable, the water quality will degrade during distribution due to the compromised hydraulic integrity of the system. The repetitive pressure variations due to intermittent operation weakens the infrastructure, leading to cracking and even bursts. When the system is pressurised (i.e. in operation) this results in leaking, but when the system is turned off, the pressure drop can create the reverse effect: an ingress of contaminated groundwater or surface water through the cracks in the pipe walls or joints (Sakomoto et al., 2020). This absence of pressure also presents the opportunity for backflow from stagnant private storage to introduce contaminated water into the system (Lee & Schwab, 2005). In parallel, water-borne pathogens and bio-films may proliferate in stagnant pipe-water when the system is not flowing (Charalambous & Laspidou, 2017; Kumpel & Nelson, 2014; Lee & Schwab, 2005).

This makes centralized disinfection difficult and ineffective, as chlorination levels needed to counteract contamination are harder to maintain due to the short duration of supply (Ercumen et al., 2015; Sakomoto et al., 2020; Ashbolt et al., 2014). The go-to remedial measure adopted is to add more chlorine, however, over-chlorination is also undesirable, leading to carcinogenic disinfection by-products as well as undesirable taste and odour (Mohan V & Abhijith GR, 2021). Ultimately, the contaminated water is flushed down the next time that water flows through the pipes and consumed at the tap.

IWS has been linked to diarrhoeal diseases, including amoebiasis, typhoid, and cholera, as well as infectious hepatitis, all amounting to a staggering 17 million cases of infections per year (Bivins et al., 2017). To avoid contracting water-borne diseases, customers must take measures to either disinfect the water at point of use or purchase water from private water vendors (World Health Organization, 2011). The most accessible and effective home water treatment is decontamination by boiling, a method adopted by 1.1 billion people (Rosa & Clasen, 2010). However, the coping cost incurred when boiling the water (e.g. buying fuel) may not be worth the price, as water that is boiled is immediately vulnerable to recontamination in the absence of safe storage, especially in hygiene-challenged environments. Moreover, with this strategy, households may be forced to store water in open containers, leading to increased risks of vector-borne diseases such as dengue fever as well as further water quality degradation (Sakomoto et al., 2020; Wright et al., 2004).

Costs spent on mechanisms for dealing with untimely, inadequate and insufficient water supply incurs what the literature refers to as ‘coping costs’ and are borne by the consumer (Totsuka et al., 2004). Examples of this include the energy cost for boiling the water, installing storage tanks, rainwater collection tanks, pumps (e.g. suction pumps to draw more water from the network or lift it up to storage tanks), or water filters. In higher income population groups, people have the option to buy water from private water vendors to refill their storage tanks or deliver barrels of spring water for drinking, but often this water is of questionable quality and costs much more than municipal water (Remigio et al., 2019). These types of ‘coping costs’ borne by the consumer have been estimated to reach as much as 7.6% of reported income - on top of the cost of water utility bills (Vásquez et al., 2009). This reveals a profound personal concern for safe and reliable drinking water, externalised as a willingness

to pay for it (Dauda et al., 2015). Perhaps the most significant coping cost which is not as easily measured is the welfare cost. For example, the price paid for falling sick due to consumption of unsafe water, in terms quality of life, paying for medication, or days off work. There is also the time cost of queuing and transporting water, for those who have to travel to obtain alternative sources from e.g. public standpipes. Incidentally, those doing the travelling are usually women and children, which links intermittency to gender imbalances in society (Abraham et al., 2021).

IWS are often a result of a water utility not having sufficient water resources or the necessary functioning supply infrastructure to continuously supply water to the entire population that depends on it. An absolute scarcity of water is just one of three main causes of intermittency, despite often being the only form that is cited by governments and water utility companies. An insufficient water supply can be classified as issuing from a scarcity of water, poor management, and techno-economic scarcity (or a combination of the three) (Lutaaya & Echelai, 2021; Totsuka et al., 2004). These issues are often exacerbated by unplanned and rapid urbanisation, as well as other constraints, such as irregular electricity supplies and deteriorating infrastructure – which in turn affects water scarcity and ease of management, and so on and so forth (Lutaaya & Echelai, 2021; Vairavamoorthy, 2021).

The management of the water supply is usually the joint responsibility of the local government and the water utility. In low-income countries, poor financial accountability among local governance is a huge problem, leading to a lack of trust between the consumer on one side, and the supplier and government on the other side (Galaiti et al., 2016; Majuru

et al., 2016). As a result, poor management of the water supply is generally perceived as a self-induced factor (Mohan V & Abhijith GR, 2021).

Techno-economic scarcity, also referred to as “system capacity constraints” in the literature, is when in principle there is a sufficient water supply volume to satisfy demand, but the hydraulic capacity of the water distribution system is inadequate due to leakage and water wastage (Klingel, 2012; Mohan V & Abhijith GR, 2021). Thus, there is a reduction in the available amount of water below the required demand from the consumer. Due to the local government and water utilities having inadequate financial capability, this is unable to be rectified and so there is a scarcity of water (Totsuka et al., 2004). Water intermittency therefore also occurs due to the combination of technical system inadequacy and insufficient funds to fix these.

Whatever the root cause of intermittency, the direct hydraulic impacts of operating an IWS – including lower system pressures and an increased risk of leakage – inevitably in turn impact the quality and efficacy of the distribution infrastructure itself and increases its maintenance and rehabilitation requirements and expenses (Abraham et al., 2021; Galaitsi et al., 2016; Totsuka et al., 2004). These expenses can be visualized as the ‘coping costs’ of the utility.

Information available on intermittent water supplies shows that it is present all over the world in varying degrees of severity, with a prevalence in developing countries. An estimated 1 billion people live with water intermittency (Bivins et al., 2017; Vairavamoorthy, 2021).

However, there is a discrepancy in numbers reported in literature, in part due to the fact that there is no standard definition that establishes exactly what constitutes an intermittent water supply. Indeed, there is no standard method for reporting or measuring piped water

continuity or reliability (Majuru et al., 2018; WHO, 2017). For example Agathokleous & Christodoulou (2016) adopt the view that an IWS is a system where water is supplied for less than 24 hours, while Coelho et al. (2003) consider that a system is intermittent if water arrives at intervals (hours, days or weeks). As a result of this lack of standardization, it is difficult to compare studies, and by extension, to transfer knowledge from one IWS to another (Galaitis et al., 2016). This is despite there being a desire for the sharing of knowledge between utilities, as highlighted in the recent survey of intermittent water supply systems by the International Water Association (IWA) (Farmani et al., 2021).

Furthermore, since there is little guidance provided to utilities on how to calculate their hours of supply, it makes sense that these may not match the hours of supply that customers receive water. For example, reporting the hours that the utility run their pumps inputting to the distribution system or operate their valves does not equal the hours of water that would be delivered if there is not enough total water to begin with or it does not reach all households. Therefore, household-reported outages may better capture this variability than utility-supplied information on their provided hours of supply (Rawas et al., 2020).

Despite these clear gaps in knowledge and the large number of people affected, there has been limited attention paid to measurement tools or methodologies that capture the quality of service provided to customers (The International Benchmarking Network, 2021).

Water supply data across the board in developing countries is badly monitored, poorly logged in non-digital form, in the local language and typically does not take into account the consumption from homemade coping strategies used by consumers (Klingel, 2012). Moreover, utilities often face a lack of up-to-date, reliable GIS data on the water distribution

system (Abraham et al., 2021). The ultimate consequence of this is that water utilities have a poor knowledge of how a system behaves, as well as the condition (and even location) of system components (Galaiti et al., 2016). To be able to operate a water network both effectively and efficiently, detailed knowledge of the system and its components is required, including location of pipes, quantity and power of pumps, size and location of reservoirs, fluctuation and magnitude of demand etc (Kumpel & Nelson, 2016). Therefore, there must first be an emphasis on documenting and understanding the network, in order to operate the system appropriately, but also in the long run, allow for contingency planning, water safety planning, regular maintenance, and ultimately, scope for sustainable expansion (Lutaaya & Echelai, 2021).

At governmental level, this knowledge gap prevents planners from tailoring water management policies (de Marchis et al., 2015). At utility level, the regulatory agencies and water utilities managers are hindered from providing a more equitable supply (Ilaya-Ayza et al., 2017; Gottipati & Nanduri, 2014; Ameyaw et al., 2013). Without accurate data, it is difficult to estimate real economic losses or the monetary investment offset by consumers' willingness to pay, and by extension, the budget needed to improve the water supply (Vásquez et al., 2009). This lack of information also trickles down to customer level, where it impedes effective communication with customers, especially surrounding water supply schedules and any service interruptions (Lutaaya & Echelai, 2021). The utility feels that it has nothing of value to communicate, and so abstains from engaging with its stakeholders, but in fact this prevents it from gaining valuable feedback and fosters a feeling of uncertainty in the capability and commitment of the utility from the customer side.

That being said, it is easy to see how this legitimate lack of data could be used as an excuse to avoid committing to pragmatic interventions to address the IWS, but experiences show that effective implementation of interventions in intermittent water management and operations is possible, if driven by the full commitment from every person involved, from the highest level of the water utility corporation to every member of staff (Lutaaya & Echelai, 2021). It is important to point out that, despite IBNET adopting a negative view that the “likelihood of the data being collected by utility managers is limited in the short term” (The International Benchmarking Network, 2021), there have been some encouraging cases of such displays of commitment from the utility. For example in Uganda, Kampala Water has put in place an aggressive performance management system, including performance-based incentive contracts, to promote accountability and transparency. Thanks to this, it has managed to optimise its network to provide a solution for reaching more people with limited resources – and actively continues to work towards reaching its goal of 100% coverage (Lutaaya & Echelai, 2021).

In some cases, lack of monitoring knowledge even gives rise to opportunities for corruption. Intentional intermittency should only be a tool to ration a scarce resource – however, it can also be manipulated to ration or control technical, economic, and social development by tying certain groups of people to the water supply situation (IEG, 2012). Privilege is prioritised for personal gain, and water scarcity is imposed on the less privileged, exacerbating inequality (Totsuka et al., 2004). The fact that there is no rigorous data available on the water intermittency in terms of water quantity and location of service, makes it nearly impossible to expose this practice. The result is that both corruption and intermittency are often widely accepted as a part of life by those who are subject to it.

The WHO recognized this lack of data as inhibiting research and progress in the direction of remediating intermittent water supplies, and by association improving health (World Health Organization, 2003). Moreover, little data exists that shows the impact on water quality and health in intermittent supplies quantitatively, and there are also no clear guidelines on how a given intermittent system should be operated to safeguard quality at the customer side (Abraham et al., 2021; Sakomoto et al., 2020). As a result, the WHO requested more data on the number of failed water systems, exact parts of systems that have failed and specific reasons of the failures (World Health Organization, 2003). However, studies since then have found that in general, data on real supply hours, particular distribution problems, recurring variations in supply, and patterns of intermittency still remain unmapped (Danilenko et al., 2014; Lee & Schwab, 2005; Totsuka et al., 2004). IBNET noted that “there has been limited attention paid to measures that capture the quality of service provided to customers [...] A more comprehensive set of quality of service indicators could be developed” (The International Benchmarking Network, 2021).

Recently, smart solutions in water systems in developed cities have leveraged advances in water sensors and IT solutions paired with cloud analytics to monitor systems in real time. Moving towards these smart water systems has proven to be beneficial for both utilities and customers (Abraham et al., 2021). However, while sensing and digital technologies can be helpful, their potential can only be realised through improved governance and utility management, and by building a skilled and committed workforce (Simukonda et al., 2018). Moreover, causes and problems of water supply intermittency and their management options are generally discussed by the utility without the input of the most relevant stakeholders: the citizens themselves. This seems counter-effective, as they are the ones facing the problems

of the IWS, and could in fact provide valuable insights not obtainable otherwise (Simukonda et al., 2018).

1.2 Citizen science

Gordienko (2013) defines citizen science as referring to “the general public engagement in scientific activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources”. In other words, citizens and scientists collaborate to co-generate knowledge, benefitting everyone involved. Citizen science differentiates itself from other forms of public participation in scientific research through ‘active’ engagement (Wiggins & Crowston, 2011a). In the last decade, participation involvement has opened up beyond data collection to research design, data analysis and interpretation, and so participation is now classified into different categories based on the level of engagement, the type of project (e.g. conservation versus exploratory) and the topic being studied (e.g. astronomy) (Wiggins & Crowston, 2011b). In practice, citizen science is often a means of using curious citizens to classify information, recognise patterns, solve problems and draw out-of-the-box conclusions (Wiggins & Crowston, 2011). For example, Zooniverse – cited as “the world’s largest and most popular platform for people-powered research” has over 600 million classifications powered by 1.6 million registered citizens (Zooniverse, 2021). Zooniverse takes information collected by researchers and asks citizens to assist in classifying and analysing it.

Other terms used instead of citizen science include civic science, participatory science and community science. The terminology surrounding citizen science remains open since it first appeared more than two decades ago, indicating that citizen science is still an evolving

practice. However in 2018 the European Commission listed it as one of eight priorities of its open science initiative (European Commission, 2018). According to (Bautista-Puig et al., 2019) citizen science creates a new scientific culture to cater to the decision making at the cross-roads of science, society, and policy. However, the use of citizen science relies heavily on the acceptance of this *modus operandi* by the scientific community and policy makers. Analysis of peer reviewed papers on citizen science shows that there has been a significant rise in the amount of formal research on the methodology underpinning citizen science and validation techniques since 2003, while studies on the motivations of citizens are more recent still (Follett & Strezov, 2015).

These trends lead the author to believe that citizen science is gaining traction and is fast becoming recognised for its ability to gather data across massive geographical areas and time frames, which would otherwise not be financially, spatially or temporally feasible to collect (Cohn, 2008; Elijah et al., 2017a; Gura, 2013). Although questions around data accuracy remain, a growing number of publications argue that the cost-effectiveness of citizen science data outweighs data quality issues (Theobald et al., 2015, Gardiner et al., 2012).

Moreover, citizen generated data and interpretation has proven to be as reliable and accurate as professionally gathered data, even in water resource applications (Albus et al., 2020; Baalbaki et al., 2019; Brouwer et al., 2018; Peckenham et al., 2012), with one study finding that comparing citizen data to professional data yielded an agreement of 91% in some cases (Albus 2020). It is documented that successful projects rely on multiple means to enhance data accuracy, including iterative project development, volunteer training and testing, replication across volunteers and more, depending on the project application (Kosmala et al., 2016). This research sought to incorporate as many of these mechanisms as possible into the

methodology, to ensure a successful outcome. However, since the author could find no one-size-fits-all mechanism for validating data, a custom validation technique was developed specifically for validating data points in the context of sparse data sets.

Studies express that it is the researcher's role to ensure that the research questions are appropriate to the skill-level of the participants, and that there is a clear protocol in place for location, collection and method of data collection (Bonney et al., 2009; Cohn, 2008). Moreover, to ensure that the integrity of the research is not questioned, scientists must ensure that citizens understand that the data must be reliable if it is to be used in decision-making process (Buytaert et al., 2014). Both of these points were actively incorporated into this research.

Citizen science has been extensively used in developed countries in the field of biology, especially ecology and environmental science, to monitor natural bodies of water (Follett & Strezov, 2015; Kullenberg & Kasperowski, 2016). This typically focuses on qualitative assessments, measures a limited amount of water quality parameters, or the data generated is restricted to monitoring and rarely results in the implementation of active remedial strategies. A survey launched across European science networks in 2020 found that 62.7% of respondents participated in a citizen science project grounded in the natural sciences compared to 6.2% for engineering projects, and that only 25.4% of respondents associated their citizen science projects with enabling concrete actions (Moczek et al., 2021).

The application of citizen science to water engineering issues has so far been limited to taking, reading and reporting tap water quality samples, and that mostly in the developed world

(Brouwer et al., 2018). The Dutch authorities are also considering citizen science as a possible means to bridge a gap in water awareness in the general public (Minkman et al., 2017).

However, the introduction of low-cost, low-maintenance and robust sensing technology in the last few years has created opportunities for application in monitoring and understanding water resource management in the developing world as well (Abraham et al., 2021; Buytaert et al., 2014). The Internet and smartphones has also enhanced world-wide connectivity, giving rise to further opportunities for citizen science applications in the developing world. As of 2021, 4.66 billion people have access to the Internet (a 7% growth on the previous year) with 5.22 billion active mobile phone users (7 out of 10 of them using Android smart phones) and 4.48 billion using social media (Kemp, 2021). As of 2020, the percentage of population in developing countries with access to 3G or 4G coverage reached 92.2% (International Telecommunication Union, 2020). In contrast, only 37% of the population in the least developed countries have access to improved water supplies (WHO/UNICEF Joint Monitoring Programme for Water Supply, 2021). Currently in this part of the world, citizens are at most recruited and trained as emulators, to temporarily collect water samples in boreholes or shallow wells (Baalbaki et al., 2019; Elijah et al., 2017b). Typically, the number of citizens recruited is relatively low, ranging from 8 to 46 in these particular studies.

The application of citizen science to monitor water supply intermittency has never previously been examined (to the best of the author's knowledge). This may be because in the developing world there are often no reliable sources of utility-generated data to compare to, or a perceived lack of will to use it. Sceptics may refrain from using citizen science data, claiming that it is not possible to validate it, against official sources – but it is exactly in these

regions where there is no official data that citizen science can be argued to be the most useful, since it fills a data gap need.

Critically, in an IWS it is likely that citizen reported data at household level would better capture the variability of supply than a utility could otherwise, since the water flow is subject to so many factors between the source and the tap in an IWS (Rawas et al., 2020). So far, methods to understand water intermittency have been to collect data either through the local water board or by conducting household surveys and one-time on-site water tests (Agathokleous & Christodoulou, 2016; Guragai et al., 2017). Arguably, surveys can reach a large sample size and can cover large areas – with a limit, linked to the available staffing and finances. Hence, a typical household survey will only be done a maximum of once a year, whereas citizens would have the potential to collect data on an hourly, daily basis or weekly basis depending on the frequency of supply, and multiple times a year if needed. This would collect far greater quantities of data than could be achieved otherwise and could be used to compare against other sources of information where available.

Importantly, citizens can also flag aspects of the intermittency that would otherwise be overlooked, voice their demand satisfaction levels, and share insights that they have gathered from personal experience or culture which would otherwise remain unknown (Buytaert et al., 2014). Combining citizen-collected information with formal scientific data results in a more relevant understanding of the issue being studied, and using demand satisfaction as a framework for understanding and managing IWS has already been demonstrated (Taylor et al., 2019). Ultimately, this would lead to a more accurate representation of the intermittency, helping to make better-informed decisions in policy, management and financial planning (Kumpel et al., 2012; Kumpel & Nelson, 2016).

In fact, multiple international agreements, including the Aarhus Convention on Participatory Management for Environmental Matters (UNECE 1998), the Dublin Principles (1992), and the Bonn Recommendations for Action (Secretariat of the International Conference on Freshwater 2001), insist that policies pertaining to water issues be developed based on consultations with those affected (Morinville & Harris, 2014).

Moreover, using a bottom-up approach to decision-making serves as intrinsic motivation to citizens to participate, as it empowers them with a vehicle to express their needs and influence decisions. This sense of inclusion is particularly motivating for poorer communities, that often feel marginalised (Buytaert et al., 2014). As well as using citizen science to improve their own understanding, scientists may seize this opportunity to educate citizens in their field, for example to improve their health (Macknick & Enders, 2012). As a result, research that employs citizen-science can attract funding from governments of developed countries, who appreciate that research should have a positive and measurable societal impact (Gura, 2013).

In fact, motivation to participate is a major impediment to the widespread use of citizen science, especially in more long-term endeavours. Hence sources of motivation must be considered by scientists designing the research methodology, so as to maintain engagement (Rutten et al., 2017). Motivation may be due to intrinsic benefits, such as gaining a feeling of empowerment from participating, or extrinsic benefits, i.e. a reward (Buytaert et al., 2014; Cohn, 2008; Gura, 2013). Extrinsically motivated citizens need a personal reward to participate, which is a one-off reward system, whereas intrinsically motivated people feel rewarded all along from their participation. As a result, extrinsic motivation typically will not promote as effective engagement as intrinsic motivation (Buytaert et al., 2014). Hence, the

key to successful citizen-science recruitment lies in tapping into the intrinsic motivations of the citizens. Nonetheless, care should be taken to ensure that this does not lead to an exclusion of potential participants who are simply less confident in participating, despite potentially being the most affected by project outcomes (Buytaert et al., 2014).

Another impediment to the uptake of citizen science by decision-makers in the water sector may be linked to a fear that participants may use this as an opportunity to push their political agendas. This would undoubtedly throw into question the reliability of data, however, one must also see the other side of the coin: without data, users of a water supply cannot demonstrate scarcity, unreliability, contamination or other issues, limiting their ability to lobby local authorities for improvements (García & Brown, 2009).

Luckily, thanks to web-based services that allow for applications to connect in real-time to servers where data can be stored, scientists are now able to securely collect data with exact time and location stamps, which alleviates some of the concern (Williams et al., 2011). Moreover, data anomalies and errors can be flagged thanks to a built-in analytical screening process based on participant submissions, e.g. by using filters (Bonney et al., 2009). Furthermore, submitted data can be automatically assessed by the mobile application, e.g. by ranking it against other similar or nearby inputs, which would allow identification of users who are more or less reliable, and those participants who are considered more able or reliable might be given larger or more complex tasks (Gura, 2013). Web-based services also permit for a more interactive research design, for example by introducing automatic or personalised feedback to the user, to encourage continued participation and limit disengagement (Buytaert et al., 2014).

In summary, a combination of political, social, economic, natural and technical factors all contribute to the development and sustenance of water supply intermittency. Hence, any solution to the problems of an IWS must be interdisciplinary (Simukonda et al., 2018). For this reason, the research in this thesis is not purely engineering but rather multi-disciplinary. It naturally follows that an interdisciplinary team should be sought in order to design a solution to such a multi-faceted problem. The research lead recognized that her being versed only in engineering would be a limitation to the research, and sought out specialists from who could provide insights outside the Engineering domain - particularly in the social sciences.

Because the research is not *rooted* in social science but rather the methodology *makes use of* social science tools in the engineering context of urban water, seeking a broad social science expert to join the research team was deemed insufficient. Instead, a social scientist specialising in water and environmental policy with experience in urban Asia was sought out in the presence of Dr Jensen of the National University of Singapore's School of Public Policy. Dr Jensen's perspective added a component of resilience into the consideration of the research, while her skills helped to design effective communication and retention strategies with citizens and stakeholders alike.

Insights into the economic, geographic and demographics of Kathmandu were gained through regular consultation with Prof Tripathi of Nepal Engineering College. A Kathmandu resident, Prof Tripathi also provided a local's perspective on the IWS, on conducting research there as a foreigner, as well as on cultural sensitivities that would otherwise have remained unknown to the research lead and whose ignorance would have disserved the research. Ultimately, the information provided by Prof Tripathi served to decide on areas of particular interest, and where citizens would be particularly receptive to the research. For example, she revealed that

a specific community had previously suffered from parachuting science, and suggested that the research lead address this issue in the community meeting. Moreover, Prof Sabitri's language skills and social contacts came in helpful to secure local contacts, organize meetings and reach the ordinary citizen in words that they could understand and in terms that would resonate with their personal water woes.

The detailed social insights from Prof Tripathi combined with the socio-economic expertise of Dr Jensen meant that the research was able to maintain its objectives while tailoring the methodology framework to a very specific South East Asian urban water context.

The originality and success of the research lies in its ability to successfully collect reliable data in complicated environments. However, since the data set was sometimes sparse and the sample-size considered relatively small in statistical terms, guidance was sought from a statistician (Dr Onof) on the appropriate statistical methods to be used to evaluate the level of success of the methodology and the reliability of each data point it had yielded. His guidance led the research to opt for the use of conventional statistical methods for the former and for the creation of a custom approach for the latter, since the interest was on each data point and not on the whole data set.

The root of the intermittency problem lies in the fact that the water utility and ministerial managers do not possess the necessary data collection assets and resources to properly manage the water distribution system. The extent of the problems associated with IWS give the impression that any interventions to improve their performance are practically and economically infeasible (Mohan V & Abhijith GR, 2021). Hence, to address the need for knowledge and data on IWS in low-income settings, this research sought to implement and

test a practical, low-cost, citizen-science approach to collect data on intermittent water systems in low-income countries. Citizen science has proved to be a means of “tackling otherwise intractable, laborious or costly research problems” and it is therefore conceivable that it could be a source of reliable and useful data on intermittent water systems, if controlled for quality assurance and shown to be reliable (Gura, 2013).

While this research will not allow a utility to scale up to 24×7 supply, for reasons of cost or resource capacity constraints or even policy issues, it can be seen as an interim step to improve urban water supplies in low-income settings and the management of the existing IWS. Improvements may include improved identification and characterisation of the physical condition of the supply system in order to repair or replace broken system parts, more equitable distribution of water, educating households on the importance of ensuring their water is safe to drink (e.g. by disposing of first-flush water, storing water in clean containers etc), and disseminating accurate information on water supply schedules so that uncertainty in delivery is reduced, allowing households to receive a more reliable supply and have restored trust in the utility (Ray et al., 2018).

2. Research Aim and Objectives

The overall aim of the research was to determine the feasibility of citizen science as a viable solution to collecting reliable data in an IWS in a low-income setting for the first time, and thereby alleviating the problem of water supply data-scarcity. At the time that this research began, citizen science had mainly been applied to the natural world, such as astronomers asking people to record sightings of constellations of stars or planets. This research takes citizen science in a new direction by applying it to the built environment in developing countries, specifically to help monitor water supply delivery, to help decision-makers by providing them with the reliable data that they need to make better informed decisions about management and investment of water supply infrastructure, and to empower impacted citizens. Therefore, the research objectives are to determine, in the context of IWS in low-income settings:

- 1) If the method employed is feasible and effective in providing useful data, and
- 2) If the method and data is reliable enough to be used and accepted as valid by key water supply decision-makers.

To achieve these objectives, the research sought to answer questions across the social science and statistic fields, while maintaining its engineering context. The line of investigation:

- Assessed whether data sampling structures were appropriate, in terms of size and population configuration;

Stemming from this, it would then be possible to assess whether the data sampling allowed for robust data validation and to extract meaningful information from the dataset.

- Developed statistical mechanisms to assess and ensure the reliability of the data;

The novelty of the research lies in developing new means of processing the data at hand, to develop new data validation techniques adapted to the sometimes uncertain data sampling structure generated through citizen-science.

- Determined influencers of citizen participation;

Although the literature does provide material on the motives for citizen science participation, it does not do so in the context of water engineering. In this niche context, there is very little that the volunteers receive in return for their participation in the short term, and so novel motivators must be sought and potential influences understood to allow for future wide-spread deployment of the method.

- Evaluated utility managers' perceptions of using citizen science in resolving the IWS.

Based on these outcomes, the research's final objective was to put together a novel framework to conduct such experiments in the IWS setting in future.

The research was conducted in a severely resource-constrained urban environment, in Kathmandu, Nepal, though in a way that would be replicable as much as possible in developing countries with varying low-income and scarce-data profiles as much as possible. Nepal has 2.27% of the world's freshwater (Nepal Central Bureau of Statistics, 2019). However in the capital city Kathmandu there is a deficit of supply, with demand in service areas at 195 MLD and supply at a maximum of 150 MLD in the rainy season and only 90 MLD in the dry season, so that most households only receive water for an hour every 4th day (Kathmandu Upatyaka Khanepani Limited, 2019).

At the very least, the hypothesis was that this citizen science approach to collecting data would fill technical knowledge gaps around water supply intermittency patterns that were

previously unknown and hence would yield an operational benefit to the water utility. In the best case, it was hoped that the method could be used to empower households affected by intermittency, raise the political priority of reliable access to water, and activate water officials to attribute more resources to alleviating the problem of water intermittency in under-served areas.

This research thesis begins with a Research Methodology chapter which outlines how the citizen science approach for characterising intermittent water systems was developed, describes the tools that were created, and explains how both were analysed to ensure feasibility, reproducibility, and the production of statistically reliable and meaningful data. This is followed by the Results chapter, which presents and analyses the obtained citizen science data and information and summarises the most important findings of the research. The Discussion chapter then assimilates the key findings from the various quantitative and qualitative findings of this research and provides explanations (or in some cases plausible hypotheses) for these findings. The chapter also discusses the policy relevance of obtaining IWS data through citizen science from having presented the citizen science methodology and findings to local water utility managers, to determine if they would accept the data as useful in improving their understanding of the intermittency issues in their supply systems and devising evidence-based solutions. Lastly, the chapter formulates guidelines for best practice when using citizen science for this purpose and formulates a protocol defining strategic methods and highlighting key steps to follow in order to successfully execute a citizen science project in the IWS context of developing countries. The thesis concludes with a chapter of Conclusions which concisely summarises the key contributions to knowledge of this research

and the recommendations for further research. The appendices include the complete database collected from the citizen volunteers.

The research described in this thesis was presented at the 17th International Computing and Control for the Water Industry Conference at Exeter, United Kingdom in 2019, as well as at the Intermittent Water Supply: Current Research and Future Collaborations workshop hosted in Sheffield, United Kingdom, in 2020 by the University of Sheffield and Stellenbosch University. One peer-reviewed international conference proceeding paper has been published as of the date of submission of this thesis: J. Xing, Z. Ruixi, R. Zen, N.A. Sanjaya, L. Sioné, I. Khalil, S. Bressan, 2019, *Microbiological Water Quality Test Results Extraction from Mobile Photographs*, 21st International Conference on Information Integration and Web-based Applications and Services, Munich, Germany, December 2–4, 2019. At the time of submission of this thesis, three journal publications were in preparation for submission in 2021-22; the papers were tentatively titled: (1) Sioné, L., Templeton, M.R., Onof, C., Jensen, O., Bressan, S., Tripathi, S. Is data derived from a citizen science approach accepted by water managers? A case study in Nepal. Target journal: *Citizen Science: Theory and Practice* or *Water Resources Research*, (2) Sioné, L., Templeton, M.R., Onof, C., Statistical methods for citizen science in data-scarce settings. Target journal: *Environmental Monitoring and Assessment*, and (3) Sioné, L., Templeton, M.R., Onof, C., Jensen, O., Bressan, S., Can citizen science raise the political priority of reliable access to water through evidence-based monitoring? Target journal: *Waterlines*.

3. Research Methodology

This chapter summarises the methods that were used to conduct key stakeholder interviews and to collect data on intermittent water supplies using citizen science in Kathmandu, Nepal. Since one of the main objectives of this research was to develop and test the citizen science-based methodology itself and to generate a robust methodology that could potentially be taken up by water providers and researchers in other countries and settings, the entire process is described in extensive detail below.

3.1 Semi-structured interviews with key stakeholders

The research followed a curated process for generating knowledge from important stakeholders through semi-structured interviews, as outlined in Figure 1. The process starts with identifying stakeholders, and building a stakeholder register with details of all the identified stakeholders. Stakeholders are then contacted for interviews, from which two types of information will be gained; First, information on the stakeholder himself, in terms of his engagement towards the research. Stakeholders' engagement may be categorised into one of five levels of salience: "Unaware", "Resistant", "Neutral", "Supportive", and "Leading"(Riahi, 2017). Determining the level of engagement of each stakeholder at the start of the projects ensures that, if any stakeholder is not in a desired phase of engagement, steps may be taken to amend this. Ensuring that stakeholders are or become supportive of the project is key to the method being adopted for future work. In the second instance, information is collected from the interview on the topic of the research (here, the IWS in Kathmandu). This may be in the form of pre-existing information (which may or may not be

publicly available), or in the form of personal knowledge generation on the stakeholder's part. An example of pre-existing information would be water delivery schedules, while an example of personal information would be that the interviewee reveals from personal knowledge that the schedules are not adhered to. Clearly, both sets of information would be valuable.

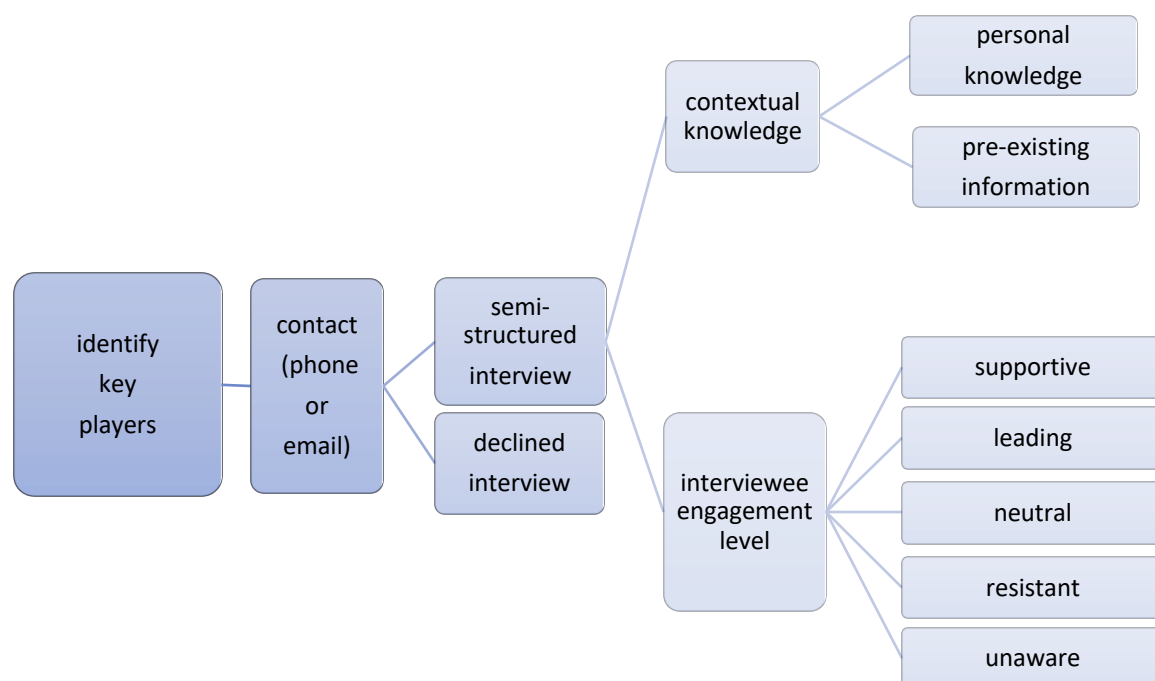


Figure 1. Planning for stakeholder engagement analysis and knowledge extraction

Since an over-arching aim was to help *decision-makers* by providing them with data on the water supply infrastructure, the methodological approach started by identifying all the key decision makers in the water supply sector, based on the interactions with the key player: the water provider. Semi-structured interviews were then held with those stakeholders to

determine, to the best of their knowledge, what information was available and genuine, and to get their views on the current water supply intermittency challenges and what kinds of data would be helpful in their roles. Key stakeholders playing a role in the delivery of water supply were carefully chosen, following the literature recommendation of inviting participants that represent typical stakeholder groups, but also a range of views within those same groups, if possible (Land et al., 2017). These were identified as belonging to

- Industry
- Government
- Development aid agencies
- Non-Governmental agencies benefitting research in the domain of water supply
- Charities funding projects to improve water supply
- Journalism reporting on national water supply
- Academia in water supply and management
- Concerned citizens

In Kathmandu, stakeholders from ten different organizations were identified by a systematic breakdown of key players in the water industry (Figure 2). A top-down approach was used to identify the relevant organizations, starting at governmental level:

- *Government of Nepal.* The government of Nepal's Ministry of Energy, Water resources and Irrigation is in charge of all things water related. Specifically, the department of Drinking Water and Sewerage manages all policy surrounding water.

- *KUKL*. KUKL is the public company which manages all of the water supply and sanitation system of the Kathmandu Valley. It is committed to providing a quantitative, qualitative and reliable service to its customers at an affordable price.
- *Kathmandu Valley Water Supply Management Board (KVWSMB)*. KVWSMB is the asset owner of the water supply and sewerage system in Kathmandu Valley. Officially an autonomous government body, its role is both towards KUKL and towards the Ministry of Water Supply and Sanitation. On the one hand it provides licenses to service providers (i.e. KUKL) for the operation and management of water supply. On the other hand, it develops service policies and monitors the quality of KUKL's service, to ensure "supply of sufficient potable water with an acceptable residual pressure head at an affordable price to its consumers" (Government of Nepal, 2014).
- *Asian Development Bank (ADB)*. The ADB is a development bank, which provides loans to Asian governments to support social and economic development projects. As discussed in the literature review, it provided extensive support to the Nepalese government in improving the water supply and sanitation services through the Melamchi Water Supply Project (MWSP). Partners on the project are the Government of Nepal, the Melamchi Water Supply Development Board, and JICA. Past partners include the World Bank, Norad (Norwegian Agency for Development Cooperation), and Sida (Swedish International Development Cooperation Agency, NDF (Nordic Development Fund), and OPEC (which provides aid to non-oil exporting countries).
- *World Bank Group*. The World Bank is a development bank with similar interests to the ADB. It is a past partner on the Melamchi Water Supply Project, along with Norad, Sida, NDF, and OPEC. Despite bowing out of the project, it remains a key player in the water industry in Nepal and across the world.

- *Japan International Cooperation Agency (JICA)*. JICA is a governmental agency which is a part of Japan's official development assistance effort. It provides varying forms of aid to Asian countries, aiming to promote economic and social development through the provision of technical advice, loans, and assistance. Like the ADB, it has been essential in supporting the government in improving water supply and sanitation services through the Melamchi Water Supply project.
- *International Water Management Institute (IWMI)*. The International Water Management Institute is a research institute which has been working on behalf of the Nepalese government since the 1980s. IWMI's early contributions include policy inputs on the National Planning Commission's irrigation master plan, helping the Department of Irrigation craft a participatory management action plan for the Banganga Irrigation System and conducting case studies for the Government of Nepal's Indrawati River Basin water transfer plan. More recently, IWMI has expanded to looking at water management as well as planning, with research exploring participatory budgeting, social accountability and reducing corruption in the WASH sector (Otto et al., 2019).
- *Global Water Partnership Nepal (locally known as JVS)*. Global Water Partnership Nepal promotes networking in the domain of Integrated Water Resources Management (IWRM).
- *Tribhuvan University*. Tribhuvan University is a public institution for higher education, located in the centre of Kathmandu Valley. The oldest university in Nepal, it has a long history of research in the domain of water and population studies.
- *Water Aid*. Water Aid is a charity which raises funds to help marginalised communities and people in vulnerable situations take action for their rights to water and sanitation.

Water Aid also exchanges with government and decision-makers to ensure accountability for providing long-term access to water.

- *Valley Drinking Water Victim's Struggle Committee (VDWVSC)*. The Committee is an activist group which uses social media (Facebook) to facilitate and encourage civic engagement to combat the political inaction in the water sector in Kathmandu. Main activities consist of organising protests and drafting demands for local and federal governments to guarantee supply of drinking water to homes.

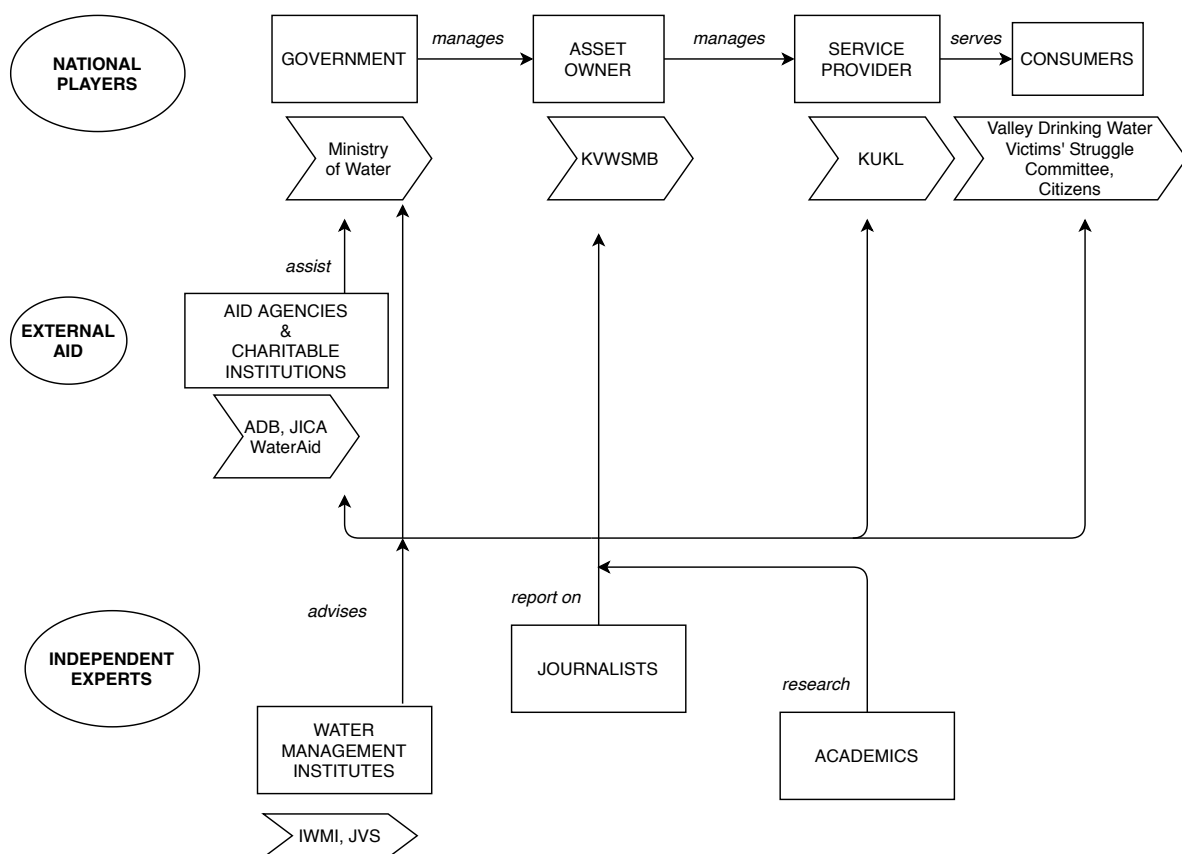


Figure 2. Schematic of the relationship of key players in the water supply industry

A review of each organisation revealed their activities and projects relating to the water supply, as well as the project managers. Those managers were then contacted through email, requesting an interview. If unresponsive after 3 weeks, or where no email address was available, the help of a local facilitator was solicited. The facilitator attempted to contact the managers first by telephone, or in person as a last resort. The facilitator for this project was chosen as Sabitri Tripathi, a female professor at Nepal Engineering College. Prof Tripathi was chosen to translate and facilitate exchanges on a cultural level, because of her superior English and Nepalese speaking skills. Indeed, although all interview subjects claimed to be fluent in English, this was not always the case and Prof Tripathi would occasionally have to intervene, for example when the subject did not know how to express himself in English, or if the subject was unclear about a question. Moreover, it had been observed that the subjects were more comfortable speaking in the presence of a local person.

Nineteen people of interest were contacted in total, with sixteen responding positively. Semi-structured interviews were conducted between the 13th of June and the 17th of July 2019. The interviewees gave their consent for the interviews to be used in this research, but to protect their privacy, their names and specific professional functions have been omitted from this thesis document. If further evidence or follow up is required, the author has an un-anonymized list with corresponding contact details. Details on the anonymized interviewees and the organizations that they belong to are summarized in Table 1.

Table 1. Details of interviewed key stakeholders

Date	Industry	Position
19/6/19	Government of Nepal	Ministry of Water Supply, Department of Drinking Water and Sewerage (DWSS), Senior division Engineer
14/6/19	Government of Nepal	Former high-level member of the Ministry of Water Supply and Sanitation
18/6/19	KUKL	Branch Chief
17/6/19	KUKL	High level manager in the Water Quality Section
20/6/19	KVWSMB	High level Director
19/6/19	KVWSMB	Hydrogeologist
21/6/19	ADB	Urban development specialist, Kathmandu Valley Water Supply Improvement Project
19/6/19	IWMI	Researcher in Hydrogeology & Water Resources Management
	IWMI	High level manager
19/6/19	JICA	Manager for the JICA-KUKL initiative
19/6/19	JICA	High level Officer for Water Supply and Sanitation
13/6/19	JVS	High level member of JVS, former Secretary of the Ministry of Water Resources at Government of Nepal
13/6/19	News industry	Freelance journalist
17/6/19	Tribhuvan University	Professor of Population Studies
20/6/19	WaterAid	High level Program Officer
17/7/19	World Bank Group	Senior Water and Sanitation Specialist

Details on the interviewees who were contacted unsuccessfully for interviews are summarized in Table 2.

Table 2. Details of unavailable stakeholders

Industry	Position
KUKL	High level Manager
VDWVSC	High placed member
The Kathmandu Post	Journalist

Of these, two interviewees remained unresponsive: the member of the Valley Drinking Water Victims' Struggle Committee, and the journalist for the Kathmandu post. Both persons are considered political activists, in a country where freedom of speech is fragile, with suppression on journalists and media freedom on the rise in recent years (Human Rights Watch, 2019), although the reasons for their lack of response were undetermined. Lastly, the high-level manager of KUKL first accepted and then declined the invitation due to work constraints. Indeed, at the time of the interview, KUKL was under pressure for their delayed repairs to pipe leakages and their uncoordinated development efforts, according to an article in The Kathmandu Post (Poudel, 2019). Furthermore, KUKL had not submitted its annual audit report for the 9th year in a row and had yet to respond to a Right to Information petition (Samiti, 2018). Under the Company Act Law, the state-owned water utility company should publish audit reports, decisions from general meeting and other essential information on a yearly basis or be scrapped by the Tax Office after the third year. However, since the government is the major shareholder of KUKL, it has been repeatedly pardoned, leading to

accusations of corruption (Anonymous, 2017) .Click or tap here to enter text.Click or tap here to enter text.

The interviews were held at company headquarters in Kathmandu, except for interviews with the

- Professor of Population Studies, which took place in the lobby of the Marriott Hotel, Kathmandu;
- Senior Water and Sanitation Specialist at the World Bank, which was held over Skype on account of her work keeping her in abroad;
- Journalist, which was conducted in a public place, due to concerns over his safety in light of the aforementioned suppression of free speech.

The content of the semi-structured interviews was discussed in advance with the social scientist Dr Jensen, who would then help guide the interview using social science techniques seldom employed in an engineering context, while the research lead focused on extracting the desired information. Interviews were conducted with a panel of three people present, consisting of the author of this Thesis, the facilitator of the meeting, and depending on the situation, either a person to provide gender balance or to provide expert advice if needed, as the topic treated was multi-disciplinary. Nepalese culture is male-dominated – as illustrated by the proportion of male interviewees – and it was previously observed that male interviewees were most comfortable when speaking to another male, even if the questions were asked by a female. Hence, Professor Michael Templeton also participated in some interviews.

As the interviewees were largely in the business of policy and management as opposed to engineering, a policy expert, Dr Olivia Jensen of the National University of Singapore, was invited to complement the panel by contributing expert knowledge and improve the quality of the interview.

Before the interview started, interviewees were made aware that the interview material was intended to be included in this thesis and could then refuse to continue if they so wished, though this never occurred. The interviews were recorded where permission was given from the interviewees.

As the interviews progressed, information about the research travelled by word of mouth and social networks in Kathmandu, and various persons spontaneously made contact to learn about the research first-hand (Table 3). The most prominent of these from the standpoint of management of the water supply system was the Assistant Manager at KUKL. Importantly, this experience illustrated the power of word-of-mouth communication in Nepal. By the time the last interview was conducted, the interviewees greeted the research team expectantly.

Table 3. Additional interested stakeholders

Industry	Position
Government Of Nepal	Ministry of Water Supply, Department of Drinking Water and Sewerage (DWSS), Central Water Quality Testing Lab, Water Quality analyst
JICA	Wash engineer
JICA	WASH program advisor
CEAPRED	Researcher and Program Coordinator
KUKL	Assistant Manager

Importantly, the interviews revealed that little to no information on quantity, quality or timeliness of the water supply reaching the end-user was being systematically recorded by the water utility company, KUKL. Moreover, it transpired that information was not shared between co-workers and departments within KUKL, nor with collaborating entities such as the ADB.

3.2 Design of a smartphone application for water intermittency data collection by citizens

Data was to be collected daily on quantity, quality and timeliness of the water reaching the end-user. It should be noted that although the citizen scientists would be requested to log data daily, it is anticipated that they would only record data when prompted to do so e.g.

when the water supply does not behave as they expected, or when they are triggered by something related to their water e.g. they need to purchase more bottled water.

The citizen science tool was designed to exploit the rising trend of Information Technology, especially mobile phone technology, in developing countries. As highlighted in the Literature review, mobile phone technology is now as prevalent amongst the poor as amongst the rich, and Nepal's mobile-cellular telephone subscriptions per 100 inhabitants jumped from 0.04 to 139.45 between 2000 and 2018 (International Telecommunication Union, 2020), with both men and women possessing mobile subscriptions.

Collecting data through mobile phones is not only a time and cost-effective method, but it also relieves us from the added challenge of introducing a tool that is not usually used by the population. People already use their mobile phones for all sorts of tasks, and collecting data on their water supply is just one more on the list.

It was decided to design the tool as a mobile phone application, as opposed to a web or text application. This would ensure that the data communicated by the citizen scientists could be easily amalgamated and stored securely on a web-platform, without the need for transposing any information.

As previously mentioned, this research constitutes the first citizen-science led monitoring project pertaining to the water supply delivery. Therefore, although apps and portals for water monitoring do exist, it is not possible to use them in the context of this research principally because the app and everything within it are designed to be used by trained personnel and not ordinary untrained people.

The most user-friendly existing app and portal that was found was that of mWater (<https://www.mwater.co>). The mWater app fulfils all the necessary criteria to successfully record data on the water supply, and in practice it would be possible for citizens to use the app. However, inspection of the app revealed a number of concerns that favoured developing a purpose-build app for the research. Firstly, learning to use the mWater app required a lengthy one and a half days of specialist training, according to mWater. Moreover, using the app for repetitive monitoring required a large number of compulsory questions and steps that were not pertinent to the aims of this research, but which on the contrary, could lead to increased dropout rate amongst impatient users. For example, users must create a “site”, then selecting what type of site, and then further select a survey type to report the data into.

Once this is done, the portal asks the user further questions about the water point and the user themselves. Then, the user must go back to the homepage and select to start a monitoring survey from a long list. Amongst the list are surveys applicable to the research (mWater standard water quality test report and mWater standard functionality report), but these contain many questions, some of which are not pertinent to the research.

It is possible to use the mWater portal to create a customized survey. However, the survey must be deployed to specific and known enumerators. This implies that enumerators have been recruited beforehand and that they are willing to share their personal contact details. It was decided to avoid this step, given the extra ethical approval implications of holding personal details. This requirement would also unnecessarily limit the participation of willing citizen scientists who might be uncomfortable sharing their personal details. To fulfil ethical approval requirements set by the Imperial College Research Ethics Committee, it was made clear that all data collected was done so confidentially, with its use only for research purposes.

Any participant details would be kept anonymous and only data pertinent to water supply would be published. Furthermore, participants could voluntarily withdraw from the study at any time without giving a reason. The only requirement was that participants were at least 18 years of age.

As a result of the lack of a pre-existing adequate app for the purposes of this study, it was decided to custom-build one which would avoid the pitfalls described above. The code to the app can be accessed via GitHub at <https://github.com/richard-G/nwBrowser/tree/master>. The application was developed to have the following characteristics:

- to be compatible across multiple platforms: Android, and an internet browser
- to maintain an identical User Interface (U.I.) across all platforms, see Figure 3 .
- to be available in English and in the local language (Nepali).

This maximised user eligibility, reaching as many different profiles of citizen scientists as possible, regardless of income level (reflected by the brand of phone owned, i.e. cheaper Androids) or education level (reflected by the language mastered, i.e. English for the more educated and Nepali for the less educated).

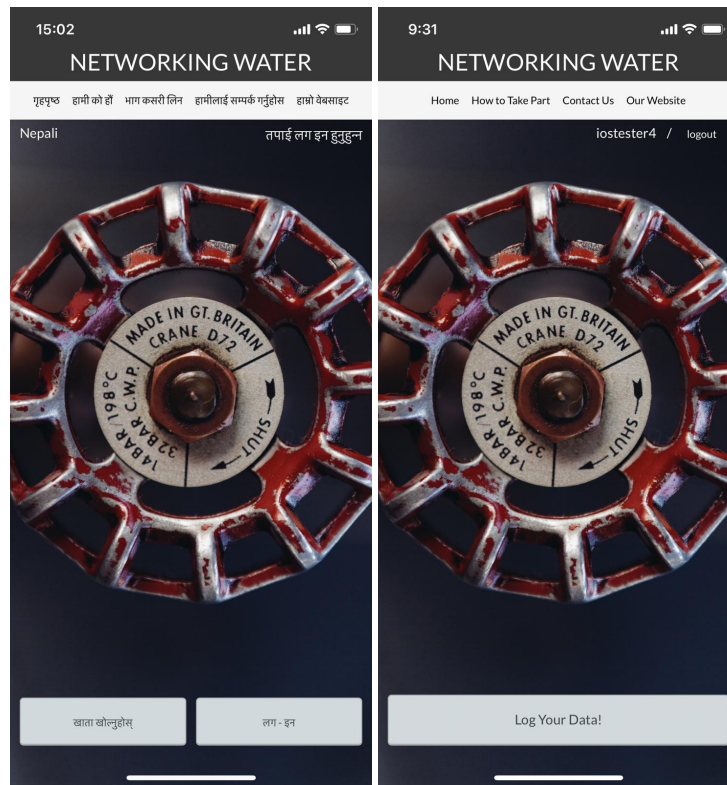


Figure 3. Home screen of the created mobile app in (L) Nepali and (R) English

The app was named “nwData” and was available on the Play Store, and as a web platform via the website www.networkingwaterdata.com. In effect “nwData” is a diminutive of the name given to the project “Networking Data”, which was chosen to reflect the human network nature of the research and the physical network of the water supply system. However it was also chosen as a mnemonic for the citizens to remember: “n” for Nepal, “w” for water.

The app was designed for first time users to start by setting up a user-profile which gathered basic information from the user. The user-profile automatically created an anonymous user ID on the server, which was linked to the user’s IP address, unique to the phone. A “Locate me” button was linked to a Google Map Application Programming Interface (API) and allowed users to pinpoint their location with one click. The location was then automatically converted

into latitude and longitude coordinates and uploaded to the server. The user could create a username to be linked with the account.

Once the user-profile was created, users could then log data by clicking on the “Log Your Data” button. This triggered a series of short and simple questions about the water supply to appear on the screen one after the other. The questions were designed through consultations with the end-users, and based around the end-users’ perceptions of an “abnormal” water supply, since it is abnormal occurrences (or “rare events”) that motivate consumers to use the app. In an intermittent water supply, the “normal” scenario is where end-users do not know when to expect the water, the quality of the water when it arrives, nor how long it will stay for. Therefore “abnormalities” are the arrival of water, and any change in water quality. The questions in the app therefore asked the end-user to report on water timeliness and quality, specifically: whether the water was supplied today, the time at which they noticed the water was supplied, the time at which its delivery was stopped, and whether the water had a colour, taste or odour (Figure 4).

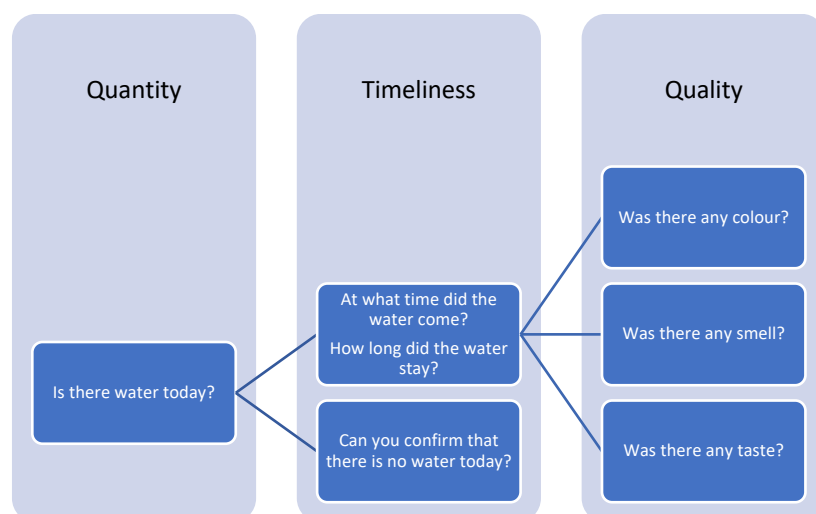


Figure 4. Logic flow diagram of the questions asked by the app

The application used the world-wide recognised traffic light system where green means positive (water was supplied) and red means negative (water was not supplied), to make it as intuitive for the users to report on whether or not they had received water. The data-logging session started out by asking the user if they received water today, and the date of use is automatically uploaded to the server. The green button was pressed to indicate that water arrived , and the red button to indicate that it did not (Figure 5).

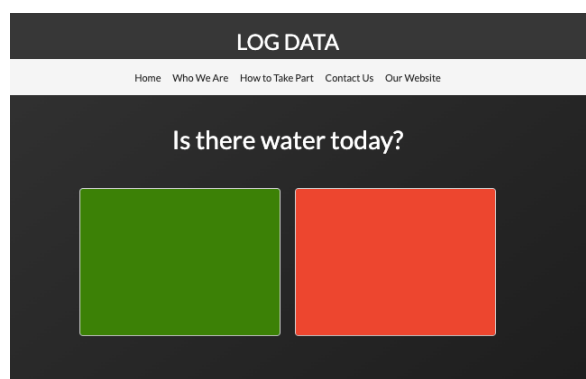


Figure 5. The simple traffic light response system of the app

Users could only answer subsequent answer questions by selecting an answer from a drop-down menu (Figure 6). Questions were phrased as simply as possible, and the choice of answers was always one-worded or numerical, to reduce communication issues.

Figure 6. Users select answers from a drop-down box to answer timeliness questions

Branching logic was integrated into the application through dynamic fields. Conditional questions allowed the app to direct the user only to questions that pertained to their specific case, reducing time and effort for them, and reducing data clutter for the researcher. For example, if the user responded that they did not have water supplied today, subsequent questions about quality would be automatically skipped. The session would then automatically close, thanking the user for his or her input.

The app and web platforms were hosted and deployed through the cloud computing service Amazon Web Services. Data collected through the app was automatically transferred to the AWS cloud and remotely stored there. AWS was chosen for its scalable and adaptable web hosting solutions, as well as for its well-known security and reliability when it comes to protecting and accessing data. Access to both the data recorded by the users and on the users themselves was password protected.

Finally, this subchapter culminates in a framework for designing the citizen-science data collection tool (Figure 7).

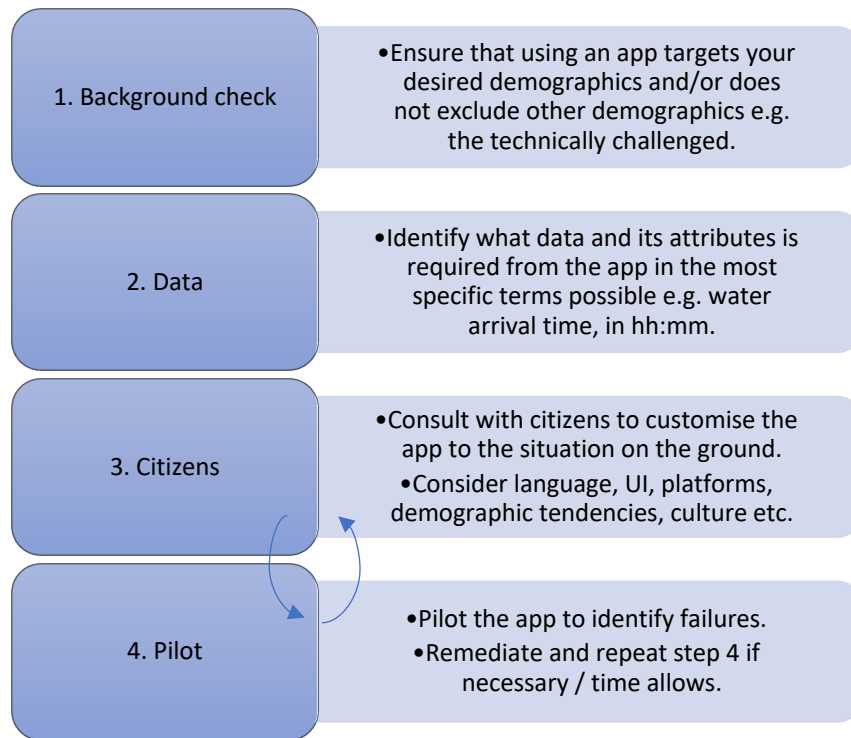


Figure 7. Framework for designing the app

3.3 Recruiting and retaining citizen scientists

It was decided that material would be needed for prospective participants to refer to, both in web format and in paper format for those who were less technologically confident.

A website was created using the website builder Wix. It aimed to provide information about the project to prospective participants and to lend a sense of legitimacy to the project. Like the app, the domain name was chosen to be Networking Water, and the website was www.networkingwater.com. It was anticipated that of the people visiting the website, English would not be their mother tongue, and that they would be mostly looking for reassurance

that the project was purely research-orientated and not in any way commercial nor otherwise motivated. Therefore, the website was designed to exhibit clearly structured content, employ approachable and simple language, and support the text with images to convey key messages.

The site's homepage explained the purposes of the research, why citizens were needed, how they could participate, how this would benefit them and even be beneficial for them. The site provided a way for the public to contact the researchers for more information and report any problems with the website, the app or anything else that they felt might be important. Finally, the website provided access to other aspects of the project: a link to download the app, a link to the Networking Water social media page, and a link to the WaterAid webpage for more information on water issues in the developing world.

Flyers (Figure 8) were printed for distribution to prospective volunteers, summarising the information from the website. They served the dual purpose of informing and reminding participants about the project.

NETWORKING WATER



Project Participants' Pack

Building a network of people to monitor the network

PROJECT SCOPE

In many emerging countries water distribution systems that were originally designed for a continuous mode supply are now operated intermittently.

This has several negative consequences that ultimately prevent the sustainable distribution of a safe water supply.



**BY 2030 EVERYONE
WILL HAVE SAFE WATER
TO DRINK**

#GlobalGoal

One of the major problems is a genuine lack of available and accurate data.

We believe that citizens are the key step to obtaining this crucial data.

Consequently we are hoping to demonstrate and promote the use of citizen science as an effective and affordable means of achieving universal access to drinking water for all.

HOW TO CONTACT US

If you require any assistance or further information, please do not hesitate to contact us. We would love to help!



Email: laure.sione09@imperial.ac.uk

Key Dates
We will be in Kathmandu from:
18/03/2018 – 30/03/2018
But just because we leave does not mean the project has to stop! We would be very grateful if you could continue to help us to help you by continuing to collect data.

For more information visit:
www.networkingwater.com


www.facebook.com/NetworkingWater


[@NetworkingWater](https://twitter.com/NetworkingWater)

HOW IT WORKS

Taking part is easy, just complete the steps below and you will be ready to start logging your data.

1. Download our app
2. Create an account
3. Complete our questionnaire
4. Start logging data!

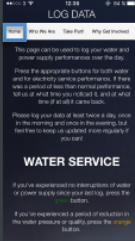
Whenever you experience a break in service, simply go to our home page, click "Report a break in service" and let us know what time it occurred and whether it was a water or power cut.

Reporting any breaks in service will take just a few minutes each day; the hard part is remembering to do it!

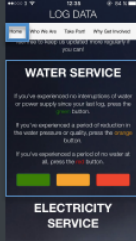
DATA COLLECTION METHOD



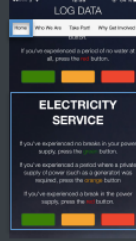
Create an account
or log your data



Information about
how to log your
data



Log your water
service data by
selecting the
appropriate button



Log your electricity
service data by
selecting the
appropriate button



Figure 8. The flyer that was given to participants to summarise the app

The Networking Water social media page was created on Facebook (Figure 9), to benefit both the participants and the researchers. Facebook was chosen because it was already a very extensively used social media platform in Nepal. On the user side, it lent a sense of community for the participants who followed the page, but also allowed them personal one-on-one contact with the researcher. On the research side, it was an already established medium to communicate quickly and easily with participants. Throughout the project, the Facebook page would be used to encourage the volunteers to keep logging data, congratulate them on their participation, keep them informed about the outcomes of meetings with their local policy makers and water managers, research publications and presentations at conferences.

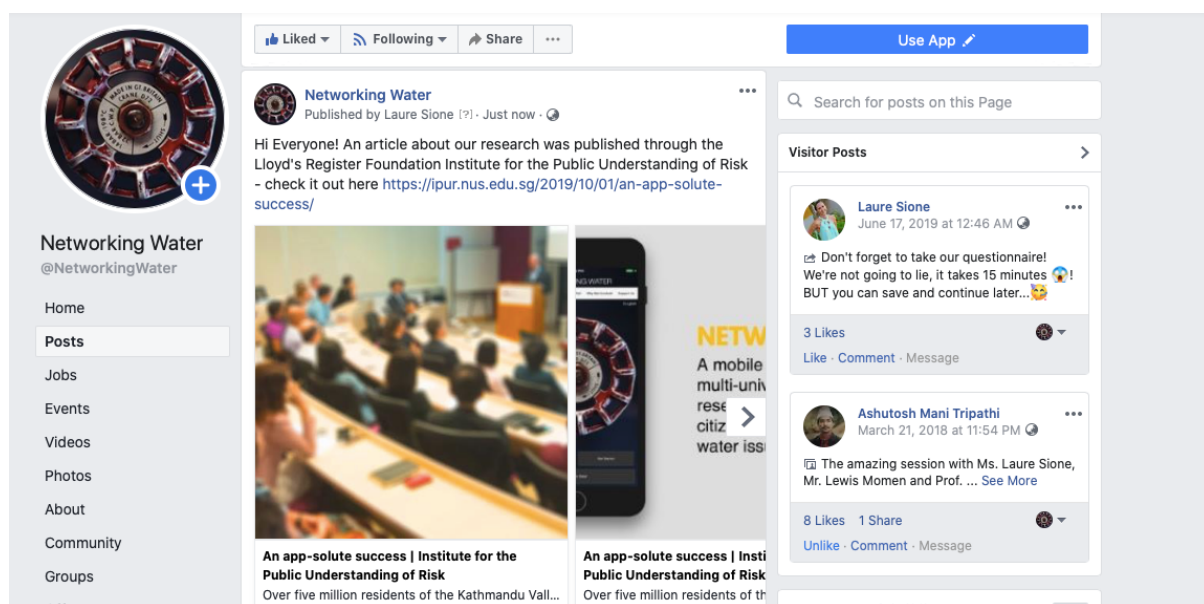


Figure 9. The Networking Water Facebook page

A strategy for recruiting and retaining citizen scientists was elaborated, in collaboration with citizens from the start.

Leaders were contacted from the participating communities (further details provided below), covering the whole region of Kathmandu where the water is supplied. An overview of the research and an outline of the citizen science project was presented to the leaders, and their help was enlisted to organize community meetings. In turn, they presented this information to their communities and set a date and time for all of those interested to congregate with the researchers.

The community meetings had two purposes: first, reaching out to as many prospective participants as possible, and second, to learn what motivated prospective participants to come to the meetings in the first place, in order to incorporate this in the strategy to retain participation. This is a novel approach to citizen science project design because it includes citizens in decisions being made in the study design phase. The citizens are not simply a means to an end, and instead play an active and intentional role in steering the design and execution of the project.

At the congregations, the researchers presented the research to the public, with facilitators at hand – Professor Tripathi and some student-volunteers from Nepal Engineering College (Figure 10).



Figure 10. Citizen participants gather to learn about the project. The author is on the right

In total, the author ran 12 sessions across different neighbourhoods, with approximately 12 persons attending each session. The session covered the role of citizens in the research and how the community could benefit from participating. At the end of the session, those committed to participating were invited to stay behind. Informal interviews were conducted with each person in turn, to find out about their personal water griefs. At the end of the interview the participant was guided through using the app on their own phone, assisted by a native Nepali-speaker if necessary. Participants were instructed to use the app on a daily basis even though it was anticipated that they may only be prompted to use the app when their water supply does not behave as they expect. Lastly, they were invited to join the Facebook page and answer a survey designed to provide further information on their

demographics e.g. questions asking their sex, age, location, frequency of water supply, and whether they were users of Facebook.

The interviews immediately exposed that a recurring concern amongst participating citizens was their conscious lack of knowledge about the quality of the water that they received. There was a common feeling of resentment towards the bodies governing the water supply, with it being stated that they repeatedly went to the offices of KUKL to complain about the poor water quality, some even bringing in samples for testing according to an interview with the interviewed representative from KUKL. Despite the citizens' repeated efforts to draw attention to the poor water quality, the complaints were dismissed and the citizens had recently turned to joining street protests about the situation (Figure 11).



Figure 11. A protest for better water supply took place while the research was under way, Kathmandu, 15th

June 2019 (Anonymous, 2019)

The app already provided the citizens with a tool to record where, when and what type of problem they had with their water, providing legitimacy to their claims to the water utility, KUKL. In addition, to address concerns about water quality, commercially available water quality test kits were freely distributed so that participants could personally test their water. Tests measuring critical drinking water quality parameters were purchased by Imperial College London from mWater for this purpose.

The mWater tests were chosen because, despite being designed for frontline health workers, utility water managers and organizations, they were deemed simple enough to be used by members of the public. A further reason for choosing mWater was that they offered a range of tests for purchase, to test different or similar parameters, and each test required a different level of knowledge to perform. For this study, three types of tests were purchased, with a difficulty level ranging from easy to difficult:

- Chlorine test strip, indicating free and total chlorine levels
- Presence / absence test for *E. coli* with a 100ml bag
- *E. coli* and total coliform count using a 1ml Nissui Compact Dry EC plate.

The chlorine test strip was the easiest test to perform. It required a strip of paper to be dipped in a cup of water and the results could be read immediately. The presence / absence test was a slightly more difficult test to perform, requiring a bag to be filled with water up to the 100ml mark. The *E. coli* and total coliform test was hardest to perform, requiring users to have previously carried out the bag test, and to then use a pipette to extract 1ml of water from the bag and deposit it on the EC plate. The range of difficulty of the tests allowed this study to

assess the level of successful test performance which could be expected to be achieved by citizen scientists with previous basic training.

The tests were trialled before distributing them to the volunteers, scrutinising their ease of use and quality. A positive control chlorine test was carried out on water dosed with bleach, while positive control *E. coli* tests were used with water from a local river known to be contaminated with faeces. According to mWater, the test takes 24 hours to yield a result when stored at an ambient temperature of 25 to 40 degrees Celsius. However ambient temperatures at the time of study in Kathmandu were not consistently above 25 degrees: the daytime temperatures reached a high of 29 degrees, and overnight temperatures reached a low of 16 degrees, resulting in the test needing up to 48 hours instead of only 24 hours. This is a constraint of the test, meaning that it may only be reliable for citizen science projects like this one in certain countries and/or seasons of the year, where incubation of the test kit was done in citizens' homes rather than in a controlled-temperature laboratory setting with incubator equipment.

Individual tests were put together in zip-lock bags to form kits. Each kit contained a chlorine test strip, a presence / absence test, an EC plate test, and a pack of antibacterial wipes. Each citizen who volunteered to test their water quality was taught how to carry them out and how to dispose of the test kit materials afterwards. Kits were labelled one to four and distributed in sets of four to each willing citizen, along with an instructions sheet in Nepali to refer back to in case of doubt on the testing procedures. A quarter of an hour was devoted to train the citizens to perform the tests (Figure 12), using the training material provided by mWater. Training time was intentionally minimised to ensure that the citizens attention was retained. The three tests could be performed consecutively in five minutes by trained persons.

Instructions were also given on using aseptic technique to limit contamination, and safe disposal of the used tests.

The citizens were instructed that kits numbered one, two and three should be used individually on different days when water was received. Kit number four was to be used on the same water supply as kit number three, as it would serve as a quality-control measure to ascertain whether the citizens were performing the test reproducibly.



Figure 12. Training volunteers to use a water quality test kit (the author is on the right)

In exchange for providing the test kits free of charge, the citizens were instructed to take photographs of the test results 24 hours after they had been executed and share them via the Facebook page. In return, they received a prompt interpretation of the results, and tailored advice on how to treat and/or use the water that they had tested.

This sub-chapter concludes with a framework to strategically recruit and retain citizen scientists in the wider developing country context (Figure 13).

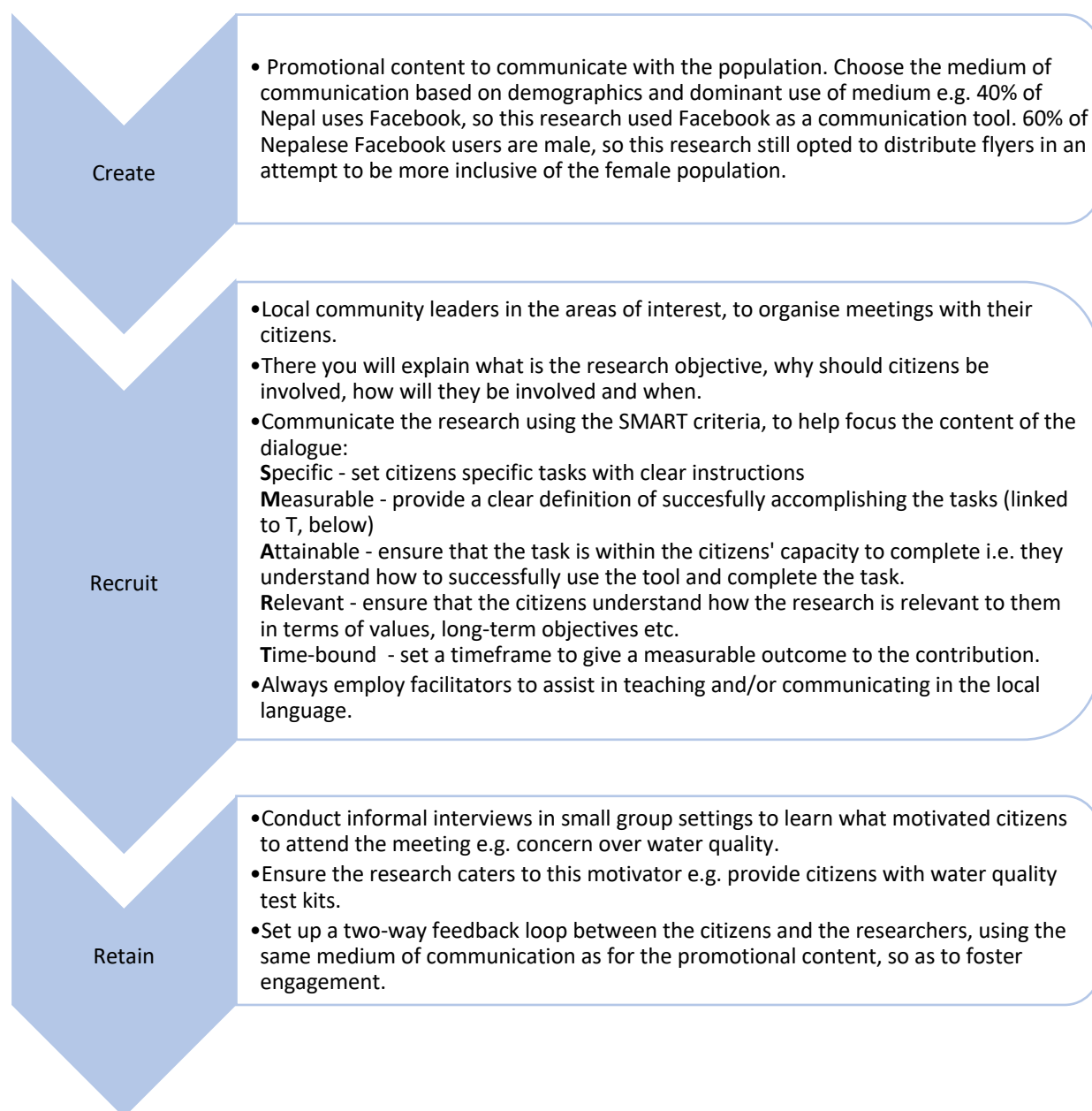


Figure 13. Citizen recruitment & retention framework

3.4 Pilot study in March 2018

The pilot phase was conducted in between 18th and 30th March 2018. The study was planned for two weeks, but participants were told that they could keep collecting data if they wished. The pilot was used to test the app's performance and the rolling out of the tool. One hundred and two participants were actively selected to take part in the study, all of whom were students aged between 18 and 21 enrolled at Nepal Engineering College. Young engineering students were chosen to participate in the pilot for multiple reasons. First, their familiarity with using technology made them ideal critics of the app. Second, their superior knowledge of English facilitated the pilot's implementation. Finally, there was no need to stimulate them to participate as they were inherently interested in the study due to their educational background and chosen fields of study. Still, as recognition for facilitating the pilot study of the research, they were awarded a "certificate of participation".

It was initially thought that potentially the electricity intermittency in Nepal may be linked to the water intermittency, since if the electricity supply fails, electrical components in the water supply (such as pumps) stop working. Therefore, with this in mind, the pilot phase was rolled out to monitor both water and electricity services. The app asked about the electricity supply in exactly the same way as it asked about the water supply: with the 'green' button corresponding to no breaks in power supply and 'red' to a break in electricity supply. However, analysis of the pilot data on the electricity supply revealed early on that there was no clear link with the water supply, and that facet of the investigation was discontinued.

The pilot confirmed that the Facebook page was widely adopted as a means of communication with participants. It was used to flag technical issues, organise meetings, and

provide updates. It also revealed that the volunteers were keen to connect with the researchers on a personal level, confirming the need for informal interviews during the full-scale roll out. The students' English was below the expected standard, and so it was anticipated that the level of English of the participants in the full-scale study would be even lower than planned. To remedy this, multiple facilitators were employed to assist in the later full-scale data collection.

The pilot revealed that participants were sometimes prone to skip questions in the app, to save time and avoid questions that were deemed too personal in nature. In response to this, the questions were re-phrased, amalgamated and tailored so that multiple pieces of information could be inferred from a single answer.

Furthermore, streamlining measures were taken to reduce the time and effort needed to use the app. This included implementing the Google Maps API, introducing cookies so as to remove the "get started" page which required participants to systematically log their name and location through multiple steps every time they logged data, and introducing a timestamp feature. This resulted in each data log being attributed to an anonymous user ID, with an automatic time and geolocation stamp attached.

3.5 Full-scale deployment in June 2019

The full-scale study incorporated the changes from the pilot and recruited a larger number of participants dispersed geographically over a wider part of the city of Kathmandu, capturing different neighbourhoods experiencing different levels of water supply intermittency. It took

place throughout the month of June 2019. Ten communities were contacted through the community leaders. Communities were intentionally contacted in a staggered way so that data collection could also be staggered over time. This allowed opportunities to follow up with each community at identical intervals in time. As in the pilot, volunteers were asked to collect information on their water supply for two consecutive weeks but invited to continue for as long as they wanted.

During the meetings, it was stressed that the research would not solve the poor quality of the water services and that the test kits were for the participants' personal use. It was explicitly stated that the research was not providing a solution to the problems of the poor quality and quantity of water supplied by KUKL, in order to manage the participants' expectations of the outcomes of the study. Participants were reminded that they were free to withdraw from the study, should this information displease them and a small number did indeed leave at that point.

The water quality test kits were distributed with the primary intent of hooking people into the project and providing a sense of empowerment - not to infer results about the method or determine scientific links between intermittency and water quality. It was observed that the interest in participating in the project increased significantly after the water quality test kits were mentioned, as witnessed by all of the facilitators.

Participants were trained to record every day whether they had received water in their home or not, which was then compared against official water supply schedules published by KUKL.

Nepalese culture and society is extremely different to that in the UK, and many unforeseen challenges had to be either accepted or dealt with on the spot.

On a bureaucratic level:

- The water utility employees could exhibit uncooperative and sexist behaviour.
- Official documents were published only in Nepali and on paper, not electronically.

Most official documents electronically available were photographs uploaded to a webpage, often of poor image quality (Figure 14). Moreover, it is difficult to use translation software on an image, and so a translator was necessary to read the documents.

क्र.सं.	मिति	पानी वितरण हुने क्षेत्रहरू	कैफियत
१	२०७३/४/११ पहिलो	का.म.न.पा. वडा नं. १६ वनस्पती र महेरी आदि क्षेत्रहरू।	महेरी आदी क्षेत्रहरूमा देखुका।
२	२०७३/४/१२ दोस्रो	पानीपोखरी भर्ने।	
३	२०७३/४/१३ तेस्रो	का.म.न.पा. वडा नं. १६ का नयाँबजार, सोह्रखुटे आदि क्षेत्रहरू।	
४	२०७३/४/१४ चौथो	पानीपोखरी भर्ने।	
५	२०७३/४/१५ पाचौं	का.म.न.पा. वडा नं. १३ का बाहिरी, चेतनामार्ग, विजयमार्ग, छाउनीचोक, मेघदुत क्लब र सिमानामार्ग आदि क्षेत्रहरू।	
६	२०७३/४/१६ छैटौं	पानीपोखरी भर्ने।	
७	२०७३/४/१७ सातौं	किमडाल, का.म.न.पा. वडा नं. १५ धिमल्लो, का.म.न.पा. वडा नं. १६ एराहिटी, भूकूनीटोल, चमती र का.म.न.पा. वडा नं. १३ का बाफत टेम्पो पार्क आदि क्षेत्रहरू।	
८	२०७३/४/१८ आठौं	पानीपोखरी भर्ने।	
९	२०७३/४/१९ नवौं	का.म.न.पा. वडा नं. १५ स्वयम्भू, विजेश्वरी, डल्लु, चागल आदी क्षेत्रहरू।	
१०	२०७३/४/२० दशौं	पानीपोखरी भर्ने।	

Figure 14. A water supply schedule downloaded from the KUKL website, 20th June 2019

- Nepal follows the lunar calendar, which made it harder to arrange meetings and to decipher the water supply schedules.
- There is no publicly available data on real time water arrival (e.g. via flow meters) to compare the data generated through the citizen science tool.

On a cultural level:

- The research relied heavily on translators, reducing the level of inference that could be directly obtained from face-to-face meetings of the author with citizens.
- A small number of participants used the modes of communication (e.g. Facebook) to attempt to invade the author's privacy.
- The strong sense of community in Nepal was both an advantage and a disadvantage. Although many people came to the meetings, only a few actually participated in the study. This is because many people relied on neighbours and family members to participate on their behalf. On the other hand, news about the research travelled far through word of mouth, which resulted in some people participating despite not being a part of the selected communities.
- Nepalese society is heavily patriarchal, which led to multiple issues. First, it may be detrimental to the study to have men dominating the scene as it is mainly women who deal with the everyday household needs surrounding water, and so they are more aware of water-related issues (Raut et al., 2020; Wali et al., 2020). They are also the ones who look after the children when they are ill and are therefore more invested in the safety of their water supply than men, and by extension would be expected to be more interested and committed to this kind of citizen science initiative, and this was indeed observed in several of the community meetings (Figure 15). Males were less willing to engage than females, perhaps because the research lead (the author) was female in this case. Females were unwilling to participate if their male counterparts were already participating.

Some meetings were heavily gender imbalanced (Figure 16). The male-dominated meetings resulted in the women refusing to speak or volunteer.



Figure 15. Highly interested female participants at a community meeting in Bagdole



Figure 16. A male-dominated meeting

On a development level:

- Wireless mobile telecommunications technology (e.g. 3G) is not constantly available in Nepal, depending on the mobile phone contract, the location or even the time of day. This meant that some people were unable to install the app on their phones during the meetings in some cases and were therefore lost as active participants.
- Some communities had previously been subject to “parachuting science”, where research organisations and NGOs misled the citizens into thinking that they would receive help to resolve the water situation if they assisted them in their research. These communities were understandably reluctant to engage initially.
- The data collection was planned to last over two weeks for each citizen participant, however some participants actually received water less frequently than every two weeks. This resulted in some people not being able to participate.

These largely societal challenges highlight once again the need for a social science expert to be a part of the multi-disciplinary team when dealing with such a complex situation. Thanks to the involvement of Dr Jensen, major challenges were avoided in this research (though clearly minor challenges could not be avoided altogether) and the citizens were able to collect data as intended. The alternative would have resulted in the logical flow of events to break down, culminating in at best a bias in the data and at worst insufficient data to infer results from.

The data received from participants was grouped per geographical location in terms of the community that their address belonged to. It was assumed that everybody in a community

gets their water at the same time, according to the published water utility schedule. Therefore, if one person says they have water, then anyone else in that community can confirm that.

When response to a stimulus is recorded as 0 or 1 (0 being representative of “water off” and 1 being “water on”) and the response rate is very small, it is important to bear in mind that logistic regression will produce biased results, as the logistic curve does not provide a good fit to the tails of its distribution. This can be solved by having a larger sample of data or by specifically subsampling those segments that are both important to the analysis and sparsely populated, in this case by obtaining a set of volunteers that measures the intermittent water situation in rare events, i.e. when water arrives. Since predicting the non-occurrence of a rare event is easier than predicting the occurrence of a rare event, the methodology tests whether people can recognise the rare event and report it, by validating the contributions of participants as correct or incorrect, based on corroboration from their peer group.

It should be emphasised that it was not the purpose of the study to understand the technical reasons behind why some streets do or do not receive water, but rather to assess the correctness of the responses based on the equivalent responses received by others in the same group.

However, in practice there can be multiple treatment plants or water storage tanks feeding into a water distribution network. Therefore, different parts of the neighbourhood may be fed by different plants. Sometimes the official schedules gave the name of the treatment plant and its associated distribution zone, and sometimes not, so it was necessary to make assumptions about that based on the addresses of the participants.

The data was carefully cleaned for duplicates and inconsistencies. Individual participant's data was checked for reliability by comparing answers logged through the app to those from the survey. Data was considered unreliable if entries contrasted with information provided by the participant from the initial survey e.g. a participant was considered unusable if a participant's GPS coordinates did not match the address given in the survey, or if they did not submit any location information. Data was also considered unreliable if app responses contained more than one contrasting data entry e.g. if a 'Green' entry and a 'Red' entry were submitted at close intervals.

The data cleaning process is depicted below, for future reference (Figure 17).

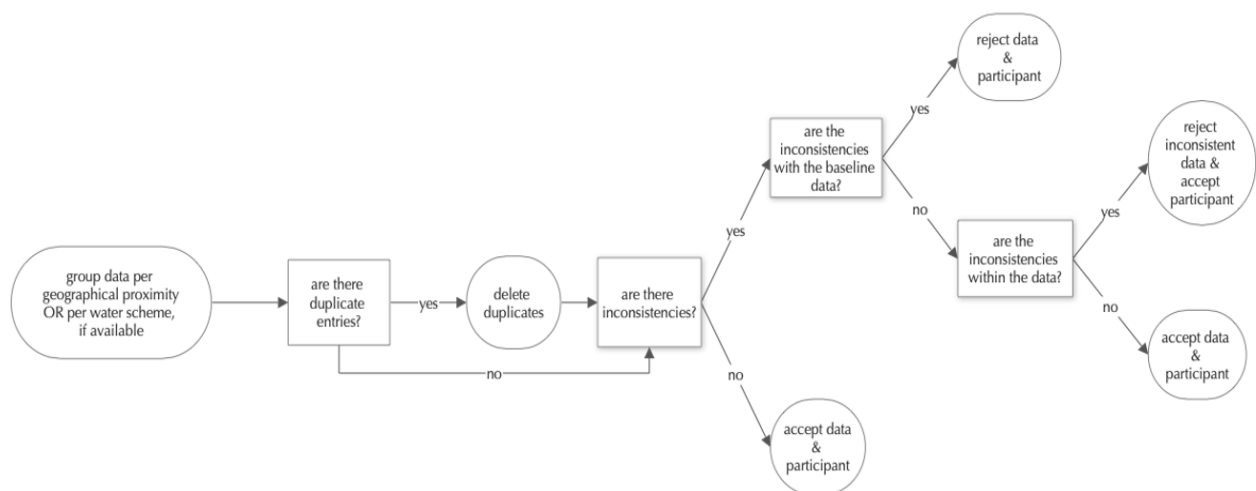


Figure 17. Data onboarding process

4. Results

4.1 Pilot phase

The pilot phase began on the 19th of March 2018 with a community meeting, and officially ended on the 2nd of April 2018. However, participants were encouraged to continue until the 12th of April or as long as they could. In the end, citizens actually carried on collecting data until the 19th of May 2018. This high level of engagement was highly encouraging.

One hundred and two individuals participated in piloting the study and completed the survey. The data from the pilot was carefully cleaned for duplicates and inconsistencies, as per the methodology described earlier. This cleansing resulted in the final data set for the pilot amounting to 488 data points, collected from 41 participants, over 83 days, on 62 different days (i.e. on several days there were multiple data points received). Analysis was performed on the pilot data with the purpose of identifying potential improvements which could be implemented in the full-scale study.

Although 102 persons responded to the survey, only 61 persons recorded one or more pieces of data. This sharp decline at the start of the study suggests that once the interested persons had learned more about the project and experienced the effort that goes into participating, they were put off from continuing. Therefore, the pilot results inferred that informing participants adequately at the start of the project leads to a desirable natural selection of only committed individuals. This highlighted the need to adequately inform prospective participants on the scope of their involvement.

Furthermore, informal interviews with the students revealed that there was a wide variability in the students' English skills. Therefore the survey, which was only in English, discouraged participants from pursuing it further. Based on this, it was decided that the full-scale study would employ language facilitators who would assist participants in filling out the survey.

The dialogs with the participants also highlighted the fact that since the younger generation are typically not the head of their household, they are not as knowledgeable about their water supply and are less concerned about it. Although this issue arose from an intentional bias (i.e. using only student volunteers), it was decided that future work should target participants who are involved in the decisions surrounding the use of water in their home, specifically heads of households and/or women.

Probing questions revealed that it had been wrongly assumed that all houses were linked to municipal water supply, with some households choosing to not use it (e.g. using private wells instead). For the full scale study, only communities located in areas where the water supply network was known to be well developed were selected, typically inside of the Ring Road surrounding Kathmandu. Moreover, care was taken to confirm with the participants that their homes were indeed linked to the municipal water supply.

The number of daily individual responses first peaked at twenty-one on the 21st of March 2018, two days after the initial meeting. Over the course of the pilot, there was a steady but slow decline in the number of daily participatory responses which closed at fifteen on the 2nd of April, as shown by Figure 18. The line of good fit had an R^2 value of 0.79. Its gradient was negative and close to zero indicating that the number of participants declined slowly over time (Figure 18). A strategy to maintain enthusiasm in the volunteers was sought for the full-scale

study, to ensure that this trend was not exacerbated. The full scale roll out did this by regularly providing information and encouragement to participants through the Facebook page.

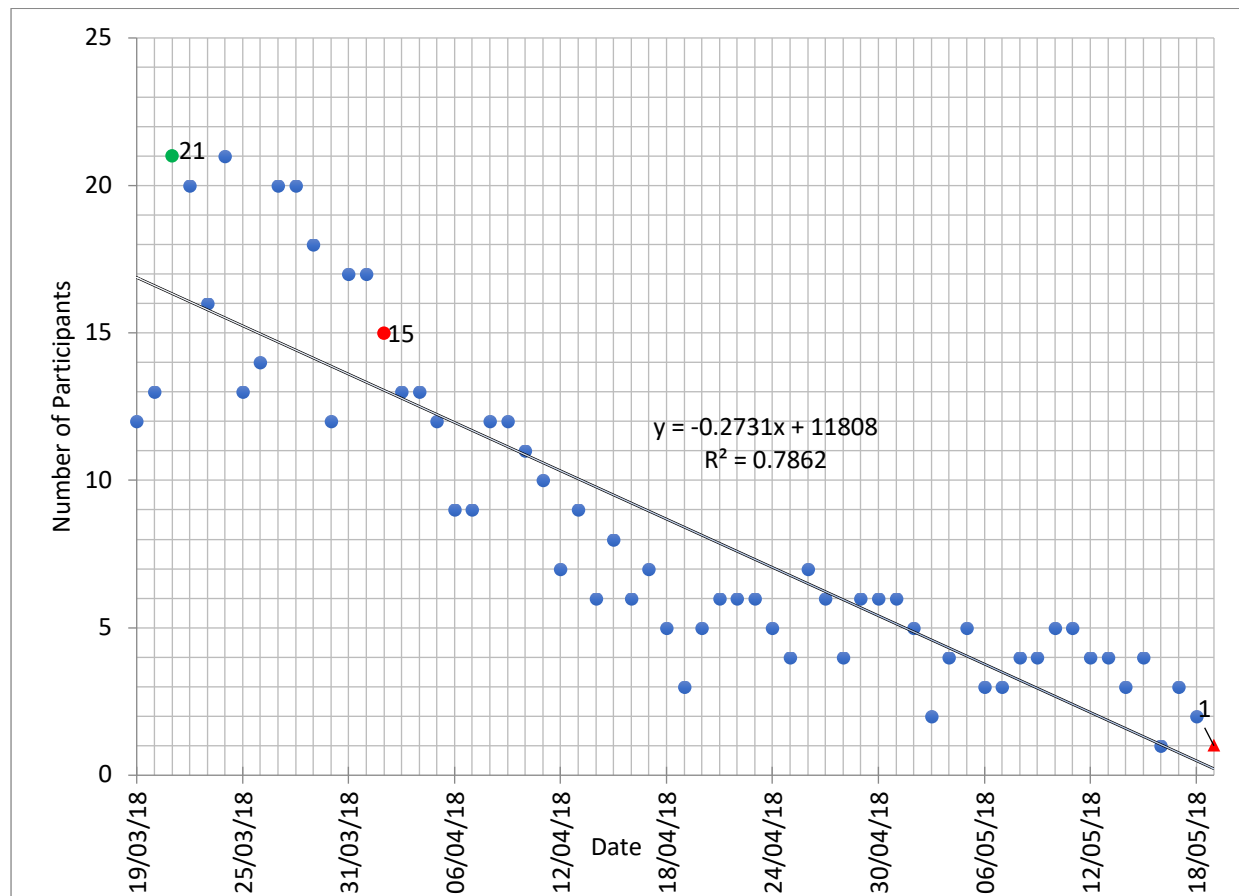


Figure 18. The variation in participant numbers throughout the pilot period and beyond

The analysis of the data confirmed the presence of intermittency, as expected. There were 179 water service data points recorded over the extended 83-day period of the pilot. The number of water cuts as a percentage of the total entries was 13.4%. This level of intermittency is considered relatively low in Nepal. The average time between entries (found by totalling the number of days each participant was active for and dividing this by the total number of responses) varied between 2.3 days and 3.4 days depending on the neighbourhood inhabited by the students, Duwakot or Changuarayan. The average response interval is still relatively high despite the low level of intermittency, which illustrated that it would be

impractical to attempt to assess the productivity of participants in terms of number of data points collected over time, as the number of recordings per participant will vary with the frequency of their water supply, which in turn varies by location – seemingly at neighbourhood level according to the pilot, but potentially also at street level.

Also, most participants did not answer the question which required them to actively measure water pressure. Following up with informal discussions with the participants, it was evident that they found it too onerous. This result revealed that the participant will only donate his time for effortless tasks or tasks that do not require more than one or two minutes, so it is unproductive to include more complicated tasks. Therefore, the app was revised for the full-scale phase to only ask short and simple questions requiring a response time of under a minute, and all superfluous input steps eliminated. Moreover, even though the Nepalese participants spoke some English, the survey showed that communicating in English was difficult, and so the more succinct the tasks, the better. Future research should employ a professional translator and translate the tools.

Participants were asked to rank nine potential reasons for their participation in the study, from one to nine with nine being the most important. The results suggest that on average, interest in the project was the principal motive. Therefore, the volunteers met the criteria of displaying a genuine personal interest in participating in the project. This outcome emphasised the need to maintain interest, and in an effort to do that, it was decided that the field work on site should start by giving a detailed explanation of the study at the beginning of the trip, and a strategy for maintaining frequent communication should be sought.

The younger generation are typically not head of the household and are therefore less concerned by the supply of water and do not know very much about it. Although this arises from an intentional bias (i.e. using only student volunteers), it is recommended to remove this bias in future work, especially as smartphone coverage is on the rise with the older population and so this should not be a barrier to participation. Ideally the head of the household should be involved in the data collection.

Extra data on the volunteers themselves was collected in order to run statistical tests on what factors makes a participant 'reliable' or not, based on their collected data. Specifically, it was planned to compare male and female participatory responses to test whether gender affected the quality and quantity of the data collected. However, this was quickly dismissed in the pilot phase as a viable statistical investigation after the survey results were observed. Since the volunteers were from a pool of Engineering College students, and also from a country where females are discouraged from pursuing further education, the participants in the pilot phase turned out to be dominantly male. Statistics on female participation was hence too low to be able to take the analysis on gender any further.

The app needed to contain an automatic registration of the GPS coordinates of the logged data. This was crucial as it was already established from the survey that (1) volunteers did not log their addresses properly and (2) the built-in GPS for the survey was not accurate enough for the purposes of the study. The end product of the app used a Google Map Application Programming Interface (API) that allowed the volunteers to pinpoint their location (latitudinal and longitudinal coordinates) by clicking on a button, rather than inputting it themselves. Following this, users would only need to input their name when logging their data, which

would then be crosschecked with the database of surveys to associate each response with a location. Without the API, users had to input their coordinates on every response they made, greatly increasing the amount of time needed to log an incident and the likelihood of errors. However, data results later suggested that even these minimal extra actions needed on the part of the volunteer were still confusing and off-putting. Therefore, it was desirable to create an automatic tracker eliminating these extra steps before the next phase of the study.

It was noticed that participants were not keen to openly engage during the training step of the pilot phase. Once the session was over and the students dismissed, many came up to the researchers to ask more personal or detailed questions about the research behind the project, and this ended up taking much more time and generating more interest than the actual session.

Therefore, the second session was carried out in a completely different manner. Visual aids were abandoned and instead the author talked freely about their research. At the end of this talk, the author and an undergraduate researcher from Imperial College London (Lewis Momen) walked around the room and initiated dialogues with single students or small clusters instead of taking questions. This created much more enthusiasm amongst the volunteers and built personal ties. As a result, the participants wanted to be able to communicate with the researchers more quickly than through the website. Based on the results from the survey, an overwhelming majority of participants (95.4%) used Facebook. It was therefore decided to set up a social media group page on Facebook (<https://www.facebook.com/NetworkingWater/>) which could be used as a multi-use platform where:

- the researchers could communicate information and promote the study to participants
- the participants could easily communicate with the researchers on a daily basis
- the participants could post to each other about the project and invite others to learn about it through Facebook.

This initiative was very well received by the participants. During the two weeks in Kathmandu, the Networking Water Facebook page was used daily to:

- exchange messages with students
- resolve technical issues and take note of changes which needed to be made in the app. However, any changes made to the mobile application could not be instantaneous. It took at least 24 hours for an update to be pushed through to the app store, and even then it would be up to the volunteers to choose to update to the new version on their devices.
- resolve comprehension issues (e.g. the questionnaire was reworded in parts where it was noticed that participants were struggling, and additional options for answers were added based on the reaction of the volunteers)
- organise informal meetings
- provide study updates.

Importantly, thanks to communication with the volunteers, it was realised that not all of them had access to municipality-supplied water. In fact, it had been (wrongly) initially assumed that all houses were linked to municipal water supply, with some choosing not to use it. Although still useful from a citizen science point of view, responses that did not concern the municipal

water supply would not give any insight into the water supply network. Data not pertaining to the municipality therefore needed to be isolated, so as not to report erroneous information on the state of the water supply. In light of this information, a question was added in the app asking if the participants' water supply was from the municipality, and if not then from where. For future studies, the sample population should be sorted in advance so that only those linked to municipal water are selected to participate further.

Due to time constraints and problems in acquiring approval from the Android app store, the app was not finished in time for the initial roll out in Nepal. Instead, a web-based version of it was deployed using the custom-built website networkingwaterdata.com. This had exactly the same design and data-collecting questions as the app, and stored data in the same way, using Amazon Web Services. However it created some major disadvantages for the end user:

- it did not automatically detect the GPS position of users. Users were instead asked to locate themselves in terms of a street name and postcode, but this was prone to user error or a given address being too vague, rendering any subsequent responses from that individual unreliable.
- it was only accessible through an internet browser, and not all browsers. Whilst in Nepal, one participant revealed that the website could not be operated upon the popular Opera Internet browser. A solution to this could not be found (except using another Internet browser), which eliminated four affected participants from the study.
- on the majority of modern smartphones, websites are not allowed to store cookies on users' phones. This meant that user accounts that automatically recognised the participant each time they visited the website (after the initial account setup), could not be created. In other words, participants had to record their name and location every time

they wanted to log in data through a “get started” form, which was a tedious task and led to them quickly being fed up.

These constraints greatly reduced the ease of collecting data and generated some confusion and reluctance to participate within the volunteer group, who already struggled to understand instructions due to a language and culture barrier. A translator was used in group settings, however it was clear that confusion often remained, especially when communicating on a one-to-one basis.

These important lessons learned from the pilot were incorporated into the full-scale study.

The summary of the key actionable points were to:

- Revise the app to (i) minimise the number of tasks and (ii) reduce the time it takes to log answers to under a minute.
- Include an automatic registration of the GPS coordinates of the logged data
- Seek out communities where there is a large proportion of houses connected to the piped water supply i.e. in this case, within the Ring Road.
- Ask the community leaders to specifically target heads of households and/or women when recruiting for meetings.
- At meetings, clearly state the dedication in terms of time and duties required from prospective participants, to wean out uncommitted individuals
- At meetings, clearly state that households not connected to the municipal water supply are excluded from the study.
- Employ one language facilitator per three participants, to assist them in filling out the survey, downloading the app and anything else they might need to get started.
- Translate all written material into the local language.

- Connect with individual participants as much as possible
- Keep in regular contact with the participants

Engagement by the volunteer participants carried on over two months, which was encouraging. These data sets were then incorporated into our full-scale data set, where 36 % of the final set comes from the contribution of the pilot.

4.2 Full scale study

Some communities collected more data per person than others e.g. Changunarayan and Kathmandu centre, revealing that those communities were particularly engaged in the study (Table 4).

Table 4. Breakdown of full-scale responses per community

Communities	Number of participants	Number of entries	Number of contributions per person
NA	3	10	3
Nagarjun	1	1	1
Bhimtar	1	2	2
Pida	1	4	4
Kirtipur	1	7	7
Surabinayak	3	57	19
Madhyapur Thimi	7	17	2
Bandol	5	11	2
Tarakeshwar	7	39	6
Lalitpur	24	95	4
Changunarayan	23	263	11
Kathmandu center	18	197	11
Kopan	16	113	7
Total	110	816	-

The data collection was planned as a two-week study per participant, though participants were told that they could continue collecting data after that if they wished. The data collection was staggered over time per community, so that the research lead could follow up with them all at identical intervals in time. Therefore, one might expect that there would be a natural drop off in responses when the first few communities started to reach their two

week mark. However, in practice this was not seen, probably because many users chose to go beyond two weeks anyways (Figure 19).

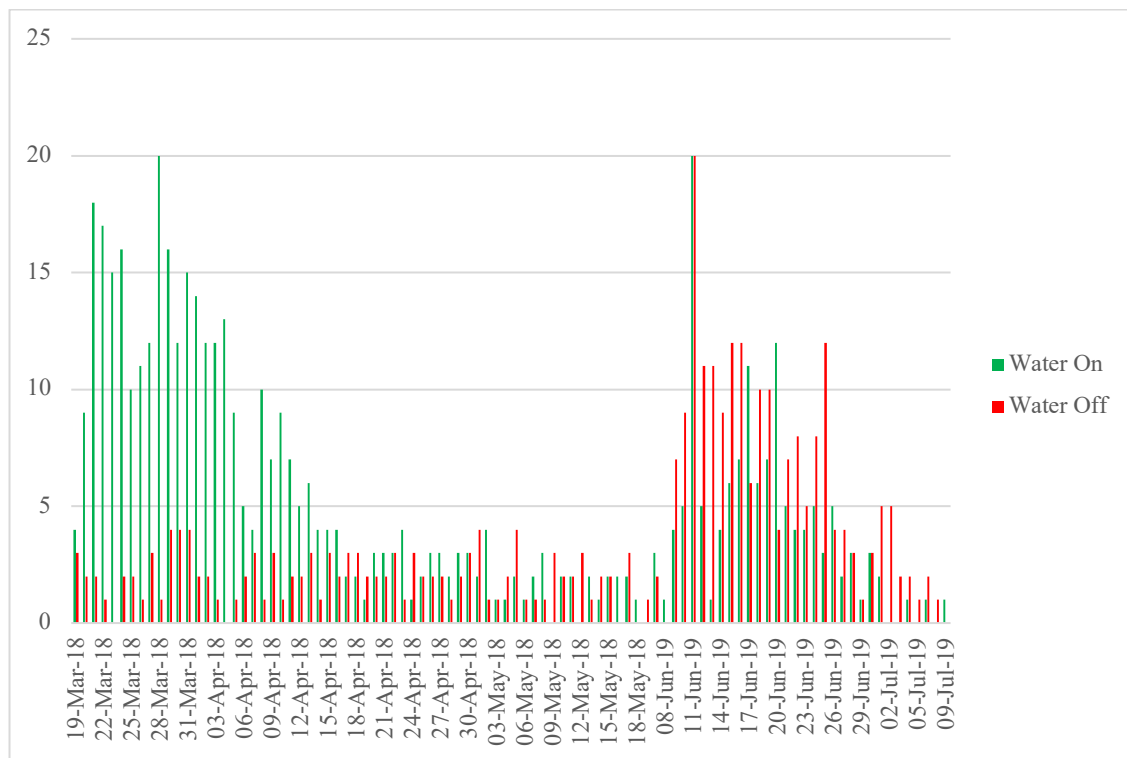


Figure 19. Responses per day, showing gradual reduction over time

The study was officially concluded after the last community's end date i.e. 28th of June, and sent out a message to all the participants thanking them for their participation. Some people chose to continue even after that: 11% of the participants (12 participants from across four communities Kathmandu, Lalitpur, Kopan and Tarakeshwar) contributing 5% to the data set. In practice this meant that people from Lalitpur (who were the first community trained) collected two weeks more of data.

With the pilot there was only one community so this gave a better indication of the response drop off rate, since there was no staggering involved. However, this would be a 'worse case'

drop off in responses, since the pilot community had a majority of 'Water On' responses, and so people did not have a lot of issues to report, meaning that their invested interest in the study was low.

The full-scale study started on the 7th June 2019 and ran for two weeks. Data was uploaded to the database for 30 days, until the 9th of July when a message was communicated to participants advising that the project was officially terminated, and their participation was no longer required. Over those 32 days, 328 data points were collected through 73 people. 4 people chose to participate in both the pilot and the full-scale study.

The final data-set constituted of the combined data collected through the pilot and through the full-scale project.

It was decided to incorporate the Pilot data in the final data set, for a number of reasons. The first was that in the grand scheme of the study, 37 out of 110 participants were from the pilot. This is a substantial number, which is the result of substantial research time, effort and funding. Moreover, the pilot used the same tool and methodology as the full-scale study and was done under the same seasonal conditions. Therefore, the only difference is the age and specific locations of the citizens recorded in the meta-data. These personal attributes varied throughout the entire study population, as it was desirable to capture a wide range of participant characteristics in order to later be able to determine whether certain characteristics distinguished a participant from another, in terms of their data quality and quantity. Clearly, incorporating the data collected from the pilot into a larger data set did not affect the validity of the data, and there were no benefits to excluding it. The cost-limitations

of the study also meant that it was not economically possible to prolong the project to recruit even more volunteers. Moreover, on a per person basis, the pilot volunteers did not use app more than those who participated in the full-scale. Therefore, the data from the pilot would not skew the final compounded data set.

The emphasis of the statistical analyses in this chapter is on employing statistical tests to support evidence extracted from numerical analysis. The tests are largely employed to understand relationships between binary variables, which by nature cannot be normally distributed. Therefore non-parametric tests are favoured over parametric ones throughout the analysis. Where the relationships being explored concerned order and not linearity, Spearman's Rank order correlation coefficient was used to attribute significance to the relationship.

The final data set was therefore comprised of 816 data entries collected by 110 participants. As the number of recordings per participant may be motivated by the frequency of their water supply, it is not appropriate to attempt to compare the productivity of participants in terms of data collected over time, nor is it appropriate to evaluate a drop-out rate. To calculate either of these, each participant would need to be evaluated based on their particular water supply cycle. So for example, if participant x received water once a week and participant y received water 4 times a week, you would have to compare their two patterns of contributions per cycle: 4 weeks for participant x and 1 week for participant y. Moreover, it is futile to do this as it has been previously established that there is no difference in relative contribution between the two groups.

The research sought to establish the reach of the method, in space and then time. Each participant was geolocated on a map and marked with a pin. The participants were grouped according to the community that they were recruited from, and each community was attributed a colour (Figure 20).

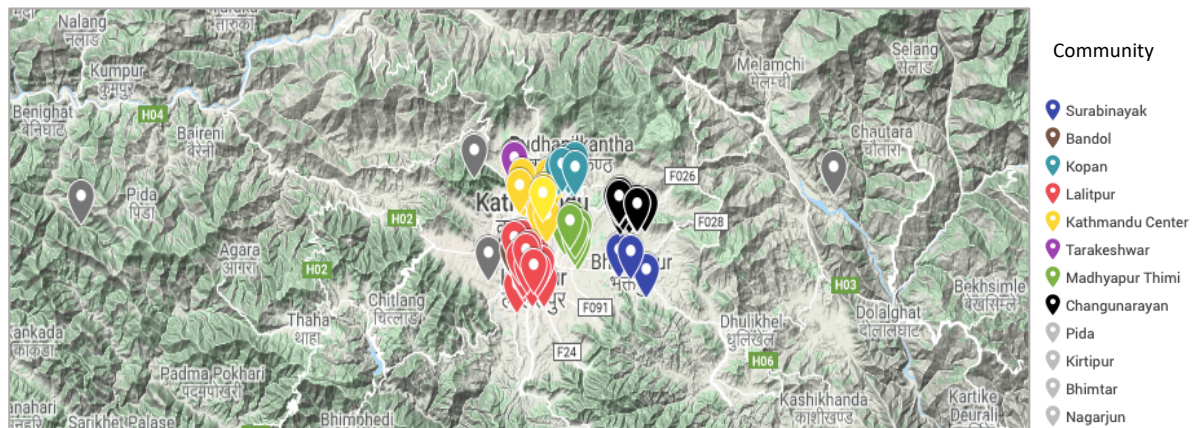
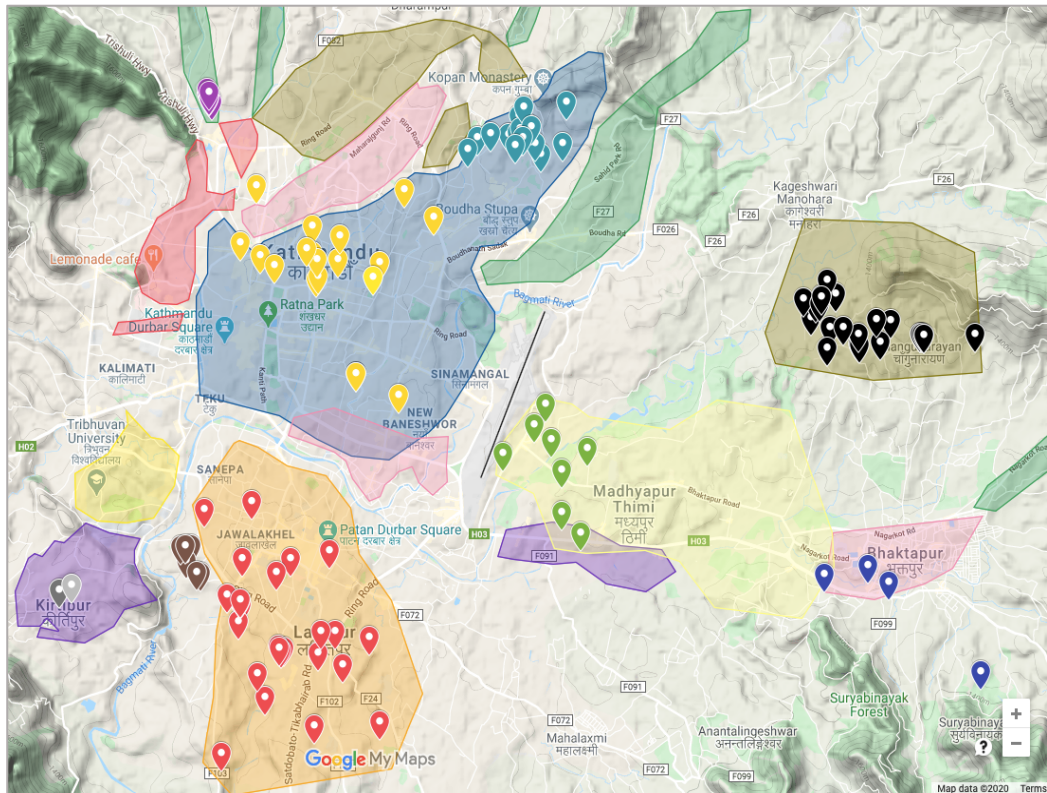


Figure 20. Map showing reach of project across Kathmandu Valley

The 110 participants covered an area of approximately 82 km², so about 14% of Kathmandu Valley's urban area which measures 570 km². As is evident from the map, most of the participants are located inside Kathmandu Valley, save for 4 shown in grey, who are in isolated communities that were not pre-selected for the project. Those participants are volunteers who it is assumed heard about the project through word of mouth (friends and family networks who were participating in the project) and took it upon themselves to participate. They are located very far from project locations, which illustrates the potential of the reach that can be obtained through a citizen science project: the furthest participant is located roughly 44km from the nearest selected participant. Although this is an interesting finding of the research, since they are participants who record data alone in their community, it is not possible to perform any kind of cluster-based quality control analysis on their data.

Kathmandu's pipe network is fed by different structures and reservoirs. A layer was added to the participant map to represent the different supply schemes serving that area. Since KUKL itself does not have accurate locations of its supply schemes, the map below was created from multiple sources, including from KUKL's online water distribution schedules which were translated from Nepali by Prof Tripathi (ADB, 2010; KUKL, n.d.; Shrestha et al., 2017). Each shaded area of the map corresponds to a supply scheme (Figure 21).



Schedule

- 24h/1d (wet) or /3d (dry)
- 1-3h/1-2d (wet) or /3d (dry)
- 1-3h/4d (wet) or /8d (dry)
- 1-3h/4d (wet) or /8d (dry)
- 1-8h/3d (wet) or /5d (dry)
- 1-2h/4d (wet) or /6d (dry)
- 0.5-2h/1-12d
- 1-3h/3d (wet) or /4d (dry)
- 1-3h/1-3d (wet) or /1-4d (dry)

Community

- 📍 Surabinayak
- 📍 Bandol
- 📍 Kopan
- 📍 Lalitpur
- 📍 Kathmandu Center
- 📍 Tarakeshwar
- 📍 Madhyapur Thimi
- 📍 Changunarayan
- 📍 Pida, Kirtipur, Bhimtar, Nagarjun

Figure 21. Curated map of participants and water schedules

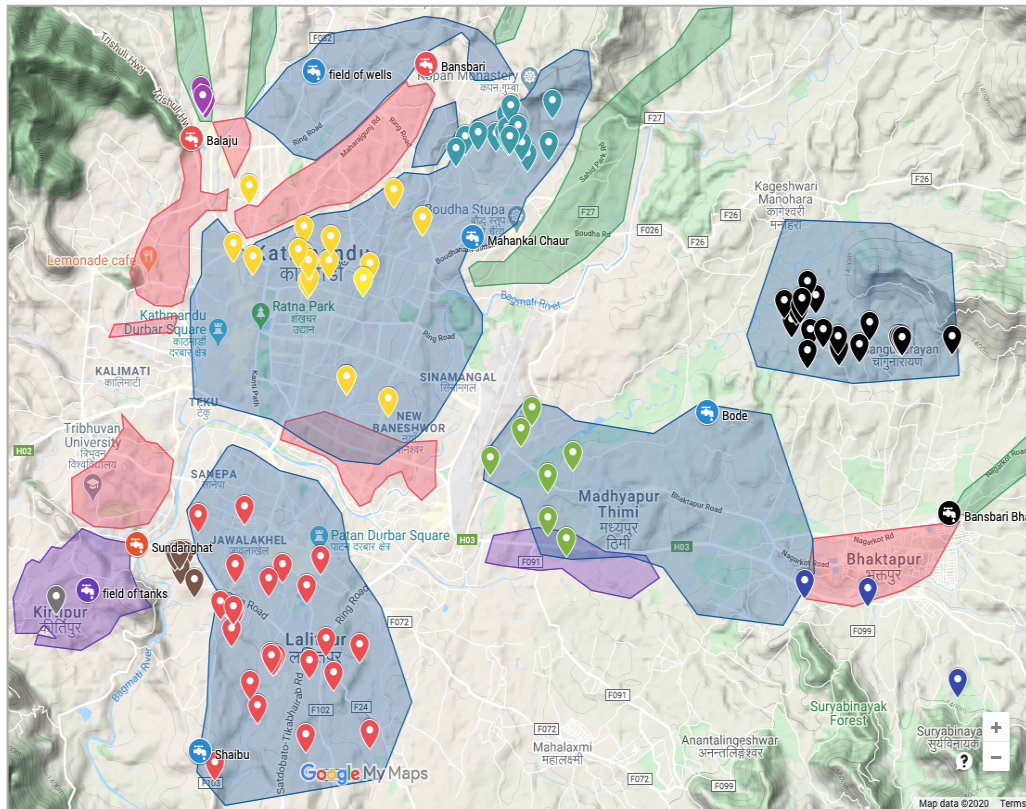
Each scheme is fed by different primary reservoirs, which in turn may feed secondary reservoirs in the service area (Table 5).

Table 5. Supply schemes as fed by reservoirs

Scheme	Primary Reservoir	Units	Capacity (m³)
 24h/1d (wet) or /3d (dry)	Mahankal Chaur	3	4500 2000 2000
 1-3h/4d (wet) or /8d (dry)	Bansbari	1	2000
 1-3h/4d (wet) or /8d (dry)	Balaju	1	3600
 1-2h/4d (wet) or /6d (dry)	Sundarighat	1	800
 1-3h/3d (wet) or /4d (dry)	Sainbhu	2	2700 2700
 1-3h/1-3d (wet) or /1-4d (dry)	Bode	2	500 500

The participants were clustered per community, and in such a way as to also overlap with the closest distribution schedule area Figure 22. It should be noted that the participants from the Bandol community do not appear to fall under a specific scheme. Although each scheme has a slightly different water schedule, it is possible to simplify the schedule layer of the map by

ignoring the hours of supply and focusing only the days of supply in the wet season, June through September, which is when this project was conducted. In all cases, the hours of supply in Kathmandu are disreputably not kept to. This reduces the schedule to: every day, between one to 3 days, every four days, and anywhere up to 12 days.



Schedule	Reservoir	Community
/3d (wet)	 Sundarighat	 Surabinayak
/4d (wet)	 Mahankal Chaur	 Bandol
/1d (wet)	 Bansbari	 Kopan
0.5-2h/1-12d	 Balaju	 Lalitpur
	 Bode	 Kathmandu Center
	 Sainbhu	 Tarakeshwar
	 Bansbari Bahktapur	 Madhyapur Thimi
	 Field of tanks	 Changunarayan
	 Field of wells	 Pida, Kirtipur, Bhimtar, Nagarjun

Figure 22. Simplified map of project locations and water supply schedules in the wet season

The final data set covered 82 km² through 110 participants from 12 communities who collectively amassed 816 data points.

The number of participants per community varied between one and 24 participants per community (Figure 23).

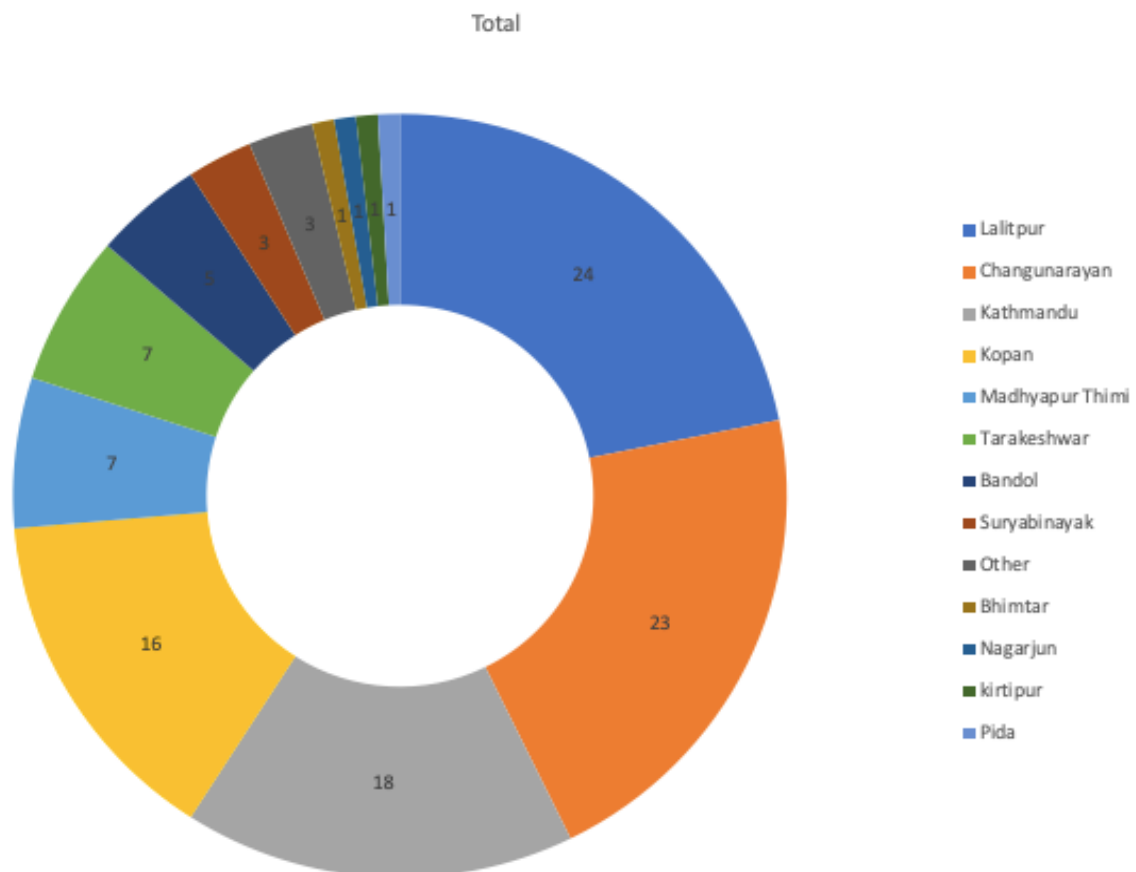


Figure 23. Respondents per community

Although every effort was made to reach the entire population of each community during meetings, it was known that not everyone in the community would be reached, and even fewer would participate. However, it was hoped that the number of participants that were successfully recruited per community would be proportional to the size of the community's population (Table 6). This was not the case. For example, Lalitpur is one of the largest

communities in Kathmandu, and a proportionally large number of people joined the project. In contrast, Changunarayan is one the smallest communities that were approached in Kathmandu, but it contributed as many persons as Lalitpur. This suggests that the number of participants is indicative of the level of interest in the project and not of the size of a community.

Table 6. Population per community (Central Bureau of Statistics, 2012)

Community	Population
Changunarayan	6 211
Kopan	48 463
Kirtipur	67 171
Madhyapur Thimi	84 142
Lalitpur	226 728
Kathmandu	1 003 285
Tarakeshwar	NA
Surabinayak	NA
Bandol	NA

The research first sought to establish the level of engagement of participants by investigating the level of participants desisting from the study i.e. drop-outs. A drop-out participant was defined as a participant who collected only one piece of data. The number of drop-out participants constituted a mere 3.8% of the total data set i.e. 31 entries from 31 participants (Table 7).

Table 7. Extracted app meta-data for single-entry inputs

ID	Date	Sex	Age (years)	Community	Frequency of supply
111111114	11-Jun-19	Female	18-25	Lalitpur	3-5 days
222222228	19-Mar-18	Male	NA	Kathmandu	NA
333333332	7-Jun-19	Male	NA	Madhyapur Thimi	NA
333333338	16-Jun-19	Male	NA	NA	NA
444444442	19-Mar-18	Female	NA	Kathmandu	NA
444444443	12-Jun-19	Female	NA	Kopan	NA
444444445	7-Jun-19	Male	NA	Madhyapur Thimi	NA
444444446	7-Jun-19	Female	NA	Kathmandu	NA
444444448	8-Jun-19	Male	NA	Nagarjun	NA
555555555	11-Jun-19	Female	26-55	Lalitpur	2 days
555555558	16-Jun-19	Female	NA	Kathmandu	NA
555555559	22-Mar-18	Male	18-25	Changunarayan	1-2 weeks
666666661	24-Mar-18	NA	18-25	Madhyapur Thimi	1 day
9803055109	7-Jun-19	Female	18-25	Kathmandu	1 day
9813470343	10-Jun-19	Female	26-55	Lalitpur	1 week
9841334843	11-Jun-19	Female	26-55	Lalitpur	2 days
9841438608	10-Jun-19	Female	26-55	Kopan	1-2 weeks
9841507800	22-Jun-19	NA	NA	Lalitpur	NA
9844100555	11-Jun-19	NA	NA	Lalitpur	NA

9846318021	11-Jun-19	Male	Over 55	Kathmandu	1-2 weeks
9849044825	11-Jun-19	Male	26-55	Kopan	3-5 days
9849221594	11-Jun-19	Male	26-55	Bandol	3-5 days
9851016674	16-Jun-19	NA	NA	Tarakeshwar	NA
9851089898	11-Jun-19	Female	26	lalitpur	1 day
9851234578	11-Jun-19	NA	NA	Lalitpur	NA
9860316389	9-Jun-19	Female	26-55	Kopan	1-2 weeks
9860332246	16-Jun-19	NA	NA	Kathmandu	NA
9861702277	11-Jun-19	NA	NA	Bandol	NA
9861702323	11-Jun-19	NA	NA	Lalitpur	NA
9865057621	10-Jun-19	Female	NA	Kopan	NA
9869529724	10-Jun-19	Male	25	lalitpur	3-5 days

There was a large amount of missing meta data for age, gender and declared frequency of water supply. Only 14 of the 31 drop-out participants indicated their frequency of water supply in the survey. In it, they claimed that they received water at least once every two weeks, so although it is very possible that some participants receive water only once a month, this is not the case for these single-entry participants. To confirm this through the data, it is possible to compare these entries to others in the same community. Sorting the participant per community reveals that Lalitpur was the community with the most single-entry participants, 10. Kathmandu was second with 7 single-entry participants. Lalitpur totals 95 entries from 24 participants, so withdrawing the single-entries leaves 85 entries from 14 participants, or an average of 6 entries per person. Repeating the process for Kathmandu

yields an average of 17 entries. Hence, the single-entries were anomalies in their communities, and it is therefore extremely likely that they were the result of individual participants deciding to end their participation.

The highest percentage of drop-out participants constituted 32% of the drop-out group and were located in Lalitpur. Out of 31 drop-out participants, 23 indicated their gender, and only 9 indicate their age. Sorting the participants per gender reveals that 13 were female, 10 were male, and 8 were unknown. Sorting the participants by age reveals that the majority of drop-outs (9 out of 13) who declared their age are between 25 and 55 years old. However, since there was a large number of participants who declared neither age nor gender, it is not possible to speculate about the role of these characteristics in the drop-out rate.

The research then sought to establish the level of engagement of participants by investigating the uptake rate of the study. The uptake rate was defined as the number of new recruits per unit time, from the start of the project until a peak is first reached. The rate of uptake is relative to the number of participants joining the project for the first time and is not related to the water service level. It is however related to the project's initiation date - since it had been arranged to visit each community in turn to initiate the project, the participants were not all recruited at once and data collection did start at the same time for all participants (Table 8).

Table 8. Community outreach schedule and recruitment attainment

Community	Date first visited	Number of participants
Surabinayak	19/03/2018	3
Changunarayan	19/03/2018	23
Kathmandu metropolitan	07/06/2019	18
Madhyapur Thimi	07/06/2019	7
Nagarjun	08/06/2019	1
Kopan	09/06/2019	16
Lalitpur	10/06/2019	24
N/A	11/06/2019	3
Bhimtar	11/06/2019	1
Bandol	11/06/2019	5
Tarakeshwar	16/06/2019	7
Kirtipur	17/06/2019	1
Pida	22/06/2019	1
Total		110

As a result, Figure 24 displays a repetitive gradual uptake in participation numbers followed by a plateau. This pattern is featured in both the pilot and the full-scale phases.

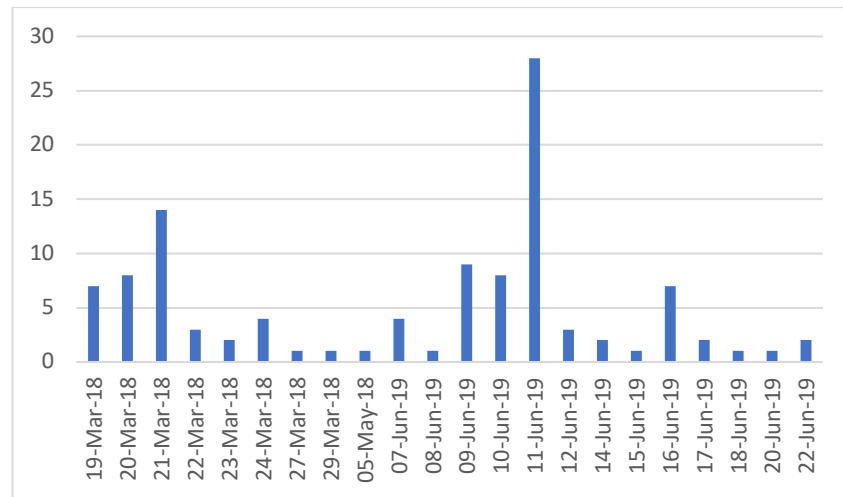


Figure 24. Number of recruits over time

Homing in on the 2018 data (Figure 25), there was only one peak of new recruits on the 21st of March 2018, which is to be expected as only one community was involved. The peak occurred two days after the initiation session and was followed by a slowly upward sloping plateau, as observed from the cumulative frequency graph. The overwhelming majority of participants (38 out of 41) joined the study within the first six days of the project, though three more participants were acquired in subsequent weeks (as shown by the bar chart), with the entire participant recruitment spanning over 8 weeks.

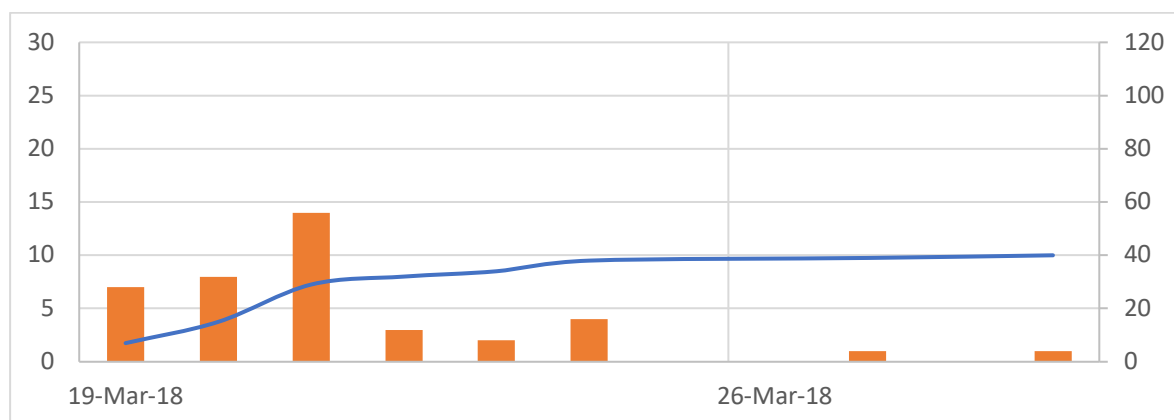


Figure 25. Cumulative Frequency Graph (blue) of citizen recruitment numbers (orange) for the pilot project,

2018

Unlike the 2018 data, the 2019 data shows two large peaks and a series of small peaks of new recruits, as would be expected from the staggered nature of the data collection (Figure 26). The largest peak occurred on the 11th of June. This is concurrent with the end of the first week of community outreach, which involved five communities. It comes 4 days after the visits to Kathmandu centre and Madhyapur Thimi, three days after the visit to Nagarjun, two days after the visit to Kopan, and one day after the visit to Lalitpur. The peak also coincided with the visits to Bhimtar and Bandol. It is possible to observe smaller peaks at the two-day mark following a community visit. The peak was immediately followed by a slowly rising plateau, leading up to the second peak.

Surprisingly, the second large peak in joining participants did not occur at the end of the second week of community outreach, which this time only involved three communities. It came instead on the 16th of June, four days after the visits to Bhimtar and Bandol, and on the same day as the visit to Tarakeshwar. This second peak is smaller than the first as by then, only one more community had been reached. However, the plateau which follows this peak presents a steeper incline as the previous one, as visits continued to two more communities, Kirtipur and Pida, on the 17th and 22nd of June.

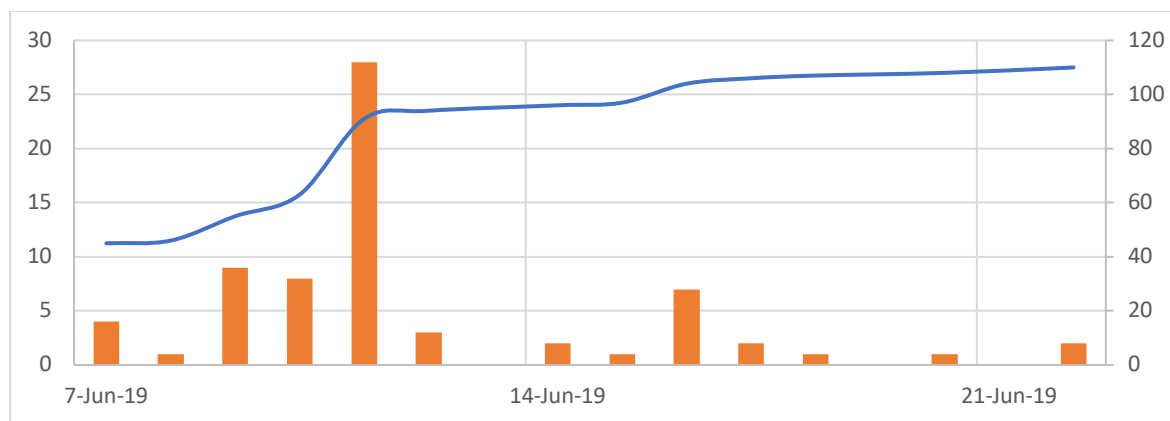


Figure 26. Cumulative Frequency Graph (blue) of citizen recruitment numbers (orange) for the full-scale phase of the study, 2019

The participant joining process was more efficient in 2019 than 2018, undoubtedly thanks to the improvements made to the methodology based on the experience from the 2018 pilot phase. In 2019, recruitment spanned two weeks and counted 69 people, whereas in 2018 it lasted six more weeks and recruited only 41 people. In conclusion, with the optimised methodology the uptake-rate can reach five users per day.

Although data was recorded until the 9th of July 2019 – two weeks after the study end date – 90% of responses for the full-scale project were collected between the 8th and the 26th of June 2019. These dates are very much in line with the study timeline: the 8th is the first day after the first community was reached, and the 26th is nearly two weeks after the last community with significant enrolment was reached (i.e. Tarakeshwar, with seven participants – the following communities were Kirtipur and Pida, both of which had only one participant).

Figure 27 charts all of the data collected by the participants over time. The entries are classified as belonging to a particular community, each of which is allocated a colour. By

breaking down the data in this way, the staggered uptake in participants is clearly visible from the waves of colours on the plots. Looking at the whole data set over time, the typical pattern is first a gradual uptake in participation, followed by a plateau and finally a gradual decline in participation, as might be expected.

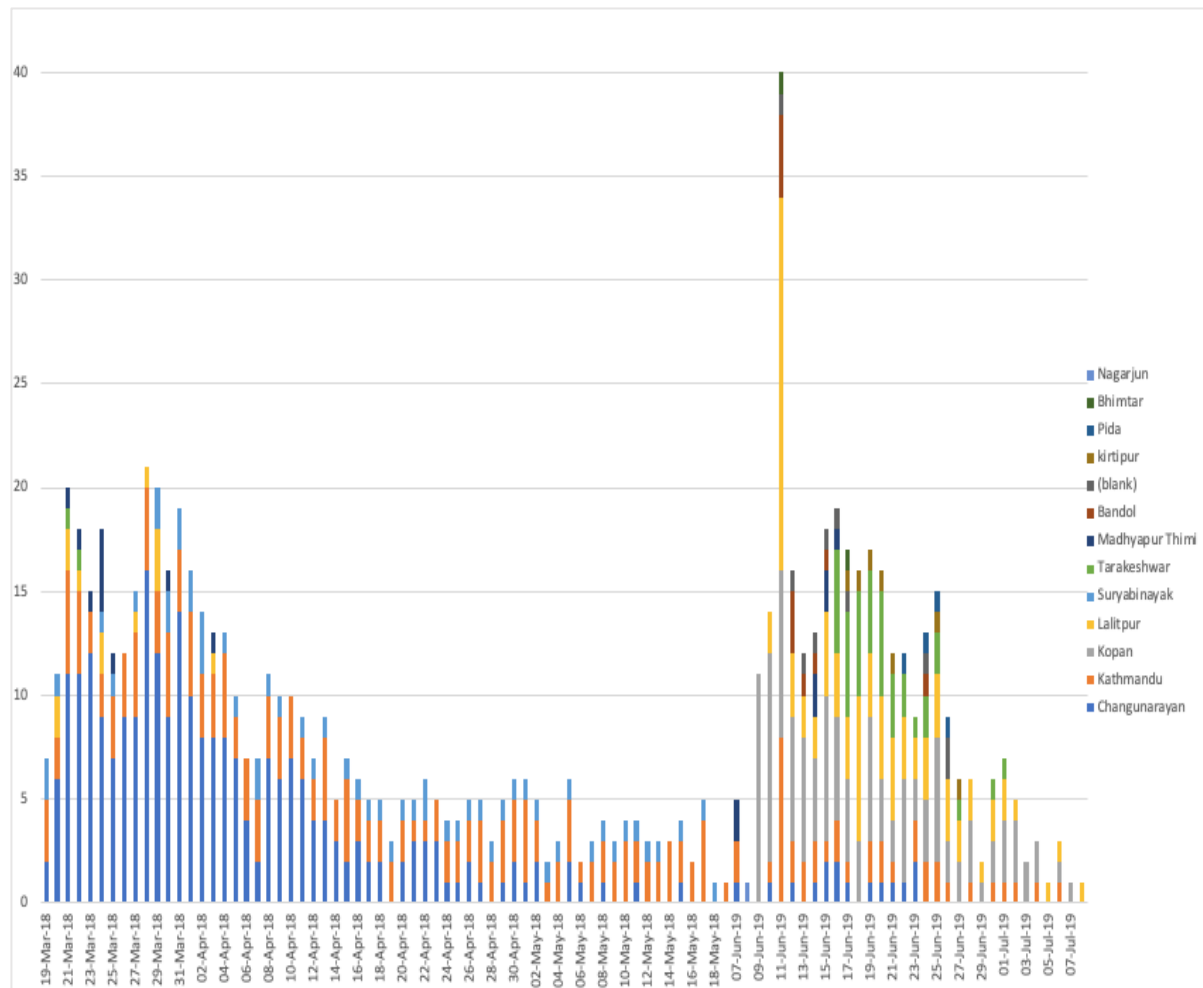


Figure 27. Rolling community uptake in data collection

Moreover, it can be observed that the two highest contributors to the total data-set were Changunarayan, which contributed 32%, and Kathmandu, which contributed 24% (Figure 28).

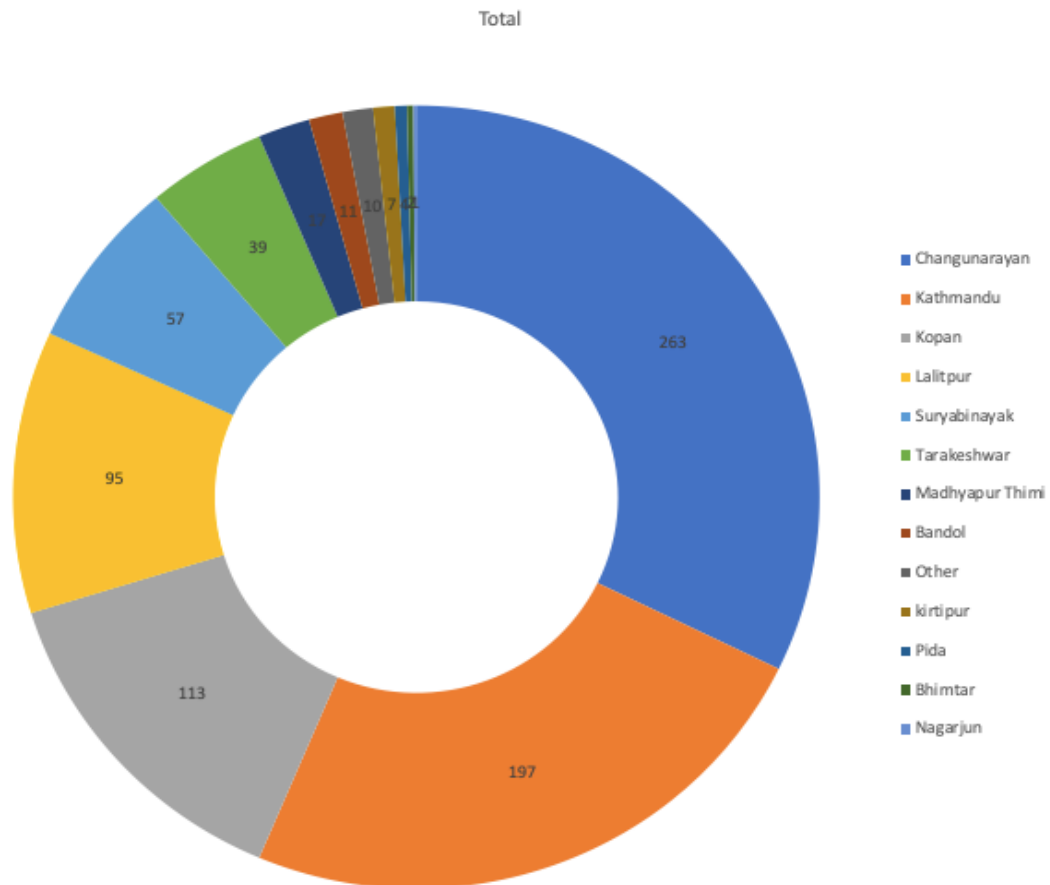


Figure 28. Contribution of each community to the final data set

Overall participation per person averaged 7 entries, however some communities (e.g. Surabinayak and Kathmandu metropolitan, hereafter referred to as “Kathmandu”) collected more data per person than others. As expected, the number of entries collected is strongly positively correlated to both time and the number of participants, as confirmed by the Spearman’s rank coefficients of 0.76 and 0.73 respectively (

Figure 29, Figure 30). The variables are not perfectly correlated as the number of entries relies not only on the number of participant or time in itself, but also how many times they physically use the app, i.e. a citizen could participate over a long time period without recording many data points. However, it is worth noting that the data shows that participants who participate the longest also record the most, irrespective of their level of intermittency.

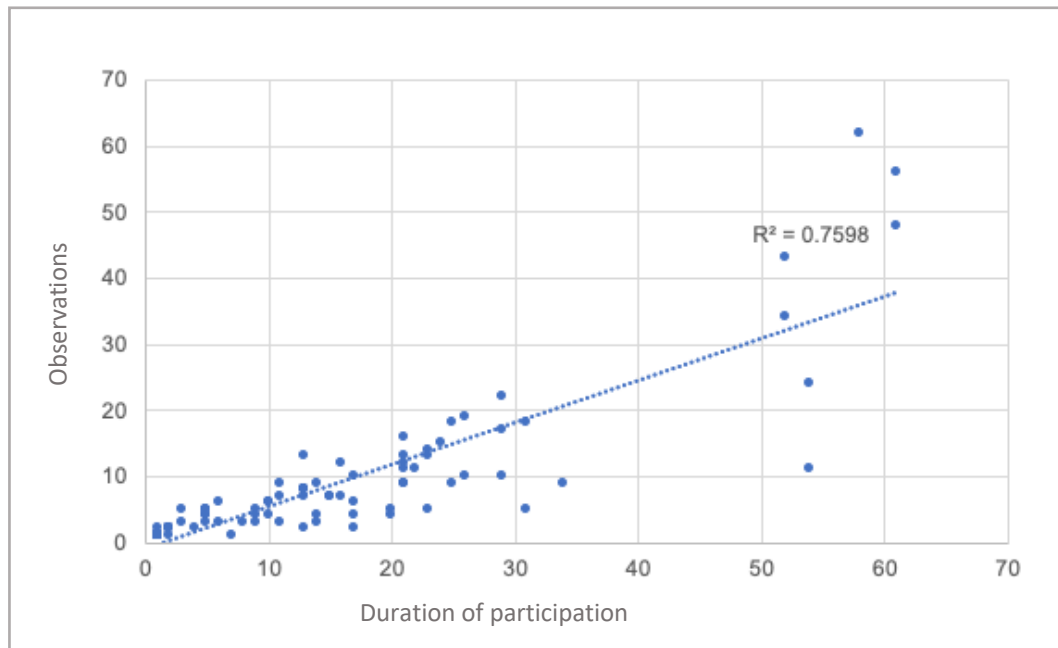


Figure 29. The correlation between number of observations and duration of participation, with each data point representing an individual participant

The expectation is clearly that the more participants are in a community, the more entries are recorded. However, it is interesting to note that this is not always the case: some communities had a high number of participants but did not exhibit a proportionally high number of entries.

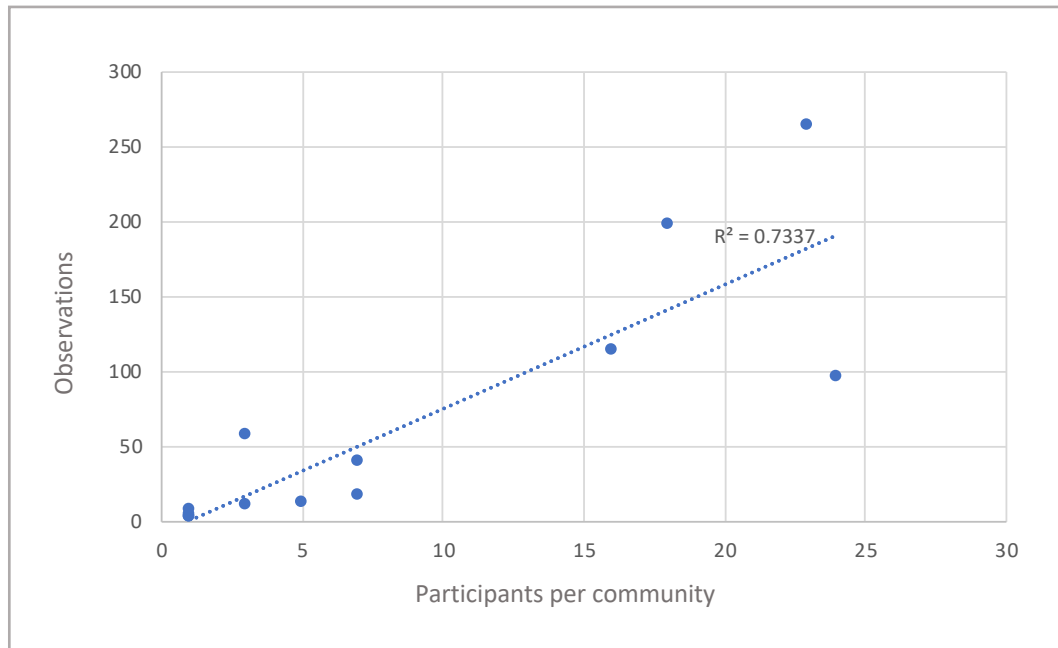


Figure 30. The correlation between the number of entries collected and the number of participants collecting them, with each data point representing a separate community

The research sought to establish whether the data set was built from unique entries, or whether some participants input multiple (repeat) entries a day. This also served to establish whether participants had followed instructions correctly. To do this, the IDs of the users were combined with their level of participation for each day, and the results were plotted. Each user was categorised as entering one of three entry types – unique entries (blue), second entries (orange) and third entries (grey). These points were then plotted on Figure 31, which displays the number of entries per day, broken down into entry type.

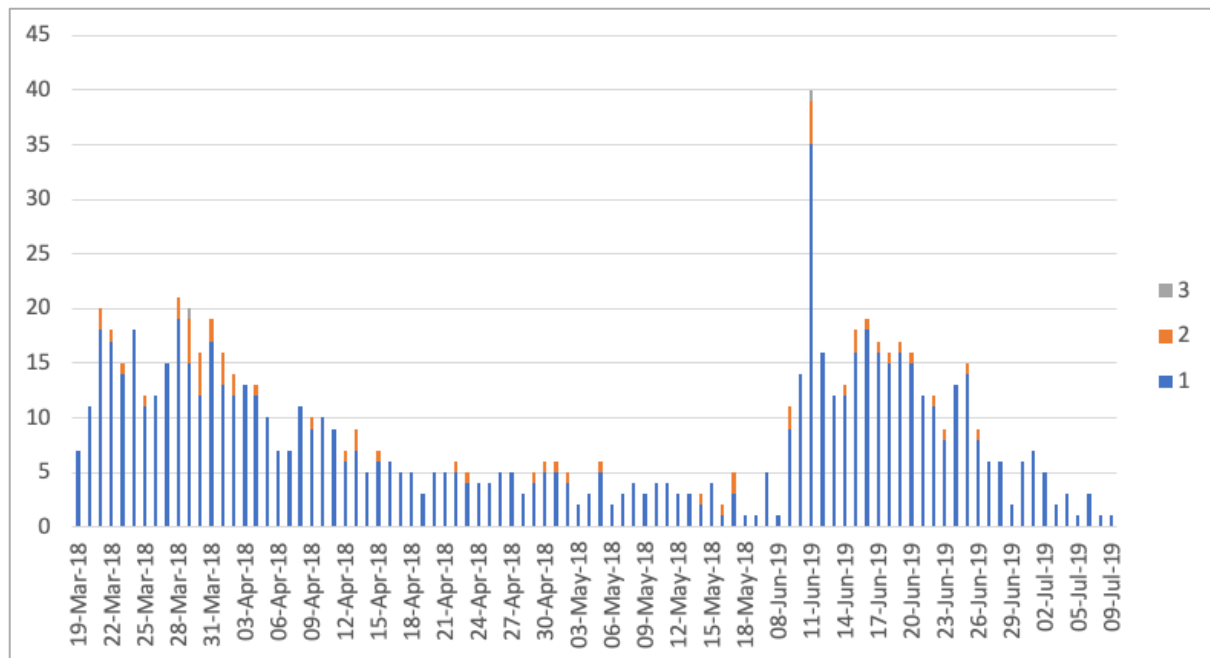


Figure 31. Data inputs per day in, broken down into unique entries (blue), second entries (orange), and third entries per day (grey)

Unique entries clearly dominate graph, affirming that people typically only report once a day, and that there is a very small proportion of people who report *more* than once a day. Since not everyone reports every day, this suggests that people either participate once on a particular day, or do not participate at all on that day. This supports the assumption that people only report when they are prompted to, i.e. when the water supply does not behave as they expect, which furthermore is not suggestive that those participants who report more than once with different answers (i.e. once indicating there is water and another time indicating that there is not water) are lying nor mistaken. As may be expected from the previous analysis, the peak in number of entries coincide with the peaks in the number of recruits, the 21st of March 2018 and the 11th of June 2019 respectively.

The research then sought to deepen this understanding by establishing whether the data set was built from unique users, or whether it is always the same participants inputting data over time. To understand the distribution of types of users over time, the research matched the IDs of users to their recorded number of inputs, according to categories: users who logged under five entries, between five and nine entries, between 10 and 20 entries, and over 20 entries, across the duration of the study (Table 9).

Table 9. Number of participants and their level of reporting

Number of reports	Number of participants
>20	6
10 – 20	18
5 – 9	24
<5	62
Total	110

The table shows that a substantial amount of data was obtained by a small number of people. However, this was because these same people contributed the longest (even longer than was asked of them), not because their participation per day was higher than the other participants. This is indicated on Figure 32 by the blue and orange users, who reported all along their study time-lines and lingered on after the rest of participants stopped.

A difference in number of entries logged is noticeable on the graph, when the entries are broken down into the number of inputs, as shown by the colours. This difference was to be expected, as different communities experience different levels of intermittency, and this

would alter the participation level accordingly. However, in the case of the pilot-phase study, the participants mostly lived in the same community and share the same level of intermittency, so the discrepancy that can be seen in reporting during that period can only be explained by a difference in user behaviour and not in water supply. The role of intermittency in participation will be explored later in this chapter.

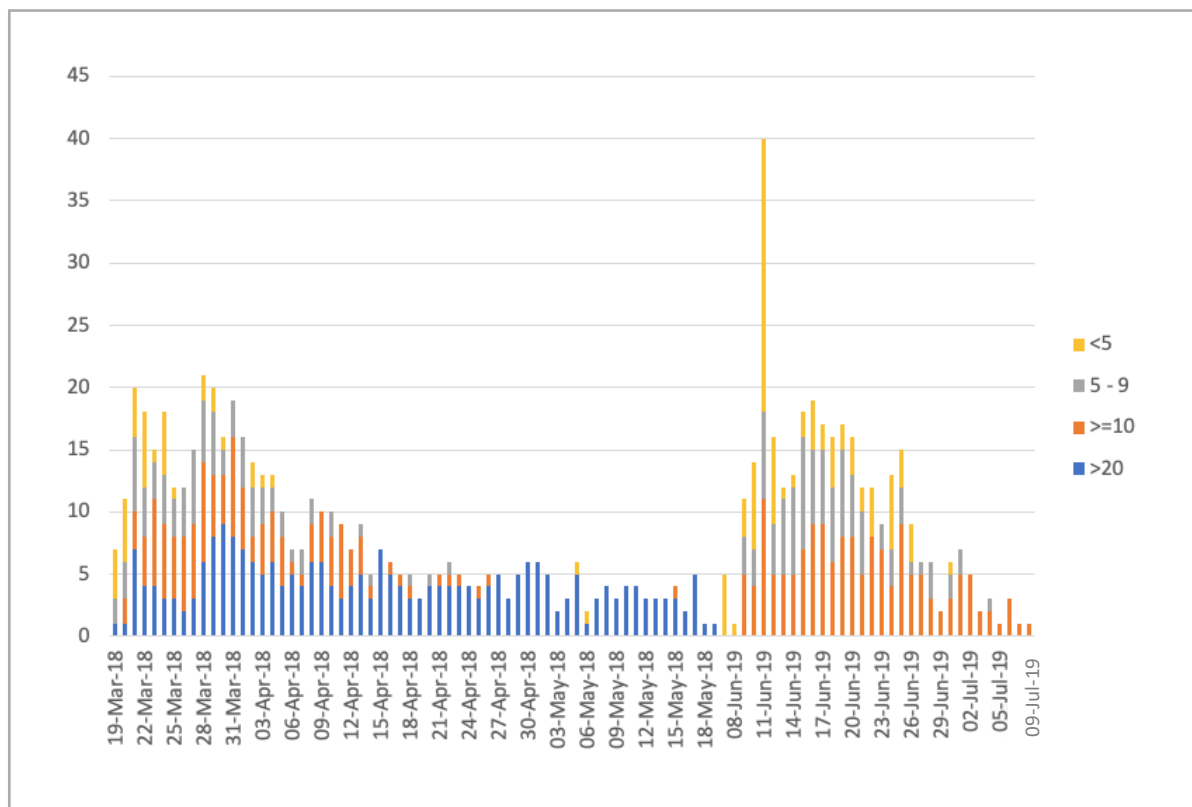


Figure 32. Total entries per day, as contributed by participants of various activity levels

Figure 32 illustrates that the proportion of entries logged by users who participated the least declined over time. In other words, at the beginning of the study (for pilot and full-scale phases) there was a high number of people who logged less, and those people tended to not continue collecting data beyond the time-frame asked of them. This is represented by the diminishing presence of the orange, grey and yellow bars after the end of the project. On the

contrary, those who participated the most were just as present at the start of the study as they were at the end, and even afterwards.

It was expected that there would be a pronounced drop off in responses when the first few communities started to reach their two-week mark. However, this was not observed in practice, possibly because many users chose to go beyond two weeks in both the pilot and the full-scale study. The graph clearly shows that even after the participants were told that the study had ended on the 28th of June 2019, 11% of citizens still continued to collect data, which ultimately resulted in an additional 5% overall contribution to the data set. These enduring participants came from Kathmandu, Lalitpur, Kopan and Tarakeshwar, and totalled 12. Since Lalitpur was visited on the 1st day of the study, it is worth noting that in practice those particular citizens collected two additional weeks of data – in other words, they participated twice as long as was asked of them.

It was investigated whether the participants would be encouraged to collect more data after the plateau stage, if they were stimulated. To that end, a prompt was sent out to the users on the 20th of June praising them for their contribution and encouraging them to continue. It was thought that this prompt would act as a stimulus and decrease the rate of decline in participation. However, as can be seen from the graph, it did not have had any discernible effect on the daily participation level, i.e. there was not more data collected than on the previous days, and the decline in data collection continued.

The main conclusions from the engagement analysis included:

- The methodology allowed coverage of 10 km² with approximately 13 participants.

- Word of mouth reached a distance in the range of 44 km in this study
- Worst-case scenario participant drop-out rate was 3.8%
- Uptake-rate could reach 5 users per day, using the recruitment methods employed
- People typically reported unique daily entries
- Participants performed better in a given time-frame: 90% of responses occur during a pre-communicated time-frame
- Beyond the given time-frame, prompts to continue are ineffective
- In the short term, daily participation does not vary significantly per participant
- In the long term, the data is dominated by a small number of 'super-participants'

In the second instance, the research sought to establish if any participant attributes – i.e. location, gender, age, income – made the method effective in generating data. The premise to participation is assumed to be either the participant's characteristics (e.g. age) or intermittency (e.g. they suffer from higher intermittency, which is linked to location).

This part of the research first sought to expose links between the level of intermittency recorded and patterns in the way that users recorded data.

Out of the total points recorded, 60% indicated the arrival of water versus 40% which indicated the absence of the arrival of water (Figure 33).

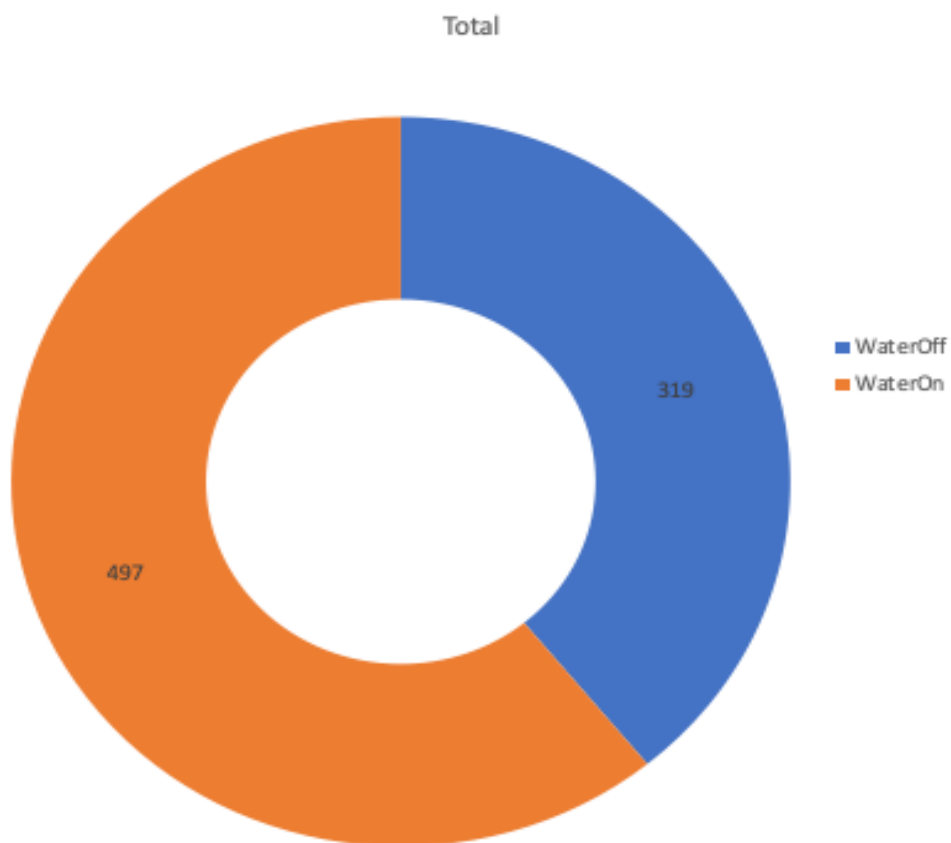


Figure 33. Intermittency records

The total data-set was plotted over time and then broken down into “water on” and “water off” entries Figure 34.

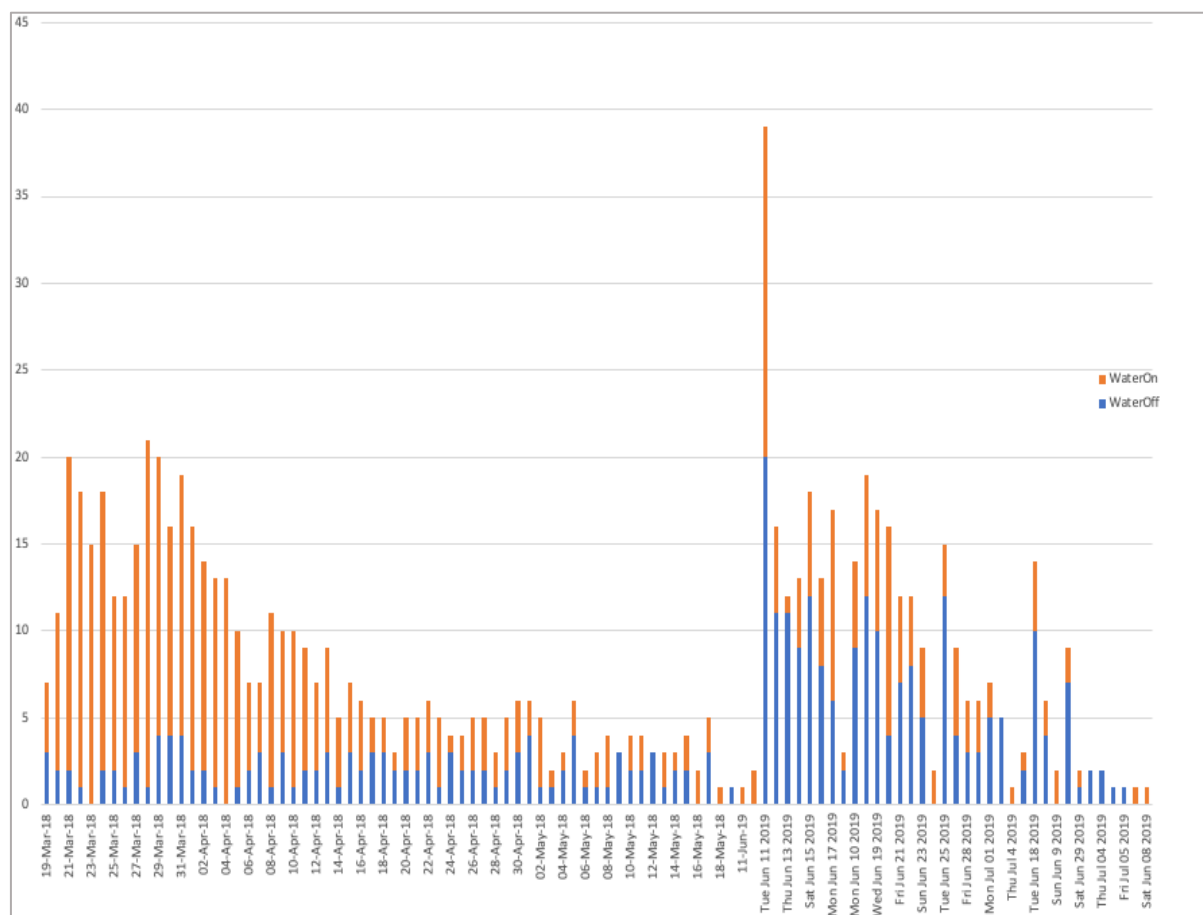


Figure 34. Time-line of data collection by entry type

Looking first at the entire graph, it is clear that the data recorded by participants from the pilot study was skewed towards a low intermittency rate, and inversely, the data recorded by participants from the full-scale study was skewed towards a high intermittency rate.

The occurrence of water green entries far outstrips the occurrence of water red entries throughout the pilot study (from the 19th of March 2018 to the 2nd of April 2018), and it is evident that these participants experienced the least intermittency of all, and so likely had the least motivation to participate. Those participants who adhered more tightly to the imposed time-frame reported only 6-9% of intermittency (expressed as a percentage of the data entries received).

To understand the distribution of types of users in the face of intermittency, the research once again matched the IDs of users to their recorded number of inputs, according to categories: users who logged under 5 entries, between 5 and 9 entries, between 10 and 20 entries, and over 20 entries, across the duration of the study. Only the participants who recorded more than 20 data points, i.e. who recorded data beyond the two weeks, also recorded more than 9% of their inputs as “water off” (Figure 35).

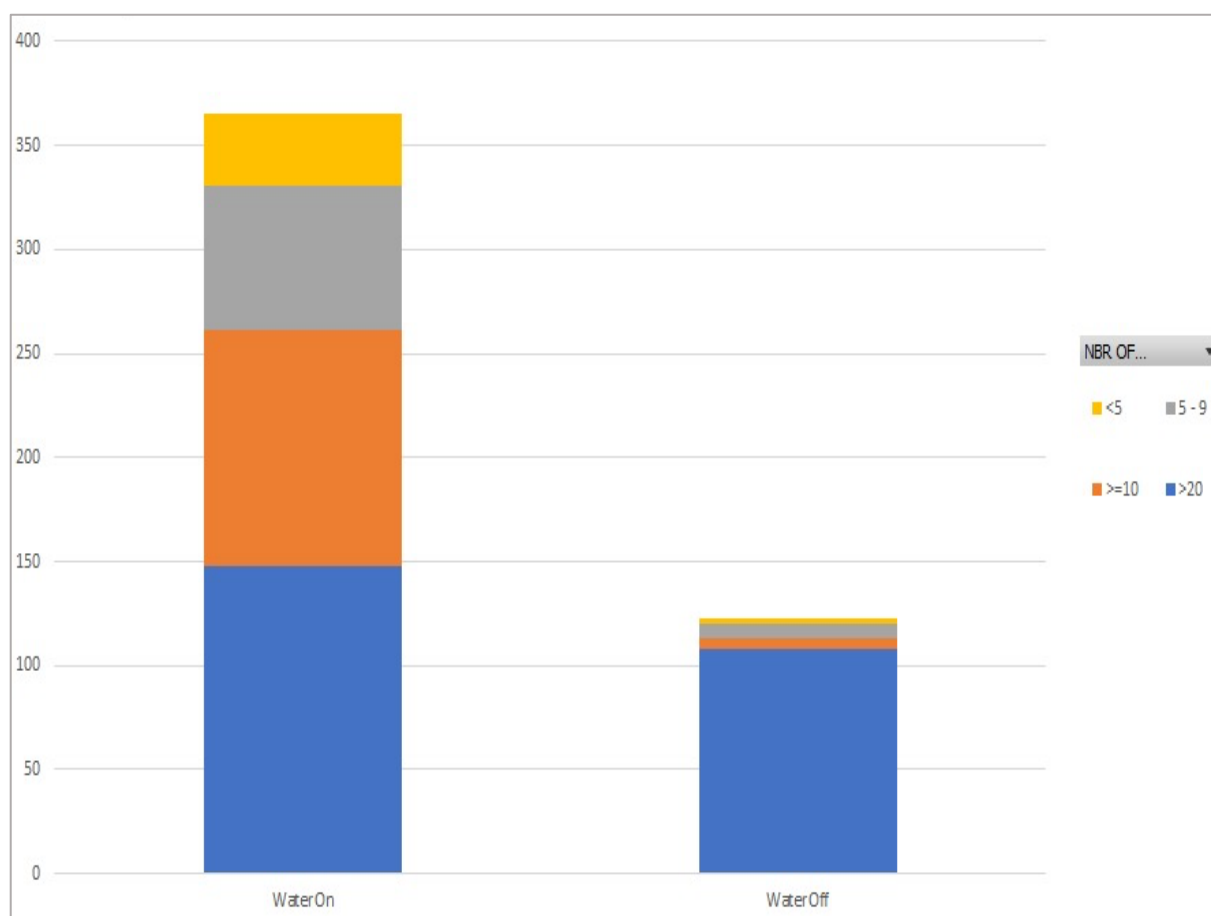


Figure 35. Number of water on and off entries per participant type, 2018

After the 2nd of April 2018, the occurrence of water green entries reduced significantly, because those people lacking intrinsic motivation stopped participating as soon as the study ended. It is possible to see that those participants who recorded the least stopped

participating before the other categories. Meanwhile, the occurrence of water red entries was maintained, suggesting that the participants who remained had been motivated by their lack of water supply all along. This data showed that nearly 90% of water red entries were reported by the same people who only reported 40% of water green entries (Figure 36).

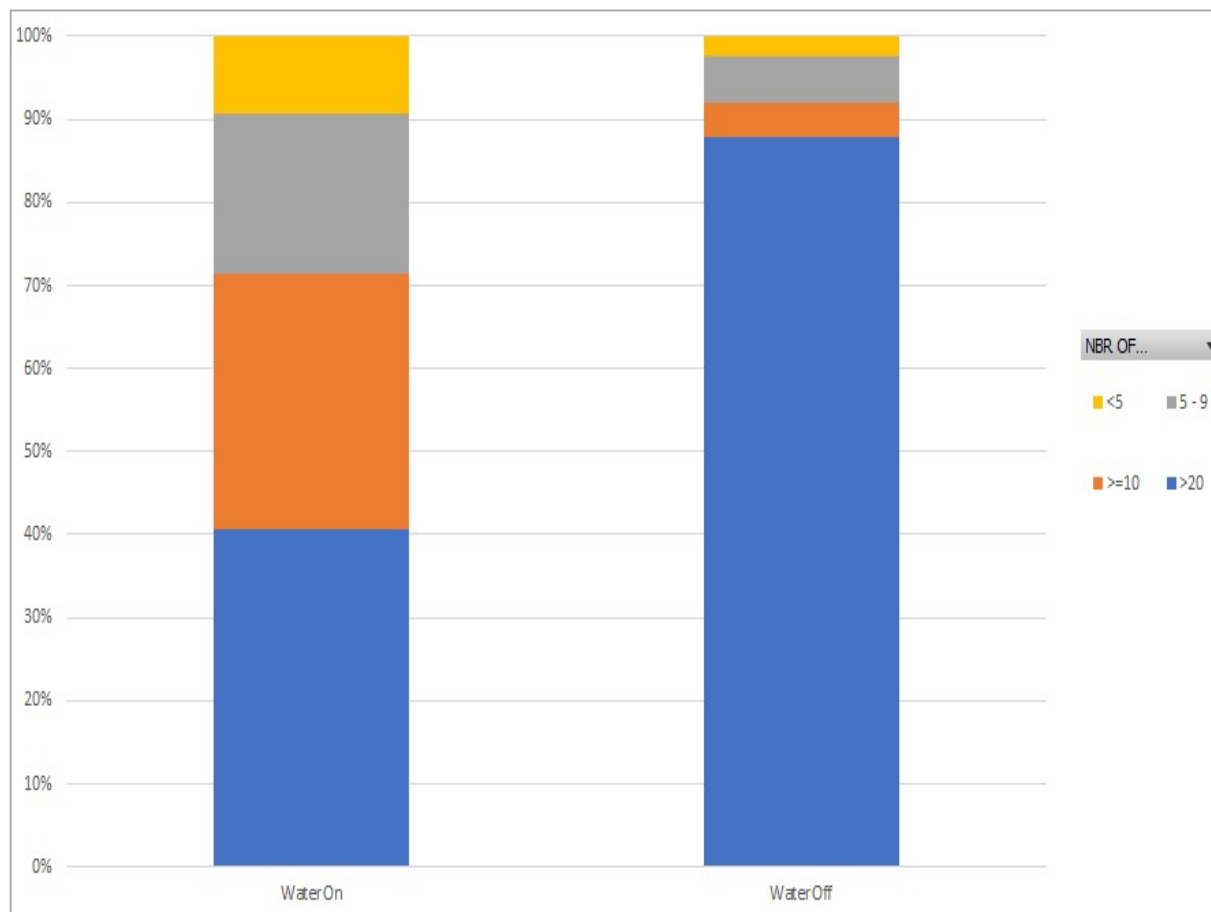


Figure 36. Categories of people report differently on the absence or presence of water, 2018

This absence of intermittency confirms the finding from the previous analysis - that it was user behaviour (i.e. motivation) which was responsible for the number of inputs per person. This absence of intermittency (which translates into a low level of participant motivation), combined with the fact the pilot recordings principally come from only two communities and that the data collection was not staggered, demonstrates the pilot data as a reliable base from

which to calculate an accurate “worst-case” decline rate in data collection. This stands at roughly -2 entries per day.

The full-scale study exhibits less of a disparity between levels of water on and water off entries, though the number of water-off entries dominated (Figure 37).

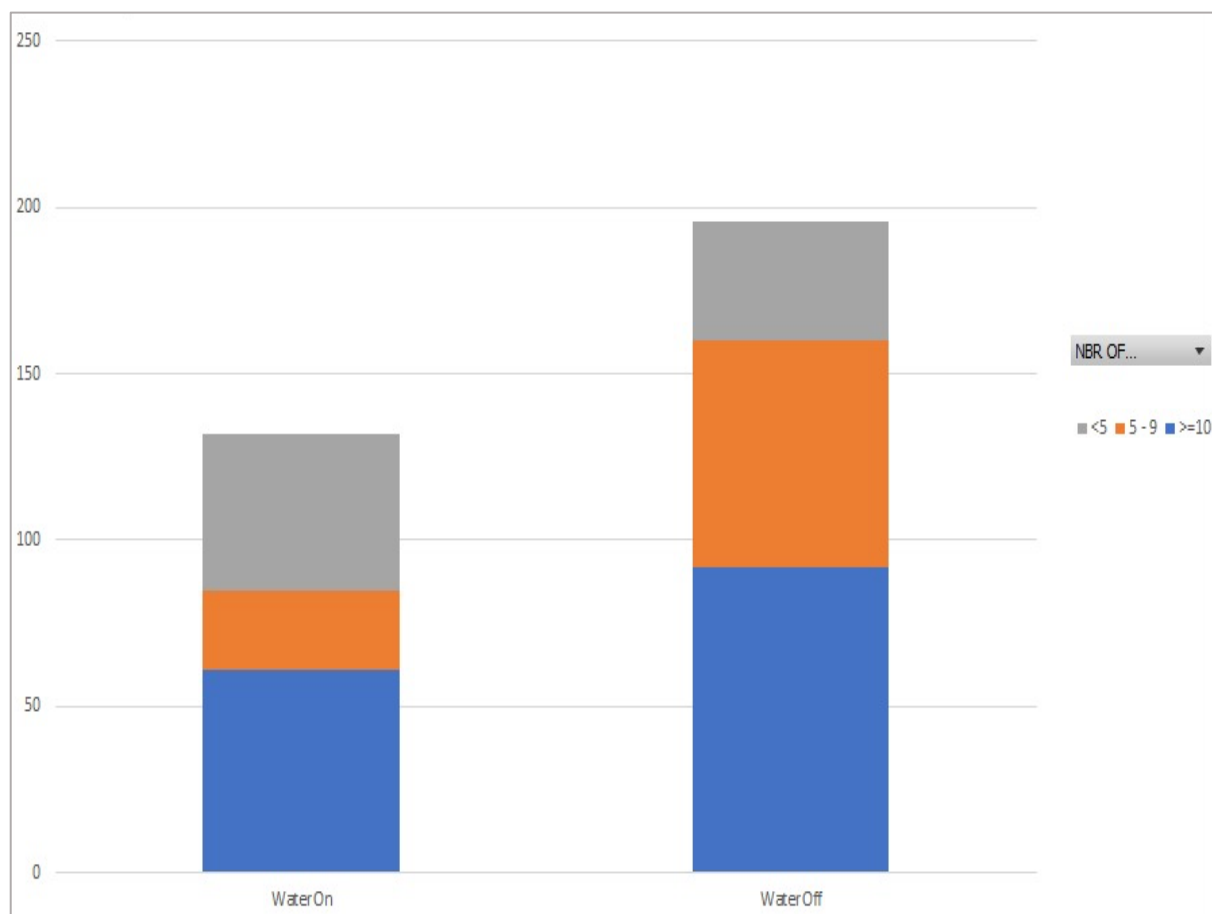


Figure 37. Number of water on and off entries per participant type, 2019

Interestingly, participants who exhibited the most intermittency, still reported nearly as much on their water supply arrival as they did on water supply failure - and more than any other group. This is reflected in the fact that about 45% of water red entries were reported by the same people who also reported 45% of water green entries (Figure 38).

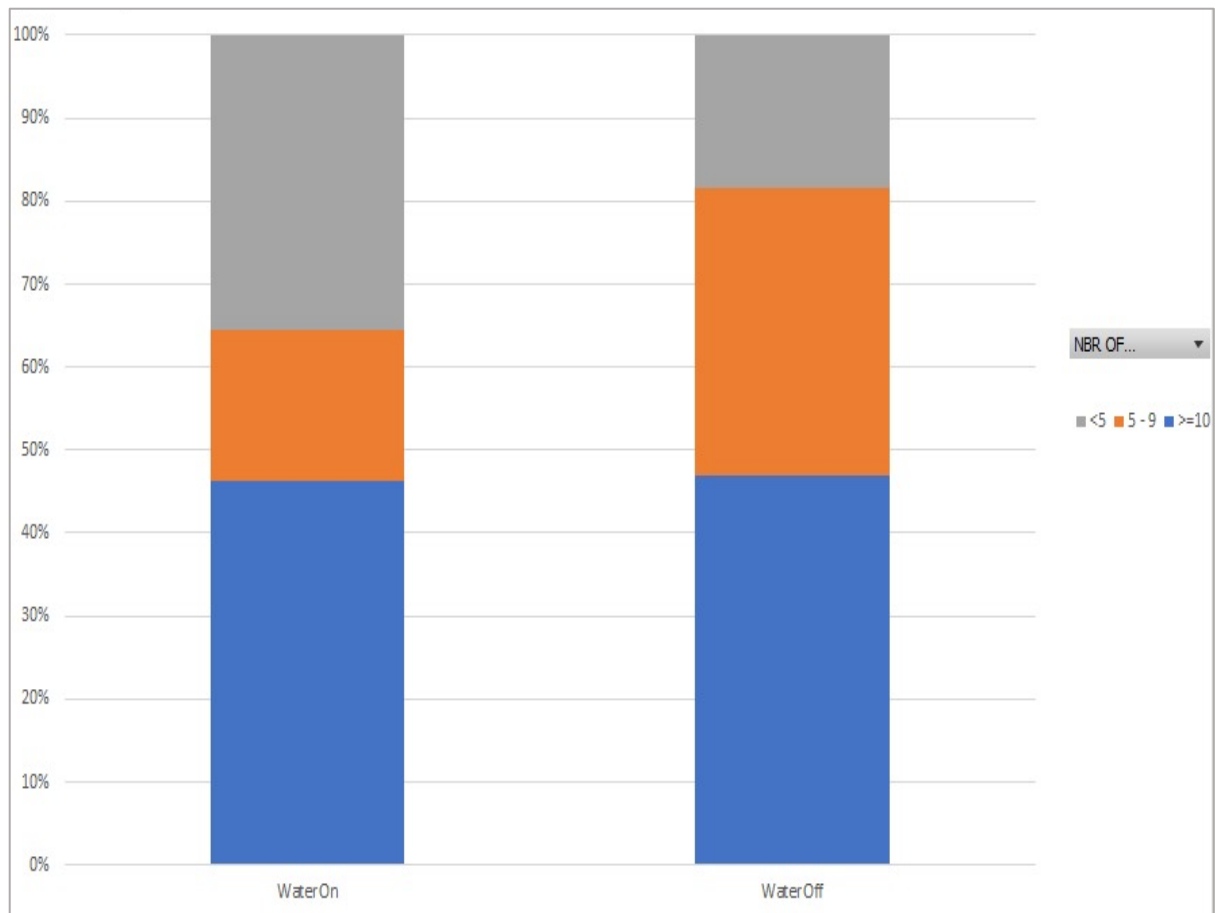


Figure 38. Categories of people Contribute differently on absence or presence of water, 2019

In conclusion, the numerical analysis shows that the type of user, in terms of number of data recorded, depends on the level of intermittency experienced. Participants exhibiting more water intermittency will participate the most, as confirmed by a positive Spearman's rank correlation coefficient of 0.5734 (Figure 39).

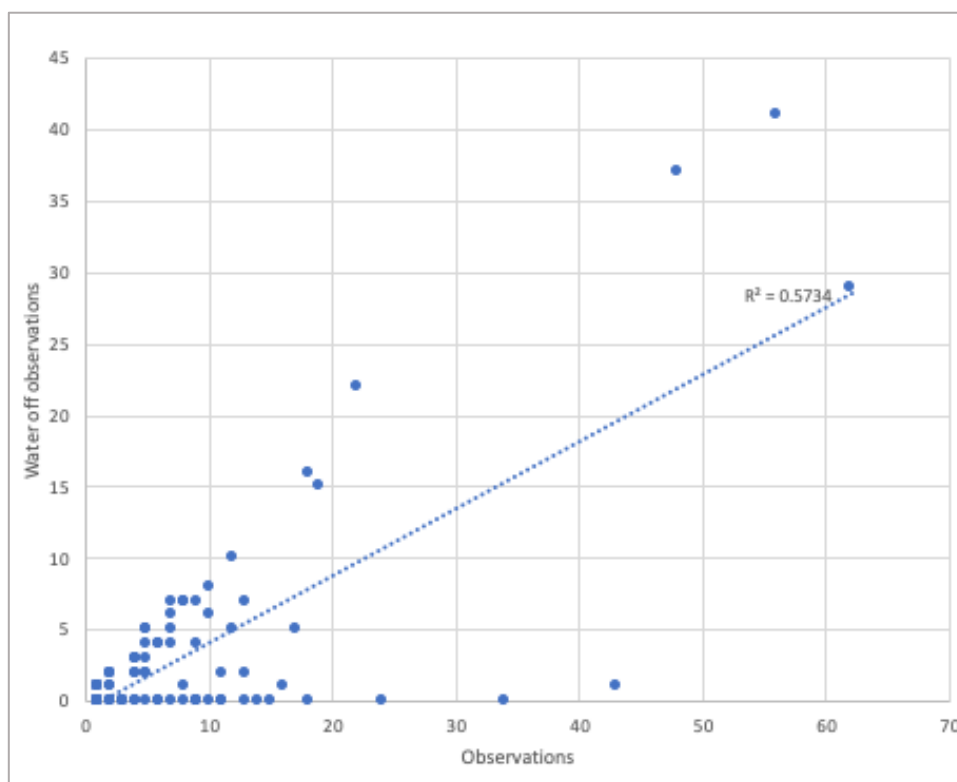


Figure 39. The correlation between intermittency and participation

To confirm this, we can further break down the data into community type, based on assumption that the intermittency level is pegged to location. Observing the level of water-on versus off entries reported by each community confirms that they indeed experienced different levels of intermittency. Kopan, Surabinayak, Bandol and Kirtipur all experienced over 60% of intermittency throughout the duration of the study although they are not located in proximity to one another (Figure 40).

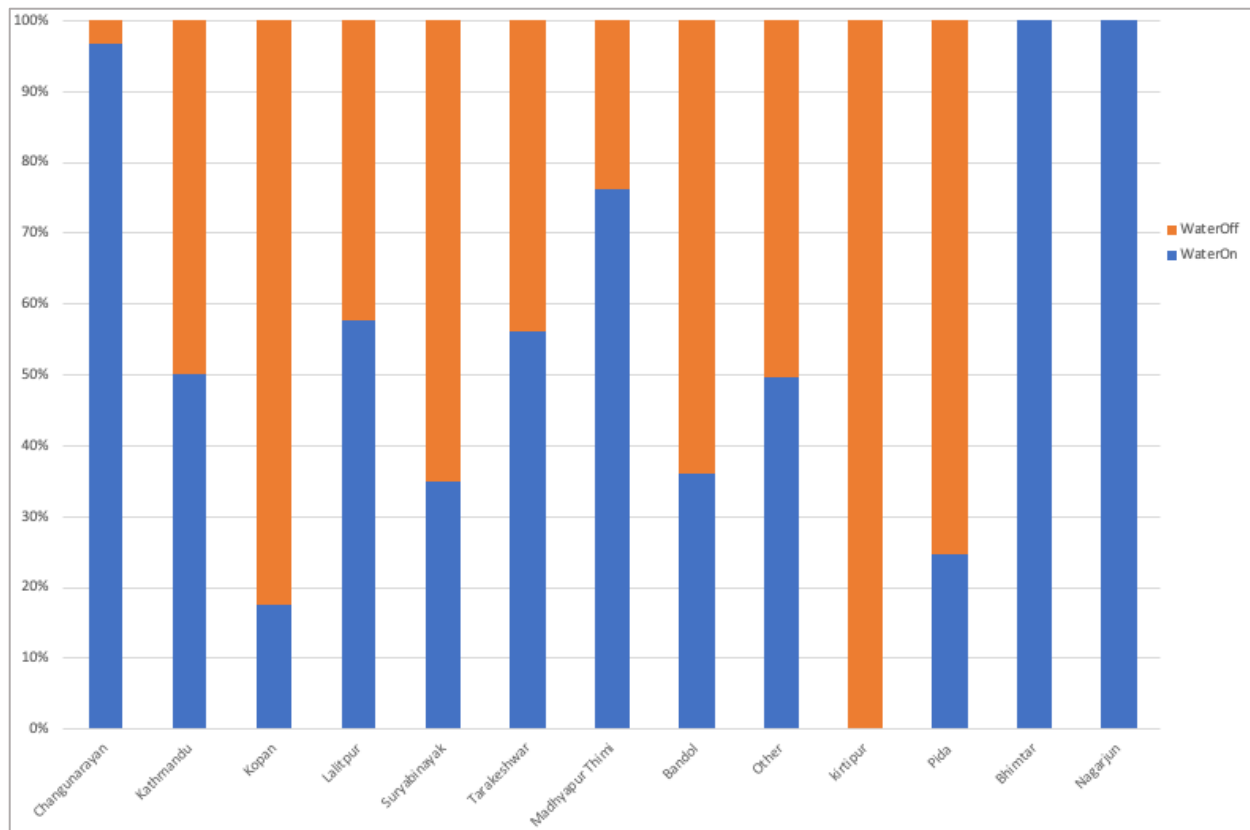


Figure 40. Intermittency level per community

This may be correlated to the distance from the participants to the tank that serves them, and to their elevation, although it was not possible to pursue this hypothesis as part of this research.

Following on from the previous analysis, it can be presumed that communities with higher records of intermittency should also contain the most devoted participants. To observe this, participants who collected over 20 data points should be disregarded, as this is indicative that they participated in both pilot and full-scale projects - so twice as long and not twice as hard.

Kopan emerges as the community with the most participants who collected over 10 points of data *and* the most entries indicating that water did not arrive (Figure 41).

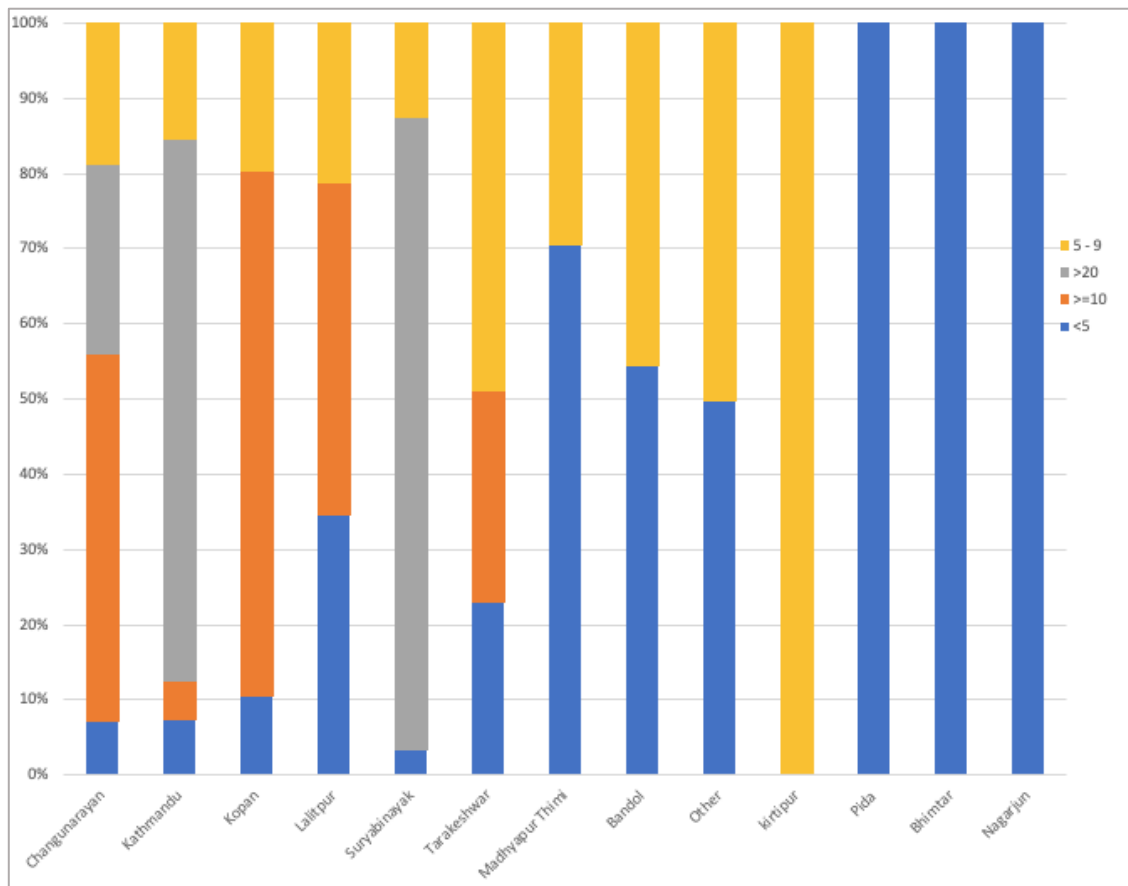


Figure 41. Response level per community

Moreover, Kopan also displayed the largest inequality between the number of intermittencies recorded and the number of water arrivals recorded (Figure 42).

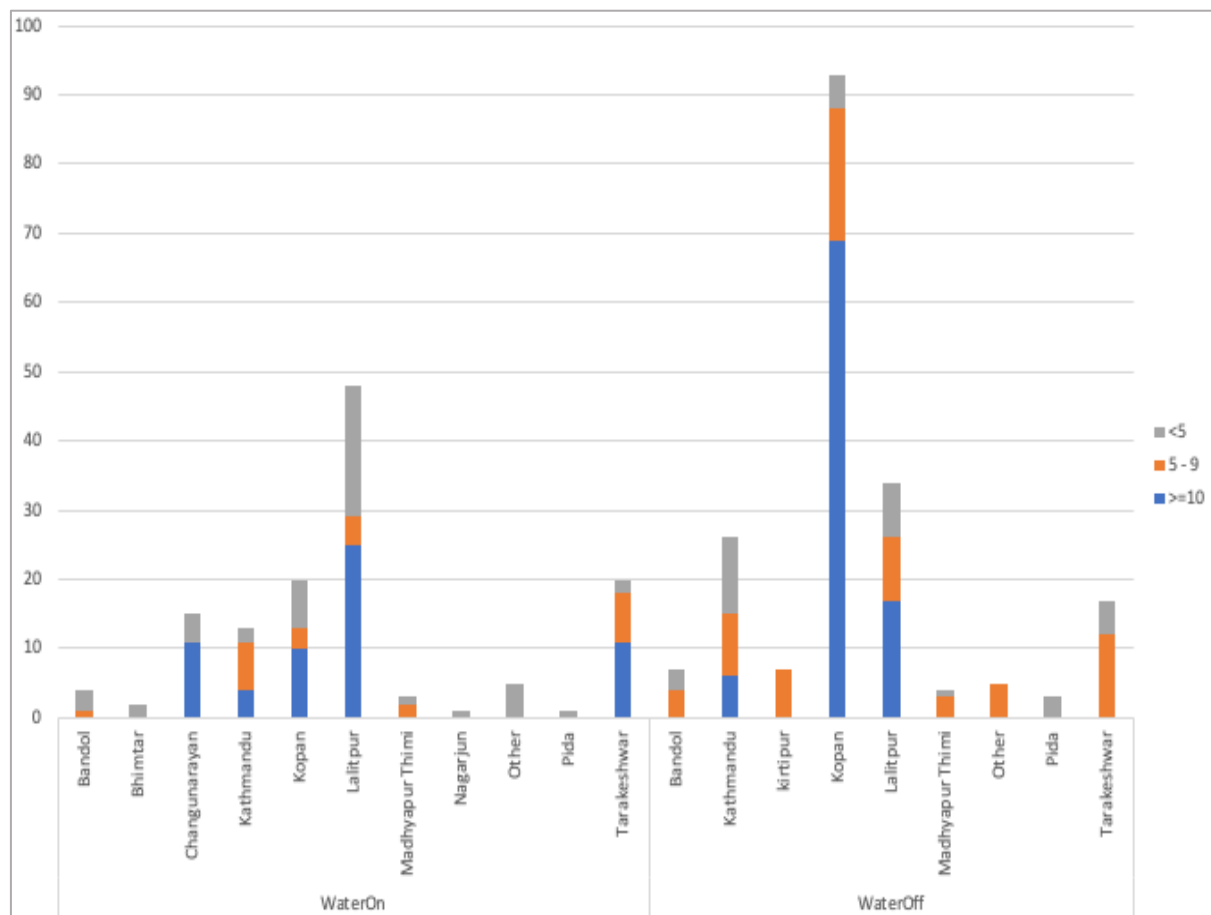


Figure 42. Response level per community per water entry type

Taking a closer look, Kopan also has one of the highest number of participants, regardless of participation type, second only to Lalitpur (Figure 43).

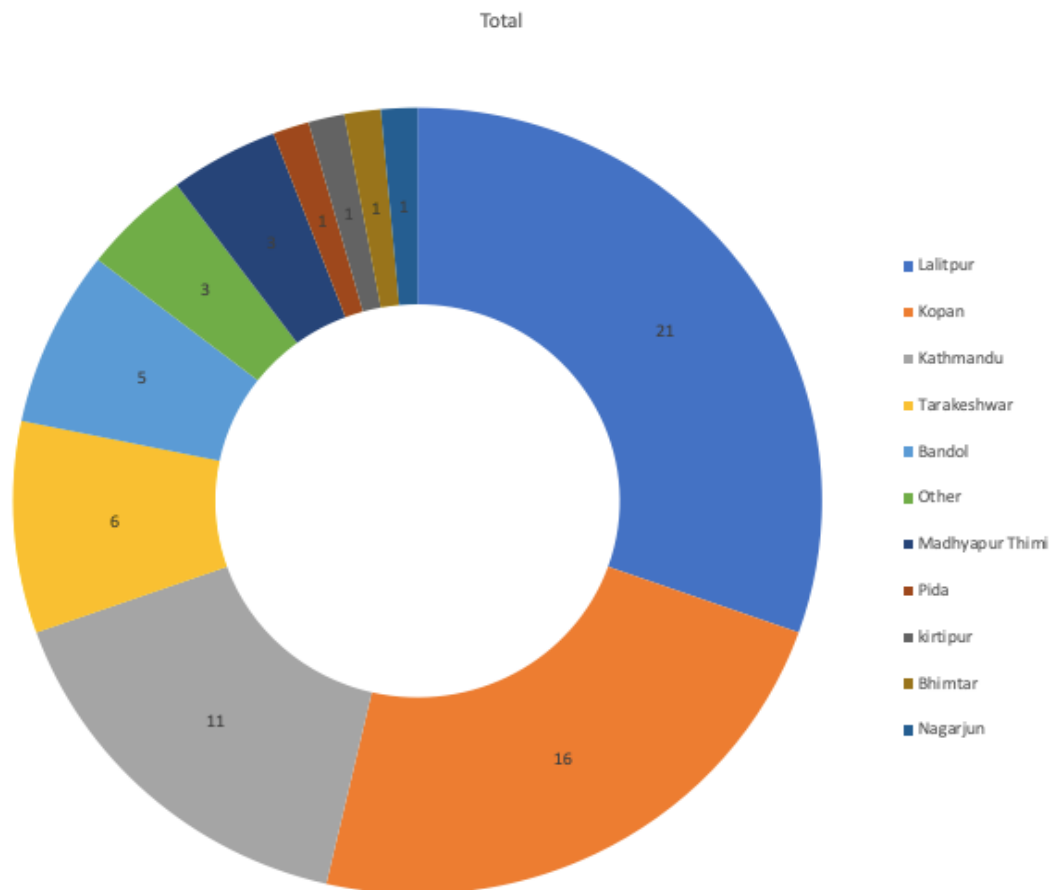


Figure 43. Participants per community, excluding participants who collected over 20 data points

Finally, Kopan recorded more data than any other community, contributing 34% of the data set. In comparison, the next community lagged behind at 25% (Figure 44).

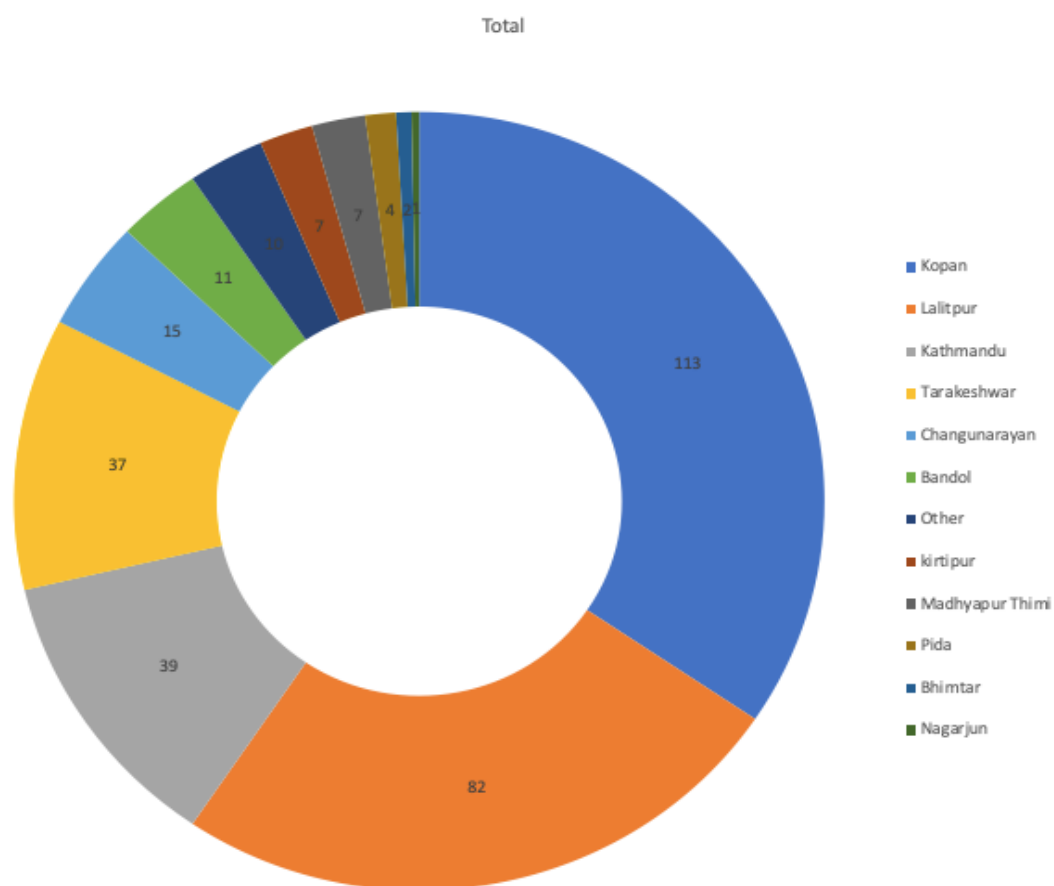


Figure 44. Entries per community, without those from participants who logged over 20 data points

To summarise, the type of users in terms of their inputs, is correlated to the level of intermittency experienced. There is a correlation between:

- high number of participants with >10 entry points, and large difference between water off / on entries, with the higher number being water off entries.
- high total number of participants in a community and large difference between water off entries and water on entries, with the higher number being water off entries.
- high total number of entries and large difference between water off entries and water on entries, with the higher number being water off entries.

In the second instance, after investigating the above links between the level of intermittency recorded and the way that users recorded data, the research sought to establish links between the level of intermittency recorded and user characteristics, gender, age and income.

Nepal is a traditionally patriarchal society. Consequently, any finding linked to gender is likely culture-specific and may not be replicable in other types of societies i.e. neutral or matriarchal.

As can be expected in light of this, breaking the data down into entries per gender revealed that there were 50 men and 38 women participating in the study, yielding a ratio of 1.32 in favour of the men. It should be noted that 20% of participants did not declare a gender, and this category will be noted as NA (Not Available) going forward. Male participants recorded approximately 67% of the total data entries, far more than their female counterparts who only recorded about 24% (Figure 45).

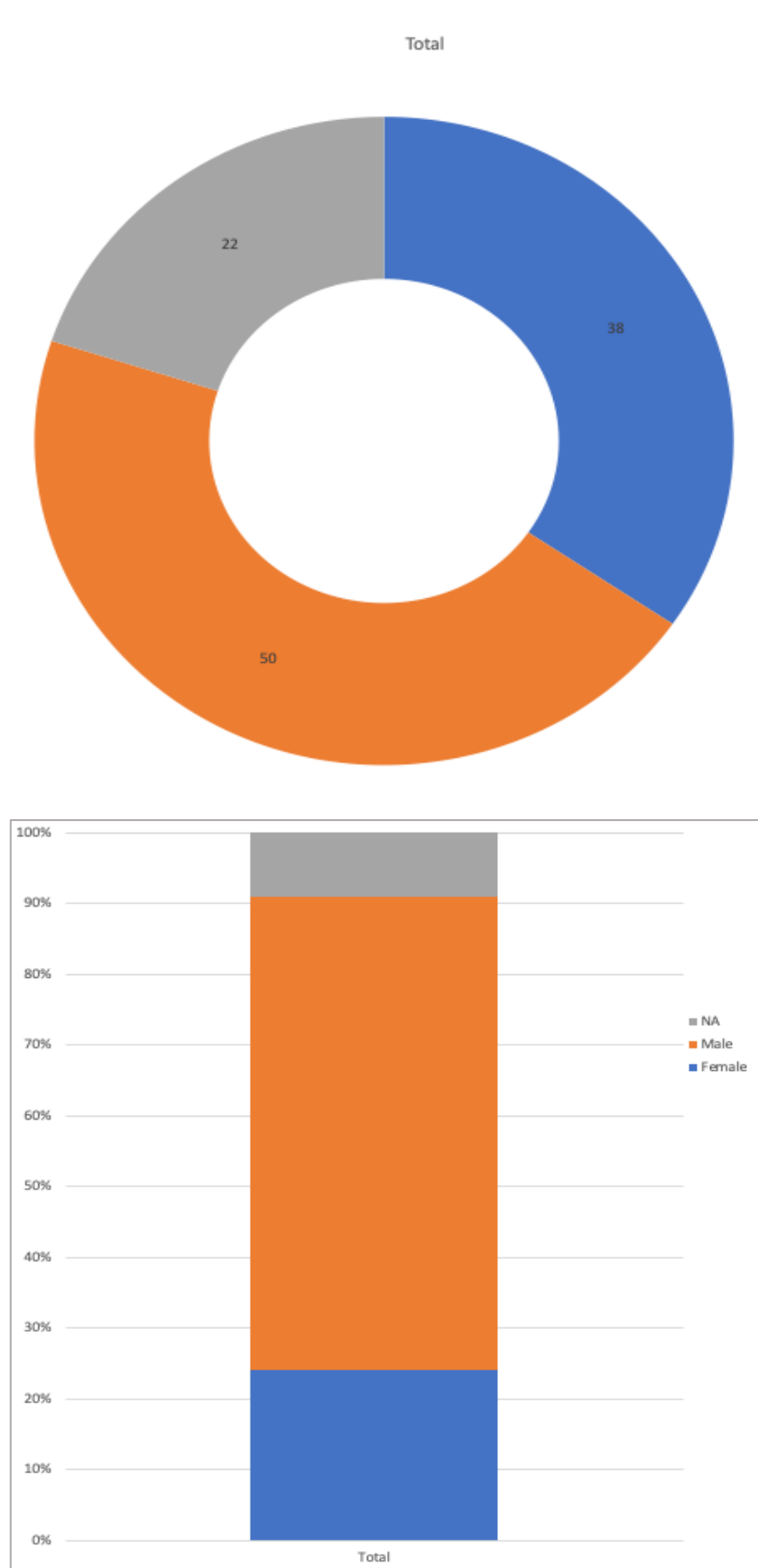


Figure 45. Gender distribution of participants (above) and of the data set (below)

Accordingly, mean participation per person in males was double that of females, with 10.94 versus 6.16 data entries per person. However, the standard deviation of female entries was significantly lower than the male entries, 4.23 versus 14.43. One would expect the standard deviation of the number of entries per person to increase with the mean, however, here it appears disproportionately so.

This implies that females tend to report in the same manner i.e. consistently high or consistently low number of data entries whereas the males are more likely to record varying amounts of data. However, it appears that there were at least as many men as women in certain recruited communities (Figure 46). This is the case for Kopan, Kathmandu, and Lalitpur.

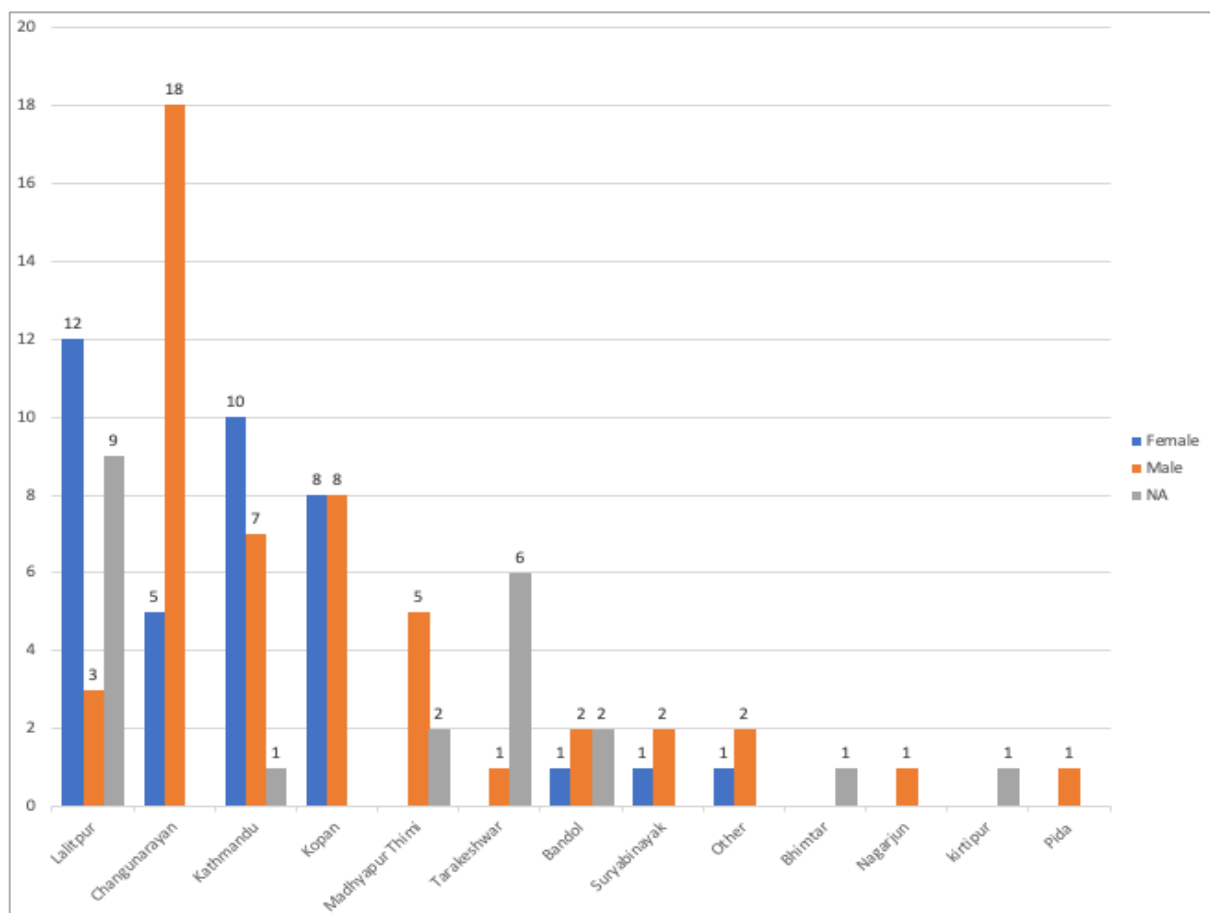


Figure 46. Participants per community per gender

Combining this information with the figure below (Figure 47), the females in the female-dominated communities do not exhibit specifically higher data contributions per person, with Kopan and Kathmandu both exhibiting 4.1 entries per female, and Lalitpur slightly higher at 4.9.

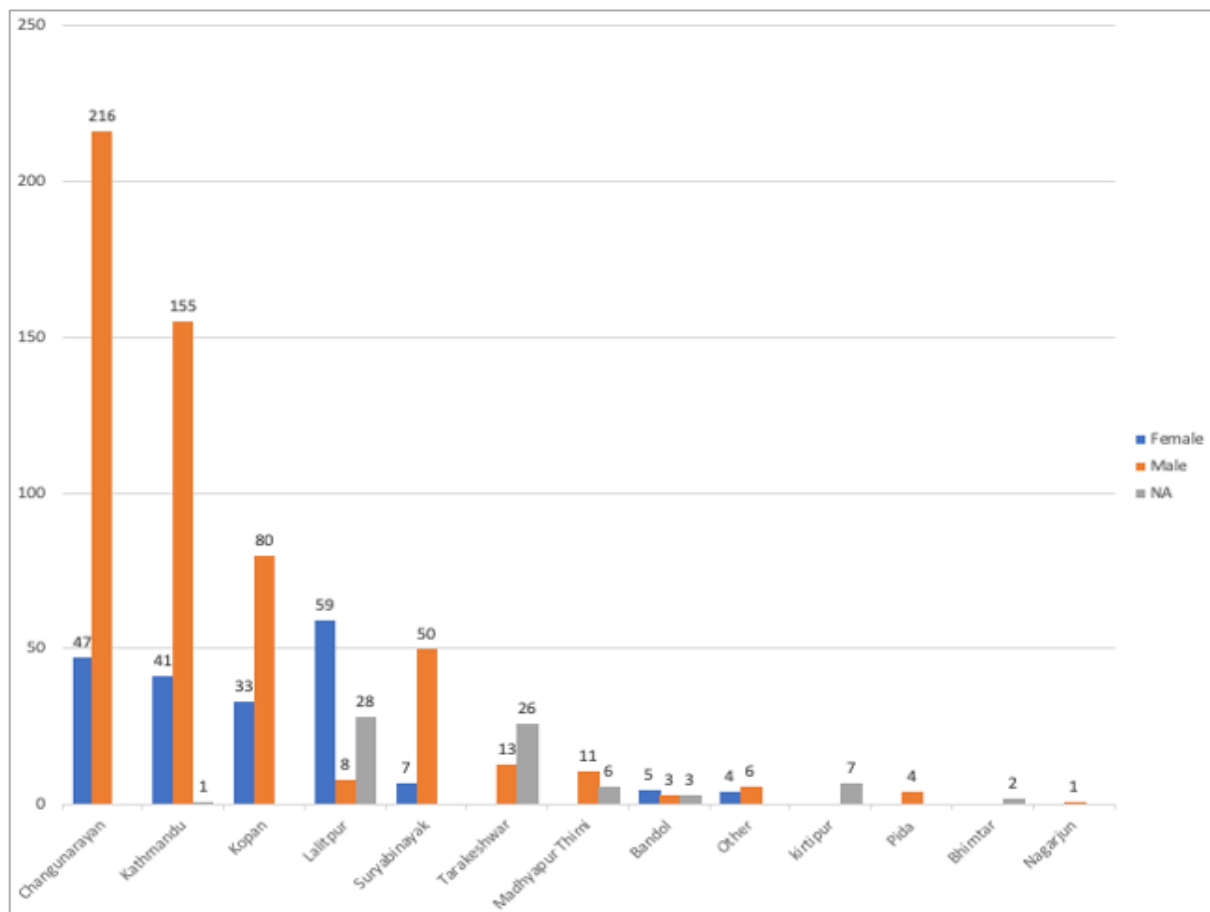


Figure 47. Participation per community per gender

The communities with particularly high female inputs were Lalitpur and, surprisingly, Bantol – both of which had better water supply than Kopan. Comparing Figure 48 and Figure 49, there does not seem to be any correlation between high female inputs and water intermittency. Out of 196 female entries, only 78 indicate intermittency – about 40%.

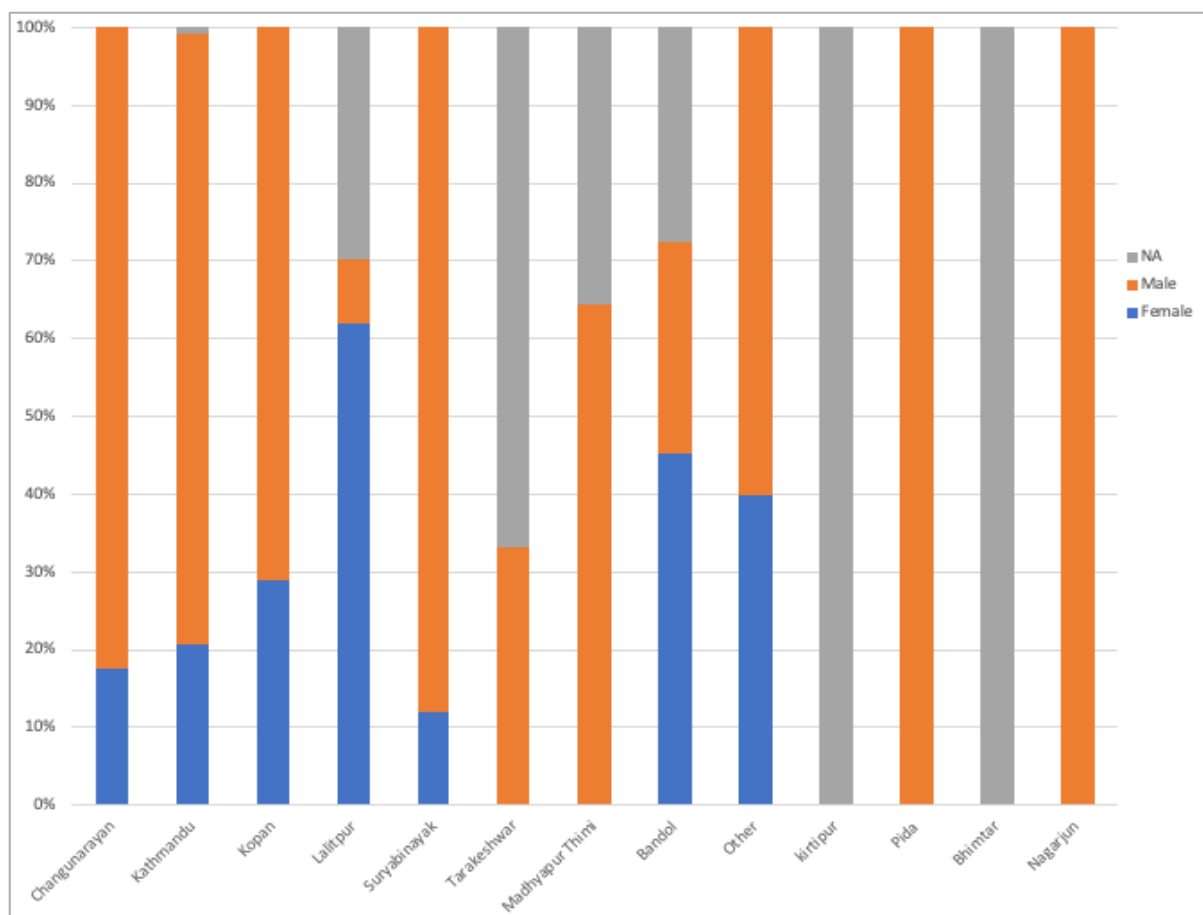


Figure 48. Gender participation per community

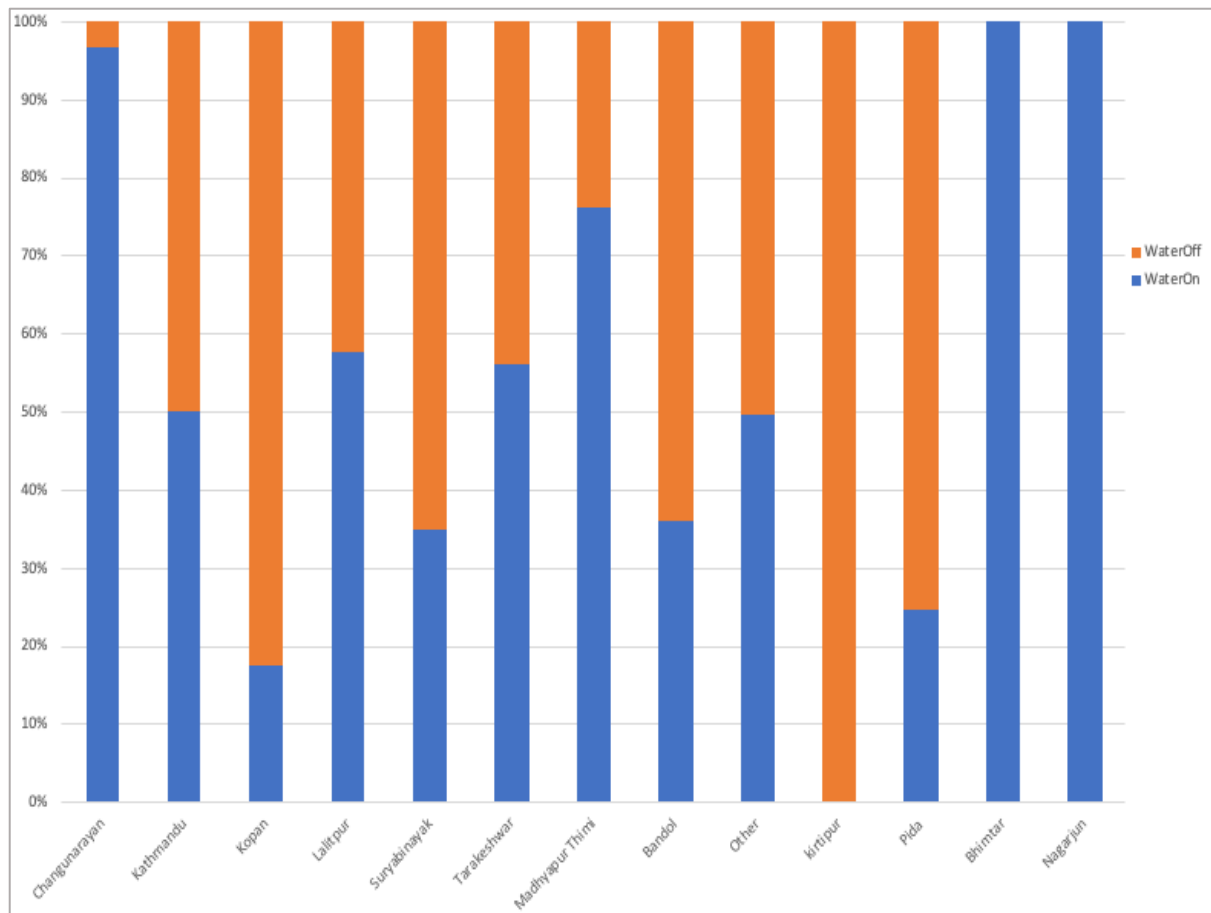


Figure 49. Intermittency level per community

There is no indication that within a given time-frame either gender is particular prone to discouragement. However, once the time-frame is removed, as was the case with the pilot study, it is possible to observe that male participation endured after the official end of the study while female participation suddenly discontinued (Figure 50).

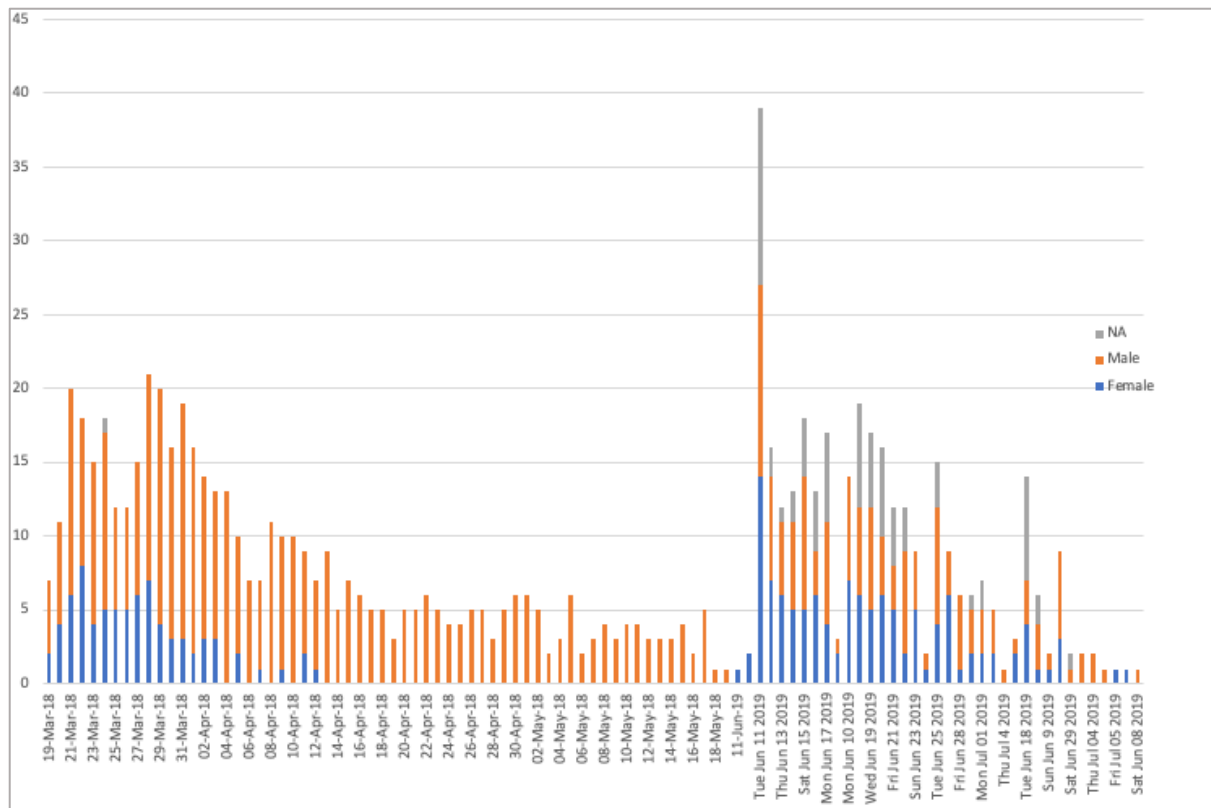


Figure 50. Gender participation over time

Both genders participated throughout the study periods, in the ratio 2.8:1 i.e. the females participated approximately 1/3rd of the daily data during the study periods (Figure 51).

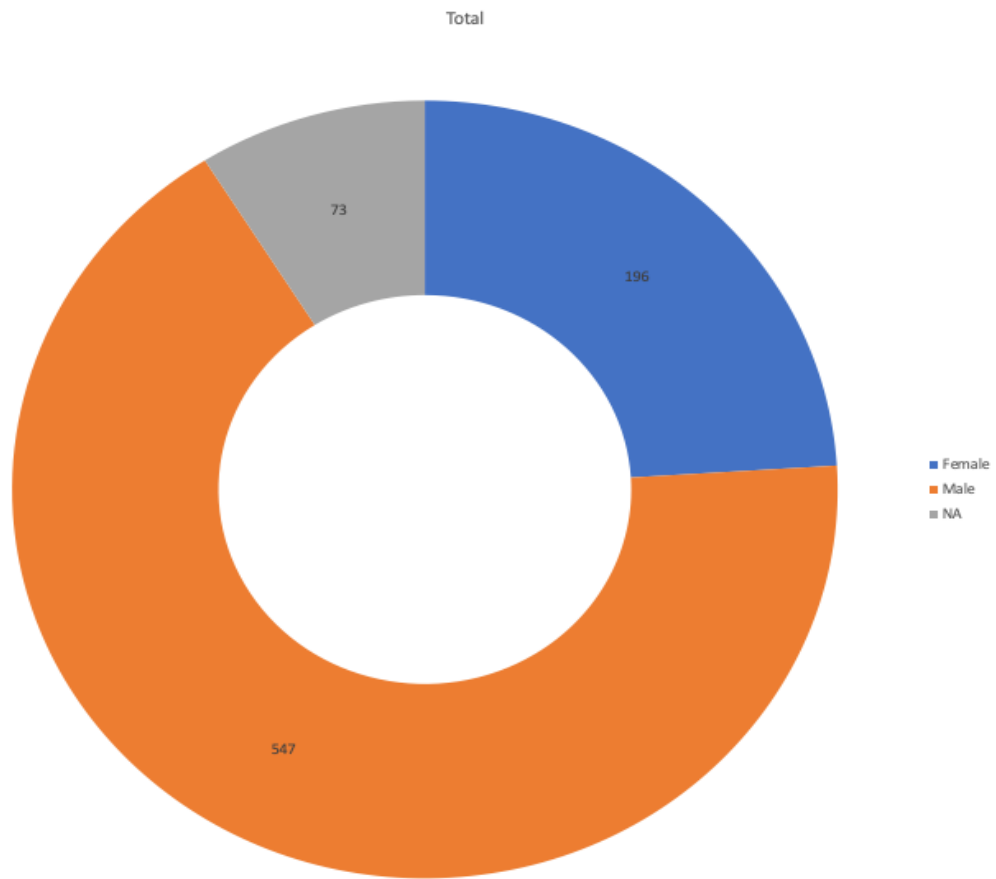


Figure 51. Gender contributions to the data-set

The proportion of off and on entries reported by each gender is approximately equal. The male ratio is 1.8 and the female 1.5, both in favour of water arrival (Figure 52).

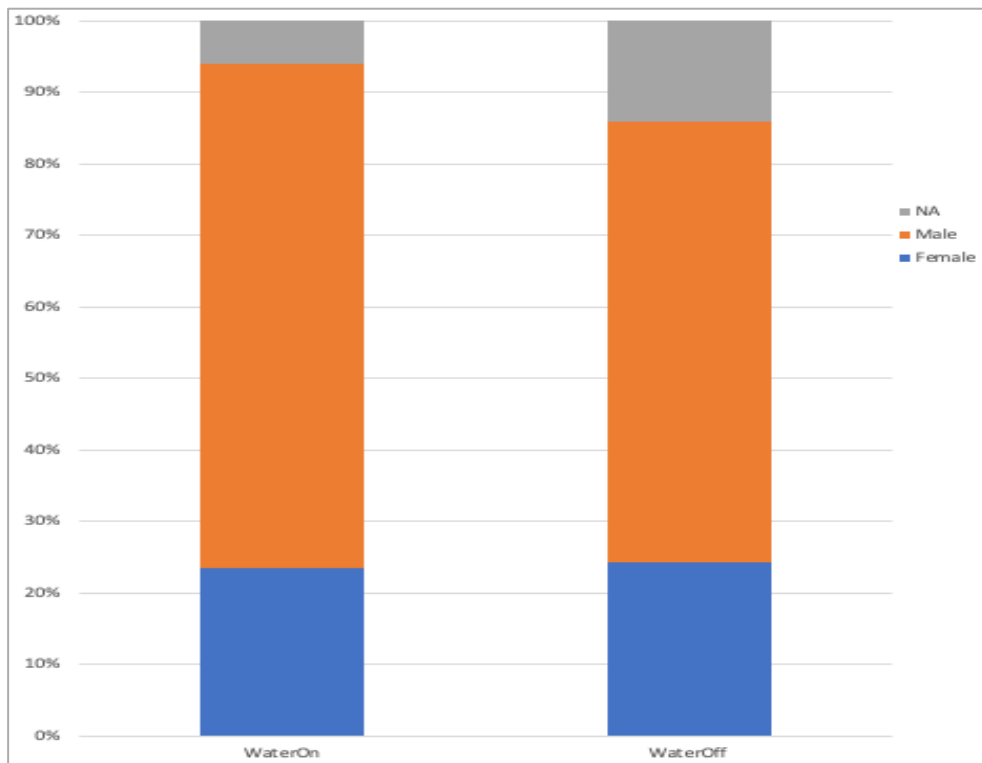


Figure 52. Gender contribution to each type of entry

In conclusion, females report consistently less data per person than males, but neither gender exhibited bias about the variability of the water supply. There does not seem to be a correlation between female participation and pronounced water intermittency, unlike what could have been assumed commonly based on the possible heightened importance of water in women's daily lives.

It was thought that participants under 25 years old (referred to from now on as "youths") would account for a larger percentage of participants, and also record more data points per person, on account of their familiarity with mobile technology. The participants were divided into age groups, exposing that youths accounted for 45% of total recruited persons - more than any other age group (Figure 53).

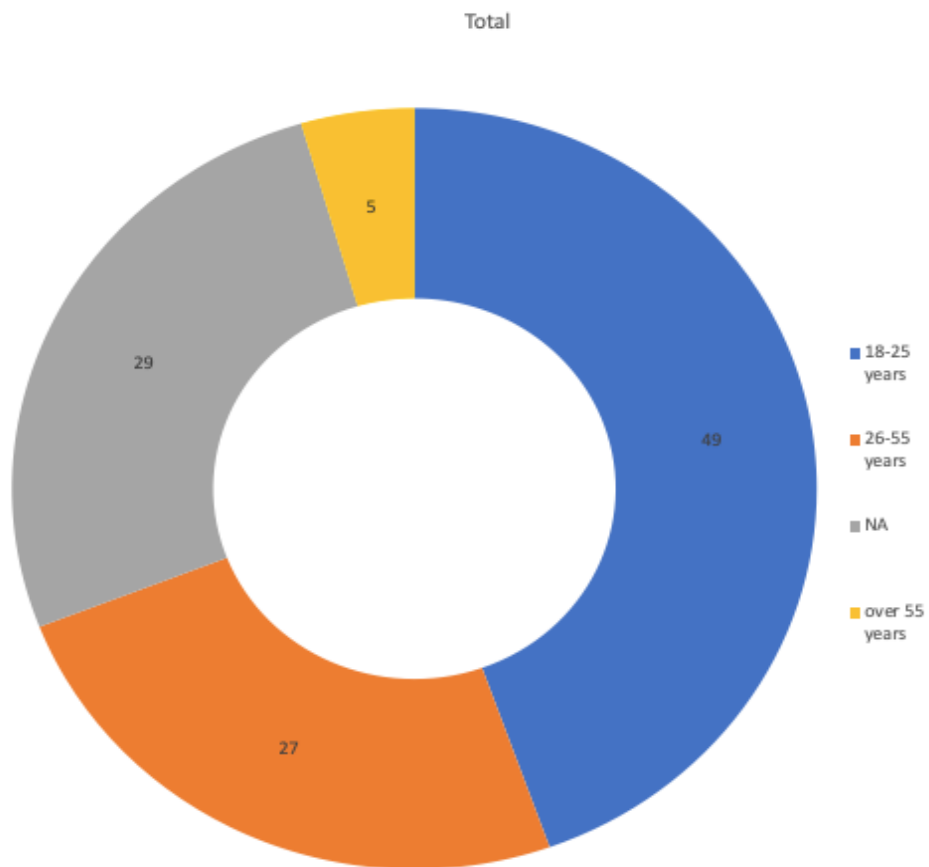


Figure 53. Respondents per age group

Youths also generated 60% of the data-set, that's 523 data points out of 816. This was more data than any other age group, and also more than all of the other groups combined (Figure 54).

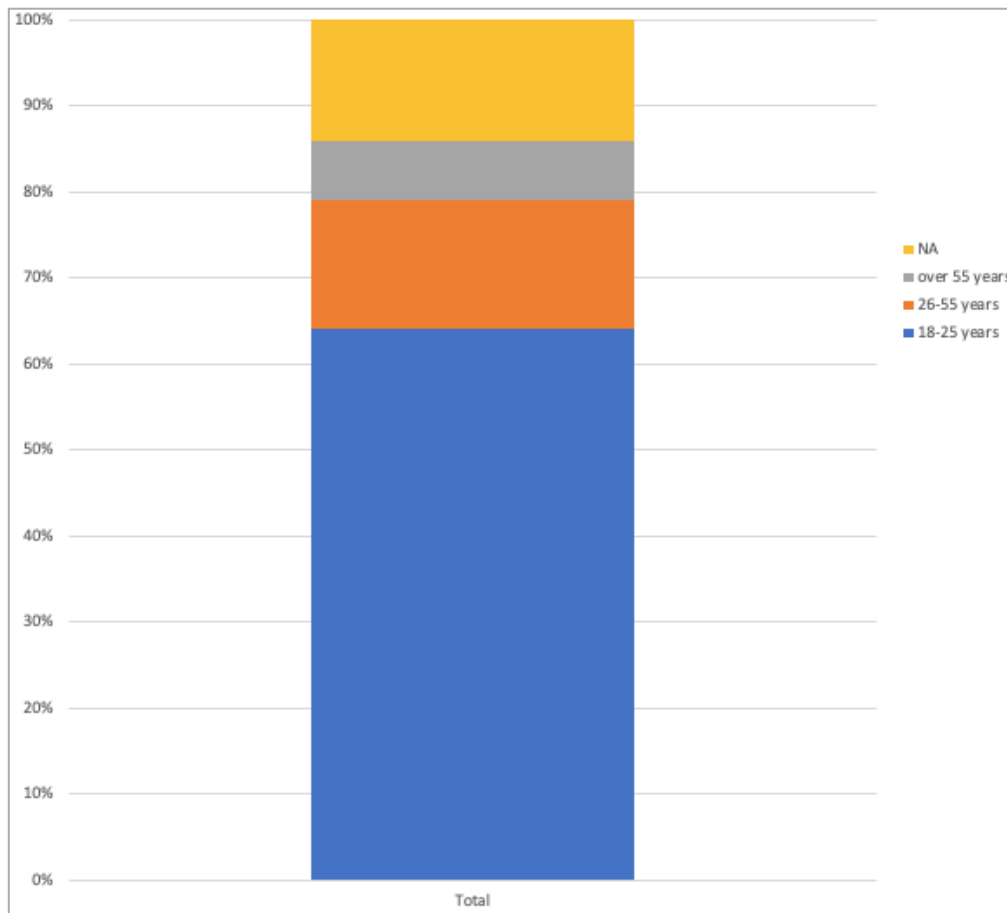


Figure 54. Percentage of responses per age group

The communities dominated by youths display the highest level of participation per person. Communities with over 65% of young participants (Changunarayan, Surabinayak and Kathmandu) register far more entries per participant than those with an older sample population (Table 10).

Table 10. Participation rates of the communities (ranked youngest to oldest, from top to bottom in the table)

Community	Participants	Entries	Entries per participant
Changunarayan	23	263	11
Surabinayak	3	57	19
Kathmandu	18	197	11
Madhyapur Thimi	7	17	2
Tarakeshwar	7	39	6
Bandol	5	11	2
Lalitpur	24	95	4
N/A	3	10	3
Kopan	16	113	7
Kirtipur	1	7	7
Pida	1	4	4
Bhimtar	1	2	2
Nagarjun	1	1	1

Youths reported nearly twice as many water-on as water-off entries, whereas all other age groups report more than double water-off entries as water-on entries. Participants who are over 55 years old reported more than triple the amount of water off as water on entries (Figure 55). Hence the analysis indicates that, the older the population, the higher their tendency to report on the failure of the water supply arrival. The younger the population, the less they report on water failure as a percentage of their records.

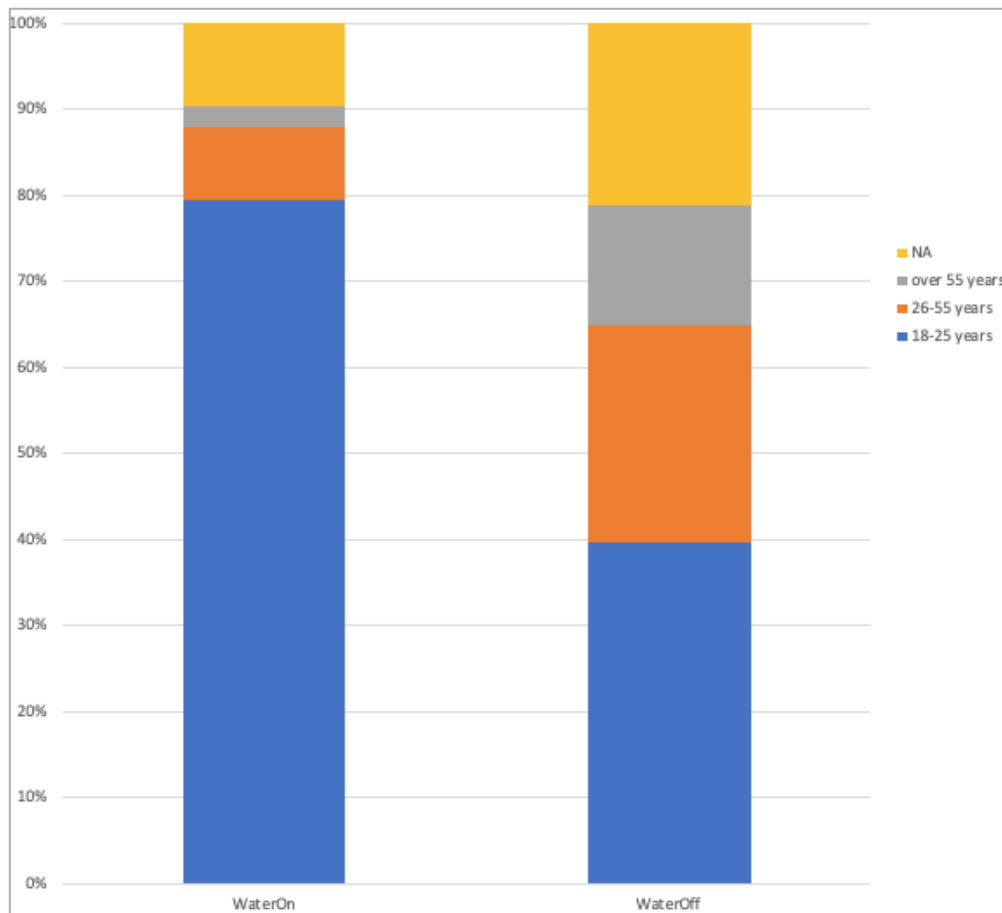


Figure 55. Responses per entry type, per gender

Comparing Figure 56 with Figure 57 shows that the younger participants seem to be in areas of lower levels of water intermittency. This may be because the young participants in the study were students at university, implying that they are at least middle-upper class citizens who can afford to live in areas with better water supply. Another reason may be due to the “family effect” – when parents have children they move to better-served areas in order to promote their family’s health and success. This could not be confirmed within the scope of this research.

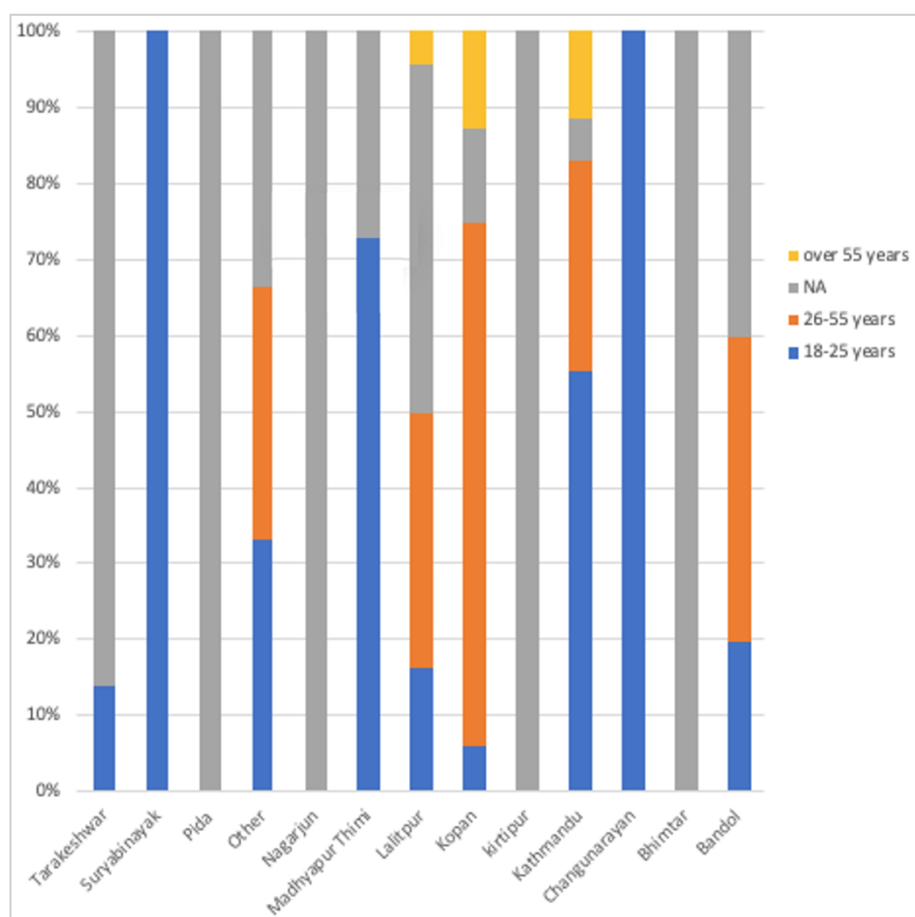


Figure 56. Community per number of participants per age group

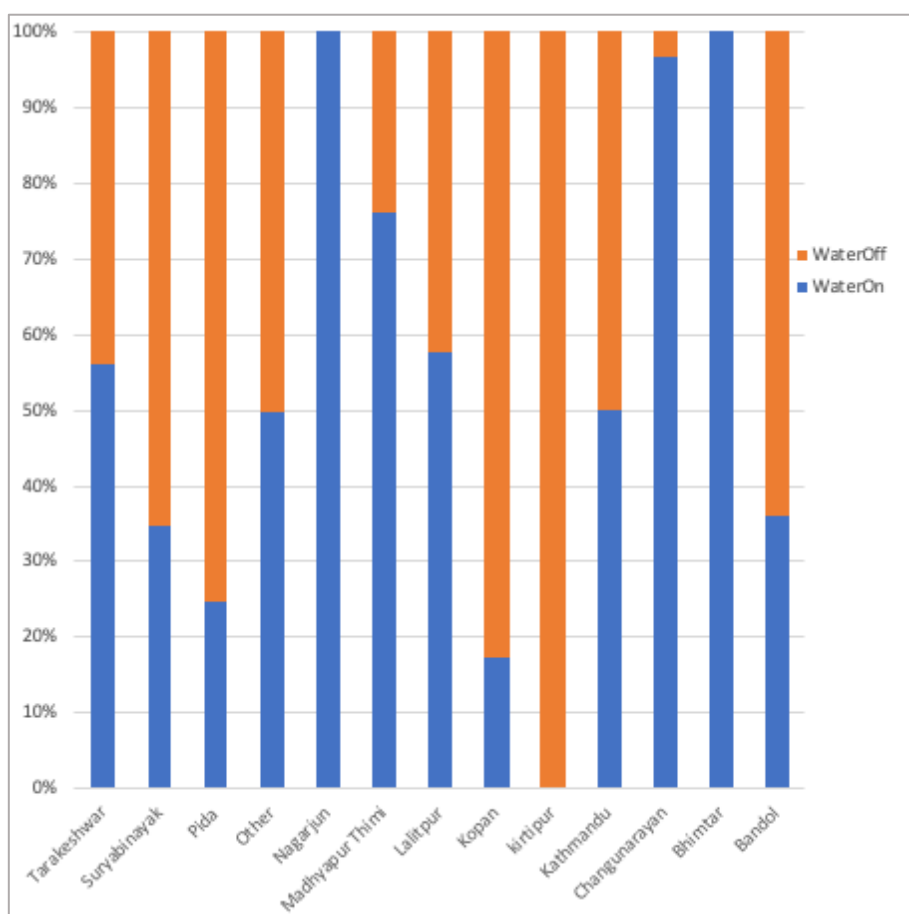


Figure 57. Community per intermittency level

Responses were validated internally, i.e. by comparing with the nearest geographic response from another participant in the same community within one day of the response (Table 11), rather than externally, i.e. against the KUKL water schedules, since the latter were shown to bear very little resemblance at all to what people were receiving in their homes (Table 12). There were also no flow meters to compare citizen responses against.

Table 11. Validated responses

				% of validated answers per group				
Community	% of validated answers	# of participants	# entries	Male	Female	18-25 age	26-55 age	Over 55 age
Surabinayak	30	3	57	26	57	30	NA	NA
Madhyapur Thimi	59	7	17	59	NA	45	NA	NA
Bandol	64	5	11	67	40	50	50	NA
Tarakeshwar	87	7	39	77	NA	77	NA	NA
Lalitpur	91	24	95	100	85	71	100	100
Changunarayan	93	23	263	93	94	93	NA	NA
Kathmandu centre	93	18	197	95	88	99	80	40
Kopan	97	16	113	96	100	100	100	93

If two people in the same community chose a “water green” response in the app within a one day time period, they have validated each other’s response. However, if one person chose “water green” and the other “water red” then the response is not validated. Equally if there was only one response in a given day, that would have been counted as not validated. Therefore, it took at least two people in a community to answer during the same time period in order to validate the analysis, and so unfortunately some communities did not have enough data points to be able to validate it against its neighbour: Nagarjun, Bhimtar, Pida, Kirtipur.

The total percentage of responses which are validated stands at 87%. Comparing the validated responses by gender and age shows that there was not a strong gender or age effect on response reliability. It was interesting also that not all of the communities performed equally well in terms of producing reliable data. Kopan with only 16 participants and 113 responses performed better than Changunarayan with 23 participants and more than double the number of responses.

Table 12. Community response performance and KUKL published delivery schedule

Communities	Validated answers (%)	Number of participants	Number of entries	Number of entries per person	Official scheduled interval (days between delivery) (extracted from KUKL website, 2019)
Surabinayak	30	3	57	19	4
Madhyapur Thimi	59	7	17	2	NA
Bandol	64	5	11	2	2
Tarakeshwar	87	7	39	6	NA
Lalitpur	91	24	95	4	2 to 3
Changunarayan	93	23	263	11	NA
Kathmandu centre	93	18	197	11	13 to 19
Kopan	97	16	113	7	NA

Since the date when the official schedule started was not known, only the frequency, it was assumed that the day with the first green entry from a participant is a benchmark for the start of the schedule. It was then possible to compare the real entries to the hypothetical water arrival dates, according to the schedule and see what percentage of the answers indicate that the schedule is correct. To check the assumption that the first entry being green is the correct assumption, the analysis was repeated by assuming that the day for the second green entry is the benchmark for the start of the schedule. The larger percentage of the two was then taken to say to what extent the actual water arrival matches the schedules. Doing this calculation for Lalitpur community, who had a high number of data points (95 entries) and the highest number of participants (24), starting in June which is what we have the schedule for, this gives only 41% agreement with the schedule using the first assumption, or 52% using the second. This was typical of what was found in the other communities as well. This indicates clearly that the official schedules are not an accurate reflection of the actual water supply delivery scheduling. Even by directly comparing the responses of any individual in these communities with the official schedules, the highest agreement percentage that was found was 69%.

How can we be sure that the schedule is wrong and not the participants? In Lalitpur there was as many as 24 people reporting, so although it is possible that that many people would be wrong, it seems highly unlikely. Lalitpur also had one of the most clearly indicated schedules (every 2 to 3 days) compared to some communities which had only part of a schedule (e.g. Kopan, whose population must assume that they may get water any day of the week, between the hours of 3:00 and 4:45 pm), and many of these communities do not have schedules at all

(4 out of 9). Therefore, actually the citizen science data was a more robust and reliable source of information than the official schedules.

The main conclusions from the analysis of the participant characteristics are:

- Participants exhibiting more water intermittency will participate the most
- The older population have a higher tendency to report on the failure of the water supply arrival
- A high level of citizen science reliability was observed (86-88%), and there is no noticeable gender effect on response reliability
- Citizen science data is a more accurate source of information about the real water supply delivery than the official schedules, with only a maximum of 69% agreement between the two in any of the participating communities.

4.3 Stakeholder engagement analysis

The stakeholders were interviewed to assess whether they viewed the methodology and the data collected as useful to them, in their respective fields.

For each interview, the research identified main messages reported by the interviewees, and based on those, inferred what this implied for the stakeholders and for the research. These findings were tabulated, as in Table 13, except for the interview with one employee of KUKL which did not contain enough material to infer implications, and so was summarised in plain text instead. The 14 full interview tables can be found in Appendix B.

Table 13. Main interview findings from a branch chief at KUKL

Main interview findings	Implication for stakeholders	Implications for research
It is unclear who owns the water resource and what rights they have over it.	Managers need more robust water policies to be able to enforce everyone's right to the water e.g. by preventing stealing water at the source.	It is likely that everyone feels they own the resource, so all stakeholders should be treated as having equal rights over it.
There is unequitable service, even within the same area.	Customers feel frustrated that the water is not distributed in a systematic and deliberate manner.	
There is no systematic data collection on water delivery. There is no primary data. Official statistics claim that 99% of households are metered but this is not the case.	There is no data available on water distribution on the KUKL side. KUKL needs to look to its customers for data.	The research tool could be used in lieu of water meters and water meter readers. Publicly available data is flawed and should not be taken at face value.
Shortage of manpower at KUKL.	KUKL needs to reduce its dependence on manpower to facilitate management and	The research monitoring tool employs IT and so would not need so much manpower.

	operations, or increase its number of employees.	
People believe that their complaints are better heard if they present them in person.	If KUKL had an official feedback system, people would not need to go in person to their offices.	People may think using an app is not as useful as going in person.
There is no need for citizens to lie about their water supply to make more of a point as their situation is already dire.	KUKL could use the data collected by citizens directly without statistical validation.	Data validation is desired but not critical to the project's success.
Validity of data is important.	KUKL still values validity in data despite currently not having any data, or any validation methods in place.	Since KUKL does not have any pre-existent data, alternative means of validation should be sought.
No routine water quality monitoring.	KUKL needs a systematic way of monitoring water quality. They could use citizens to carry out routine checks on water quality, and only carry out spot-checks themselves.	The research tool could easily be transformed into a routine monitoring tool for water quality by dedicated households.

Affirmation that the research should be carried out by citizens, government and KUKL.		Confirmation of the usefulness of the research in addressing water-supply challenges from different angles in a cost-effective way.
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The stakeholders' (13 out of 14) views on the current way that the system is managed by KUKL are that

- The water supply is poorly managed
- KUKL is understaffed and that the staff are not committed to their work
- KUKL does not have any monitoring system in place for the existing water supply network
- KUKL does not possess any data on the location or operation of the existing water supply network
- KUKL does not have enough financial or human resources to acquire this data
- Publicly available data and official statistics surrounding the water supply is unreliable
- KUKL does not deliver water in accordance to the schedules they declare
- KUKL does not readily take on feedback from or give feedback to the customers
- KUKL is physically unable to provide adequate water distribution until the Melamchi project is completed
- The system's operations are manual as opposed to automated
- KUKL does not have the capacity to make use of large amounts of data or of sophisticated software.

Only one interviewee (who was from KUKL) did not seem to welcome the research. In contrast to the other interviewees from KUKL, this interviewee did not recognise that the service provider suffered from a lack of data, disagreed that the water was contaminated, and maintained that it did not need any assistance. No supporting evidence was provided, so it was not possible to investigate the nature of these assertions further. However, he agreed with the other interviewees on two points: first, that customers were not concerned by the quality of their water, and second, that it is not possible to hold KUKL accountable for its operations.

All the stakeholders expressed the sentiment that the water supply is not only inadequate but also inequitable. They also voiced that customers felt disappointed in KUKL and had lost faith in the government's ability to provide them with adequate and safe water, as per the constitution. All, except the interviewee from the ADB, were of the opinion that Melamchi would be finished in the near future, and that this would solve the current water intermittency problem. Despite this belief, all of the interviewees agreed that customers are rightly trying different means to pressurise both KUKL and the government into improving the current water service provision in the meantime.

The interviewees not directly involved with water provision (i.e. the university professor and the journalist) both expressed the belief that KUKL must possess data and that the government would intervene if it knew the severity of the situation. Contrary to professionals involved in the water supply management, they also believed that the citizens would be willing to engage in the research. The laymen and the female interviewees all expressed the

sentiment that women were especially concerned with the water supply, and that it was therefore important to include them in the research.

The stakeholders' engagement was categorised as belonging to one of five levels, namely, "Unaware", "Resistant", "Neutral", "Supportive", and "Leading" (Table 14). These categories translate into stakeholders who, through their narrative and behaviour, exhibit passive opposition, active opposition, neutral, passive support, or active support for the project.

Table 14. Stakeholder engagement

Name	Industry	Type of Stakeholder	Level of Stakeholder Engagement
Senior engineer Ministry of water supply	Government of Nepal	Political	Supportive
High member of Ministry of water supply	Government of Nepal	Political	Leading
Hydrogeologist	KVWSMB	Political	Leading
High-level Branch manager	KUKL	Professional	Supportive
High-level section manager	KUKL	Professional	Resistant
Urban development specialist	ADB	Professional	Leading
Researcher	IWMI	Professional	Supportive
High-level manager	IWMI	Professional	Supportive
Manager	JICA-KUKL	Professional	Supportive
High-level officer	JICA	Professional	Leading
High-level manager	JVS	Professional	Supportive
Senior manager	WaterAid	Professional	Leading
Senior water specialist	World Bank Group	Professional	Supportive
Journalist	News industry	Layman	Supportive
Professor	Tribuhvan University	Layman	Neutral

The research only identified one stakeholder as being actively opposed to the use of a citizen science tool for monitoring the water supply in Kathmandu. All of the other stakeholders except the professor were either passively supportive of the project or actively supporting its development by providing constructive criticism, feedback and assistance. Contrary to what may have been expected, there was no perceived systematic difference in the level of support exhibited by those interviewees who were directly working with the water utility versus those who were not.

None of the interviewees raised the topic of soundness or quantity of the data collected until it was raised by the interviewer. All the interviewees (except one from KUKL) articulated that since there was no systemic and systematic monitoring in place, the only persons capable of sharing data on the water supply quantity and quality were the customers. The consensus was that individuals would be the most reliable source of accurate water supply data, and the mode of collection via an app was hailed as effective and rallying. However, concerns were raised that citizens would be reluctant to engage due to ill-feelings towards KUKL and the government. The interviewees agreed that the validity of this primary data should be verified, whilst simultaneously affirming that there was no previously established data to compare it to. The suggestion of internal validation methods was met with enthusiasm, and interviewees even expressed that there should be flexibility in the margins of error of the validation.

The stakeholders (except one from KUKL) welcomed the use of the research tool in Nepal as a low-cost and valuable method of filling a data gap for the operator. However, the tool was also perceived to have other uses at operational, policy, and grass-roots level.

Those interviewees working directly under or with KUKL perceived the research tool as a means to intervene at operational level. It was labelled as

- A system improvement for the water service provider
- A complementary method of collecting data in the water sector
- A versatile monitoring tool who's use can evolve with the water supply system over time
- A call for systematic monitoring of the water supply network

Those interviewees who worked in collaboration with the water service provider (but not directly under their authority) perceived additional policy benefits to the research tool. It was labelled as

- A precursor for designing operational policies
- A bottom-up cascading pressure mechanism, to compel government to put pressure on the water service provider to improve their management
- An institutional Dispute Settlement Mechanism. An institutional dispute is when a conflict of interest arises between an institution's own financial interests pose a risk of undue influence on decisions involving its primary interests
- A means of influencing the water service provider into answering its customers' complaints
- A means of promoting transparency in operations
- A means of keeping the private market for water in check in terms of providing clean and affordable water
- A proof of concept that citizens can successfully manage water monitoring operations
- A mobilization tool, rallying people to demand their rights to water

- An empowerment tool, giving citizens the knowledge needed to make informed decisions surrounding their water supply and use

It is observed that those interviewees working directly under or with KUKL envision long-term goals, whereas those who worked in collaboration with the water service provider but not directly under their authority see it as a means of achieving change in the short to medium term.

In contrast, one manager at KUKL rejected the concept of citizen involvement, and the interviewee from JVS was of the opinion that KUKL would be against adopting a citizen-science tool as part of its operations.

Although the research had its own agenda for the application of the research tool, the stakeholders had alternative suggestions for its use. A number of professionals voiced the opinion that the tool would be useful in remote areas, which may be less of a priority for the government, and where the water supply system is small with no water operator. Opinions diverged on the application of the tool in urban versus rural settings. While everyone agreed that the Small Towns Community Management projects led by the ADB were successful, the journalist believed applying the tool to a rural setting would not be appropriate since those remote areas may not have the mobile coverage needed, and the pool of citizen volunteers would be reduced.

Looking to the long term, all of the professionals agreed that the tool would be useful to monitor the success of the Melamchi project once it is finished. However, the interviewee from the ADB ventured that the tool could be taken further by also being used a reporting

tool on the leaks expected once Melamchi is operational. Indeed, visible surface leaks are expected to be numerous, but the locations are not known. The tool could therefore mobilize citizens to report on the location and magnitude of the leaks to the ADB. Following in these footsteps, a number of interviewees praised the versatility of the tool and envisioned that it could be used for all sorts of monitoring activities surrounding the water sector, including monitoring the locations of water transport vehicles to ensure that they reach their intended destination at the correct times.

5. Discussion

5.1 Participants and participation

The relatively high validation percentage of responses regarding water delivery to households (86%) suggests that overall the citizen science data is robust and in the case of Kathmandu, it actually provides a more accurate representation of the schedule of water supply than the official published schedule from the water utility company. Moreover, the reasonably high participant turnout, number of entries and number of communities covered by the research support that it is an effective strategy to collect large amounts of data spread out over a large geographical area in a short space of time.

The research established a positive correlation between the level of intermittency and level the participation of a citizen and of a community. Although this may be expected, it also implies that the methodology is particularly well adapted to extremely intermittent environments – which is also typically where resources are the most lacking, and so the low-cost property of the tool will be especially useful.

With regards to participant characteristics, there were no discernible differences in the reliability of male versus female respondents, although the degree to which this finding would translate to other cultural settings is uncertain. A limitation of the research is that the lead researcher and trainer of volunteers was female (the author), which may have had an effect on encouraging female participation more than if the trainer had been male. It was also observed that the younger participants reported less on water failures as a percentage of

their records. The reason behind this was not determined as it was outside the scope of this study, however, it may be explained by another limitation of the research, which was that the young participants were mostly recruited through Nepal Engineering College, implying that they may have hailed from more privileged backgrounds.

5.2 Benefits to stakeholders

The key stakeholder interviews generally supported the hypothesis that this approach to data collection is valuable in the context of low-income, data-scarce water management scenarios, and did not have any concerns surrounding the validity or accuracy of the data collected. In fact, KUKL subsequently produced their own app for this same purpose. The “Official Mobile App of Kathmandu Upatyaka Khanepani Limited for Leakage and Complaints” was launched in February 2020 (available on the google play store <https://play.google.com/store/apps/details?id=com.app.kukl&showAllReviews=true>), and is the first initiative of this kind by the service provider. Correspondence with officials from KUKL and KVWSMB confirmed that the research contributed to the development and deployment of this unprecedented gambit (Appendix D).

The outcomes of the research can be divided as being beneficial to the principal stakeholder - the utility - in two main aspects, operational optimisation and demand-side management.

5.2.1 Operational optimisation

For the water utility company, the data generated from the app can fill a knowledge gap on the system's operations. This data can be used to develop strategies to improve the supply-side management, ranging from system operations to investment decisions. This thesis considers the worst-case event that there is no possibility of further investment in the system, and focuses instead on discussing how the data resulting from the methodology could be strategically used to optimise the operations of the current water supply system.

The spatio-temporal data gathered from citizens could be used to build a map of the current water supply, and extrapolate this to obtain information on the amount of water supplied per household per unit time. It could then verify that this meets the WHO standards on minimum water quantity for domestic and personal consumption. Those households failing to meet this standard could be identified and the utility could then develop strategies to remediate this, such as altering its operations to distribute water more evenly through the system (for example by instructing the valve-men to leave the valves open for longer in the under-served areas) or providing rebates in billing.

Developing countries often have multiple structures in place to provide water, and the utility could develop collaborative strategies with those structures to ensure that they overlap to compensate for gaps that are exposed by the data recorded through citizens. In the Kathmandu context, KUKL could use the data to develop strategies in collaboration with KVWSMB, in an effort to coordinate the utilisation of the non-piped structures that the board operates to deliver water to citizens, should there be a failure in the piped-water system. For example, if multiple citizens within a region of Kathmandu signalled via validated app

responses that they had not received water as per KUKL's schedule, KUKL would be in a position to relay this information to KVWSMB, who could in turn direct tankers to those areas in need of water. Since KUKL and KVWSMB operate in the same districts of Kathmandu using different water delivery methods, data sharing and cooperation between the two entities could serve to complement each other's water delivery services. This would result in better equity of water access over time and space, as well as a more efficient and seamless water distribution system. Improved collaboration between KUKL and KVWSMB can only lead to positive development in the successful management of water delivery in Kathmandu.

The mapping exercise combined with data coming in real time would alert KUKL to malfunctions at specific locations in its system. Failures in the piped system can often result from technical personnel neglecting to perform their functions, but there is currently no way of monitoring this. The data collected by citizens would give the utility information on the times and locations that the technical personnel operating the valves, giving it better control over both the operations and the staff: failure to operate a valve would translate to a failure to supply water at that point and time, which would be flagged by the citizens. KUKL would then be able to take remedial action in near real-time and monitor staff that raise repeated flags. In this way, KUKL will also be in a position to streamline its human resources and start to promote transparency and a better work ethic within the company. More than this, it would allow the utility to start building resilience in the system, for example by having emergency measures in place to replace absentee staff.

In conclusion, without reducing the intermittency in delivery service, the data collected through the tool could permit for a higher degree of control over the equity of the water

delivery per household or neighbourhood, and over operational personnel, leading to optimised operation of the intermittent water system in its current state.

It is important to note that because this is a bottom-up approach to problem solving as opposed to top down, the data generation stream may have to be adjusted over time as the utility hones in on the problem at hand and refines its needs from the data. In this way, the data collection initiative should aim to become an iterative process rather than a set task. Hence there is a real need for the citizens to stay invested in the throughout the problem-solving process, and to cultivate a knowledge co-creation mindset in order to avoid having to start recruiting citizens from scratch every time there is a need for new data.

Taking a simple example: if the utility decides to check if the system performs as expected in areas A, B and C, but upon receiving data from those areas it appears that only area A is suffering, it would then require more information from citizens living in A. It would then need to recruit more citizens in that area, and so the citizen recruitment process would begin again. Perhaps later down the line, it appears that the issue in A is different to the utility's assumptions, and so it needs to collect different data from area A. Again, the process would have to begin again.

Instead, information can be fed back to citizens at different stages of the problem-solving process (Figure 58). This allows the utility to change its data collection strategy at any point along the way - whether that means going forward with more data collection or different data criteria altogether, or even going backwards and deciding to change the application of the data – eliminating the need to recruit new citizens for each task. One could even argue

that once the feedback loop is well established, it could even enable citizens to recruit more participants in their area (should the need arise), removing the need for the utility to go out into the field more than once per area, cutting down on time and manpower.

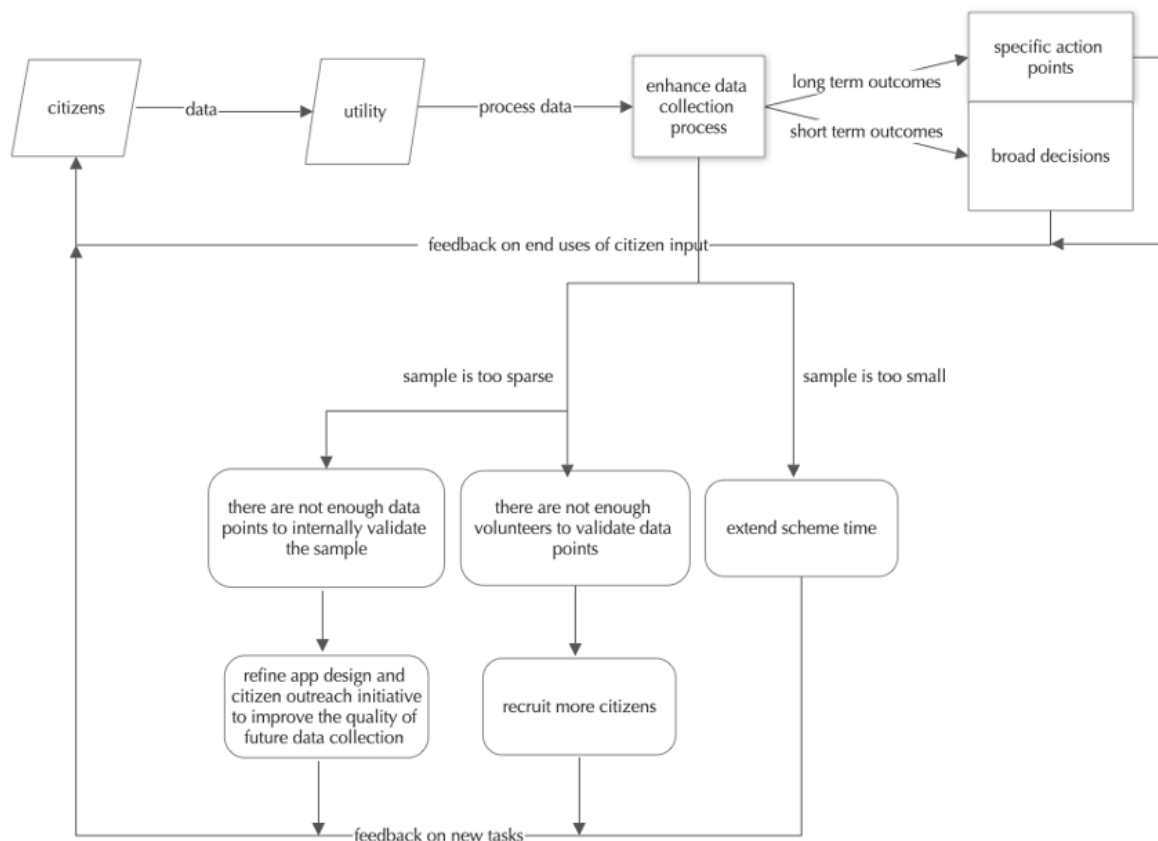


Figure 58. The citizen-utility feedback loop

The advantage of having such feedback loops further lies in the fact that the utility does not need to immediately define either the number of participants, the spatial or temporal resolution at the start of the experiment. Instead, it can determine this based on the incoming data. The behaviour of the IWS will dictate the desirable spatial resolution of the location of interest. This should imperatively be decided in collaboration with the citizens being recruited in those areas, as only they will know how the water delivery varies geographically. For

example, in certain areas it may be that water delivery varies per street (so each street should be visualized as a spatial unit) whereas in others it may be per block (so one block would be a spatial unit, with each block comprising innumerable streets). This, in turn, would dictate how many citizens the utility should aim to recruit. The data validation technique developed in this thesis requires a minimum of 3 participants per spatial unit in order to obtain a valid data point. The utility can then choose to build on this number or not – though this decision will of course depend almost entirely on the level of success that it encounters when recruiting citizens.

The behaviour of the IWS will similarly dictate the desirable temporal resolution of the data collected. The utility should collaborate closely with citizens in *each* unit area, to learn how the water delivery varies over time – daily, weekly, fortnightly or even over longer periods. The utility should then pick the *longest* time period to adhere to, and decide how many cycles of data it wishes to obtain in order to satisfy its stakeholders requirements for validation. Failure to adopt the longest time period experienced in a unit area would result in incomplete information on the area at hand, and loss of citizen participants. For example, if two citizens in the same area receive water, one of them weekly and the other monthly then the utility should ensure that its data collection period extends at least one month, otherwise one of the participants will not have the opportunity to record data and will lose interest. It should also ensure that each citizen has at least 2 peers to validate his data point, and that if stakeholders require more than one round of data to satisfy their criteria for validity, the data collection period is extended in monthly increments.

Hence, the feedback loops not only provide scope for flexibility in the design of the citizen-science data collection initiative, but also in the actual gathering of the data.

Citizens in Nepal are actively campaigning for improved water services through protests (as discussed previously), sending a clear message that they wish to be heard and for action to be taken. Setting up a citizen-science data collection initiative and actively setting up a feedback loop on the use that the citizen's data is being put to sends the message that their needs are heard and in the process of being met. More specifically, sharing feedback on the process outcomes (i.e. what concrete actions were taken as a direct result of the data) clearly demonstrates to the citizens that they are a part of a circular value chain and eliminates the "us versus them" mentality, again helping to promote citizen retention.

Still, it must be stressed that the citizens are only one dimension in the overarching goal of generating value for the improvement of the IWS, with the other dimensions being the methodological framework, the tool and the feedback mechanism (Figure 59), and each dimension depends on the other in order for value to be created. In other words, although the IWS can be approached as an engineering issue, because of the inter-disciplinary nature of the problems it creates, a citizen-science approach to monitoring an IWS must take into account environmental, economic, and socio-political factors in order to be successful.

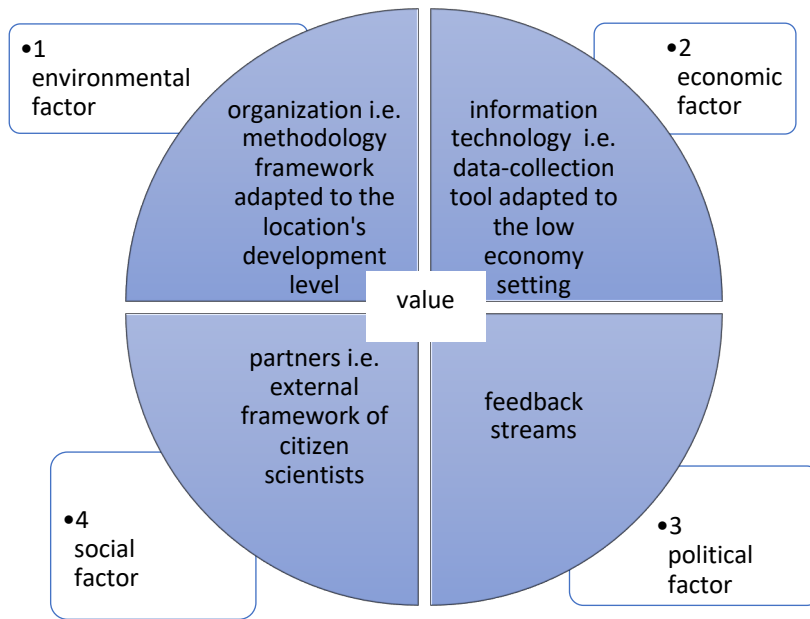


Figure 59. The 4 dimensions of value creation in an IWS setting

5.2.2 Demand-side management

Aside from using the actual data collected through the app, the utility could also benefit from using the app as a strategy *in itself*, to improve its demand-side management. The app could be disseminated to clients as a customer complaint tool, allowing them to be in direct contact with KUKL when they need to signal a failure in their water delivery. This would signal to customers that KUKL takes an active interest in their grievances and is not shying away from constructive criticism, restoring trust in the utility's work ethic – even if not in its operations.

5.2.3 Other benefits

A major benefit raised by funders was the 'value for money' of the approach – i.e. compared to installing flow meters throughout the city, this approach has the potential to provide

similarly useful operational data for a much reduced cost. Indeed, the poor economic profile of developing countries would typically not allow a utility to install flow meters at large scale. Moreover, installing flow sensors on water distribution pipes would first require precise geo-localisation of such pipes, since Kathmandu does not currently possess precise maps of the water distribution network. Even if this hurdle were overcome, employing flow sensor technology would require hiring and training of technical personnel in calibrating and maintaining the meters, as well as planning for potential future costs of repair and spare parts. Finally, to replicate the data collection style employed in the research methodology, one would need to choose a flow meter with remote data communication, and with a daily minimum data update frequency, which are extremely costly. According to Bell Water Systems such a meter could cost up to £225 (Bell Flow Systems, 2016). According to this quote, in order to collect data from the 110 citizen scientist's water supply, the utility would have had to spend £24 750 on flow sensors. It should also be noted that because of multiple illegal connections, it would not have been possible to place sensors higher up in the distribution network (i.e. at a water mains instead of at household level) in an attempt to capture information *en masse* for multiple households.

Interestingly, the water supply funders interviewed suggested that this approach may be especially valuable in smaller communities, even more so than in large urban centres, since the capacity to collect samples and manage data is reduced to an even greater degree in small communities, and community members may also feel more buy-in.

From the perspective of the development partners (e.g. ADB), using a citizen-science app is the ideal opportunity to establish a bottom-up approach to the systematic reviewing of project deliverables in the absence of a strong government. The support needed to encourage

a grass-roots movement to monitor national projects would be minimal, aside from disseminating information on why they should participate: to achieve a better functioning water system. Since this is every citizen's desire, that is all the motivation that they would need to participate. The app would allow the developing partners to engage unbiased individuals to monitor their large projects, limiting its reliance on approval from the government, in an environment where governmental employees make for difficult associates. For example, as of writing, the latest contractor to work on Melamchi abandoned the project, protesting that they were being coerced into paying bribes to Nepali bureaucrats, while the Nepali officials retaliated that the bribes were actually payment promised local taxes. This dispute halted the project for several months, while the government refused to go ahead with another contractor. The ADB suggested also that the method could be useful for reporting leakages, once the water supply system in Kathmandu reaches a more developed and reliable state, which would also limit its reliance on both government approval and local workforce.

From a civic standpoint, having the opportunity to monitor both water quality and quantity can be extremely useful in helping households to better manage their water quantity, quality and expectations. Thanks to the monitoring activities the household will be more aware of the quantity of water previously received, the time elapsed since then, and the quality of that water. This would in turn allow them to assess their water deficit and plan their finances to purchase the correct amount of water and the type of water (in terms of quality), according to their needs. Furthermore, because people will be in a position of control over their water, it is not unlikely that the just-in-case approach to water collection will be slowly abandoned as people get used to diversifying their water sources in an organized and predictable way. This would have a cascading effect on the entire water sector: currently, the sales of water

coping mechanisms is a thriving business, based on the fact that people are in constant fire-fighting mode. The fear that someone else will get better or more water than them pushes desperate citizens to constantly improve their coping mechanisms by buying more powerful pumps and better filters, building bigger tanks to store more water, buying any available source of water etc. But through increased awareness and understanding of water quality, citizens will be more alert to the correct pricing of different water sources based on quality, thereby protecting themselves against exploitation from private water vendors and regulating the private water market.

This type of social empowerment is a driver for change and progress at managerial level. Increased awareness of civilians on their level of access to clean water also empowers them to demand remediation efforts from their water utility – this may take many forms, from water tariff reforms to increased system interventions. With regards to managing expectations, educating civilians on their level of access to clean and affordable water also translates to empowering them to exercise their rights and demand that those rights be upheld by the government, which is responsible for providing effective, sustainable and quality water supply to the people.

That being said, without being opposed to citizen involvement *per se*, policy-makers may have other reasons to not adopt an app as a monitoring mode. One reason could be a fear that the app would expose the level of control that the government has over the utility. Fears of blame aside, app-driven data presents risks for the government and utility, which largely stem from the privacy concerns of consumers. The uptake of such an app would force the government to take on data breach notification responsibilities and to develop Privacy laws, at the very

least. Failure to do this could result in a lack of trust on the consumer end, and an abandonment of the app. Another reason could be a fear of the use of apps for engaging in disinformation campaigns and promoting political reforms.

Although the research shows evidence of public acceptance of technological surveillance tools, some consumers will always be wary about the government having access to more personal information than they wish to disclose, and of the possible repercussions that result from reporting negative information about a powerful company. In many countries, there is a general fear of persecution. To ease concerns over backlash during the research, it was explained to the citizen scientists that the technological tool only generated aggregated and anonymized data, which could then not be traced back to an individual. This worked very well at the time of the study, however it should be anticipated that any evolution in the authoritarian tendencies of the political regime could undoubtedly influence whether people choose to participate, or not. Hence, it is suggested that if this approach is used in future in Nepal or in other countries, the app be run by an independent provider in order to ensure the trust of the users. This would in effect replicate exactly what was done in this research, where only the author had access to the data and personal information linked to participants.

In order to completely dispel these fears from all the stakeholder's perspectives, there would need to be evidence of close cooperation between government authorities and technology companies - but with few signs that the government is amassing the number of trained operational personnel needed to track failures in the water supply manually, technology may be an alluring option to everyone involved, to fill the gaps effectively and at a low cost.

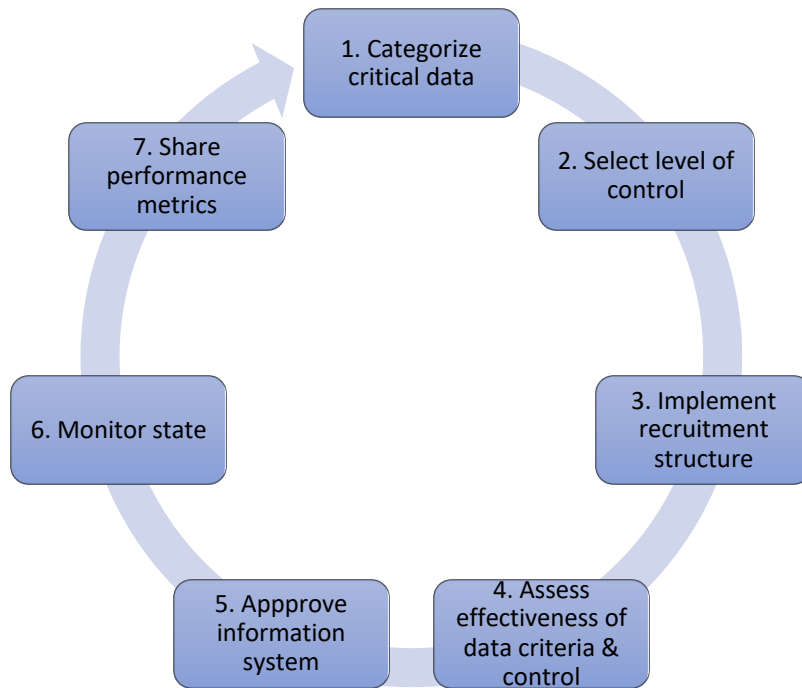
To conclude, in the short term the citizen-app is clearly a useful tool to rebuild trust in the

water utility, by simultaneously making customers feel empowered while identifying low-effort high-reward remediation opportunities in the water supply network. In the long term, the approach would promote an inclusive approach to water management, where the water provision strategy is designed around the citizen's needs – needs that would be exposed by their data – and not the other way around.

5.3 Protocol

For the work in this thesis to be easily replicated by utilities around the developing world, a set of frameworks was put in place and an overarching protocol designed.

The internal implementation framework (Figure 60) outlines how a utility would go about structuring a citizen science data collection initiative and can be visualized as “background work” to actually setting up the citizen network and data collection process. The external implementation framework (Figure 61) outlines how a utility would proceed to execute the citizen science data collection initiative. The two frameworks work in tandem, as described in the protocol that follows.



1. Categorize critical data

- What data does the water utility need e.g. arrival time of water?
- How sensitive does the data need to be e.g. time resolution in minutes, hours or days ?
- What is the temporal and spatial resolution of the data?
- Is the adverse impact of not having this level of resolution or sensitivity worth the extra investment?

2. Select level of control

The utility should determine whether it requires more than the proposed 3 consecutive reports to validate a data point.

3. Implement recruitment

Implement recruitment measures within areas of interest, applying the criteria highlighted in steps 1 & 2.

4. Assess effectiveness of the data criteria & control

- Are the controls operating as intended?

- Can they be streamlined?

- Is the data meeting the requirements of the water utility? i.e. collecting enough data, does the sensitivity need to be adjusted, is the data being collected correctly?

5. Approve information system

If the data is acceptable, the utility should continue operations in this way until enough data is collected or the issue resolved.

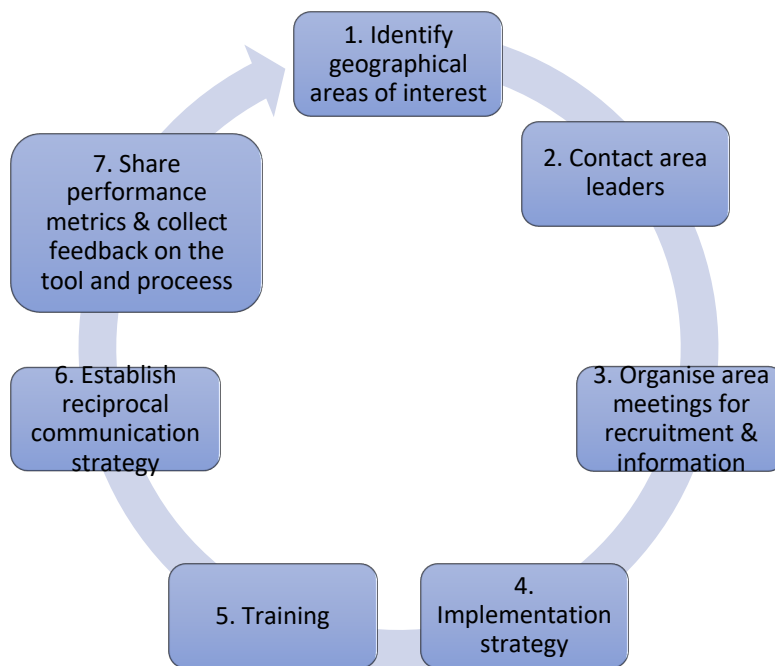
6. Monitor state

The utility should continuously monitor for changes to the information system and reassess control effectiveness.

7. Share performance metrics

The utility should share the performance metrics of the initiative, both internally and externally to improve transparency and work ethic.

Figure 60. Internal implementation framework



1. Identify geographical areas of interest

Which communities are of interest? It may be desirable to focus on one area at a time to learn and improve from each implementation.

2. Contact area leaders

Use a local translator to make leaders and later citizens more comfortable.

3. Organise area meetings for recruitment & information

Ensure that information flows both ways: the research lead should inform citizens on the initiative & inform themselves through informal interview on participant motivations for partaking in the research. This will form the basis to design a retention strategy.

This step can and should be used to collect information to make sure that the internal implementation framework is sound. For example, if the framework designated a time frame of 1 week but citizens report water every 2 weeks, the internal framework should be revised to take the into account as part of a risk -reduction strategy to maximise the number of citizens recruited. It will

lose nothing by extending the time frame but lose 1 week if data if the information is ignored.

4. Implementation strategy

The utility should respond to the citizen's motivations to participate (see point 3).

5. Training citizens to record data on the tool

Local translators and enumerators should be use to train the citizens and respond to their questions. Ideally use 1 enumerator per 3 citizens, with a mix of male and female enumerators for gender balance.

6. Establish reciprocal communication strategy

e.g. Facebook

7. Share performance metrics & collect feedback on the tool and proceess

The utility should share the performance metrics of the initiative as a strategy to demonstrate transparency and ethic and by extension, promote the retention of citizens

Figure 61. External implementation framework

Finally, the protocol below (Table 15) is intended to guide the user through each phase of the project, specifying which processes should be put in place from each framework at each phase, and highlighting the synergies between the frameworks.

Table 15. Protocol for carrying out a citizen-science data collection initiative in an IWS setting

Phase of project	Processes
Project brief	- Identify key stakeholders & establish their requirements from the project - Initiate steps 1 & 2 from the internal framework
Planning	- Create tool - Initiate step 1 of the external framework
Delivery	- Initiate steps 3,4,5,6 from the external framework - Initiate step 3 from the internal framework
Material collected	- Initiate step 4 from the external framework (“material” here refers to both citizens and the data they collect)
Intake & sorting	- Initiate step 4 from the internal framework
Quality assurance	- Initiate step 5 from the internal framework
Sorting & output	- Initiate steps 6 & 7 from the internal framework

5.4 Resulting good practices

In terms of resulting good practices for conducting citizen science in intermittent water supplies, if a community has a low validation score, further investigation is needed to see whether intermittency really is highly variable in that community or whether there are just not enough volunteers. This is also relevant when considering how translatable is this method to other countries - one should think carefully about what is “rare” in the context of the intermittency in that location (i.e. is it rare having water or not having water) – as this affects the design of the methodology. The relative male dominance culturally in Nepal compared to other countries may also affect the successful uptake and whether training approaches need to be adapted.

A recommendation for further research would be to validate this data against data from flow meters, if these could be installed; this was not possible during the course of this study, due to budget and time constraints.

It was also beyond the scope of this study to assess the reliability of the water quality data that was supplied by the citizen scientists – i.e. the water quality testing was used in this study as a successful hook to encourage participation rather than to rigorously assess water quality trends. Further research could focus on the ability of citizen science to perform readings of water quality test results. This would involve distributing more test kits, asking the citizens to read and report the results, and comparing those to a professional scientist’s readings of the results, as well as comparison of their water quality test kit results with those derived from the same samples tested in certified laboratories. It would also be useful to develop machine

learning-based image recognition algorithms so that the water quality testing could be automated even further, reducing the possibility of errors by citizens mis-counting coliforms or mis-interpreting the colour outputs of the tests, for example.

Additionally, it may be interesting to use this citizen-driven water quality monitoring approach in research seeking to link this water quality data to proxy health measures, by getting people to record what are the sources of their drinking water both inside and outside of the home and supply data on proxy health measures, such as day absences from school or work due to gastrointestinal illness .

Conducting the same research in other countries with the same app and the same training techniques would also be valuable to understand the degree to which these need to be adapted each time. During the course of this PhD, the author co-supervised a final-year undergraduate's project which took an initial look at this in Peru (Richard Glass) and found that a slightly different approach was needed there, because of different levels of intermittency (there is a much higher water reliability than in Nepal) and different levels of participant characteristics (generally a slightly more educated population).

A recommendation for future replications of this research would be to interview as many stakeholders as possible in the early development of the methodology, as they are a the most reliable source of information in countries where public data and information is dubious e.g. countries where freedom of speech is restricted. This would save time trying to locate information that may simply not be available. For example, a considerable amount of time was spent in this research trying to acquire information about the household water

consumption, based on the fact that public data shows that 99% of households are metered. However the reality is that meters are only sometimes present on properties, and are not used nor even in working order.

Another recommendation would be to hold discussion groups with citizens as early on as possible, to understand what their personal experiences and grievances are when it comes to their water supply. These personal vexations may differ from what is perceived by those in charge, and catering to them is crucial to gaining and retaining participants' trust and cooperation. For example in this case, the industry players failed to recognize that citizens were concerned about the water quality. If the research is conducted in the global south, it would also be preferable to divide the discussion groups by sex, as women may tend to be intimidated by men which results in them speaking less freely, as was observed in this research on occasion.

Based on the stakeholder interviews, the research could seek to collect evidence of the usefulness of citizen science in monitoring a project's success post-completion, for example by collaborating with the ADB on applying the tool to identify and report on water leaks post-Melamchi.

With more time, the research findings could have been presented to policy-makers to establish if they would consider using citizen-science input to shape policy-discussions on water supply improvement projects in future, based on the successful findings. It would also be interesting to present the findings to the water utility company, to determine whether this proof of concept creates a behavioural change in KUKL's managerial culture and the way it runs its operations. The fact that they have now implemented their own app along the same

lines as the one used in this research suggests that such a follow-up investigation into the managerial culture may be possible.

Conclusions

This research offers novel frameworks and protocol for the effective design and delivery of a citizen-science approach to monitoring water supply intermittency in developing countries. The approach channels intangible customer dissatisfaction into producing tangible data that both stimulates and facilitates interventions in the piped water delivery system, while empowering citizens.

To re-cap, the research objectives were to determine, in the context of intermittent water supplies in low-income settings:

- 1) If the method employed is feasible and effective in providing useful data, and
- 2) If the method and data is reliable enough to be used and accepted as valid by key water supply decision-makers.

The study showed, for the first time, that it is possible, with limited resources, time and personnel, to train a network of citizen scientists to provide water supply intermittency data that is validated and that is viewed as being operationally useful to key stakeholders, such as water utility managers and infrastructure funders. Importantly, both the method and the data were trusted by the vast majority of decision-makers interviewed in this research.

The data received by this method was shown to be internally consistent and a more accurate reflection of the reality than the previous official understanding reflected in published water schedules. The method was effective across the citizen demographic characteristics that were tested (e.g. sex, age), however the degree to which this finding was affected by the context of Nepalese culture and the particular training methods employed remains uncertain. Citizen

science approaches to monitor water supply intermittency like the one invented in this study may be applicable in other low-income, data-scarce settings, though these may need adaptation based on the local cultural contexts and/or the severity of the location-specific intermittency experienced. Extending this approach to water quality monitoring and related health outcomes would be valuable as a next step.

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Appendices

Appendix A. Raw Citizen Science Data

ID	Date	Sex	Age	timestamp	Lat.	Long.	buttonPicked
849359 369	Tue Jun 11 2019	Fem ale	26-55 years	17:51:09	27.7200 026	85.3224 6684	waterRed
849359 369	Mon Jun 24 2019		26-55 years	19:27:56	27.7200 026	85.3224 6684	waterRed
849359 369	Tue Jun 25 2019		26-55 years	21:53:26	27.7200 026	85.3224 6684	waterRed
849359 369	Sun Jun 30 2019		26-55 years	19:17:27	27.7200 026	85.3224 6684	waterGreen
986222 775	Tue Jun 11 2019	Fem ale	26-55 years	17:49:17	27.7117 823	85.3230 5644	waterRed
986222 775	Wed Jun 12 2019		26-55 years	14:51:45	27.7117 823	85.3230 5644	waterRed
980190 4050	Thu Jun 20 2019	NA		21:34:00	27.7394 483	85.3041 1937	waterGreen
980190 4050	Fri Jun 21 2019			21:49:43	27.7394 483	85.3041 1937	waterRed
980190 4050	Sat Jun 22 2019			19:23:35	27.7394 483	85.3041 1937	waterRed
980190 4050	Mon Jun 24 2019			12:58:16	27.7394 483	85.3041 1937	waterGreen
980279 3052	Tue Jun 11 2019	Mal e	18-25 years	07:57:41	27.6706 387	85.3003 8509	waterRed

980279 3052	Wed Jun 12 2019		18-25 years	19:14:18	27.6706 387	85.3003 8509	waterGreen
980305 5109	Fri Jun 07 2019	Fem ale	18-25 years	15:45:41	27.7155 133	85.3129 0834	waterRed
980316 3441	Sun Jun 16 2019	NA		22:29:17	27.7392 172	85.3042 6966	waterRed
980316 3441	Mon Jun 17 2019			22:53:36	27.7392 172	85.3042 6966	waterGreen
980316 3441	Tue Jun 18 2019			22:21:28	27.7392 172	85.3042 6966	waterRed
980316 3441	Wed Jun 19 2019			20:15:32	27.7392 172	85.3042 6966	waterRed
980316 3441	Thu Jun 20 2019			19:33:09	27.7392 172	85.3042 6966	waterGreen
980316 3441	Fri Jun 21 2019			20:34:36 .	27.7392 172	85.3042 6966	waterRed
981008 9900	Tue Jun 18 2019	NA		22:42:14 .	27.7405 594	85.3033 995	waterRed
981008 9900	Wed Jun 19 2019			22:19:36 .	27.7405 594	85.3033 995	waterRed
981200 8024	Sun Jun 16 2019	NA		21:57:50 .	27.7404 773	85.3032 9901	waterRed
981200 8024	Mon Jun 17 2019			22:27:28 .	27.7404 773	85.3032 9901	waterGreen
981200 8024	Tue Jun 18 2019			19:38:06 .	27.7404 773	85.3032 9901	waterRed
981200 8024	Wed Jun 19 2019			22:20:28 .	27.7404 773	85.3032 9901	waterRed

981200 8024	Thu Jun 20 2019			21:18:18 .	27.7404 773	85.3032 9901	waterGreen
981200 8024	Tue Jun 25 2019			12:43:27 .	27.7404 773	85.3032 9901	waterRed
981347 0343	Mon Jun 10 2019	Fem ale	26-55 years				
984115 1723	Sun Jun 09 2019	Fem ale	26-55 years	20:55:41 .	27.7370 65	85.3597 7045	waterRed
984115 1723	Mon Jun 10 2019		26-55 years	19:44:54 .	27.7370 65	85.3597 7045	waterRed
984115 1723	Thu Jun 13 2019		26-55 years	18:52:56 .	27.7370 65	85.3597 7045	waterRed
984115 1723	Sat Jun 15 2019		26-55 years	20:42:55	27.7370 65	85.3597 7045	waterRed
984115 1723	Sun Jun 16 2019		26-55 years	20:54:47 .	27.7370 65	85.3597 7045	waterGreen
984115 1723	Tue Jun 18 2019		26-55 years	18:28:10 .	27.7370 65	85.3597 7045	waterRed
984115 1723	Wed Jun 19 2019		26-55 years	20:04:06 .	27.7370 65	85.3597 7045	waterRed
984115 1723	Fri Jun 21 2019		26-55 years	16:04:59 .	27.7370 65	85.3597 7045	waterRed
984115 9222	Tue Jun 11 2019	NA		19:20:51 .	27.6384 574	85.3059 9812	waterGreen
984115 9222	Wed Jun 12 2019			07:55:42 .	27.6384 574	85.3059 9812	waterGreen
984119 4992	Sat Jun 15 2019	NA		17:10:00 .	27.6548 108	85.3164 1147	waterRed

984119 4992	Tue Jun 18 2019			19:50:15 .	27.6548 108	85.3164 1147	waterGreen
984119 4992	Wed Jun 19 2019			22:03:29 .	27.6548 108	85.3164 1147	waterRed
984133 0048	Mon Jun 10 2019	Male	over 55 years	18:13:45 .	27.7158 45	85.3224 2848	waterRed
984133 0048	Tue Jun 11 2019		over 55 years	09:56:37 .	27.7158 45	85.3224 2848	waterRed
984133 0048	Wed Jun 12 2019		over 55 years	11:01:06 .	27.7158 45	85.3224 2848	waterRed
984133 0048	Thu Jun 13 2019		over 55 years	18:06:05 .	27.7158 45	85.3224 2848	waterRed
984133 0048	Sat Jun 15 2019		over 55 years				
984133 0048	Mon Jun 17 2019		over 55 years				
984133 0048	Fri Jun 21 2019		over 55 years				
984133 0048	Fri Jun 28 2019		over 55 years				
984133 0048	Thu Jul 4 2019		over 55 years				
984133 4843	Tue Jun 11 2019	Female	26-55 years	18:33:12	27.6621 979	85.3093 6342	waterGreen
984136 4492	Sun Jun 09 2019	Male	over 55 years	21:29:43 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sun Jun 09 2019		over 55 years	21:36:13 .	27.7311 434	85.3637 0157	waterRed

984136 4492	Tue Jun 11 2019		over 55 years	05:02:12 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Tue Jun 11 2019		over 55 years	05:04:20 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Wed Jun 12 2019		over 55 years	05:53:16 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Thu Jun 13 2019		over 55 years	11:09:20 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Fri Jun 14 2019		over 55 years	07:09:01 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sat Jun 15 2019		over 55 years	06:48:19 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sun Jun 16 2019		over 55 years	22:27:42 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Tue Jun 18 2019		over 55 years	05:56:55 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Wed Jun 19 2019		over 55 years	07:24:04 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Wed Jun 19 2019		over 55 years	21:03:48 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sun Jun 23 2019		over 55 years	15:25:15 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Tue Jun 25 2019		over 55 years	09:45:31 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Tue Jun 25 2019		over 55 years	21:30:43 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Wed Jun 26 2019		over 55 years	08:40:43 .	27.7311 434	85.3637 0157	waterRed

984136 4492	Thu Jun 27 2019		over 55 years	08:49:34 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sun Jun 30 2019		over 55 years	08:12:22 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Tue Jul 02 2019		over 55 years	21:12:20 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Wed Jul 03 2019		over 55 years	06:49:54 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sat Jul 06 2019		over 55 years	07:24:22 .	27.7311 434	85.3637 0157	waterRed
984136 4492	Sun Jul 07 2019		over 55 years	08:25:08 .	27.7311 434	85.3637 0157	waterRed
984139 9334	Tue Jun 11 2019	Fem ale	26-55 years	07:25:53 .	27.6683 459	85.2995 2642	waterGreen
984139 9334	Wed Jun 12 2019		26-55 years	07:25:53 .	27.6683 459	85.2995 2642	waterRed
984139 9334	Thu Jun 13 2019		26-55 years	07:25:53 .	27.6683 459	85.2995 2642	waterRed
984139 9334	Fri Jun 14 2019		26-55 years	07:25:53 .	27.6683 459	85.2995 2642	waterRed
984139 9334	Sat Jun 15 2019		26-55 years	07:25:53 .	27.6683 459	85.2995 2642	waterRed
984143 5647	Wed Jun 12 2019	NA		18:55:20 .	27.6705 19	85.2984 6242	waterRed
984143 5647	Mon Jun 24 2019			18:02:46 .	27.6705 19	85.2984 6242	waterGreen
984143 8608	Mon Jun 10 2019	Fem ale	26-55 years	20:12:28 .	27.7341 088	85.3579 696	waterRed

984145 8349	Tue Jun 11 2019	Fem ale	26-55 years	22:11:07 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Wed Jun 12 2019		26-55 years	19:20:23 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Thu Jun 13 2019		26-55 years	18:46:37 .	27.6614 233	85.3096 06	waterRed
984145 8349	Fri Jun 14 2019		26-55 years	22:18:48 .	27.6614 233	85.3096 06	waterRed
984145 8349	Sun Jun 16 2019		26-55 years	20:23:11 .	27.6614 233	85.3096 06	waterRed
984145 8349	Mon Jun 17 2019		26-55 years	21:12:31 .	27.6614 233	85.3096 06	waterRed
984145 8349	Tue Jun 18 2019						
984145 8349	Thu Jun 20 2019		26-55 years	22:37:29 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Fri Jun 21 2019		26-55 years	21:28:09 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Mon Jun 24 2019		26-55 years	12:56:16 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Wed Jun 26 2019		26-55 years	16:51:46 .	27.6614 233	85.3096 06	waterGreen
984145 8349	Mon Jul 01 2019		26-55 years	18:46:13 .	27.6614 233	85.3096 06	waterRed
984145 8779	Tue Jun 11 2019	Mal e	over 55 years	17:44:51 .	27.6548 548	85.3172 8473	waterRed
984145 8779	Wed Jun 19 2019		over 55 years	17:42:46 .	27.6548 548	85.3172 8473	waterGreen

984145 8779	Tue Jun 25 2019		over 55 years	19:15:45 .	27.6548 548	85.3172 8473	waterRed
984145 8779	Fri Jun 28 2019		over 55 years	17:33:19 .	27.6548 548	85.3172 8473	waterGreen
984145 8779	Sun Jun 30 2019		over 55 years	17:54:53 .	27.6548 548	85.3172 8473	waterGreen
984147 2020	Fri Jun 14 2019	Fem ale	26-55 years	11:17:29 .	27.6471 725	85.3137 7738	waterGreen
984147 2020	Sat Jun 15 2019		26-55 years	18:13:35 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Mon Jun 17 2019		26-55 years	18:06:49 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Tue Jun 18 2019		26-55 years	21:25:38 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Fri Jun 21 2019		26-55 years	21:44:23 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Sun Jun 23 2019		26-55 years	19:58:47 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Mon Jun 24 2019		26-55 years	19:24:02 .	27.6471 725	85.3137 7738	waterRed
984147 2020	Wed Jun 26 2019		26-55 years	16:40:50 .	27.6471 725	85.3137 7738	waterRed
984150 7800	Sat Jun 22 2019	NA		16:40:22 .	27.6589 403	85.3089 4046	waterRed
984160 6694	Sun Jun 09 2019	Mal e	over 55 years	18:21:05 .	27.7344 107	85.3594 9461	waterGreen
984160 6694	Mon Jun 10 2019		over 55 years	19:15:42 .	27.7344 107	85.3594 9461	waterRed

984160 6694	Tue Jun 11 2019		over 55 years	17:36:30 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Wed Jun 12 2019		over 55 years	10:28:07 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Thu Jun 13 2019		over 55 years	06:21:55 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Fri Jun 14 2019		over 55 years	20:03:20 .	27.7344 107	85.3594 9461	waterGreen
984160 6694	Sat Jun 15 2019		over 55 years	12:30:17 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Mon Jun 17 2019		over 55 years	20:30:48 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Tue Jun 18 2019		over 55 years	17:35:19 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Wed Jun 19 2019		over 55 years	07:38:46 .	27.7344 107	85.3594 9461	waterGreen
984160 6694	Thu Jun 20 2019		over 55 years	20:01:41 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Sat Jun 22 2019		over 55 years	20:14:07 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Fri Jun 28 2019		over 55 years	08:36:23 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Sat Jun 29 2019		over 55 years	12:49:40 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Sun Jun 30 2019		over 55 years	09:01:34 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Mon Jul 01 2019		over 55 years	10:25:27 .	27.7344 107	85.3594 9461	waterGreen

984160 6694	Tue Jul 02 2019		over 55 years	08:42:36 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Wed Jul 03 2019		over 55 years	09:16:32 .	27.7344 107	85.3594 9461	waterRed
984160 6694	Thu Jul 04 2019		over 55 years	09:54:32 .	27.7344 107	85.3594 9461	waterRed
984161 1928	Tue Jun 11 2019	Fem ale		05:46:06 .	27.6699 022	85.3254 0588	waterGreen
984161 1928	Sat Jun 15 2019			17:20:34 .	27.6551 681	85.3164 2053	waterRed
984161 1928	Sun Jun 16 2019			21:29:38 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Tue Jun 18 2019			19:38:16 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Wed Jun 19 2019			20:19:13 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Fri Jun 21 2019			20:10:27 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Sat Jun 22 2019			20:38:35 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Sun Jun 23 2019			22:00:52 .	27.6551 681	85.3164 2053	waterRed
984161 1928	Tue Jun 25 2019			18:53:56	27.6551 681	85.3164 2053	waterRed
984161 1928	Wed Jun 26 2019			21:19:09 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Thu Jun 27 2019			20:12:45 .	27.6551 681	85.3164 2053	waterGreen

984161 1928	Fri Jun 28 2019			20:22:11 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Sun Jun 30 2019			18:06:49 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Tue Jul 02 2019			18:23:05 .	27.6551 681	85.3164 2053	waterRed
984161 1928	Fri Jul 05 2019			22:12:47 .	27.6551 681	85.3164 2053	waterRed
984161 1928	Sat Jul 06 2019			20:38:05 .	27.6551 681	85.3164 2053	waterGreen
984161 1928	Tue Jul 09 2019			00:06:06 .	27.6551 681	85.3164 2053	waterGreen
984171 4554	Sun Jun 9 2019	Male	26-55 years				
984171 4554	Tue Jun 25 2019		26-55 years				
984185 3027	Tue Jun 11 2019	Female	26-55 years	19:24:31 .	27.7122 256	85.3233 9928	waterRed
984185 3027	Wed Jun 19 2019		26-55 years	19:19:45 .	27.7122 256	85.3233 9928	waterGreen
984185 3027	Thu Jun 20 2019		26-55 years	19:21:30 .	27.7122 256	85.3233 9928	waterGreen
984185 3027	Sun Jun 23 2019		26-55 years	21:53:23 .	27.7122 256	85.3233 9928	waterGreen
984185 3027	Mon Jun 24 2019		26-55 years	20:10:00 .	27.7122 256	85.3233 9928	waterRed
984185 3027	Tue Jun 25 2019		26-55 years	20:47:36 .	27.7122 256	85.3233 9928	waterRed

984185 3027	Wed Jun 26 2019		26-55 years	22:54:41 .	27.7122 256	85.3233 9928	waterGreen
984185 3027	Mon Jul 01 2019		26-55 years	23:02:37 .	27.7122 256	85.3233 9928	waterRed
984185 3027	Tue Jul 02 2019		26-55 years	21:23:39 .	27.7122 256	85.3233 9928	waterRed
984185 3027	Sat Jul 06 2019		26-55 years	00:10:51 .	27.7122 256	85.3233 9928	waterRed
984331 3434	Sun Jun 09 2019	Fem ale	26-55 years	17:00:34 .	27.7357 851	85.3611 345	waterGreen
984331 3434	Mon Jun 10 2019		26-55 years	09:02:08 .	27.7357 851	85.3611 345	waterRed
984331 3434	Tue Jun 11 2019		26-55 years	09:20:32 .	27.7357 851	85.3611 345	waterRed
984331 3434	Wed Jun 12 2019		26-55 years	13:04:58 .	27.7357 851	85.3611 345	waterRed
984331 3434	Thu Jun 13 2019		26-55 years	14:36:44 .	27.7357 851	85.3611 345	waterRed
984331 3434	Fri Jun 14 2019		26-55 years	13:23:55 .	27.7357 851	85.3611 345	waterRed
984331 3434	Sat Jun 15 2019		26-55 years	11:33:18 .	27.7357 851	85.3611 345	waterRed
984331 3434	Sun Jun 16 2019		26-55 years	15:44:56 .	27.7357 851	85.3611 345	waterRed
984331 3434	Wed Jun 19 2019		26-55 years	10:45:06 .	27.7357 851	85.3611 345	waterGreen
984367 8789	Sun Jun 16 2019	NA		18:05:57	27.7411 788	85.3033 9434	waterRed

984367 8789	Mon Jun 17 2019			18:24:35 .	27.7411 788	85.3033 9434	waterGreen
984367 8789	Tue Jun 18 2019			21:40:47 .	27.7411 788	85.3033 9434	waterRed
984367 8789	Thu Jun 20 2019			21:38:47 .	27.7411 788	85.3033 9434	waterGreen
984367 8789	Mon Jun 24 2019			20:03:51 .	27.7411 788	85.3033 9434	waterGreen
984367 8789	Sun Jun 30 2019			07:21:56 .	27.7411 788	85.3033 9434	waterRed
984367 8789	Mon Jul 01 2019			05:25:58 .	27.7411 788	85.3033 9434	waterRed
984369 0732	Tue Jun 11 2019	NA		17:59:11 .	27.6428 042	85.3227 2681	waterGreen
984369 0732	Tue Jun 11 2019			18:36:20 .	27.6428 042	85.3227 2681	waterGreen
984369 0732	Tue Jun 11 2019			18:37:56 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Sat Jun 15 2019			21:32:56 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Sun Jun 16 2019			21:43:31 .	27.6428 042	85.3227 2681	waterGreen
984369 0732	Mon Jun 17 2019			21:47:46 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Tue Jun 18 2019			17:25:40 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Thu Jun 20 2019			09:05:05 .	27.6428 042	85.3227 2681	waterGreen

984369 0732	Fri Jun 21 2019			07:36:00 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Tue Jun 25 2019			18:33:58 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Thu Jun 27 2019			21:17:38 .	27.6428 042	85.3227 2681	waterRed
984369 0732	Sat Jun 29 2019			08:28:45 .	27.6428 042	85.3227 2681	waterGreen
984369 0732	Mon Jul 01 2019			18:13:04 .	27.6428 042	85.3227 2681	waterGreen
984410 0555	Tue Jun 11 2019	NA		17:55:08 .	27.6544 588	85.3167 4749	waterGreen
984530 0555	Tue Jun 11 2019	NA		18:29:31 .	27.6621 554	85.3093 5958	waterGreen
984530 0555	Thu Jun 13 2019			07:57:21 .	27.6621 554	85.3093 5958	waterRed
984530 0555	Sat Jun 22 2019			18:52:53 .	27.6621 554	85.3093 5958	waterRed
984530 0555	Mon Jun 24 2019			15:03:07 .	27.6621 554	85.3093 5958	waterRed
984631 8021	Tue Jun 11 2019	Male	over 55 years	07:58:26 .	27.7148 074	85.3269 9917	waterRed
984736 3242	21-Mar-18	Male	18-25 years	1:06:38 .	27.7016 03	85.4214 38	waterGreen
984736 3242	21-Mar-18		18-25 years	19:21:58	27.7016 03	85.4214 38	waterGreen
984736 3242	22-Mar-18		18-25 years	17:07:43	27.7016 03	85.4214 38	waterGreen

984736 3242	23-Mar-18		18-25 years	20:03:41	27.7016 03	85.4214 38	waterGreen
984736 3242	28-Mar-18		18-25 years	2:17:31	27.7016 03	85.4214 38	waterGreen
984736 3242	28-Mar-18		18-25 years	13:18:47	27.7016 03	85.4214 38	waterGreen
984736 3242	29-Mar-18		18-25 years	11:10:39	27.7016 03	85.4214 38	waterGreen
984736 3242	29-Mar-18		18-25 years	23:35:12	27.7016 03	85.4214 38	waterGreen
984736 3242	30-Mar-18		18-25 years	14:27:29	27.7016 03	85.4214 38	waterGreen
984736 3242	30-Mar-18		18-25 years	20:27:40	27.7016 03	85.4214 38	waterGreen
984736 3242	31-Mar-18		18-25 years	11:40:23	27.7016 03	85.4214 38	waterGreen
984736 3242	1-Apr-18		18-25 years	19:26:01	27.7016 03	85.4214 38	waterGreen
984736 3242	3-Apr-18		18-25 years	15:49:03	27.7016 03	85.4214 38	waterGreen
984736 3242	6-Apr-18		18-25 years	1:50:39	27.7016 03	85.4214 38	waterGreen
984736 3242	8-Apr-18		18-25 years	19:23:12	27.7016 03	85.4214 38	waterGreen
984736 3242	9-Apr-18		18-25 years	12:03:12	27.7016 03	85.4214 38	waterGreen
984736 3242	15-Apr-18		18-25 years	23:47:58	27.7016 03	85.4214 38	waterGreen

984736 3242	16-Apr-18		18-25 years	19:25:12	27.7016 03	85.4214 38	waterGreen
984736 3242	21-Apr-18		18-25 years	14:27:19	27.7016 03	85.4214 38	waterGreen
984736 3242	26-Apr-18		18-25 years	12:50:23	27.7016 03	85.4214 38	waterGreen
984736 3242	27-Apr-18		18-25 years	19:19:13	27.7016 03	85.4214 38	waterGreen
984736 3242	30-Apr-18		18-25 years	18:50:33	27.7016 03	85.4214 38	waterGreen
984736 3242	2-May-18		18-25 years	23:34:27	27.7016 03	85.4214 38	waterGreen
984736 3242	Fri Jun 14 2019		18-25 years	21:01:27 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sat Jun 15 2019		18-25 years	10:39:24 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sat Jun 15 2019		18-25 years	21:02:39 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sun Jun 16 2019		18-25 years	17:53:23 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sun Jun 16 2019		18-25 years	22:07:56 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Mon Jun 17 2019		18-25 years	20:06:22 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Wed Jun 19 2019		18-25 years	11:01:37 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Thu Jun 20 2019		18-25 years	23:26:13 .	27.7018 224	85.4213 525	waterGreen

984736 3242	Sat Jun 22 2019		18-25 years	14:18:02 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sun Jun 23 2019		18-25 years	12:38:46 .	27.7018 224	85.4213 525	waterGreen
984736 3242	Sun Jun 23 2019		18-25 years	21:47:52 .	27.7018 224	85.4213 525	waterGreen
984805 7313	Mon Jun 10 2019	Mal e	26-55 years	08:04:55 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Tue Jun 11 2019		26-55 years	06:21:53 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Wed Jun 12 2019		26-55 years	07:37:32 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Thu Jun 13 2019		26-55 years	20:43:34 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Fri Jun 14 2019		26-55 years	21:23:11 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Mon Jun 17 2019		26-55 years	04:59:06 .	27.7337 444	85.3601 0404	waterGreen
984805 7313	Wed Jun 19 2019		26-55 years	09:22:42 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Thu Jun 20 2019		26-55 years	07:14:22 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Fri Jun 21 2019		26-55 years	08:32:11 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Sat Jun 22 2019		26-55 years	10:56:12 .	27.7337 444	85.3601 0404	waterGreen
984805 7313	Mon Jun 24 2019		26-55 years	07:24:39 .	27.7337 444	85.3601 0404	waterRed

984805 7313	Tue Jun 25 2019		26-55 years	05:43:58 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Wed Jun 26 2019		26-55 years	16:36:56 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Thu Jun 27 2019		26-55 years	10:12:57 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Fri Jun 28 2019		26-55 years	08:46:22 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Mon Jul 01 2019		26-55 years	21:29:24 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Tue Jul 02 2019		26-55 years	20:19:59 .	27.7337 444	85.3601 0404	waterRed
984805 7313	Thu Jul 04 2019		26-55 years	10:13:14 .	27.7337 444	85.3601 0404	waterRed
984904 4825	Tue Jun 11 2019	Male	26-55 years				
984918 8304	Tue Jun 11 2019	Female	26-55 years	17:41:30 .	27.7185 37	85.3273 4587	waterRed
984918 8304	Tue Jun 11 2019		26-55 years	19:02:29	27.7185 37	85.3273 4587	waterRed
984918 8304	Thu Jun 13 2019		26-55 years	13:49:49 .	27.7185 37	85.3273 4587	waterGreen
984918 8304	Fri Jun 14 2019		26-55 years	21:13:05	27.7185 37	85.3273 4587	waterRed
984918 8304	Wed Jun 19 2019		26-55 years	10:43:34 .	27.7185 37	85.3273 4587	waterRed
984918 8304	Thu Jun 20 2019		26-55 years	18:06:13 .	27.7185 37	85.3273 4587	waterGreen

984918 8304	Sun Jun 23 2019		26-55 years	17:23:24 .	27.7185 37	85.3273 4587	waterRed
984922 1594	Tue Jun 11 2019	Mal e	26-55 years	07:27:32 .	27.6706 691	85.2993 7937	waterRed
984951 0999	Tue Jun 11 2019	Mal e	26-55 years	07:21:38 .	27.7148 914	85.3233 1344	waterRed
984951 0999	Fri Jun 14 2019			20:12:17 .	27.7148 914	85.3233 1344	waterRed
984974 2659	Fri Jun 14 2019	NA		21:00:26 .	27.6849 247	85.3568 8162	waterRed
984974 2659	Fri Jun 14 2019			21:01:23 .	27.6849 247	85.3568 8162	waterGreen
984974 2659	Sat Jun 15 2019			08:33:14 .	27.6849 247	85.3568 8162	waterRed
984974 2659	Sat Jun 15 2019			08:35:09 .	27.6849 247	85.3568 8162	waterGreen
984974 2659	Sun Jun 16 2019			16:57:22 .	27.6849 247	85.3568 8162	waterRed
985101 4040	Tue Jun 11 2019	NA		07:38:36 .	27.7316 133	85.6425 401	waterGreen
985101 4040	Mon Jun 17 2019			07:40:11 .	27.7316 133	85.6425 401	waterGreen
985101 6674	Sun Jun 16 2019	NA		22:02:12 .	27.7398 323	85.3037 0198	waterRed
985107 7192	Mon Jun 10 2019	Mal e	26-55 years	14:40:52 .	27.7336 137	85.3523 1113	waterGreen
985107 7192	Tue Jun 11 2019		26-55 years	08:16:12 .	27.7336 137	85.3523 1113	waterGreen

985107 7192	Sat Jun 15 2019		26-55 years				
985108 2350	Sun Jun 09 2019	Male	26-55 years	18:57:53 .	27.7327 971	85.3627 4583	waterRed
985108 2350	Sat Jun 15 2019		26-55 years	09:43:08 .	27.7327 971	85.3627 4583	waterRed
985108 2350	Mon Jun 24 2019		26-55 years	19:25:59 .	27.7327 971	85.3627 4583	waterRed
985108 2350	Fri Jun 28 2019		26-55 years	21:32:53 .	27.7327 971	85.3627 4583	waterRed
985108 2350	Mon Jul 01 2019		26-55 years	21:44:26 .	27.7327 971	85.3627 4583	waterRed
985108 9898	Tue Jun 11 2019	Female	26-55 years	18:31:17 GMT+0545 (+0545)	27.6630 427	85.3069 067	waterGreen
985112 8857	Mon Jun 17 2019	NA		13:29:32 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Tue Jun 18 2019			08:10:59 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Wed Jun 19 2019			07:49:57 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Thu Jun 20 2019			07:58:06 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Fri Jun 21 2019			11:05:38 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Tue Jun 25 2019			17:29:47 .	27.6637 422	85.2765 2299	waterRed
985112 8857	Thu Jun 27 2019			12:41:44	27.6637 422	85.2765 2299	waterRed

985123 4578	Tue Jun 11 2019	NA		18:40:17 .	27.6550 29	85.3162 9794	waterRed
986006 1111	20-Mar-18	Fem ale	18-25 years	22:30:27	27.7032 98	85.4423 99	waterGreen
986006 1111	22-Mar-18		18-25 years	0:13:33	27.7032 98	85.4423 99	waterGreen
986006 1111	22-Mar-18		18-25 years	22:59:46	27.7032 98	85.4423 99	waterGreen
986006 1111	Fri Jun 07 2019		18-25 years	15:49:29 .	27.7252 026	85.3394 7468	waterGreen
986006 1111	Wed Jun 12 2019		18-25 years				
986006 1111	Fri Jun 21 2019		18-25 years				
986013 6640	21-Mar-18	Mal e	18-25 years	16:10:12	27.7398 891	85.3037 263	waterGreen
986013 6640	22-Mar-18		18-25 years	18:27:24	27.7398 891	85.3037 263	waterGreen
986013 6640	Sun Jun 16 2019		18-25 years	22:27:17 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Mon Jun 17 2019		18-25 years	17:41:21 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Mon Jun 17 2019		18-25 years	22:54:34 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Tue Jun 18 2019		18-25 years	21:58:01 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Wed Jun 19 2019		18-25 years	21:38:05 .	27.7401 965	85.3040 4838	waterGreen

986013 6640	Thu Jun 20 2019		18-25 years	19:58:54 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Fri Jun 21 2019		18-25 years	21:06:18 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Sat Jun 22 2019		18-25 years	18:37:59 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Sun Jun 23 2019		18-25 years	17:15:07 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Tue Jun 25 2019		18-25 years	21:46:15 .	27.7401 965	85.3040 4838	waterGreen
986013 6640	Thu Jun 27 2019		18-25 years	23:54:55 .	27.7401 965	85.3040 4838	waterGreen
986031 6389	Sun Jun 9 2019	Fem ale	26-55 years				
986033 2246	Sun Jun 16 2019	NA		17:59:00 .	27.7164 585	85.3213 2349	waterRed
986074 9001	Tue Jun 11 2019	NA		18:16:43 .	27.6434 064	85.3345 4179	waterGreen
986074 9001	Tue Jun 11 2019			18:26:14 .	27.6434 064	85.3345 4179	waterRed
986091 0000	Mon Jun 10 2019	Fem ale	26-55 years	09:36:40 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Tue Jun 11 2019		26-55 years	21:17:55 .	27.7349 803	85.3600 4945	waterGreen
986091 0000	Thu Jun 13 2019		26-55 years	20:41:39 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Sun Jun 16 2019		26-55 years	20:20:10 .	27.7349 803	85.3600 4945	waterRed

986091 0000	Mon Jun 17 2019		26-55 years	17:07:42 .	27.7349 803	85.3600 4945	waterGreen
986091 0000	Thu Jun 20 2019		26-55 years	20:37:13 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Sat Jun 22 2019		26-55 years	17:11:16 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Sun Jun 23 2019		26-55 years	21:02:52 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Mon Jun 24 2019		26-55 years	16:31:31 .	27.7349 803	85.3600 4945	waterRed
986091 0000	Tue Jun 25 2019		26-55 years	18:30:17 .	27.7349 803	85.3600 4945	waterRed
986091 0456	Sun Jun 09 2019	Fem ale	26-55 years	17:50:09 .	27.7384 518	85.3607 5856	waterRed
986091 0456	Mon Jun 10 2019			21:26:40 .	27.7384 518	85.3607 5856	waterRed
986170 2277	Tue Jun 11 2019	NA		17:57:36 .	27.6663 973	85.3020 941	waterGreen
986170 2323	Tue Jun 11 2019	NA		17:50:46 .	27.6508 811	85.3124 118	waterGreen
986495 4365	20-Mar-18	Mal e	18-25 years	21:14:15	27.7030 7	85.4331 72	waterGreen
986495 4365	22-Mar-18		18-25 years	20:36:11	27.7030 7	85.4331 72	waterGreen
986495 4365	23-Mar-18		18-25 years	19:32:22	27.7030 7	85.4331 72	waterGreen
986495 4365	24-Mar-18		18-25 years	21:07:24	27.7030 7	85.4331 72	waterGreen

986495 4365	25-Mar-18		18-25 years	18:16:54	27.7030 7	85.4331 72	waterGreen
986495 4365	26-Mar-18		18-25 years	20:08:48	27.7030 7	85.4331 72	waterGreen
986495 4365	29-Mar-18		18-25 years	20:22:40	27.7030 7	85.4331 72	waterGreen
986495 4365	30-Mar-18		18-25 years	21:13:38	27.7030 7	85.4331 72	waterGreen
986495 4365	31-Mar-18		18-25 years	21:20:11	27.7030 7	85.4331 72	waterGreen
986495 4365	1-Apr-18		18-25 years	20:33:24	27.7030 7	85.4331 72	waterGreen
986495 4365	2-Apr-18		18-25 years	21:12:01	27.7030 7	85.4331 72	waterGreen
986495 4365	3-Apr-18		18-25 years	21:17:44	27.7030 7	85.4331 72	waterGreen
986495 4365	9-Apr-18		18-25 years	22:03:48	27.7030 7	85.4331 72	waterGreen
986495 4365	11-Apr-18		18-25 years	21:49:35	27.7030 7	85.4331 72	waterGreen
986495 4365	Mon Jun 10 2019		18-25 years				
986505 7621	Mon Jun 10 2019	Fem ale	18-25 years	07:29:09 .	27.7353 243	85.3619 8317	waterRed
986952 9724	Mon Jun 10 2019	Mal e	26-55 years				
111111 111	21-Mar-18	Mal e	18-25 years	18:19:37	27.7256 187	85.3391 059	waterGreen

111111 111	23-Mar-18		18-25 years	20:16:02	27.7256 187	85.3391 059	waterGreen
111111 111	27-Mar-18		18-25 years	13:53:03	27.7256 187	85.3391 059	waterGreen
111111 111	28-Mar-18		18-25 years	21:47:54	27.7256 187	85.3391 059	waterGreen
111111 111	31-Mar-18		18-25 years	19:14:38	27.7256 187	85.3391 059	waterGreen
111111 111	2-Apr-18		18-25 years	12:17:11	27.7256 187	85.3391 059	waterGreen
111111 111	3-Apr-18		18-25 years	21:30:30	27.7256 187	85.3391 059	waterGreen
111111 111	4-Apr-18		18-25 years	19:47:14	27.7256 187	85.3391 059	waterGreen
111111 111	6-Apr-18		18-25 years	12:17:58	27.7256 187	85.3391 059	waterGreen
111111 111	7-Apr-18		18-25 years	23:28:34	27.7256 187	85.3391 059	waterGreen
111111 111	8-Apr-18		18-25 years	23:14:25	27.7256 187	85.3391 059	waterGreen
111111 111	9-Apr-18		18-25 years	23:30:16	27.7256 187	85.3391 059	waterGreen
111111 111	10-Apr-18		18-25 years	22:53:43	27.7256 187	85.3391 059	waterGreen
111111 111	13-Apr-18		18-25 years	11:33:59	27.7256 187	85.3391 059	waterGreen
111111 111	13-Apr-18		18-25 years	20:27:24	27.7256 187	85.3391 059	waterGreen

111111 111	15-Apr-18		18-25 years	7:46:19	27.7256 187	85.3391 059	waterGreen
111111 111	15-Apr-18		18-25 years	23:06:32	27.7256 187	85.3391 059	waterGreen
111111 111	23-Apr-18		18-25 years	18:34:45	27.7256 187	85.3391 059	waterGreen
111111 111	26-Apr-18		18-25 years	0:36:43	27.7256 187	85.3391 059	waterGreen
111111 111	27-Apr-18		18-25 years	23:52:33	27.7256 187	85.3391 059	waterGreen
111111 111	1-May-18		18-25 years	23:03:00	27.7256 187	85.3391 059	waterGreen
111111 111	8-May-18		18-25 years	11:42:57	27.7256 187	85.3391 059	waterGreen
111111 111	10-May-18		18-25 years	5:05:57	27.7256 187	85.3391 059	waterGreen
111111 111	13-May-18		18-25 years	22:26:43	27.7256 187	85.3391 059	waterGreen
222222 222	22-Mar-18	Male	18-25 years	19:19:27	27.6726 28	85.3709 35	waterGreen
222222 222	23-Mar-18		18-25 years	9:21:40	27.6726 28	85.3709 35	waterGreen
222222 222	24-Mar-18		18-25 years	20:11:48	27.6726 28	85.3709 35	waterGreen
333333 333	21-Mar-18	Female	18-25 years	17:08:09	27.7213 23	85.3443 4	waterRed
333333 333	22-Mar-18		18-25 years	14:20:41	27.7213 23	85.3443 4	waterGreen

333333 333	26-Mar-18		18-25 years	15:06:46	27.7213 23	85.3443 4	waterGreen
333333 333	27-Mar-18		18-25 years	14:17:41	27.7213 23	85.3443 4	waterGreen
333333 333	29-Mar-18		18-25 years	16:04:34	27.7213 23	85.3443 4	waterGreen
333333 333	30-Mar-18		18-25 years	16:23:05	27.7213 23	85.3443 4	waterGreen
333333 333	1-Apr-18		18-25 years	14:03:54	27.7213 23	85.3443 4	waterGreen
333333 333	2-Apr-18		18-25 years	10:46:39	27.7213 23	85.3443 4	waterGreen
444444 444	20-Mar-18	male	18-25 years	18:16:02	27.7263 09	85.3122 57	waterGreen
444444 444	21-Mar-18		18-25 years	19:52:04	27.7263 09	85.3122 57	waterGreen
444444 444	22-Mar-18		18-25 years	19:30:54	27.7263 09	85.3122 57	waterGreen
444444 444	23-Mar-18		18-25 years	21:38:29	27.7263 09	85.3122 57	waterGreen
444444 444	24-Mar-18		18-25 years	22:57:34	27.7263 09	85.3122 57	waterGreen
444444 444	25-Mar-18		18-25 years	23:00:27	27.7263 09	85.3122 57	waterGreen
444444 444	26-Mar-18		18-25 years	22:06:49	27.7263 09	85.3122 57	waterGreen
444444 444	27-Mar-18		18-25 years	23:36:21	27.7263 09	85.3122 57	waterGreen

444444	28-Mar-18		18-25	22:09:16	27.7263	85.3122	waterGreen
444			years		09	57	
444444	29-Mar-18		18-25	22:34:41	27.7263	85.3122	waterRed
444			years		09	57	
444444	30-Mar-18		18-25	22:30:31	27.7263	85.3122	waterGreen
444			years		09	57	
444444	31-Mar-18		18-25	22:26:15	27.7263	85.3122	waterGreen
444			years		09	57	
444444	1-Apr-18		18-25	23:34:45	27.7263	85.3122	waterGreen
444			years		09	57	
444444	3-Apr-18		18-25	23:24:16	27.7263	85.3122	waterGreen
444			years		09	57	
444444	4-Apr-18		18-25	22:02:04	27.7263	85.3122	waterGreen
444			years		09	57	
444444	5-Apr-18		18-25	23:42:50	27.7263	85.3122	waterGreen
444			years		09	57	
444444	6-Apr-18		18-25	22:33:47	27.7263	85.3122	waterRed
444			years		09	57	
444444	7-Apr-18		18-25	22:58:36	27.7263	85.3122	waterRed
444			years		09	57	
444444	8-Apr-18		18-25	22:40:48	27.7263	85.3122	waterRed
444			years		09	57	
444444	10-Apr-18		18-25	0:00:39	27.7263	85.3122	waterRed
444			years		09	57	
444444	11-Apr-18		18-25	22:04:24	27.7263	85.3122	waterRed
444			years		09	57	
444444	12-Apr-18		18-25	23:30:06	27.7263	85.3122	waterRed
444			years		09	57	

444444	13-Apr-18		18-25	22:07:33	27.7263	85.3122	waterRed
444			years		09	57	
444444	14-Apr-18		18-25	23:03:13	27.7263	85.3122	waterRed
444			years		09	57	
444444	15-Apr-18		18-25	23:11:27	27.7263	85.3122	waterRed
444			years		09	57	
444444	16-Apr-18		18-25	23:56:02	27.7263	85.3122	waterRed
444			years		09	57	
444444	17-Apr-18		18-25	23:11:15	27.7263	85.3122	waterRed
444			years		09	57	
444444	18-Apr-18		18-25	21:09:55	27.7263	85.3122	waterRed
444			years		09	57	
444444	19-Apr-18		18-25	22:06:24	27.7263	85.3122	waterRed
444			years		09	57	
444444	20-Apr-18		18-25	22:58:39	27.7263	85.3122	waterRed
444			years		09	57	
444444	21-Apr-18		18-25	23:23:29	27.7263	85.3122	waterRed
444			years		09	57	
444444	22-Apr-18		18-25	22:43:40	27.7263	85.3122	waterRed
444			years		09	57	
444444	23-Apr-18		18-25	22:40:27	27.7263	85.3122	waterRed
444			years		09	57	
444444	24-Apr-18		18-25	23:04:18	27.7263	85.3122	waterRed
444			years		09	57	
444444	25-Apr-18		18-25	23:50:59	27.7263	85.3122	waterRed
444			years		09	57	
444444	26-Apr-18		18-25	21:44:19	27.7263	85.3122	waterRed
444			years		09	57	

444444	27-Apr-18		18-25	23:21:57	27.7263	85.3122	waterRed
444			years		09	57	
444444	28-Apr-18		18-25	22:51:20	27.7263	85.3122	waterRed
444			years		09	57	
444444	29-Apr-18		18-25	23:06:15	27.7263	85.3122	waterRed
444			years		09	57	
444444	30-Apr-18		18-25	22:42:40	27.7263	85.3122	waterRed
444			years		09	57	
444444	1-May-18		18-25	23:06:27	27.7263	85.3122	waterRed
444			years		09	57	
444444	3-May-18		18-25	23:16:25	27.7263	85.3122	waterRed
444			years		09	57	
444444	4-May-18		18-25	23:43:25	27.7263	85.3122	waterRed
444			years		09	57	
444444	5-May-18		18-25	22:09:05	27.7263	85.3122	waterRed
444			years		09	57	
444444	6-May-18		18-25	23:15:02	27.7263	85.3122	waterRed
444			years		09	57	
444444	7-May-18		18-25	23:06:16	27.7263	85.3122	waterRed
444			years		09	57	
444444	9-May-18		18-25	22:16:14	27.7263	85.3122	waterRed
444			years		09	57	
444444	10-May-18		18-25	21:42:03	27.7263	85.3122	waterRed
444			years		09	57	
444444	11-May-18		18-25	20:56:58	27.7263	85.3122	waterRed
444			years		09	57	
444444	12-May-18		18-25	23:29:07	27.7263	85.3122	waterRed
444			years		09	57	

444444 444	14-May-18		18-25 years	0:10:52	27.7263 09	85.3122 57	waterRed
444444 444	14-May-18		18-25 years	23:26:49	27.7263 09	85.3122 57	waterRed
444444 444	15-May-18		18-25 years	19:59:32	27.7263 09	85.3122 57	waterRed
444444 444	17-May-18		18-25 years	0:01:09	27.7263 09	85.3122 57	waterRed
444444 444	17-May-18		18-25 years	19:22:22	27.7263 09	85.3122 57	waterRed
444444 444	19-May-18		18-25 years	23:54:00	27.7263 09	85.3122 57	waterRed
555555 555	Tue Jun 11 2019	Fem ale	26-55 years				
666666 666	29-Mar-18	Mal e	18-25 years	16:23:21	27.6773 8	85.3114 16	waterGreen
666666 666	29-Mar-18		18-25 years	20:55:22	27.6773 8	85.3114 16	waterGreen
777777 777	Wed Jun 12 2019	Fem ale					
777777 777	Thu Jun 20 2019						
777777 777	Thu Jun 20 2019						
888888 888	21-Mar-18	Mal e	18-25 years	18:28:13	27.7043 306	85.4161 1111	waterGreen
888888 888	22-Mar-18		18-25 years	17:27:51	27.7043 306	85.4161 1111	waterGreen

999999 999	21-Mar-18	Fem ale	18-25 years	16:12:58	27.7054 714	85.4270 2942	waterGreen
999999 999	23-Mar-18		18-25 years	19:22:18	27.7054 714	85.4270 2942	waterGreen
999999 999	24-Mar-18		18-25 years	20:28:39	27.7054 714	85.4270 2942	waterGreen
999999 999	26-Mar-18		18-25 years	19:25:52	27.7054 714	85.4270 2942	waterGreen
999999 999	28-Mar-18		18-25 years	17:41:13	27.7054 714	85.4270 2942	waterGreen
999999 999	29-Mar-18		18-25 years	17:03:10	27.7054 714	85.4270 2942	waterGreen
999999 999	30-Mar-18		18-25 years	15:54:45	27.7054 714	85.4270 2942	waterGreen
999999 999	31-Mar-18		18-25 years	19:18:01	27.7054 714	85.4270 2942	waterGreen
999999 999	3-Apr-18		18-25 years	18:21:48	27.7054 714	85.4270 2942	waterGreen
111111 112	Mon Mar 19 2018	Mal e	18-25 years	20:22:48	27.6662 11	85.4151 57	waterGreen
111111 112	Tue Mar 20 2018		18-25 years	20:15:19	27.6662 11	85.4151 57	waterGreen
111111 113	21-Mar-18	Fem ale	18-25 years	17:34:25	27.7095 877	85.4170 972	waterGreen
111111 113	22-Mar-18		18-25 years	18:50:25	27.7095 877	85.4170 972	waterGreen
111111 113	23-Mar-18		18-25 years	17:32:47	27.7095 877	85.4170 972	waterGreen

111111 113	25-Mar-18		18-25 years	21:27:57	27.7095 877	85.4170 972	waterGreen
111111 113	26-Mar-18		18-25 years	19:11:21	27.7095 877	85.4170 972	waterGreen
111111 113	28-Mar-18		18-25 years	5:59:41	27.7095 877	85.4170 972	waterGreen
111111 113	28-Mar-18		18-25 years	22:30:02	27.7095 877	85.4170 972	waterGreen
111111 113	2-Apr-18		18-25 years	4:28:58	27.7095 877	85.4170 972	waterGreen
111111 114	Tue Jun 11 2019	Fem ale	18-25 years				
111111 115	5-May-18	Mal e	18-25 years	14:39:46	27.7032 5	85.4327 7	waterGreen
111111 115	6-May-18		18-25 years	9:46:51	27.7032 5	85.4327 7	waterGreen
111111 116	20-Mar-18	Mal e	18-25 years	20:28:28	27.7015 992	85.4214 766	waterGreen
111111 116	28-Mar-18		18-25 years	18:46:33	27.7015 992	85.4214 766	waterGreen
111111 116	1-Apr-18		18-25 years	20:03:35	27.7015 992	85.4214 766	waterGreen
111111 116	2-Apr-18		18-25 years	20:35:26	27.7015 992	85.4214 766	waterGreen
111111 116	4-Apr-18		18-25 years	18:23:29	27.7015 992	85.4214 766	waterGreen
111111 116	13-Apr-18		18-25 years	22:08:10	27.7015 992	85.4214 766	waterGreen

111111 116	14-Apr-18		18-25 years	20:42:42	27.7015 992	85.4214 766	waterGreen
111111 116	20-Apr-18		18-25 years	12:18:34	27.7015 992	85.4214 766	waterGreen
111111 116	22-Apr-18		18-25 years	22:45:24	27.7015 992	85.4214 766	waterGreen
111111 117	24-Mar-18	fem ale	18-25 years	9:06:57	27.6511 482	85.4433 5958	waterGreen
111111 117	25-Mar-18		18-25 years	9:33:35	27.6511 482	85.4433 5958	waterGreen
111111 117	27-Mar-18		18-25 years	17:00:02	27.6511 482	85.4433 5958	waterGreen
111111 117	29-Mar-18		18-25 years	5:02:28	27.6511 482	85.4433 5958	waterGreen
111111 117	1-Apr-18		18-25 years	5:29:06	27.6511 482	85.4433 5958	waterGreen
111111 117	2-Apr-18		18-25 years	12:36:47	27.6511 482	85.4433 5958	waterGreen
111111 117	7-Apr-18		18-25 years	9:59:01	27.6511 482	85.4433 5958	waterGreen
111111 118	27-Mar-18		18-25 years	19:24:34	27.7033 63	85.4212 9074	waterGreen
111111 118	28-Mar-18		18-25 years	7:31:24	27.7033 63	85.4212 9074	waterGreen
111111 118	29-Mar-18		18-25 years	21:18:43	27.7033 63	85.4212 9074	waterGreen
111111 118	30-Mar-18		18-25 years	8:59:11	27.7033 63	85.4212 9074	waterGreen

111111 118	31-Mar-18		18-25 years	10:35:41	27.7033 63	85.4212 9074	waterGreen
111111 118	1-Apr-18		18-25 years	23:48:32	27.7033 63	85.4212 9074	waterGreen
111111 118	4-Apr-18		18-25 years	1:58:30	27.7033 63	85.4212 9074	waterGreen
111111 118	5-Apr-18		18-25 years	23:54:08	27.7033 63	85.4212 9074	waterGreen
111111 118	8-Apr-18		18-25 years	0:56:24	27.7033 63	85.4212 9074	waterGreen
111111 118	10-Apr-18		18-25 years	1:46:14	27.7033 63	85.4212 9074	waterGreen
111111 118	11-Apr-18		18-25 years	8:29:19	27.7033 63	85.4212 9074	waterGreen
111111 118	16-Apr-18		18-25 years	0:58:36	27.7033 63	85.4212 9074	waterGreen
111111 118	17-Apr-18		18-25 years	22:27:05	27.7033 63	85.4212 9074	waterGreen
111111 118	21-Apr-18		18-25 years	1:25:42	27.7033 63	85.4212 9074	waterGreen
111111 118	22-Apr-18		18-25 years	14:08:13	27.7033 63	85.4212 9074	waterGreen
111111 118	23-Apr-18		18-25 years	13:40:45	27.7033 63	85.4212 9074	waterGreen
111111 118	25-Apr-18		18-25 years	17:59:33	27.7033 63	85.4212 9074	waterGreen
111111 118	26-Apr-18		18-25 years	1:53:17	27.7033 63	85.4212 9074	waterGreen

111111 119	19-Mar-18	male	18-25 years	23:01:53	27.7091 499	85.4145 957	waterGreen
111111 119	24-Mar-18		18-25 years	6:33:08	27.7091 499	85.4145 957	waterGreen
111111 119	26-Mar-18		18-25 years	1:30:40	27.7091 499	85.4145 957	waterGreen
111111 119	31-Mar-18		18-25 years	5:52:48	27.7091 499	85.4145 957	waterGreen
111111 119	18-Apr-18		18-25 years	22:39:19	27.7091 499	85.4145 957	waterGreen
222222 221	21-Mar-18	male	18-25 years	18:06:17	27.7058 662	85.4126 4667	waterGreen
222222 221	23-Mar-18		18-25 years	15:01:24	27.7058 662	85.4126 4667	waterGreen
222222 221	27-Mar-18		18-25 years	17:47:18	27.7058 662	85.4126 4667	waterGreen
222222 221	29-Mar-18		18-25 years	21:56:24	27.7058 662	85.4126 4667	waterGreen
222222 221	3-Apr-18		18-25 years	14:45:34	27.7058 662	85.4126 4667	waterGreen
222222 221	4-Apr-18		18-25 years	18:09:27	27.7058 662	85.4126 4667	waterGreen
222222 221	5-Apr-18		18-25 years	15:57:13	27.7058 662	85.4126 4667	waterGreen
222222 221	8-Apr-18		18-25 years	17:44:46	27.7058 662	85.4126 4667	waterGreen
222222 221	10-Apr-18		18-25 years	13:37:55	27.7058 662	85.4126 4667	waterGreen

222222 223	Sun Jun 09 2019	Male		19:44:40 .	27.7337 255	85.3604 6593	waterRed
222222 223	Sun Jun 09 2019			19:49:13 .	27.7337 255	85.3604 6593	waterRed
222222 223	Mon Jun 10 2019			13:25:36 .	27.7337 255	85.3604 6593	waterGreen
222222 223	Wed Jun 12 2019			16:33:06 .	27.7337 255	85.3604 6593	waterRed
222222 223	Sat Jun 15 2019			16:58:29 .	27.7337 255	85.3604 6593	waterGreen
222222 223	Sun Jun 16 2019			11:10:56 .	27.7337 255	85.3604 6593	waterRed
222222 223	Mon Jun 17 2019			19:55:48 .	27.7337 255	85.3604 6593	waterRed
222222 223	Sat Jun 22 2019			08:33:49 .	27.7337 255	85.3604 6593	waterRed
222222 223	Sat Jun 22 2019			20:53:04 .	27.7337 255	85.3604 6593	waterRed
222222 223	Tue Jun 25 2019			13:53:50 .	27.7337 255	85.3604 6593	waterRed
222222 224	20-Mar-18	female	18-25 years	18:53:49	27.6686 07	85.3096 76	waterGreen
222222 224	21-Mar-18		18-25 years	18:20:35	27.6686 07	85.3096 76	waterGreen
222222 224	24-Mar-18		18-25 years	13:24:53	27.6686 07	85.3096 76	waterGreen
222222 224	28-Mar-18		18-25 years	12:03:10	27.6686 07	85.3096 76	waterGreen

222222 225	22-Mar-18	fem ale	18-25 years	22:58:24	27.7032 98	85.4323 99	waterGreen
222222 225	23-Mar-18		18-25 years	23:18:12	27.7032 98	85.4323 99	waterGreen
222222 225	24-Mar-18		18-25 years	22:58:46	27.7032 98	85.4323 99	waterGreen
222222 225	25-Mar-18		18-25 years	22:07:54	27.7032 98	85.4323 99	waterGreen
222222 225	26-Mar-18		18-25 years	23:00:50	27.7032 98	85.4323 99	waterGreen
222222 225	27-Mar-18		18-25 years	22:20:19	27.7032 98	85.4323 99	waterRed
222222 225	28-Mar-18		18-25 years	21:40:53	27.7032 98	85.4323 99	waterGreen
222222 225	31-Mar-18		18-25 years	21:21:20	27.7032 98	85.4323 99	waterRed
222222 225	5-Apr-18		18-25 years	19:45:31	27.7032 98	85.4323 99	waterGreen
222222 225	9-Apr-18		18-25 years	22:25:01	27.7032 98	85.4323 99	waterGreen
222222 225	11-Apr-18		18-25 years	0:04:27	27.7032 98	85.4323 99	waterGreen
222222 226	23-Mar-18	male	18-25 years	8:45:37	27.7078 354	85.4135 744	waterGreen
222222 226	24-Mar-18		18-25 years	9:54:10	27.7078 354	85.4135 744	waterGreen
222222 226	26-Mar-18		18-25 years	8:04:41	27.7078 354	85.4135 744	waterGreen

222222 226	27-Mar-18		18-25 years	8:08:24	27.7078 354	85.4135 744	waterGreen
222222 226	28-Mar-18		18-25 years	18:30:42	27.7078 354	85.4135 744	waterGreen
222222 226	29-Mar-18		18-25 years	19:19:09	27.7078 354	85.4135 744	waterGreen
222222 226	30-Mar-18		18-25 years	19:49:06	27.7078 354	85.4135 744	waterGreen
222222 226	31-Mar-18		18-25 years	20:39:09	27.7078 354	85.4135 744	waterGreen
222222 226	1-Apr-18		18-25 years	7:15:47	27.7078 354	85.4135 744	waterGreen
222222 226	4-Apr-18		18-25 years	5:01:11	27.7078 354	85.4135 744	waterGreen
222222 226	8-Apr-18		18-25 years	8:15:33	27.7078 354	85.4135 744	waterGreen
222222 226	9-Apr-18		18-25 years	22:10:47	27.7078 354	85.4135 744	waterGreen
222222 226	11-Apr-18		18-25 years	20:23:12	27.7078 354	85.4135 744	waterGreen
222222 226	14-Apr-18		18-25 years	19:33:40	27.7078 354	85.4135 744	waterGreen
222222 227	19-Mar-18	fem ale	18-25 years	22:21:59	27.6972 54	85.3302 26	waterGreen
222222 227	20-Mar-18		18-25 years	19:05:20	27.6972 54	85.3302 26	waterGreen
222222 227	22-Mar-18		18-25 years	19:58:49	27.6972 54	85.3302 26	waterGreen

222222 227	25-Mar-18		18-25 years	11:47:31	27.6972 54	85.3302 26	waterGreen
222222 227	27-Mar-18		18-25 years	23:31:16	27.6972 54	85.3302 26	waterGreen
222222 227	28-Mar-18		18-25 years	21:51:26	27.6972 54	85.3302 26	waterGreen
222222 228	19-Mar-18	male	18-25 years	20:06:55	27.6972 54	85.3302 26	waterGreen
222222 229	21-Mar-18	male	18-25 years	15:33:38	27.6924 952	85.3646 929	waterGreen
222222 229	24-Mar-18		18-25 years	20:41:50	27.6924 952	85.3646 929	waterGreen
222222 229	25-Mar-18		18-25 years	8:59:18	27.6924 952	85.3646 929	waterGreen
333333 331	19-Mar-18	male	18-25 years	19:34:39	27.6649 313	85.4267 3439	waterRed
333333 331	29-Mar-18		18-25 years	23:18:44	27.6649 313	85.4267 3439	waterRed
333333 331	30-Mar-18		18-25 years	9:49:19	27.6649 313	85.4267 3439	waterRed
333333 331	30-Mar-18		18-25 years	15:00:51	27.6649 313	85.4267 3439	waterRed
333333 331	31-Mar-18		18-25 years	14:22:26	27.6649 313	85.4267 3439	waterGreen
333333 331	31-Mar-18		18-25 years	20:02:22	27.6649 313	85.4267 3439	waterRed
333333 331	1-Apr-18		18-25 years	19:15:21	27.6649 313	85.4267 3439	waterRed

333333 331	2-Apr-18		18-25 years	8:25:23	27.6649 313	85.4267 3439	waterRed
333333 331	2-Apr-18		18-25 years	19:38:02	27.6649 313	85.4267 3439	waterRed
333333 331	4-Apr-18		18-25 years	11:45:58	27.6649 313	85.4267 3439	waterGreen
333333 331	5-Apr-18		18-25 years	18:49:41	27.6649 313	85.4267 3439	waterRed
333333 331	7-Apr-18		18-25 years	12:55:52	27.6649 313	85.4267 3439	waterRed
333333 331	8-Apr-18		18-25 years	12:01:30	27.6649 313	85.4267 3439	waterGreen
333333 331	9-Apr-18		18-25 years	20:16:37	27.6649 313	85.4267 3439	waterRed
333333 331	11-Apr-18		18-25 years	15:56:33	27.6649 313	85.4267 3439	waterRed
333333 331	12-Apr-18		18-25 years	20:37:35	27.6649 313	85.4267 3439	waterRed
333333 331	13-Apr-18		18-25 years	15:43:00	27.6649 313	85.4267 3439	waterRed
333333 331	15-Apr-18		18-25 years	8:31:34	27.6649 313	85.4267 3439	waterRed
333333 331	16-Apr-18		18-25 years	13:55:10	27.6649 313	85.4267 3439	waterGreen
333333 331	17-Apr-18		18-25 years	17:25:17	27.6649 313	85.4267 3439	waterRed
333333 331	18-Apr-18		18-25 years	13:37:45	27.6649 313	85.4267 3439	waterRed

333333 331	19-Apr-18		18-25 years	14:14:49	27.6649 313	85.4267 3439	waterRed
333333 331	20-Apr-18		18-25 years	12:07:37	27.6649 313	85.4267 3439	waterGreen
333333 331	21-Apr-18		18-25 years	12:20:28	27.6649 313	85.4267 3439	waterRed
333333 331	22-Apr-18		18-25 years	12:50:43	27.6649 313	85.4267 3439	waterRed
333333 331	22-Apr-18		18-25 years	23:29:34	27.6649 313	85.4267 3439	waterRed
333333 331	24-Apr-18		18-25 years	8:32:22	27.6649 313	85.4267 3439	waterRed
333333 331	25-Apr-18		18-25 years	10:30:57	27.6649 313	85.4267 3439	waterRed
333333 331	26-Apr-18		18-25 years	9:19:52	27.6649 313	85.4267 3439	waterRed
333333 331	27-Apr-18		18-25 years	12:06:24	27.6649 313	85.4267 3439	waterRed
333333 331	28-Apr-18		18-25 years	11:42:08	27.6649 313	85.4267 3439	waterGreen
333333 331	29-Apr-18		18-25 years	18:22:30	27.6649 313	85.4267 3439	waterRed
333333 331	30-Apr-18		18-25 years	14:23:11	27.6649 313	85.4267 3439	waterRed
333333 331	1-May-18		18-25 years	15:37:51	27.6649 313	85.4267 3439	waterRed
333333 331	2-May-18		18-25 years	14:17:51	27.6649 313	85.4267 3439	waterGreen

333333 331	3-May-18		18-25 years	18:48:42	27.6649 313	85.4267 3439	waterGreen
333333 331	4-May-18		18-25 years	22:32:28	27.6649 313	85.4267 3439	waterRed
333333 331	5-May-18		18-25 years	12:48:59	27.6649 313	85.4267 3439	waterRed
333333 331	7-May-18		18-25 years	14:11:48	27.6649 313	85.4267 3439	waterGreen
333333 331	8-May-18		18-25 years	15:11:06	27.6649 313	85.4267 3439	waterRed
333333 331	9-May-18		18-25 years	9:28:51	27.6649 313	85.4267 3439	waterRed
333333 331	10-May-18		18-25 years	21:09:27	27.6649 313	85.4267 3439	waterGreen
333333 331	11-May-18		18-25 years	11:25:31	27.6649 313	85.4267 3439	waterRed
333333 331	12-May-18		18-25 years	12:50:45	27.6649 313	85.4267 3439	waterRed
333333 331	13-May-18		18-25 years	13:40:51	27.6649 313	85.4267 3439	waterRed
333333 331	15-May-18		18-25 years	13:05:33	27.6649 313	85.4267 3439	waterRed
333333 331	17-May-18		18-25 years	11:11:10	27.6649 313	85.4267 3439	waterRed
333333 331	18-May-18		18-25 years	21:05:29	27.6649 313	85.4267 3439	waterGreen
333333 332	Fri Jun 07 2019	Mal e		15:49:33 .	27.6856 96	85.3721 7408	waterRed

333333 334	20-Mar-18	Male	18-25 years	20:54:46	27.7011 1	85.4156 78	waterGreen
333333 334	21-Mar-18		18-25 years	19:39:55	27.7011 1	85.4156 78	waterGreen
333333 334	23-Mar-18		18-25 years	18:37:44	27.7011 1	85.4156 78	waterGreen
333333 334	24-Mar-18		18-25 years	10:02:36	27.7011 1	85.4156 78	waterGreen
333333 334	26-Mar-18		18-25 years	18:36:59	27.7011 1	85.4156 78	waterGreen
333333 334	27-Mar-18		18-25 years	19:05:52	27.7011 1	85.4156 78	waterGreen
333333 334	28-Mar-18		18-25 years	17:10:58	27.7011 1	85.4156 78	waterGreen
333333 334	31-Mar-18		18-25 years	20:10:54	27.7011 1	85.4156 78	waterGreen
333333 334	3-Apr-18		18-25 years	20:20:40	27.7011 1	85.4156 78	waterGreen
333333 334	7-Apr-18		18-25 years	11:41:30	27.7011 1	85.4156 78	waterGreen
333333 334	10-Apr-18		18-25 years	19:30:02	27.7011 1	85.4156 78	waterGreen
333333 335	20-Mar-18	female	18-25 years	21:35:51	27.6762	85.3029	waterRed
333333 335	21-Mar-18		18-25 years	21:20:22	27.6762	85.3029	waterRed
333333 335	22-Mar-18		18-25 years	18:03:44	27.6762	85.3029	waterRed

333333 335	24-Mar-18		18-25 years	22:02:19	27.6762	85.3029	waterRed
333333 335	27-Mar-18		18-25 years	18:51:02	27.6762	85.3029	waterRed
333333 335	29-Mar-18		18-25 years	0:11:43	27.6762	85.3029	waterRed
333333 335	3-Apr-18		18-25 years	19:29:38	27.6762	85.3029	waterGreen
333333 336	Tue Jun 11 2019	Male					waterRed
333333 336	Wed Jun 12 2019						waterRed
333333 336	Thu Jun 13 2019						waterRed
333333 336	Fri Jun 14 2019						waterRed
333333 336	Sat Jun 15 2019						waterRed
333333 337	Mon Jun 17 2019	Female	26-55 years				
333333 337	Mon Jun 24 2019		26-55 years				
333333 337	Wed Jun 26 2019		26-55 years				
333333 337	Wed Jun 26 2019		26-55 years				
333333 338	Sun Jun 16 2019	Male	18-25 years				

333333 339	21-Mar-18	Male	18-25 years	17:16:46	27.7174 157	85.3092 7395	waterGreen
333333 339	21-Mar-18		18-25 years	17:35:17	27.7174 157	85.3092 7395	waterGreen
333333 339	22-Mar-18		18-25 years	16:44:24	27.7174 157	85.3092 7395	waterGreen
333333 339	24-Mar-18		18-25 years	9:45:17	27.7174 157	85.3092 7395	waterRed
333333 339	25-Mar-18		18-25 years	5:45:46	27.7174 157	85.3092 7395	waterRed
333333 339	26-Mar-18		18-25 years	5:36:26	27.7174 157	85.3092 7395	waterRed
333333 339	28-Mar-18		18-25 years	5:19:42	27.7174 157	85.3092 7395	waterRed
333333 339	29-Mar-18		18-25 years	13:31:13	27.7174 157	85.3092 7395	waterRed
333333 339	30-Mar-18		18-25 years	7:31:31	27.7174 157	85.3092 7395	waterRed
333333 339	30-Mar-18		18-25 years	15:06:51	27.7174 157	85.3092 7395	waterRed
333333 339	31-Mar-18		18-25 years	5:14:50	27.7174 157	85.3092 7395	waterRed
333333 339	1-Apr-18		18-25 years	2:40:16	27.7174 157	85.3092 7395	waterRed
333333 339	1-Apr-18		18-25 years	16:49:59	27.7174 157	85.3092 7395	waterGreen
333333 339	2-Apr-18		18-25 years	5:49:40	27.7174 157	85.3092 7395	waterGreen

333333 339	3-Apr-18		18-25 years	16:23:45	27.7174 157	85.3092 7395	waterGreen
333333 339	4-Apr-18		18-25 years	3:51:10	27.7174 157	85.3092 7395	waterGreen
333333 339	4-Apr-18		18-25 years	22:40:39	27.7174 157	85.3092 7395	waterGreen
333333 339	5-Apr-18		18-25 years	15:51:55	27.7174 157	85.3092 7395	waterGreen
333333 339	6-Apr-18		18-25 years	9:05:07	27.7174 157	85.3092 7395	waterRed
333333 339	7-Apr-18		18-25 years	8:27:11	27.7174 157	85.3092 7395	waterRed
333333 339	8-Apr-18		18-25 years	5:20:20	27.7174 157	85.3092 7395	waterGreen
333333 339	9-Apr-18		18-25 years	2:58:48	27.7174 157	85.3092 7395	waterRed
333333 339	9-Apr-18		18-25 years	18:04:01	27.7174 157	85.3092 7395	waterRed
333333 339	10-Apr-18		18-25 years	6:20:34	27.7174 157	85.3092 7395	waterGreen
333333 339	11-Apr-18		18-25 years	9:26:20	27.7174 157	85.3092 7395	waterGreen
333333 339	12-Apr-18		18-25 years	18:09:25	27.7174 157	85.3092 7395	waterGreen
333333 339	13-Apr-18		18-25 years	17:22:44	27.7174 157	85.3092 7395	waterRed
333333 339	14-Apr-18		18-25 years	16:12:35	27.7174 157	85.3092 7395	waterGreen

333333 339	15-Apr-18		18-25 years	15:00:04	27.7174 157	85.3092 7395	waterRed
333333 339	16-Apr-18		18-25 years	10:50:40	27.7174 157	85.3092 7395	waterRed
333333 339	17-Apr-18		18-25 years	9:10:27	27.7174 157	85.3092 7395	waterRed
333333 339	18-Apr-18		18-25 years	8:17:34	27.7174 157	85.3092 7395	waterRed
333333 339	19-Apr-18		18-25 years	4:10:24	27.7174 157	85.3092 7395	waterGreen
333333 339	20-Apr-18		18-25 years	18:54:10	27.7174 157	85.3092 7395	waterRed
333333 339	24-Apr-18		18-25 years	13:48:05	27.7174 157	85.3092 7395	waterRed
333333 339	25-Apr-18		18-25 years	4:52:01	27.7174 157	85.3092 7395	waterGreen
333333 339	27-Apr-18		18-25 years	20:29:43	27.7174 157	85.3092 7395	waterGreen
333333 339	28-Apr-18		18-25 years	11:25:48	27.7174 157	85.3092 7395	waterGreen
333333 339	29-Apr-18		18-25 years	2:59:44	27.7174 157	85.3092 7395	waterGreen
333333 339	29-Apr-18		18-25 years	15:39:09	27.7174 157	85.3092 7395	waterGreen
333333 339	30-Apr-18		18-25 years	13:03:21	27.7174 157	85.3092 7395	waterRed
333333 339	30-Apr-18		18-25 years	20:20:14	27.7174 157	85.3092 7395	waterGreen

333333 339	1-May-18		18-25 years	8:13:58	27.7174 157	85.3092 7395	waterRed
333333 339	1-May-18		18-25 years	18:31:25	27.7174 157	85.3092 7395	waterRed
333333 339	2-May-18		18-25 years	3:49:58	27.7174 157	85.3092 7395	waterGreen
333333 339	2-May-18		18-25 years	17:18:34	27.7174 157	85.3092 7395	waterRed
333333 339	4-May-18		18-25 years	6:55:23	27.7174 157	85.3092 7395	waterGreen
333333 339	5-May-18		18-25 years	7:56:26	27.7174 157	85.3092 7395	waterRed
333333 339	5-May-18		18-25 years	21:12:10	27.7174 157	85.3092 7395	waterRed
333333 339	7-May-18		18-25 years	8:46:24	27.7174 157	85.3092 7395	waterGreen
333333 339	8-May-18		18-25 years	4:42:38	27.7174 157	85.3092 7395	waterGreen
333333 339	9-May-18		18-25 years	5:52:23	27.7174 157	85.3092 7395	waterRed
333333 339	10-May-18		18-25 years	11:34:35	27.7174 157	85.3092 7395	waterRed
333333 339	11-May-18		18-25 years	9:14:36	27.7174 157	85.3092 7395	waterGreen
333333 339	12-May-18		18-25 years	7:15:00	27.7174 157	85.3092 7395	waterRed
333333 339	13-May-18		18-25 years	8:02:13	27.7174 157	85.3092 7395	waterGreen

333333 339	14-May-18		18-25 years	6:43:59	27.7174 157	85.3092 7395	waterGreen
333333 339	15-May-18		18-25 years	6:10:08	27.7174 157	85.3092 7395	waterGreen
333333 339	16-May-18		18-25 years	5:55:32	27.7174 157	85.3092 7395	waterGreen
333333 339	16-May-18		18-25 years	11:06:05	27.7174 157	85.3092 7395	waterGreen
333333 339	17-May-18		18-25 years	5:15:38	27.7174 157	85.3092 7395	waterGreen
333333 339	17-May-18		18-25 years	10:31:16	27.7174 157	85.3092 7395	waterGreen
444444 441	24-Mar-18	Male	18-25 years	20:58:12	27.6757 995	85.3675 9207	waterGreen
444444 441	30-Mar-18		18-25 years	9:59:16	27.6757 995	85.3675 9207	waterGreen
444444 441	3-Apr-18		18-25 years	22:27:46	27.6757 995	85.3675 9207	waterGreen
986715 3355	Sat Jun 22 2019	Male		20:19:51 .	27.7095 388	84.8426 2674	waterRed
986715 3355	Mon Jun 24 2019			23:00:41 .	27.7095 388	84.8426 2674	waterRed
986715 3355	Tue Jun 25 2019			16:46:16 .	27.7095 388	84.8426 2674	waterGreen
986715 3355	Wed Jun 26 2019			19:16:39 .	27.7095 388	84.8426 2674	waterRed
444444 442	19-Mar-18	Female	18-25 years	20:31:35	27.6938 81	85.3380 907	waterRed

444444 443	Wed Jun 12 2019	Fem ale		08:06:42	27.7318 371	85.3505 6131	waterRed
444444 445	Fri Jun 7 2019	Mal e	18-25 years				
444444 446	Fri Jun 7 2019	Fem ale	18-25 years				
444444 447	23-Mar-18	Mal e	18-25 years	20:27:02	27.7116 734	85.4156 6902	waterGreen
444444 447	23-Mar-18		18-25 years	21:59:11	27.7116 734	85.4156 6902	waterGreen
444444 447	28-Mar-18		18-25 years	19:54:15	27.7116 734	85.4156 6902	waterGreen
444444 447	31-Mar-18		18-25 years	14:12:02	27.7116 734	85.4156 6902	waterGreen
444444 447	10-Apr-18		18-25 years	21:26:06	27.7116 734	85.4156 6902	waterGreen
444444 447	11-Apr-18		18-25 years	21:24:15	27.7116 734	85.4156 6902	waterGreen
444444 447	12-Apr-18		18-25 years	13:37:26	27.7116 734	85.4156 6902	waterGreen
444444 447	12-Apr-18		18-25 years	16:31:37	27.7116 734	85.4156 6902	waterGreen
444444 447	13-Apr-18		18-25 years	10:04:59	27.7116 734	85.4156 6902	waterGreen
444444 447	13-Apr-18		18-25 years	16:01:46	27.7116 734	85.4156 6902	waterGreen
444444 447	15-May-18		18-25 years	9:03:20	27.7116 734	85.4156 6902	waterGreen

444444 448	Sat Jun 08 2019	Mal e		06:34:55	27.7458 907	85.2612 0453	waterGreen
444444 449	20-Mar-18	Mal e	18-25 years	10:15:42	27.7021 068	85.4251 6054	waterGreen
444444 449	28-Mar-18		18-25 years	19:52:10	27.7021 068	85.4251 6054	waterGreen
444444 449	2-Apr-18		18-25 years	19:46:40	27.7021 068	85.4251 6054	waterGreen
555555 551	21-Mar-18	male	18-25 years	18:14:48	27.7087 407	85.4113 019	waterGreen
555555 551	27-Mar-18		18-25 years	17:47:00	27.7087 407	85.4113 019	waterGreen
555555 551	31-Mar-18		18-25 years	14:21:07	27.7087 407	85.4113 019	waterGreen
555555 551	1-Apr-18		18-25 years	12:57:47	27.7087 407	85.4113 019	waterGreen
555555 551	5-Apr-18		18-25 years	16:00:14	27.7087 407	85.4113 019	waterGreen
555555 551	6-Apr-18		18-25 years	18:13:20	27.7087 407	85.4113 019	waterGreen
555555 551	7-Apr-18		18-25 years	18:03:55	27.7087 407	85.4113 019	waterGreen
555555 551	8-Apr-18		18-25 years	17:39:48	27.7087 407	85.4113 019	waterGreen
555555 551	10-Apr-18		18-25 years	14:07:11	27.7087 407	85.4113 019	waterGreen
555555 552	21-Mar-18	male	18-25 years	17:59:26	27.7043 33	85.4186 11	waterGreen

555555 552	22-Mar-18		18-25 years	17:22:21	27.7043 33	85.4186 11	waterGreen
555555 552	24-Mar-18		18-25 years	23:52:47	27.7043 33	85.4186 11	waterGreen
555555 552	28-Mar-18		18-25 years	20:21:36	27.7043 33	85.4186 11	waterGreen
555555 552	31-Mar-18		18-25 years	20:33:49	27.7043 33	85.4186 11	waterGreen
555555 552	2-Apr-18		18-25 years	20:15:06	27.7043 33	85.4186 11	waterGreen
555555 552	4-Apr-18		18-25 years	21:30:54	27.7043 33	85.4186 11	waterGreen
555555 552	6-Apr-18		18-25 years	21:38:03	27.7043 33	85.4186 11	waterGreen
555555 552	10-Apr-18		18-25 years	8:02:49	27.7043 33	85.4186 11	waterGreen
555555 552	18-Apr-18		18-25 years	15:08:15	27.7043 33	85.4186 11	waterGreen
555555 553	21-Mar-18	female	18-25 years	23:37:32	27.7032 98	85.4323 99	waterGreen
555555 553	22-Mar-18		18-25 years	22:44:15	27.7032 98	85.4323 99	waterGreen
555555 553	23-Mar-18		18-25 years	23:21:34	27.7032 98	85.4323 99	waterGreen
555555 553	25-Mar-18		18-25 years	22:07:51	27.7032 98	85.4323 99	waterGreen
555555 553	26-Mar-18		18-25 years	23:00:53	27.7032 98	85.4323 99	waterGreen

555555 553	27-Mar-18		18-25 years	22:19:37	27.7032 98	85.4323 99	waterRed
555555 553	28-Mar-18		18-25 years	22:01:34	27.7032 98	85.4323 99	waterGreen
555555 553	30-Mar-18		18-25 years	22:43:19	27.7032 98	85.4323 99	waterGreen
555555 553	31-Mar-18		18-25 years	22:42:02	27.7032 98	85.4323 99	waterRed
555555 553	3-Apr-18		18-25 years	22:42:16	27.7032 98	85.4323 99	waterGreen
555555 553	5-Apr-18		18-25 years	19:44:45	27.7032 98	85.4323 99	waterGreen
555555 553	11-Apr-18		18-25 years	0:04:59	27.7032 98	85.4323 99	waterGreen
555555 553	12-Apr-18		18-25 years	21:50:20	27.7032 98	85.4323 99	waterGreen
555555 554	19-Mar-18	male	18-25 years	22:39:23	27.7032 5	85.4327 7	waterRed
555555 554	20-Mar-18		18-25 years	20:04:19	27.7032 5	85.4327 7	waterRed
555555 554	2-Apr-18		18-25 years	15:23:30	27.7032 5	85.4327 7	waterGreen
555555 554	4-Apr-18		18-25 years	18:21:26	27.7032 5	85.4327 7	waterGreen
555555 556	24-Mar-18	male	18-25 years	17:56:45	27.7080 397	85.4142 7864	waterGreen
555555 556	25-Mar-18		18-25 years	6:32:23	27.7080 397	85.4142 7864	waterGreen

555555 556	25-Mar-18		18-25 years	18:39:36	27.7080 397	85.4142 7864	waterRed
555555 556	26-Mar-18		18-25 years	5:56:30	27.7080 397	85.4142 7864	waterGreen
555555 556	27-Mar-18		18-25 years	6:10:45	27.7080 397	85.4142 7864	waterGreen
555555 556	28-Mar-18		18-25 years	5:00:19	27.7080 397	85.4142 7864	waterGreen
555555 556	29-Mar-18		18-25 years	4:38:31	27.7080 397	85.4142 7864	waterGreen
555555 556	29-Mar-18		18-25 years	18:54:35	27.7080 397	85.4142 7864	waterGreen
555555 556	1-Apr-18		18-25 years	8:52:19	27.7080 397	85.4142 7864	waterGreen
555555 556	1-Apr-18		18-25 years	17:37:56	27.7080 397	85.4142 7864	waterGreen
555555 556	3-Apr-18		18-25 years	1:26:49	27.7080 397	85.4142 7864	waterGreen
555555 556	4-Apr-18		18-25 years	6:33:02	27.7080 397	85.4142 7864	waterGreen
555555 556	5-Apr-18		18-25 years	17:31:29	27.7080 397	85.4142 7864	waterGreen
555555 556	8-Apr-18		18-25 years	6:23:47	27.7080 397	85.4142 7864	waterGreen
555555 556	9-Apr-18		18-25 years	4:54:00	27.7080 397	85.4142 7864	waterGreen
555555 556	13-Apr-18		18-25 years	18:04:06	27.7080 397	85.4142 7864	waterGreen

555555 557	21-Mar-18	male	18-25 years	21:11:53	27.7090 55	85.4146 11	waterGreen
555555 557	22-Mar-18		18-25 years	19:56:18	27.7090 55	85.4146 11	waterGreen
555555 557	23-Mar-18		18-25 years	5:37:13	27.7090 55	85.4146 11	waterGreen
555555 557	24-Mar-18		18-25 years	5:51:59	27.7090 55	85.4146 11	waterGreen
555555 557	25-Mar-18		18-25 years	6:17:34	27.7090 55	85.4146 11	waterGreen
555555 557	27-Mar-18		18-25 years	18:49:53	27.7090 55	85.4146 11	waterGreen
555555 557	28-Mar-18		18-25 years	6:07:03	27.7090 55	85.4146 11	waterGreen
555555 557	29-Mar-18		18-25 years	6:30:12	27.7090 55	85.4146 11	waterGreen
555555 557	29-Mar-18		18-25 years	17:05:07	27.7090 55	85.4146 11	waterGreen
555555 557	29-Mar-18		18-25 years	17:21:55	27.7090 55	85.4146 11	waterGreen
555555 557	30-Mar-18		18-25 years	5:34:25	27.7090 55	85.4146 11	waterGreen
555555 557	30-Mar-18		18-25 years	23:30:41	27.7090 55	85.4146 11	waterGreen
555555 557	31-Mar-18		18-25 years	6:01:54	27.7090 55	85.4146 11	waterGreen
555555 557	31-Mar-18		18-25 years	17:12:27	27.7090 55	85.4146 11	waterGreen

555555 557	1-Apr-18		18-25 years	5:24:43	27.7090 55	85.4146 11	waterGreen
555555 557	1-Apr-18		18-25 years	17:00:06	27.7090 55	85.4146 11	waterGreen
555555 557	2-Apr-18		18-25 years	4:51:52	27.7090 55	85.4146 11	waterGreen
555555 557	2-Apr-18		18-25 years	4:52:26	27.7090 55	85.4146 11	waterGreen
555555 557	3-Apr-18		18-25 years	19:51:37	27.7090 55	85.4146 11	waterRed
555555 557	4-Apr-18		18-25 years	17:30:13	27.7090 55	85.4146 11	waterGreen
555555 557	5-Apr-18		18-25 years	6:56:56	27.7090 55	85.4146 11	waterGreen
555555 557	6-Apr-18		18-25 years	19:50:00	27.7090 55	85.4146 11	waterGreen
555555 557	8-Apr-18		18-25 years	18:57:35	27.7090 55	85.4146 11	waterGreen
555555 557	9-Apr-18		18-25 years	22:49:24	27.7090 55	85.4146 11	waterGreen
555555 557	10-Apr-18		18-25 years	19:25:49	27.7090 55	85.4146 11	waterGreen
555555 557	12-Apr-18		18-25 years	4:16:06	27.7090 55	85.4146 11	waterGreen
555555 557	14-Apr-18		18-25 years	5:57:42	27.7090 55	85.4146 11	waterGreen
555555 557	15-Apr-18		18-25 years	12:25:18	27.7090 55	85.4146 11	waterGreen

555555 557	16-Apr-18		18-25 years	8:15:29	27.7090 55	85.4146 11	waterGreen
555555 557	17-Apr-18		18-25 years	14:31:41	27.7090 55	85.4146 11	waterGreen
555555 557	20-Apr-18		18-25 years	19:21:15	27.7090 55	85.4146 11	waterGreen
555555 557	21-Apr-18		18-25 years	7:25:15	27.7090 55	85.4146 11	waterGreen
555555 557	22-Apr-18		18-25 years	13:59:14	27.7090 55	85.4146 11	waterGreen
555555 557	23-Apr-18		18-25 years	5:18:30	27.7090 55	85.4146 11	waterGreen
555555 557	23-Apr-18		18-25 years	20:05:59	27.7090 55	85.4146 11	waterGreen
555555 557	24-Apr-18		18-25 years	5:36:18	27.7090 55	85.4146 11	waterGreen
555555 557	29-Apr-18		18-25 years	13:18:30	27.7090 55	85.4146 11	waterGreen
555555 557	30-Apr-18		18-25 years	6:20:36	27.7090 55	85.4146 11	waterGreen
555555 557	1-May-18		18-25 years	7:04:23	27.7090 55	85.4146 11	waterGreen
555555 557	2-May-18		18-25 years	5:39:46	27.7090 55	85.4146 11	waterGreen
555555 557	5-May-18		18-25 years	17:36:22	27.7090 55	85.4146 11	waterGreen
555555 557	8-May-18		18-25 years	20:42:04	27.7090 55	85.4146 11	waterGreen

555555 557	11-May-18		18-25 years	18:32:08	27.7090 55	85.4146 11	waterGreen
555555 558	Sun Jun 16 2019	Fem ale	18-25 years	17:55:52 .	27.7143 518	85.3345 4179	waterRed
555555 559	22-Mar-18	Mal e	18-25 years	22:11:20	27.7030 74	85.4331 74	waterGreen
666666 661	24-Mar-18	NA	18-25 years	21:03:57	27.6822 589	85.3675 5364	waterGreen
666666 662	11-Jun-19	Fem ale	26-55 years				
666666 662	18-Jun-19		26-55 years				
666666 662	18-Jun-19		26-55 years				

Appendix B. Ethical Approval Application as submitted to ICREC

Imperial College Research Ethics Committee (ICREC) Application Form

Section One - Details of Principal Investigator

If the application is a student project, please name the student's supervisor as the Principal Investigator.

Please add the student's name and details of all other co-investigators or collaborators in Section Six.

Name:	Dr Michael Templeton
Position:	Civil Engineering Department director of undergraduate studies
Address:	303, Skempton building, South Kensington Campus
Telephone:	+44 (0)20 7594 6099
Email:	m.templeton@imperial.ac.uk
Fax:	n/a
Summary of skills and experience relevant to this study:	Dr Michael R. Templeton is a chartered civil engineer and Reader in Public Health Engineering in the Department of Civil and Environmental Engineering at Imperial College London. His research focuses on the occurrence and control of chemical and biological contaminants in water, innovative water treatment processes, and effective water supply and sanitation interventions in low-income countries.
Previous experience in any procedures to be used. <i>(Including involvement with vulnerable participants if relevant):</i>	He is a Fellow of the Institution of Civil Engineers and serves on several technical advisory panels, including the Water Quality and Health Technical Advisory Group of the World Health Organization, the Water Supply and Quality Panel of the Chartered Institution of Water and Environmental Management,

	and the Sanitation and Water Management in Developing Countries Specialist Group of the International Water Association.
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Section Two - Project Summary

Full title of study:	Characterising intermittent water systems in data-scarce settings using a citizen science approach
Proposed start date:	1 st May 2019
Proposed end date:	20 th December 2019

<i>Does the study involve any of the following</i>		
Drugs/medication <i>If yes, please attach the SmPc</i>	☐ Yes	☒ No
Ionising radioactive substances/x-rays <i>If yes, please also complete appendix one</i>	☐ Yes	☒ No
Genetically modified materials <i>If yes, please also complete appendix two and attach the GM Safety Committee letter</i>	☐ Yes	☒ No

2.a Project Summary

Please provide a summary of the project, including the expected outcomes, in LAY terms (max 200 words)

The aim of the project is to determine the feasibility of citizen science in collecting reliable data about the Intermittent Water Supply in a low-income setting.

The project focuses on collecting data on water cuts and water quality in an intermittent water supply setting. It uses citizen science (i.e. using citizens) to collect data. (We are in contact with students from Nepal Engineering College and local residents in Kathmandu. The participants are recruited through a college contact at Nepal Engineering College (Prof Sabitri Tripathi) who will advertise the project to both her students and local residents, record the interest of those who want to participate and communicate it back to the researchers at Imperial College London.)

Data collection methods:

Participants are asked to

1. Fill in a questionnaire
2. Download our app and log in their particulars
3. Open the app and follow the prompts every time they notice a water cut, or any visible change in their water quality.

A select number of participants (an estimated 9 participants) will be asked to carry out simple water quality tests (more details on the tests is provided below). These participants are asked to follow an extra step:

4. Carry out the water quality tests and report what colours they see through the app.

The tests are specifically designed for members of the non-scientific community to use and are entirely safe.

Testing is done after intermittency occurs and is in two parts. The first part involves participants dipping a

strip of paper into a glass of tap water, and reporting the date and colour of the test in the app after having done so (see illustrative figure 1)

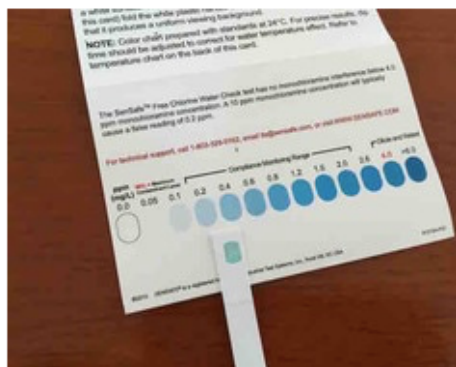


Figure - strip test

- Part two involves filling a 100ml bag with tap water and adding a safe-to-use reagent in it, and adding a drop of water to a plate (please see illustrative figure below). The participants then wait 24h before reporting the colour of the test on the app.

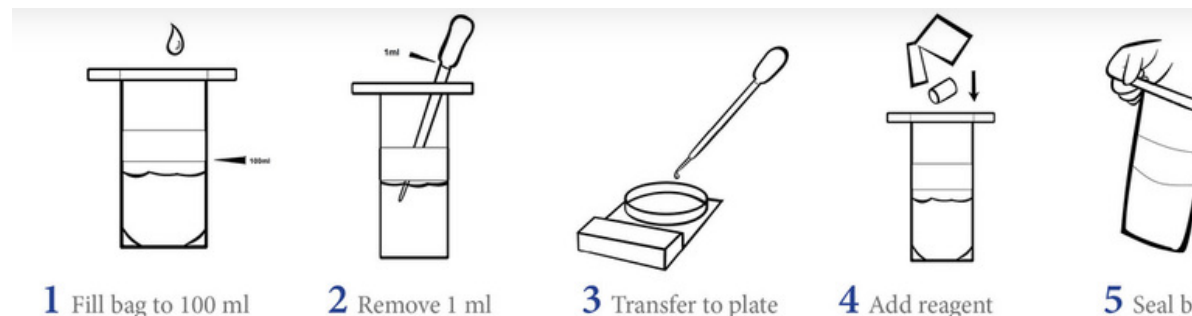


Figure - bag test

- Specially created website/app that we have self-built (with questions to be completed every time there is a water cut)

Data will be collected for 2 weeks by approximately 50 participants from Kathmandu.

After returning from Nepal data will be, anonymized, analysed and evaluated.

2.b Ethical Summary

*Please provide details of what you consider to be the ethical issues surrounding this project in LAY terms
(max 200 words)*

We are collecting some necessary personal details on the participants which if leaked could lead to a breach in privacy. Personal details regarding:

- Name: this is necessary to keep track of who gives what data.
- Sex: this is necessary to be able to say whether gender plays a role in the quality of the data collected.
- Address: this is necessary to be able to corroborate data geographically. This will let us assess a very approximate level of wealth.

In order to get around this, once the data collection period is complete, the data will be anonymized so nothing can be traced back to the participants.

We are asking certain people (anticipate 9 participants) to determine whether their water is of good or bad quality i.e. contaminated or not. Is there an ethical issue to allowing people to know that their water is contaminated, and then not doing anything about it ? If yes, then I propose to hand out a chart with the test kit, letting people know that if they report that their water is contaminated, then they should not consume it without boiling it or using chlorine tablets. If this is not enough, then I propose to distribute chlorine tablets to the participants and instruct them that in the case their water is shown to be contaminated, they should use the tablets in their water tanks before consuming the water.

2.c Peer Review

Has your research project been independently Peer Reviewed

This can be organised by the Peer Review Office (within the JRCO)

☐ Yes

☒ No

<i>Please give details below</i>		

Section Three - Project Details

3.a Protocol

Please provide details of the scientific justification for the study, and the research methodology to be used in LAY terms (max 200 words). Please attach the protocol and any questionnaires that will be used.

Collecting data using citizen science is an alternative form of data collection that is being assessed to see if it is a valid and appropriate form of data collection in a low-income developing country setting.

Intermittent Water Systems (IWS) provide water discontinuously in time and space – water is not distributed 24/7 and also not distributed in all geographic regions equally. Not only is this very impractical for people, but the cuts in water supplied in the piping results in it being unsafe to consume.

Information available on intermittent water supplies shows that it is present all over the world in varying degrees of severity. However, there is little data on intermittency, it is not of good quality and doesn't allow patterns to be mapped. The WHO has recognized the lack of relevant data on the failures of water infrastructure as inhibiting research and progress in the direction of remediating intermittent water supplies, and by association improving health. It requested more data to be collected but despite this call, intermittency persists. This is partly due to the fact that there is a lack of information on the problem at hand: water supply data is badly monitored, poorly logged in non-digital form, in the local language. This knowledge gap prevents planners from fully understanding the water supply system and its failures.

This research therefore proposes to implement a citizen-science approach to collect data on intermittent water systems in developing countries. Known as “organized research in which members of the public engage in the process of scientific investigations [...] collecting data” (Cornell Lab of Ornithology 2016), it

has proved to be a means of “tackling otherwise intractable, laborious or costly research problems” (Gura 2013). It is therefore conceivable that it could be a source of reliable and useful data on intermittent water systems, if controlled for quality assurance.

The aim is to determine if this method is a valid and appropriate form of data collection. There can be no comparison with the more traditional scientific means of data collection as this is not in place in developing countries i.e. there is no current data to compare to.

Data will be collected on the quantity and quality of service provided by the IWS i.e. on perceived water cuts and water quality.

At the very least, this proposed method to collecting data would fill a knowledge gap. At its optimal, it could be used to incite water officials to attribute more resources to studying the problem of water intermittency.

Study objective:

The overarching aim of the PhD is to determine the feasibility of citizen science in collecting reliable data in an Intermittent Water Supply in a low-income setting.

In order to do this, the citizen science approach for characterising intermittent water systems is developed and analysed, to ensure that the method is not only feasible and reproducible, but also that the data produced is statistically reliable and significant. The policy relevance of obtaining IWS data through citizen science is then ascertained by presenting the findings to water utility managers to determine if they would accept it as useful information for better understanding the intermittency issues in their supply systems so that evidence-based solutions can be devised.

Five objectives have been identified which together will allow the research to determine the feasibility of citizen science in collecting reliable data in an IWS:

1. What sample structure is appropriate ?

- Can a small sample size produce enough data to achieve statistically significant results?
- Can the sample be considered representative of the population affected by the IWS?
- How can statistically meaningful results be extrapolated from the sample if it is sparsely populated?

2. To what extent do the different stimuli (i.e. human and technological) work to obtain an appropriate sample, in terms of size and density?
3. Does participation need to be prolonged?
 - To what extent do the different stimuli work to sustain participation in the long run?
 - Is there a statistically significant link between sustained participation and the level of intermittency reported?
 - Is there a statistically significant link between sustained participation and the level of water quality reported?
4. How do you control the reliability of the data?
 - Do internal consistency tests support that the method produces reliable data?
 - Is this coherent with results produced from truth-finding algorithms used as an auto-validation technique?
 - Is there evidence of biased reporting? i.e. over or under-reporting of water quality or quantity.
 - Is there a link between participation characteristics (i.e. length or regularity) and bias?
5. Is the research accepted by policy representatives?
 - Are the utility managers' perceptions of the IWS affected by evidence drawn from the method *or* from the data itself (i.e. high valence data)?
 - Are the utility manager's perceptions on the use of citizen science affected by the evidence?
 - What are the policy implications of this?

3.b Value

Please state in LAY terms the intended value of the project (in terms of the expected outcomes) (max 200 words).

At the very least, this proposed method of collecting data would fill a knowledge gap on the quantity and quality of service provided by the Intermittent Water System i.e. on perceived water cuts and water quality. At its optimal, it could be used to incite water officials to attribute more resources to studying the problem of water intermittency.

3.c Location

Please state where the study will take place. If part or all of the study will take place abroad, please state any steps that have been taken to ensure compliance with research and ethical rules in those countries.

Kathmandu, Nepal – have been in contact with Nepal Engineering College to ensure all forms of data collection are ethically appropriate.

3.d Dissemination

Please state how and to whom the results of this study will be disseminated, including the communication of results to the research participants.

Consent is first required before taking part in the project and results will be collected confidentially through the questionnaire and the app. This data will remain confidential and any analysis that is done will remove any personal details. General analysis outcomes may be presented back to the participants in Nepal, through the project website www.networkingwater.com in order to demonstrate that their participation was useful.

3.e Previous ethical approval

<i>Has any part of this proposal received prior ethical approval?</i>	☐ Yes	☒ No

Has any part of this proposal previously been rejected by an ethics committee?	☐ Yes	☒ No
<i>If yes to either of the above, please give details and attach relevant documentation:</i>		

3.f Funding		
Has this project received funding, or is in the process of receiving funding?	☐ Yes	☒ No
<i>If yes, please provide details:</i> This project is part of the wider PhD project of Laure Sione, funded by the CDT in civil engineering and EPSRC.		

3. g Insurance and Indemnity Cover		
Have you applied to the Joint Research Compliance Office (JRCO) for indemnity cover?	☐ Yes	☒ No
<i>If no, please state when you intend to apply: do not intend to apply</i>		
<i>If you do not intend to apply, please give reasons:</i> Insurance is needed to provide cover against harmful events which could potentially be experienced by a human subject as a result of their participation in research. In this case, there is no potential risk of humans		

to come to any harm by participating in this research. Furthermore, the research does not involve any healthcare aspects e.g. clinical trials, drugs, surveys about the person's health or person.

Section Four - Participants

4.a Study population

Please state the number of research participants to be recruited, including the inclusion and exclusion criteria for recruitment.

Approximately 50 participants

Requirements for participation are consent to take part, aged over 18 and a smart phone that is able to download our app from the App Store (Apple and Android), live in an area prone to water intermittency.

4. b Vulnerable groups

Please give details of any vulnerable groups to be used in the study (e.g. those under 18, prisoners, those in a dependent relationship, the mentally ill), and give reasons for their inclusion.

Questionnaire requires all participants to be over 18. Participation is voluntary and participants are informed that they may be terminated at any time without any consequence or prior warning.

4.c Recruitment process

Please explain how you will recruit participants to the study. Please include any incentives (such as financial reimbursement). If advertising is to be used, please attach a copy of the advert. If you are planning to recruit via email, please include a copy of the email.

The participants are recruited through academic contacts at Nepal Engineering College. The academic contact informs the participants about the project and direct them to the project website for more

information. There, if they wish to participate they first have to fill in a questionnaire form. This requires participants to first give their consent to take part and to confirm they are aged over 18. It requires people to have a smart phone in order to download the app. If they don't then they are unable to participate.

Incentives are non monetary. Participants ultimately partake for their own personal gratification, and are motivated by the fact that they are ultimately helping other people and improving knowledge regarding the use of citizen science to assess water intermittency. They will be acknowledged in any important research findings.

4.d Informed Consent

- i. Please detail your process for ensuring the informed consent of all research participants.*
- ii. If vulnerable persons are to be used in the study, please give separate specific information on how you will ensure informed consent.*
- iii. If participants whose first language is not English are to be recruited, please state clearly how the details of the study will be explained and the informed consent process will be handled.*

Please attach a copy of the consent form and participant information sheet and any additional forms/information if appropriate.

To begin the questionnaire participants must confirm that they are over 18 and are giving their consent to take part with all information that they detail being collected confidentially. Failing to do this will lead to the application to partake being automatically rejected.

No vulnerable persons will be involved. All persons speak English.

4.e Withdrawal

Please state procedures for the withdrawal of participants from the study.

Participants are able to withdraw their participation in the study at any time for any reason – this is stated to them at the beginning of the questionnaire.

4.f Confidentiality

Please state the measures you have taken to ensure the confidentiality of the research participants and the data collected, including who will have access to the data. Please include information on any process to anonymise participants and their data.

All questionnaire data collected is sent to a confidential Imperial email address and data collected through the app is sent anonymously to a secure Imperial server. Only the Imperial College researchers involved directly in the project will have access to the data.

Section Five - Risks and Benefits

5.a Risks Has Imperial Colleges Risk Assessment procedures been followed	☒ Yes	☐ No
<i>If No, please explain:</i>		
Does Imperial Colleges' Insurer need to be notified about your project before insurance can be provided	☐ Yes	☒ No
Insurance for all Imperial studies is provided by a commercial insurer, (please refer to website) http://www3.imperial.ac.uk/clinicalresearchgovernanceoffice/projectplanning/clinicalresearchofficeapproval/insurance . For the majority of studies the cover is automatic. However for a minority of studies, in certain categories, the insurer requires prior notification of the project before cover can be provided.		

*If **Yes**, please provide confirmation that the appropriate insurance cover has been agreed. Please attach your Imperial College registration form and any related correspondence*

Please state briefly the precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants).

All researchers have filled in or read through the health and safety risk assessment form. Precautions mostly concern Nepal as an area of travel – for example ensuring all researchers have the appropriate and in-date immunisations.

Please state briefly the precautions being taken to protect the health and safety of research participants.

Research participants will be collecting data through an app which only requires them to log when there are water / electricity power cuts. This poses no threat to their health or safety.

Will these participants participate in any activities that may be potentially stressful or harmful in connection with this research

☐ Yes

☒ No

Please specify whether the following procedures are involved?

Any invasive procedure (s)

☐ Yes

☒ No

Physical contact

☐ Yes

☒ No

Any procedure (s) that may cause mental distress

☐ Yes

☒ No

Are you using any medical device in the UK that is CE marked and is it being used within its product limitation?

☐ Yes

☒ No

5.b Benefits

Please describe any expected benefits to the participant, researchers or others (e.g. Imperial College, Industry funders)

Incentives to participants are based on self-gratification, in the knowledge that they are ultimately helping other people and improving the knowledge-base pertinent to the use of citizen science in assessing water intermittency.

Benefits to researchers of this data are its use in analysis of water intermittency and the pertinence of using citizen science in this field. These finding will be applied within the PhD.

Section 6 – Co-Investigators/Collaborators

If there are more than 3 co-investigators, please use a separate sheet and follow the format below.

Name:	Laure Sioné
Position:	Principal researcher and coordinator
Address:	EWRE research office, Skempton Building, South Kensington Campus
Telephone:	
Email:	laure.sione09@imperial.ac.uk
Fax:	n/a
Summary of skills and experience relevant to this study:	MEng in civil engineering. Previous research trip to Nepal to establish working relationship with relevant local academics and volunteers there and assess the terrain.
Previous experience in any procedures to be used. <i>(Including involvement with vulnerable participants if relevant):</i>	Extensive research in using citizen science in developing countries.

Name:	
Position:	
Address:	
Telephone:	
Email:	
Fax:	n/a
Summary of skills and experience relevant to this study:	
Previous experience in any procedures to be used. <i>(Including involvement with vulnerable participants if relevant):</i>	

PI Declaration

I declare that:

- I undertake to abide by the ethical principles underlying the Declaration of Helsinki (1964) and subsequent amendments and good practice guidelines on the proper conduct of research.
- I undertake to abide by the Data Protection Act 1998 and any applicable local laws.
- I undertake to abide by all local rules for non-UK research.
- I will report any adverse or unforeseen events which occur to the JRCO Co-ordinator within 24 hours.
- I will provide an annual progress report of the project until the end of the study.
- I will provide notification of the end or early termination of the research project.
- I will inform ICREC if there are any changes to the research protocol or personnel which affect the ethical aspects of the project.

- I will assist ICREC in any continuing review of the project deemed necessary by the Committee or Faculty Members.
- I will re-apply for ethical approval after 5 years.
- All information on this form is correct.

Name:	Michael Templeton
Signature:	
Date:	

Would you be willing to attend the ICREC meeting to answer any questions about your proposal?

Yes ☒ No ☐

Any attendance must be by the PI named in section one of this application form. If this is a student application, the student may attend only if the supervisor is present.

Head of Department decision (please indicate below your decision and the reasons for it)	
Approval	☐
Referral to ICREC	☐
Reason:	
Signature:	
Printed Name:	
Date:	

JRCO decision (please indicate below your decision and the reasons for it)	
Approval	☐
Referral to ICREC	☐

Reason:	
Signature:	
Printed Name:	
Date:	

Template Protocol for non-CTIMPs

Characterising intermittent water systems in data-scarce settings using a citizen science approach

Version 5, 17/04/2019

MAIN SPONSOR: Imperial College London/

FUNDERS: EPSRC

STUDY COORDINATION CENTRE: N/A

IRAS Project ID: N/A

REC reference: N/A

Protocol authorised by:

Name & Role

Date

Signature

Study Management Group

Chief Investigator: Michael Templeton

Co-investigators: Laure Sione

Statistician: Laure Sione

Study Management: Laure Sione

Study Coordination Centre (*may not be applicable*)

For general queries, supply of study documentation, and collection of data, please contact:

Study Coordinator: Laure Sione

Address: Skempton Building, Imperial College London

Tel: 07896 218413

Email: laure.sione09@imperial.ac.uk

Queries

Queries should be directed to Laure who will direct the query to the appropriate person

Sponsor

Imperial College London/Imperial College is the main research Sponsor for this study. For further information regarding the sponsorship conditions, please contact the Head of Regulatory Compliance at:

Joint Research Compliance Office

Imperial College London

Room 215, Level 2, Medical School Building

Norfolk Place

London, W2 1PG

Tel: 0207 594 9459/ 0207 594 1862

<http://www3.imperial.ac.uk/clinicalresearchgovernanceoffice>

Funder

EPSRC

This protocol describes the Water Intermittency in Kathmandu study and provides information about procedures for entering participants. Every care was taken in its drafting, but corrections or amendments may be necessary.

These will be circulated to investigators in the study. Problems relating to this study should be referred, in the first instance, to the Chief Investigator.

This study will be conducted in compliance with the protocol, the Data Protection Act and other regulatory requirements as appropriate.

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EXAMPLE APPENDICES

Appendix 1. Summary of investigations, treatment and assessments

GLOSSARY OF ABBREVIATIONS

KEYWORDS

Water Intermittency, Kathmandu, Citizen Science, Data Collection

STUDY SUMMARY

TITLE Characterising intermittent water systems in data-scarce settings using a citizen science approach

DESIGN Data collection on water (cuts in supply and water quality) through an online questionnaire and self-made website and corresponding phone application. Water quality will be assessed using a simple indicative water quality test.

AIMS The overarching aim of the PhD is to determine the feasibility of citizen science in collecting reliable data in an Intermittent Water Supply in a low-income setting

OUTCOME MEASURES Participation rate i.e. sample size and density

POPULATION Kathmandu, Nepal

ELIGIBILITY Must be at least 18 years old, required to have a smart phone

DURATION 2 weeks

1. INTRODUCTION

1.1 BACKGROUND

Intermittent Water Systems (IWS) provide water discontinuously in time and space – the provision of water is therefore unreliable and unsafe for direct consumption. Water-borne pathogens proliferate in stagnant pipe-water, which is flushed down the next time that water flows through the pipes and consumed at the tap. Furthermore, since all pipe systems leak, when the water supply is switched off, the pressure drops and contaminated groundwater or surface water can enter the system through the cracks in the pipe walls or joints (World Health Organization 2011). Citizens who live with an IWS have been advised by the WHO that “all intermittent water supplies should be assumed to be contaminated and measures taken to disinfect water at the point of use” to prevent contracting water-related diseases, and typically resort to boiling tap water. Moreover, the insecurity of an untimely and insufficient water supply causes consumers to collect more water than they would use with a continuously available supply - a just-in-case versus just-on-time approach to consumption which exacerbates the problem of water scarcity in the network (Mohapatra et al. 2014) (Ingeduld et al. 2008).

The WHO has recognized the lack of relevant data on the failures of water infrastructure as inhibiting research and progress in the direction of remediating intermittent water supplies, and by association improving health. Despite this call, intermittency persists. This is partly due to the fact that there is a lack of information on the problem at: water supply data is badly monitored, poorly logged in non-digital form, in the local language and usually doesn't take into account the consumption from homemade coping strategies installed by consumers. This knowledge gap prevents planners from fully understanding the water supply system and its failures (De Marchis et al. 2015). This research therefore proposes to implement a citizen-science approach to collect data on intermittent water systems in developing countries. The aim is to determine if this method is a valid and appropriate form of data collection. There can be no comparison with the more traditional scientific means of data collection as this is not in place in developing countries i.e. there is no current data to compare to.

1.2 RATIONALE FOR CURRENT STUDY

At the very least, this proposed method to collecting data would fill a knowledge gap. At its optimal, it could be used to expose potential water utility practice lackings, and incite water officials to attribute more resources to studying the problem of water intermittency.

2. STUDY OBJECTIVES

The overarching aim of the PhD is to determine the feasibility of citizen science in collecting reliable data in an Intermittent Water Supply in a low-income setting. In order to do this, the citizen science approach for characterising intermittent water systems is developed and analysed, to ensure that the method is not only feasible and reproducible, but also that the data produced is statistically reliable and significant. The policy relevance of obtaining IWS data through citizen science is then ascertained by presenting the findings to water utility managers to determine if they would accept it as useful information for better understanding the intermittency issues in their supply systems so that evidence-based solutions can be devised.

Five objectives have been identified which together will allow the research to determine the feasibility of citizen science in collecting reliable data in an IWS:

1. What sample structure is appropriate ?
 - Can a small sample size produce enough data to achieve statistically significant results?
 - Can the sample be considered representative of the population affected by the IWS?
 - How can statistically meaningful results be extrapolated from the sample if it is sparsely populated?
6. To what extent do the different stimuli (i.e. human and technological) work to obtain an appropriate sample, in terms of size and density?
7. Does participation need to be prolonged?
 - To what extent do the different stimuli work to sustain participation in the long run?
 - Is there a statistically significant link between sustained participation and the level of intermittency reported?
 - Is there a statistically significant link between sustained participation and the level of water quality reported?

8. How do you control the reliability of the data?
 - Do internal consistency tests support that the method produces reliable data?
 - Is this coherent with results produced from truth-finding algorithms used as an auto-validation technique?
 - Is there evidence of biased reporting? i.e. over or under-reporting of water quality or quantity.
 - Is there a link between participation characteristics (i.e. length or regularity) and bias?
9. Is the research accepted by policy representatives?
 - Are the utility managers' perceptions of the IWS affected by evidence drawn from the method *or* from the data itself (i.e. high valence data)?
 - Are the utility manager's perceptions on the use of citizen science affected by the evidence?
 - What are the policy implications of this?

3. STUDY DESIGN

Data collection methods:

- Online questionnaire (this focuses upon suitability for data collection via mobile app, personal details regarding living, regularity of water and electricity cuts, water sources, water quality and treatment)
- For a select number of participants (an estimated 9 participants), a simple water quality test will be provided. The tests are safe and are specifically designed for members of the non-scientific community to use. Testing is done after intermittency occurs and is in two parts. The first part involves participants

dipping a strip of paper into a glass of tap water, and reporting the date and colour of the test after having done so (see illustrative figure)

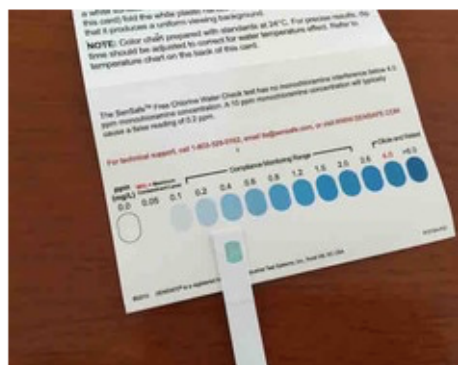


Figure - strip test

- Part two involves filling a 100ml bag with tap water and adding a safe-to-use reagent in it, and adding a drop of water to a plate (please see illustrative figure).

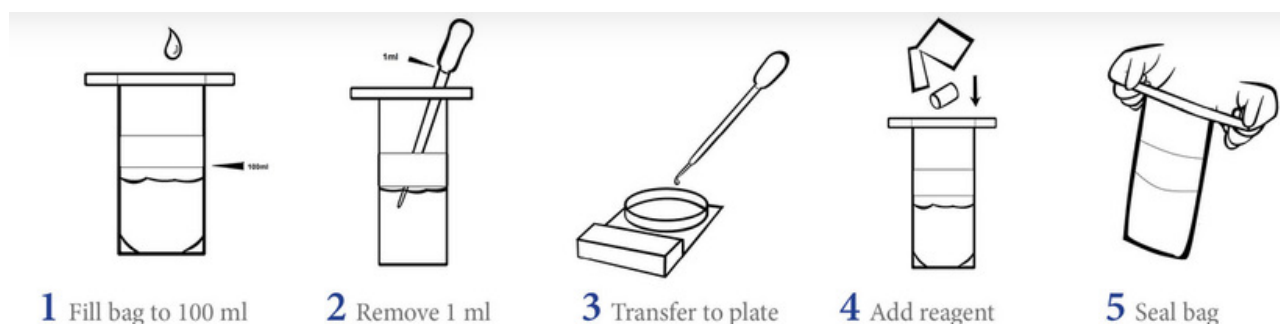


Figure 62 - bag test

- Specially created website/app that we have self-built (with questions to be completed everytime there is a water cut)

Data will be collected for 2 weeks by approximately 50 participants from Kathmandu.

The participants are recruited through a college contact at Nepal Engineering College (Prof Sabitri Tripathi) who will advertise the project and then record the interest of those who want to participate and communicate it back to the researchers at Imperial College London.

3.1 STUDY OUTCOME MEASURES

Assessment of the participant rate and data collected – is citizen science an effective way to assess water intermittency and does the data help us to assess it.

4. PARTICIPANT ENTRY

4.1 PRE-REGISTRATION EVALUATIONS

If participants have a smart phone, if they are aged 18

4.2 INCLUSION CRITERIA

Participants must be 18 and have a smart phone as they require access to the Internet. Participants are asked to enter their age-range into the website / app before proceeding with any data collection for the study.

4.3 EXCLUSION CRITERIA

If participants are not 18 and do not have a smart phone

4.4 WITHDRAWAL CRITERIA

Participants may withdraw from the study at any time

6. ASSESSMENT AND FOLLOW-UP

Yes – assessment of the data. Study will end with conclusion of if citizen science is useful as a data collection method in developing country setting.

7. STATISTICS AND DATA ANALYSIS

Sample size of approximately 50 participants with statistical analysis performed on the data collected to identify any trends. Data and all appropriate documentation will be stored for a minimum of 10 years after the completion of the study, including the follow-up period.

8. REGULATORY ISSUES

8.1 ETHICS APPROVAL

The Study Coordination Centre has obtained approval from the HoD and JRCO

8.2 CONSENT

Consent to enter the study must be sought from each participant only after a full explanation has been given, an information leaflet offered and time allowed for consideration. Signed participant consent should be obtained. The right of the participant to refuse to participate without giving reasons must be respected. In these cases the participants remain within the study for the purposes of follow-up and data analysis. All participants are free to withdraw at any time from the protocol treatment without giving reasons and without prejudicing further treatment.

8.3 CONFIDENTIALITY

The Chief Investigator will preserve the confidentiality of participants taking part in the study and is registered under the Data Protection Act.

8.4 INDEMNITY

Imperial College London holds negligent harm and non-negligent harm insurance policies which apply to this study.

8.5 SPONSOR

Imperial College London will act as the main Sponsor for this study.

8.6 FUNDING

EPSRC are funding this study.

8.7 AUDITS

The study may be subject to inspection and audit by Imperial College London.

9. STUDY MANAGEMENT

The day-to-day management of the study will be co-ordinated through Laure.

10. PUBLICATION POLICY

Details of participants will be kept anonymous and only data pertinent to water will be published. Participants will be informed of the use of their data.

10. REFERENCES

APPENDICES

Appendices should be additional information to the protocol and can consist of:

- Common Terminology Criteria for Adverse Events (NCI CTC)
- RECIST criteria
- WHO / ECOG Performance status
- PIS, Consent form, GP letter (although may be more practical to have them separate)
- Expected side effects
- Schedule of events table

This is NOT a medical study

Letter of Support

March 11th, 2019

To the Research Ethics Committee of Imperial College London

This is to inform that Ms. Laure Sione, a PhD scholar from Imperial College London has my approval and support to conduct their research on the water supply in Kathmandu, as part of their case study.

Nepal Engineering College is also supportive of this research work, involving their students to assist and collect data for the research if they wish.

The project scope has been explained to the participants and myself.

It is the participant's decision to participate or not in the study, on a voluntary basis. They are aware that they can stop participating at any time.

Sincerely,

Prof. Sabitri Tripathi

Department of Science and Humanities

Nepal Engineering College

Nepal Coordinator for the Networking Water project (Imperial College London) and sub-investigator

TEMPLATE INFORMED CONSENT FORM
FOR SUBJECTS ABLE TO GIVE CONSENT

Centre Number (if applicable): N/A

Study Protocol Number:

EudraCT number (if applicable):N/A

Full Title of Project: The Networking Water research study

Characterising intermittent water systems in data-scarce settings using a citizen science approach

Name of Principal Investigator: Dr Michael Templeton

Please initial box

1. I confirm that I have read and understand the subject information sheet dated ☐
.....11/03/19..... version 3..... for the above study and have had
the opportunity to ask questions which have been answered fully.
2. I understand that my participation is voluntary and I am free to withdraw at any time, ☐
without giving any reason, without my legal rights being affected.
3. I give permission for the researchers at Imperial College London to use the data that I provided
that is relevant to this research.
4. I agree to take part in the above study. ☐

Name of Subject

Signature

Date

Subject's date of birth

Name of Person taking consent
(if different from Principal Investigator)

Signature

Date

Principal Investigator

Date

Signature

1 copy for subject; 1 copy for Principal Investigator;

Participant Information Sheet 1

Study title: The Networking Water research study: Characterising intermittent water systems in data-scarce settings using a citizen science approach

Your Invitation: You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Your participation is entirely voluntary: you do not have to take part if you do not wish to.

Purpose of the study: Water intermittency is a problem in Kathmandu: there is no water all the time and it is not always safe to drink. This is a problem because it costs you money to buy clean water from vendors, and you get

sick from the water sometimes. There is little official data on this topic so we have decided to collect data using citizens. If this works, then we will be able to show that community people are the key to collect information that can be used to change the water situation in Kathmandu.

Your taking part in this study will be kept confidential: Your responses are confidential: everything is anonymous and only used for university research. That means no information is given to anybody about who participates in the study. Procedures for handling, processing, storage and destruction of their data are compliant with the Data Protection Act 1998.

Why have you been chosen?

Nepal has lots of issues with cuts in the water supply and water quality. Your participation is voluntary, and you may choose to terminate your participation in the study at any time and without giving any reason. A decision to withdraw at any time, or a decision not to take part, will not affect you negatively in any way. There are no risks involved in taking part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form.

What will you have to do during your participation?

1. Download our free app or access the networkingwaterdata.com website
2. Fill in our **Get Started** form
3. Complete our questionnaire
4. open the app everytime there is a water cut or change in water quality - and then just follow the prompts!

What will happen to the results of the research study?

The research results will be used as part of a PhD thesis. They will also be used in research publications to present relevant findings. We expect the first publication in Autumn 2019. We will inform you of new publications via our website. You will not be identified in any publication.

Who is organising and funding the research?

The organisation funding the research is the EPSRC (Engineering and Physical Sciences Research Council) from the United Kingdom, in association with Imperial College London.

Who has reviewed the study?

The Imperial College London HoD (Head of Department) and JRCO reviewed this study and found that it did not pose any ethical issues.

Contact for Further Information: If you would like to contact the Principal Investigator in the study to discuss this research, please get in touch through the contact page of Networking Water at www.networkingwater.com
If you would prefer to speak to a local contact, please contact Prof Sabitri Tripathi from Nepal Engineering College sabitrtripathi@yahoo.com

Please keep a copy of the written information and signed Informed Consent form for your records.

Participant Information Sheet 2 for participants testing water quality only

Study title: The Networking Water research study: Characterising intermittent water systems in data-scarce settings using a citizen science approach

Your Invitation: You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Your participation is entirely voluntary: you do not have to take part if you do not wish to.

Purpose of the study: Water intermittency is a problem in Kathmandu: there is no water all the time and it is not always safe to drink. This is a problem because it costs you money to buy clean water from vendors, and you get sick from the water sometimes. There is little official data on this topic so we have decided to collect data using citizens. If this works, then we will be able to show that community people are the key to collect information that can be used to change the water situation in Kathmandu.

Your taking part in this study will be kept confidential: Your responses are confidential: everything is anonymous and only used for university research. That means no information is given to anybody about who participates in the study. Procedures for handling, processing, storage and destruction of their data are compliant with the Data Protection Act 1998.

Why have you been chosen?

Nepal has lots of issues with cuts in the water supply and water quality. Your participation is voluntary, and you may choose to terminate your participation in the study at any time and without giving any reason. A decision to withdraw at any time, or a decision not to take part, will not affect you negatively in any way. There are no risks involved in taking part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form.

What will you have to do during your participation?

1. Download our free app or access the networkingwaterdata.com website
2. Fill in our **Get Started** form
3. Complete our questionnaire
4. Every time there is a water cut or change in water quality you should:
 - Open the app and follow the prompts
 - Perform a water quality test using the kits provided to you

Your local contact should have shown you how to do this test – if you are unsure, you can reach them through the Networking Water Facebook page, or check the instructions sheet given to you with the test kit.

What will happen to the results of the research study?

The research results will be used as part of a PhD thesis. They will also be used in research publications to present relevant findings. We expect the first publication in Autumn 2019. We will inform you of new publications via our website. You will not be identified in any publication.

Who is organising and funding the research?

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Contact for Further Information: If you would like to contact the Principal Investigator in the study to discuss this research, please get in touch through the contact page of Networking Water at www.networkingwater.com. If you would prefer to speak to a local contact, please contact Prof Sabitri Tripathi from Nepal Engineering College sabitrtripathi@yahoo.com

Please keep a copy of the written information and signed Informed Consent form for your records.

Summary of the Final Report on the Research

Characterising Intermittent Water Systems In Data-Scarce Settings Using A Citizen Science Approach

L.Sioné¹, M.R. Templeton, C. Onof

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Introduction

Intermittent Water Systems (IWS) provide water discontinuously in both time and space. Delivery is unreliable and the water itself is often unsafe for direct consumption. Costs borne by the consumer to overcome these issues reach as much as 7.6% of reported income (on top of the cost of water utility bills), revealing a personal concern for safe and reliable drinking water (Vásquez et al., 2009)(Dauda et al., 2015). The lack of relevant data on the failures of water infrastructure inhibits research in the direction of remediating IWS, and, by association, improving public health (World Health Organization, 2003).

This work discusses implementing a citizen science approach that leverages the personal concern of citizens to gain information on the quantity and quality of services provided by IWS - data which would otherwise be intractable, laborious or costly, for developing countries to gather (Gura, 2013).

Methods and Materials

The method consisted of recruiting citizen scientists and instructing them on how to record data on the cuts in their water supply. Interested participants were directed to an informative website (www.networkingwater.com) to learn more about the project, and encouraged to get involved through social media (namely, Facebook <https://www.facebook.com/NetworkingWater/>). Final participants attended an information session where they were taught to use the custom-built mobile phone application and website to record their water cuts (Figure 1). Before the two-week data-collection phase of the study began, the participants filled in a survey about the frequency and length of water cuts, which provided information for validating the data's reliability. It also provided complementary information on the participants' personal circumstances, which was used to identify trends in the characteristics of their water supply. A pilot study was initially conducted in Nepal on a group of 18-22 year olds from Nepal Engineering College.

Consent to enter the study was sought from each participant after a full explanation was given, an information leaflet offered and time allowed for consideration. Each participant signed their consent to partake, and were also told that they had the right to withdraw at any time without any reason or warning. Details of participants were kept anonymous and only data pertinent to water will be published. Participants will be informed of the use of their data.

Results and Discussion

The data obtained from the phone application and survey was analysed to determine the general feasibility of the method and the reliability of the collected data. Results showed that the methodology was feasible (i.e. it is practical and reproducible) but that the dataset collected was occasionally sparse.

While this sparsity did not present a problem for investigating the reliability of the data, it did reduce the sample size significantly and limited the ability to identify trends in the IWS' operation. Internal consistency tests (between the survey data and the collected data), and the split-half method (applied to the collected data), both revealed the data to be largely reliable. However a trend was identified where participants who declared a higher frequency of water cuts tended to be slightly less reliable, statistically speaking. This highlighted the need for complementary techniques to further ascertain the reliability of the data and of the individual participants.

Interviews with water officials showed a general acceptance to admitting the failures of the water system and a keen interests in investigating the potential application of using this citizen science technique to acquire more information on water supply.

Ethical aspects:

The project ran smoothly and as expected. Communication with the volunteers was facilitated thanks to a local university contact who accompanied the project from start to finish. Most of the approached volunteers graciously accepted to partake in the study and share their personal details.

Conclusions

In the context of developing countries, citizen science can be used in conjunction with personal communication technology to bridge the information gaps on the characteristics of intermittent water supplies. It is a feasible

and validated data collection method but requires the application of appropriate statistical analyses to be able to gain useful insights from the sometimes sparse and incomplete data sets that are gained from this approach.

Further Work

So far there are no plans to take this work further in future.

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DECLARATION OF THE END OF A STUDY

For use in all research previously approved by Imperial College Research Ethics Committee and Science, Engineering and Technology Research Ethics Committee.

To be completed by the Principal Investigator and submitted to the Imperial College Research Ethics Committee (ICREC) or Science, Engineering and Technology Research Ethics Committee (SETREC) within 90 days of the conclusion of the study or within 15 days of early termination (through the Ethics and research Governance Coordinator at jrcocoordinator@imperial.ac.uk. For questions with Yes/No delete as appropriate.

Details of Principal Investigator and Study

Name:	Prof. Michael Templeton
Campus:	South Kensington
Email:	m.templeton@imperial.ac.uk
Full title of study:	Characterising intermittent water systems in data-scarce settings using a citizen science approach
ICREC/SETREC reference number:	

Study duration

Date study commenced:	1 st May 2019
Date study ended:	14 th October 2019

Did this study terminate prematurely?	No
	<i>If yes please complete sections 1, 2 & 3.</i> <i>If no please go directly to section 4.</i>

Section One - Early Termination

What is the justification for this early termination?

Section Two - Temporary halt

Is this a temporary halt to the study?	Choose an item.
If yes, what is the justification for temporarily halting the study? When do you expect the study to re-start? <i>e.g. Safety, difficulties recruiting participants, trial has not commenced, other reasons.</i>	

Section Three - Potential implications for research participants

a. Are there any potential implications for research participants as a result of terminating/halting the study prematurely?
b. Please describe the steps taken to address them.

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Section Four - Final report on the research

Is a summary of the final report on the research attached to this form?	Yes <i>If no, please forward within 12 months of the end of the study.</i>
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Section Five - Declaration

Signature of Chief Investigator:	
Print name:	Prof. Michael Templeton
Date of submission:	14 th October 2019

Imperial College London

Science Engineering Technology Research
Ethics Committee
Level 2, Medical School Building,
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 1872

researchethicscommittee@imperial.ac.uk

13 May 2019

Dear Dr Michael Templeton

Study Title: Characterising intermittent water systems in data-scarce settings using a citizen science approach

SETREC reference: 18IC4470

The above study was reviewed by the Science Engineering Technology Research Ethics Committee on 19/03/19.

Following the review of your amended documents submitted on the 13/05/19, the Joint Research Compliance Office would like to grant full approval of the study on the basis described in the revised documents:

Documents

The documents reviewed were:

- SETREC application form (May 2019)
- Protocol (v5 17/04/19)
- Participant Information Sheet (v3 11/03/19)
- Participant Information Sheet for testing participants (v3 11/03/19)
- Informed Consent Form (v5 11/03/19)
- Questionnaire
- Letter from Nepal Engineering College

Membership of the Committee

The members of the Ethics Committee who reviewed the study were:

Chris Hughes	Marek Sergot
Tessa Denning	Mirjam Tuk
Rebecca Ward	Chris Watkins
Vivienne Kuh	Stephen Webster

Yours sincerely,



Chris Hughes,
Chair, Science Engineering Technology Research Ethics Committee

Imperial College of Science, Technology and Medicine

Appendix C. Summary of Interview Findings

Main interview findings: University professor	Implication for stakeholder engagement	Implication for research
Impression that KUKL must have data and must report to a higher authority.		No concrete knowledge on what information KUKL has and how they are held accountable.
Hope that the Melamchi will provide the respondent with water.	Faith in Melamchi is an impediment to engagement, as there is an innate belief that the water situation will be imminently resolved. It is also a sensitive topic, which should be avoided.	
Women are the ones directly implicated with the water supply as they take care of the home.	Female participation may be particularly willing to engage, and/or stimulated by discussions over water for the home.	There may be a difference in the manner that women record data compared to men. Women should be consciously included in the study.
Water is supplied as per a schedule to different parts of the city, organised by the local level offices. Supply	Customers feel reassured that the water is distributed in a systematic and deliberate manner.	Possibility of comparing the data collected to schedules obtained from local level offices.

is variable both within a neighbourhood and between neighbourhoods.		
Reliance on tanker water.	Citizens are sceptical of quality / quantity of supply.	This scepticism may be used to motivate them to participate in the research. Mention of coping methods should be avoided: it may inhibit participation as citizens have learned how to survive without normal water supply.
Every household must be connected to the water supply and must pay a minimum monthly bill, regardless of whether water is supplied or not. If the bill is not paid, the customer will be disconnected which has future legal implications.	People are hesitant to contest the system due to potential future implications.	The anonymous nature of the research tool should be used to encourage them to take it up as a means to contest the system without personal implications.
Impression that the water is metered.		KUKL may have metering data that could be compared to collected data.
No customer feedback mechanism.	Citizens are discontented, which may encourage them to take up the tool as a means of showing their discontent, and if the tool is taken up by KUKL later, as a means of receiving information.	The tool can be used as a two-way system by the utility to fill the service gap left open by the lack of customer feedback mechanism. The utility can then inform the users on the state of the water supply, and

No interest in customer feedback to KUKL.		the users can inform the utility about grievances, thereby restoring trust in the utility.
No information shared with the customer from KUKL.		
Citizens want change as they have lost faith in the system.		
Citizens are searching for ways to put pressure on the government and KUKL to rectify the water situation e.g. protests.		The research tool can be presented as another structure to influence the government and KUKL to encourage uptake.
Government only responds to political pressure.		The research should seek the approval of politicians for the methodology to be accepted.
Citizens prioritise water quantity over quality.		The research may not need to include water quality as a tandem way of supporting quantity monitoring.
Citizens purify their water supply.	This shows an inherent concern with quality, which is the intrinsic motivation for public participation.	The research method should include water quality monitoring tools and solutions to water quality issues, to respond to the inherent concern over quality. This would simultaneously support quantity monitoring and engagement.
Everyone has water problems and mobile / laptop connectivity.	All interested participants would be able to contribute.	Access to citizen scientists is expected to be equal throughout the population.

Must go through community leaders to reach citizens.		The research will feature inherently randomly sampled sub-population groups.
Citizens in power have separate pipelines to get better access to water.	Citizens in power may be less concerned with water and less willing to engage due to a fear of exposure of their illegal water access.	Citizens in power should be avoided in the research. Their engagement level may be low.
Commitment from surveyors is usually given in informal and in concrete terms. Impression that citizens would not want to cooperate	Citizens are likely to be wary of outsiders. Interested participants would only engage with individuals who demonstrate commitment to their cause.	Researchers may need local representation and should provide evidence of commitment in order to gain the trust of citizens. Rapport-building is key to building trust and securing engagement.
Research findings are not typically shared with authorities.	Sharing the research with authorities may strengthen their engagement towards remediating the situation.	Opportunity to share research with authorities.

Main interview findings: Journalist	Implications for Stakeholder engagement	Implications for research
Hope that the Melamchi will provide the respondent with water.	There is an innate belief that the water situation will be imminently resolved, combined with frustration at its lateness.	Faith in Melamchi is an impediment to engagement as people hope that there will be no need for other improvements after its arrival. It is a sensitive topic, which should be avoided.
Citizens have lost trust in government and are angry.	Citizens may be inclined to seek support from outsiders i.e. researchers, and to take up the tool as a means of showing their discontent.	
Belief that government is unaware of problems faced by common people.	If the government is not aware of the situation, then bringing their attention to it can only be beneficial for all stakeholders.	Opportunity to share research with authorities and see if there is a response. Sharing the research with government may strengthen their engagement towards remediating the situation.
Citizens need political representatives to put pressure on the government.		The research tool can be presented as another scheme to influence the government and KUKL to encourage uptake.
Government has been known to respond to media attention.	Media may be scrutinised by government in Nepal. Emphasise to all stakeholders that the project has	Attracting negative media attention should be avoided.

	been presented to government and industry officials to appease any fears of backlash.	
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Main interview findings: former member of the Ministry of Water, Government of Nepal	Implications for stakeholder engagement	Implications for research
Consumers are not aware of the implications of their poor water quality.	The customer wants to understand the risks associated to their water supply. The consumer should be able to demand more from its provider, and should put pressure on KUKL and the government to respond to their needs.	The research should seek to increase the understandings amongst consumers of the implications of an intermittent and/or contaminated water supply. This in turn should create a bond of trust with the researchers and foster engagement in the project. This research pertains to KUKL tap water supply but increased awareness may prompt the consumers to want to be educated about their other water sources, prompting a change in consumer behaviour across the board.
KUKL's service provision does not match the official schedules.	Customers are upset that they are unable to collect water at the time promised, which may encourage them to log the actual times when water is supplied.	No possibility of comparing the data collected to schedules obtained from local level offices.

Customers pump water out of the pipes.	Citizens are sceptical of quantity of supply. This scepticism may be used to motivate them to participate in the research.	
People suffer from their water supply.	Researchers should listen to the customer's water woes in order to build rapport. They should also emphasise that the research is a tool and an experiment that may have an impact in the long run but is not designed as a solution to their woes.	The data collected is likely to be trustworthy as people record their suffering.
Data collected through the research is private data and so is reliable.		This endorsement of user-collected data suggests that validation of such data is not necessary in the respondent's opinion. The respondent is also implying that public data is not reliable and should therefore be carefully considered if used in the research.
The respondent cannot appear openly critical of the government.	People are disinclined to contest the system due to potential future implications. The anonymous nature of the research tool should be used to encourage	The researchers should be open with government officials and promote the research as an effort to benefit them, to avoid any misconstrued perceptions of the purpose of the research.

	them to take it up as a means to constructively criticise the system without personal implications.	
Outside of KUKL's jurisdiction, citizens are given the means to test their water quality.	This knowledge should be shared with the consumers. By knowing that 1) the government promotes this kind of activity in Nepal and 2) lay people are able to do the quality testing themselves, citizens will likely be emboldened to take up monitoring themselves.	This implies that the government is amenable to engaging with citizens to monitor their water supply.
Belief that Melamchi will be finished soon.	Faith in Melamchi is an impediment to engagement, as there is an innate belief that the water situation will be imminently resolved. It is also a sensitive topic, which should be avoided.	
Citizens prioritise water quantity over quality.		Greater interest in quantity than quality. The research may not need to include water quality as a tandem way of supporting quantity monitoring.
The water is unsafe for consumption.	The research method should include water quality to support consumer awareness, which in turn would encourage them to use the tool more ardously.	

Perceives the app as an effective way to mobilise public participation in water monitoring.	The research could be seen as a risk-free tool for citizens to put pressure on the government and KUKL, while contributing to water monitoring efforts at KUKL.	Confirmation that citizens can be engaged to monitor their water supply effectively.
Perceives the research as a kind of system improvement.	The research could be seen as a risk-free tool for decision-makers to improve the data collection and distribution, without needing to invest in manpower, equipment or resources.	Confirmation of the usefulness of the research in addressing water-supply challenges from different angles in a cost-effective way.

Main interview findings: IWMI	Implication for stakeholder engagement	Implication for research
Despite water-related issues being largely borne by women, the water sector is male-dominated.	As a result of women feeling excluded, they are likely to be more receptive to participating in the research if directly targeted.	Research should be gender inclusive to avoid overlooking water issues and/or provide solutions that may be gender-specific.
There is a gender gap in the water sector.	To reduce any subconscious gender bias, the research team should include male leads. Furthermore, the research should seek to include as many female stakeholders as possible, to reduce bias as much as possible.	Stakeholders in managerial positions in the industry are dominantly male, possibly introducing a gender bias to the research investigating stakeholder engagement.
The government is the key player in water security for the foreseeable future. However, government organization is chaotic: when it comes to decisions around water, jurisdiction is spread over multiple ministries, and the power of	As a result, there is ample opportunity for confusion and counter-productivity surrounding policy. The lack of cohesiveness impedes the productivity of the collaboration between the government and the other stakeholders.	The government should be a partner when developing water-related strategies. Government officials from the various jurisdictions should be consulted, to ensure that the research design strategy is widely accepted and responding to an established need.

authority varies for each and within each ministerial department.	The tool should be presented as a means to improve transparency and communication within the Ministry of Water.	The research should facilitate cooperation within the water sector. Specifically, it should facilitate teamwork within the government, as well as communication between the government and the other stakeholders.
Executive decisions centre on managing the supply of water on the provider side rather than the on the consumer side or from a resource management perspective. Management interventions are designed without robust knowledge of the physical water situation.	Providing consumer-side data could shed light on the failings experienced by the consumers, to be taken into consideration when deciding where to focus resources. This would facilitate the design of management strategies as well as make them more targeted to the real and current water situation.	There is an opportunity to integrate consumers into the decision-making process from the start, thereby allowing for tailored management solutions.
The current data system is outdated by several decades.	Data distribution and communication is currently challenging. Overhauling the system may seem daunting and appear costly, compared to a low-cost and low-maintenance tool.	Opportunity to develop an information system to promote knowledge sharing and to build a data base.

KUKL has leased Kathmandu Valley water supply from KVWSB, and KVWSB has expressed that it lacks data and that it needs to fill this gap.	Decision-makers are ill equipped to respond to the intermittency challenge without the knowledge derived from data.	Opportunity to fill this data gap using the research tool, and for this to be accepted both by the service provider and by the Water Supply Board.
An information system should be accepted by the potential users and government alike.		Both government and end-users should be consulted, to ensure that the research design strategy is accepted by both parties, and that both parties accept to collaborate
Desire for the data information tool to be translatable into operational policies.		Opportunity for the knowledge and data base to be presented to policy-makers and be used to shape policy decisions.
Expressed a desire and willingness to collaborate on the research.	Ability to unite stakeholders and facilitate the promotion of new strategies in managing water.	Confirmation of the usefulness of the research in addressing water-supply challenges and improving resilience.
Perceives the research as a low-cost yet valuable tool to shape policy interventions and influence KUKL into responding in a constructive way to consumer criticism.	Stakeholders have the opportunity to play an active role in shaping policy and company decisions.	Confirmation of the usefulness of the research in addressing water-supply challenges from different angles in a cost-effective way.

Perceives the research as a complimentary tool to other means to other sources of data.		Confirmation that the research does not necessarily have to be all-encompassing or large-scale to make a meaningful contribution to the data landscape.
Remarked that decision-makers are hesitant on how to tackle the overwhelming task that is improving the water supply.	Decisions made are tentative in terms of reach, and promises are made that cannot always be kept. This is both because it is daunting to make important decisions without information, and any decision made implies taking the risk to not have the reach intended.	The research could be seen as a risk-free tool for decision-makers to kick-start the process of improving the water supply without needing to invest in manpower, equipment or resources.

Main interview findings: JICA-KUKL	Implication for stakeholders	Implications for research
Neither the government nor KUKL have data on - physical location of network - operations of the network (e.g. records of opening of valves)	Data on the current system is not usable and therefore interventions involve a best-guess approach.	Data on the current system is non-existent. The research fills a data-gap.
Any data on the water supply which is made public is unsound.		Data on the current system is erroneous. Confidence in public data is limited. This may imply that KUKL is open to employ less traditional and accurate means of data collection.
Data collection is very costly.	No new data is being collected. A cheaper alternative to acquiring data is needed if the gap is to be filled.	The research provides a low-cost alternative to fill the data-gap.
KUKL does not have financial resources to spend on acquiring this data.		The low-cost approach to the research means that it is easily accessible to KUKL.
KUKL cannot provide adequate water distribution until the Melamchi project is completed, but it has been continuously delayed for over a decade.	There is negative sentiment about the Melamchi project and fears over its completion.	The research provides a constructive way of compensating for negative feelings over the lack of water supply.

KUKL chooses to focus its resources on maintaining the current network - not on operations because of the absence of water, nor on research because of a lack of financing.	KUKL does not wish to invest in a network that is due to be obsolete when Melamchi is completed.	In the meantime, KUKL needs a low-cost approach to improving its services for its customers, as Melamchi may be delayed indefinitely.
The research methodology can be modified when Melamchi comes to include areas currently not served by KUKL.	Donor agencies need a monitoring strategy that can be adapted for when Melamchi is complete.	The methodology should be simple enough to be scalable and reproducible.
Schedules are created by the branch offices and are available on the website.	KUKL tries to distribute water in a transparent manner.	Easily accessible data to compare collected data to.
Schedules are not adhered to, because of factors external to KUKL.	KUKL needs to have an alert system for when and where water was not distributed, if they are to attempt to remediate the external events that may hinder water distribution e.g. valve operators being late.	Schedule data is flawed. Confidence in this data is limited. Statistical methods of data validation are preferred. The research tool would not bring any means of control over external factors contributing to the lack of adherence, but it would provide a means for KUKL to be aware of when the schedule is not adhered to,

		and thereby let them verify if the cause was indeed unavoidable.
There is no feedback mechanism in place, which results in customer dissatisfaction.	KUKL have no means of either appeasing the customers or of fixing their problems since they are not systematically aware of incidents.	If the research is employed as a feedback mechanism, customers would feel heard and valued, improving relations.
Monitoring of reservoir levels is done manually.	KUKL needs an updated means of monitoring its reservoir levels.	KUKL needs a modern approach to monitoring, provided by the research.
Most operations are manual as opposed to automated, but KUKL is understaffed.	KUKL needs to reduce its dependence on manpower, to facilitate management and operations.	Since supply side monitoring is difficult, the research focuses on demand-side monitoring. In all cases, a monitoring system employing IT would not need so much manpower
KUKL is an unappealing employer.	KUKL needs a strategy to find and retain quality employees.	The research tool, if employed by KUKL, would be a showcase for a more inclusive approach to its management, and likely attract talent.

Nobody records when, where and for how long water is actually distributed, except the customers.	There is no data available on water distribution on the KUKL side. KUKL needs to look to its customers for data.	Citizens are key to data collection.
Plans for each house to have a meter, and for the meter to be manually read by KUKL staff and uploaded to a server.	KUKL's future improvements are not at the forefront of modern means and could be updated.	The research tool could be used in lieu of water meters and water meter readers.

Main interview findings: KUKL	Implication for stakeholders	Implications for research
It's unclear who owns the water resource and what rights they have over it.	Managers need more robust water policies to be able to enforce everyone's right to the water e.g. by preventing stealing water at the source.	It's likely that everyone feels they own the resource, so all stakeholders should be treated as having equal rights over it.
Unequitable service, even within the same area	Customers feel frustrated that the water is not distributed in a systematic and deliberate manner.	
There is no systematic data collection on water delivery. There is no primary data. Official statistics claim that 99% of households are metered but this is not the case.	There is no data available on water distribution on the KUKL side. KUKL needs to look to its customers for data.	The research tool could be used in lieu of water meters and water meter readers. Publicly available data is flawed and should not be taken at face value.
Shortage of manpower at KUKL.	KUKL needs to reduce its dependence on manpower, to facilitate management and operations.	The research monitoring tool employs IT and so would not need so much manpower.
People believe that their complaints are better heard if they present them in person.	If KUKL had an official feedback system, people would not need to go in person to their offices.	People may think using an app is not as useful as going in person.
There is no need for citizens to lie about their water supply to make more of a point as their situation is already dire.	KUKL could use the data collected by citizens directly without statistical validation.	Data validation is desired but not critical to the project's success.

Validity of data is important.	KUKL still values validity in data despite currently not having any data, or any validation methods in place.	Since KUKL does not have any pre-existent data, alternative means of validation should be sought.
No routine water quality monitoring.	KUKL needs a systematic way of monitoring water quality. They could use citizens to carry out routine checks on water quality, and only carry out spot-checks themselves.	The research tool could easily be transformed into a routine monitoring tool for water quality by dedicated households.
Affirmation that the research should be carried out by citizens, government and KUKL.		Confirmation of the usefulness of the research in addressing water-supply challenges from different angles in a cost-effective way.

Main interview findings: JICA	Implication for stakeholders	Implications for research
Lack of documentation and monitoring is a chronic problem at KUKL.	There are no past records to build on.	The research can be used as a tool to log and record data.
Lack of reliable data from KUKL.	Lack of trust in validity of data.	The data collected through the research tool should be shown to be reliable.
Lack of capacity to collect and analyse data at KUKL.	A low-cost mode of acquiring & analysing data is needed if the gap is to be filled.	This may imply that KUKL is open to employ less traditional means of data collection.
Post-Melamchi use of the app to hold KUKL accountable for delivering water & to monitor water services. Could also be used for other monitoring project.	The stakeholders would like more accountability.	Supports the use of the research tool as an accountability and monitoring system
The government does not have official targets for the water sector	The stakeholders struggle to devise strategies to meet targets, as it is unclear what the targets are.	The research tool could be used as an instrument to establish a benchmark, establish improvement targets and eventually measure progress.
There is a lack of commitment to progress from government's side.	Stakeholders would like more commitment from the government.	Supports the use of the research tool as a tool to encourage development of water policies.

Main interview findings: Government of Nepal	Implication for stakeholders	Implications for research
Customers are increasingly asking for their water to be tested, even at their own expense.	Customers express a pronounced concern over water quality.	The research method should include water quality to support consumer awareness, which in turn would encourage them to use the tool more arduously.
There is regular “customised” monitoring of water quality, based on observations and feedback from customers. Customised meaning that the utility performs checks if it thinks that there is cause for concern.	Customer feedback drives KUKL’s monitoring and remediation efforts.	KUKL is spurred on by customer feedback. Therefore providing an easy feedback tool with traceable data would further encourage their efforts to improve the water supply.
The government is not responsible for monitoring KUKL. There is no system of penalties or support in case KUKL fails to meet standards.	The government cannot force KUKL to change its management tactics.	The willingness to ameliorate KUKL should come from within the company.
The respondent talks at length about upcoming improvement plans.	The respondent does not share any current or recent improvements.	Government may be less inclined to adopt new strategies for improvement at this stage.
There is no systematic data recording, and therefore there is a lack of water knowledge and database.	It is complicated to acquire any information or data, that is of dubious reliability.	The research should facilitate cooperation within water sector. Specifically, it should facilitate

Every ministry has a different administrative database, and access is not shared. They have discrepancies.		teamwork within the government, as well as communication of data and knowledge between the government and the other stakeholders.
Fear that the any data shared would be used by the public against the government in legal battle.	As a result they refuse to share data, which makes it difficult for others (e.g. partner agencies, donors...) to allocate the proper resources to ameliorate the situation.	If the data were citizen collected, it would be created by the public and be available to the public, which would reduce the fear of backlash and responsibility of the government.
Approval of internal methods of validating citizen-science data.		The government accepts that this is a valid way validating the collected data without in the absence of a database.
Data available about the situation in Nepal is typically collected by different organisations (e.g.UNICEF). The data is not on a single platform, and it is neither accurate nor clear.		It is best to seek internal methods of validating citizen science data.

Main interview findings: ADB	Implication for stakeholders	Implications for research
KUKL are avoiding customers because they know that they will be criticised.	This inflames customers and makes KUKL look unscrupulous.	KUKL should be emboldened to embrace criticism as constructive and praise the customers for their feedback.
Melamchi will not change the water situation drastically.	KUKL and the government preach the opposite, setting up customers for disappointment. Instead they should aim to manage expectations and improve the water situation as much as possible in the meantime.	Intermittency and poor water quality will continue to dominate the water situation in Kathmandu, so the research will continue to be relevant.
KUKL is not capable of utilizing large amounts of data or of mastering sophisticated software.	Collaborating stakeholders must all work at the same level as the provider for optimal results.	Any data collection tool should be simple to use, and the data that it collects should be basic, concise and easy to comprehend.
KUKL lacks financial discipline, which exacerbates their lack of resources, and promotes a culture of unresponsiveness and averseness to customer feedback.	This is a vicious cycle which starts with a lack of proper financial accountability. This should be addressed by the KVWSMB or the ministry.	The research tool should be able to bypass any resource issues. Further work should seek to establish a culture change.
Approval of internal methods of validating citizen-science data, with large margins of error.		

Main interview findings: World Bank	Implication for stakeholders	Implications for research
Views the research as an awareness tool for citizens to learn about water quality	If citizens are better informed, they can make smarter choices around their water supply, promoting better standards of water delivery.	The research tool should include an element of water quality testing with a feedback mechanism so that citizens learn to manage their water situation and can contest the water provider if needed.
The service provider typically avoids promoting water knowledge to avoid accountability.		
Government agencies typically fail to see the value of data.	There is a need for an overhaul of the management process if data is to be used efficiently.	The research should try to expose the value of data in day-to-day operations.
A culture change is needed to normalize systematic monitoring.		Culture changes are difficult. An easier option would be to make monitoring part of day-to-day life for citizens, thanks to the research tool, and ensure that that data is shared with authorities.
Citizens taking charge of monitoring their water supply breaks down institutional disputes. If the data starts becoming so available anyways, then the utility has no choice.	The utility would then have no choice but to attempt to remediate water supply issues.	The research tool would empower citizens to instigate change in water management.
Lack of information about the quality and quantity of water supply is sometimes a marketing technique to		The research tool will educate citizens on water quality in general, allowing them to make better

scare people into purchasing coping tools (e.g. pumps, bottled water...).		choices when purchasing alternatives (e.g. what type of water do they need after they receive their tap water, how much should they value different types of water).
Transparency is critical to improving the water management.		The research tool would force transparency between consumers and KUKL and the government, at the very least forcing a change in how KUKL responds to its customers.

Main interview findings: JVS	Implication for stakeholders	Implications for research
Community-managed water supply systems already exist outside Kathmandu successfully, but community is not trained to manage problems arising in the water supply	Citizens have limited ability to intervene in water supply issues.	The research should keep citizen hands-on interventions to a minimum, or ensure to train citizens appropriately.
Views the research as an awareness tool for citizens to learn about water quality	If citizens are better informed, they can make smarter choices around their water supply, promoting better standards of water delivery.	The research tool should include an element of water quality testing with a feedback mechanism so that citizens learn to manage their water situation and can contest the water provider if needed.
KUKL's management system does not provide the services that they are employed for.	KUKL needs to be held accountable for the services that they have vowed to provide e.g. water quality monitoring.	The research could be used as an accountability tool by government, donor agencies and the KVWSMB, shedding light on KUKL's successes and failures alike. This would force KUKL to deliver on its promises, and ensure financial accountability towards the donors. Donor agencies may also use the tool separately, to monitor project deliverables.
Belief that KUKL would not take up the research tool.	KUKL may not wish to be held accountable and mend its management.	
Belief that donor agencies would take up the research tool.		

Main interview findings: KVWSMB	Implication for stakeholders	Implications for research
KVWSMB has been trying to support citizen science tools for monitoring processes.	KVWSMB is open to using citizen science in its decision-making process.	
KVWSMB has data on the community schemes but not on KUKL.	KVWSMB has accepted that it is difficult for them to monitor KUKL's operations and so focuses its monitoring efforts elsewhere.	KVWSMB does not have data on KUKL service.
In practice, KUKL is not managing the existent system and is not monitored.	There is no up to date information on KUKL's activities and service provision.	The data collected through the research will have to be internally validated.
In these conditions, assessment of service level through public engagement will be a challenge as the public will not want to cooperate due to negative sentiments towards KUKL.	Customers will not want to engage with KUKL.	The research should not focus on KUKL as a service provider but on water provision in itself.
Some service areas do receive water as per schedule.		The data collected through the research may reflect the schedules for certain areas.

Main interview findings: WaterAid	Implication for stakeholders	Implications for research
WaterAid are piloting a community mechanism where people can express their satisfaction or dissatisfaction with a project with toll-free number.	WaterAid are trying to set up a feedback mechanism but have failed to incorporate a means to record and track claims.	The tool could be useful to them for their own monitoring purposes.
WaterAid's current monitoring system after project completion is a check-up after 3, 5 and 10 years.	Monitoring of projects is spread over time.	
Belief that because KUKL does not follow up on or keep track of complaints, it is unable to track issues in the system.		The research tool should be presented to KUKL not only as a means to log and track complaints, but as an easy way to geolocate issues in the system.
Belief that citizens should be capable of managing their water supply with some training.		The research should offer training of volunteers to manage their water supply.
Local government is very strong.	Potentially stronger than national government in its implementation of water policies.	The research should reach out to local governments for support in mobilizing citizens.
Citizens are scared of needing to pay more for the same bad service if the service is monitored.	Citizens are reluctant to engage because of monetary concerns.	Researchers should emphasize to participants that the tool is anonymous, free and the research is not concerned with monetizing the monitoring of the water supply.

Aim is to empower people so that they can demand water aid from the government – but this is translatable to other sectors.		The research tool will educate citizens on their water, empowering them to support their claims for better water service.
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Main interview findings: KUKL, water quality division.

This respondent seemed uncooperative. He frequently interrupted the interviewers, did not answer any direct questions, and declined to share any information, referring to data as “secrecy”. The respondent provided vague responses to specific questions (e.g. “do you know how much water is in the tank at all times?” - “slightly”, or, “does KVSMB monitor KUKL?” – “sometimes”) and often diverted to other subjects, giving the impression that his mastery of English was poor. As a result, the respondent seemed confused throughout the interview, regularly going back on what he said. However, there was a willingness to admit gaps in his own knowledge. For example, the respondent admitted not knowing how many treatment plants there were. When speaking freely about the water situation in Kathmandu, he often contradicted himself. For example, when asked about KUKL’s strategy to sample the water quality, he answered that there was no strategy as there was “limited staff”, but then later ascertained that “we have sufficient amount staff” when asked his opinion on the usefulness of citizen scientists in this context. This implies an averseness to the citizen science method, which is supported by his disapproval of Community Led water management initiatives in Kathmandu. However, at a later stage he contradicted himself again when questioned about the frequency of water quality monitoring, first saying there was only sampling at the source, and then saying that there was sampling in different neighbourhoods. This may simply be a communication issue, or may imply an unwillingness to admit failures on KUKL’s part, which was echoed by a strong denial that there was any bacteria in the water supply and the affirmation that the water was clean. This is in conflict to his affirmations that the customers are told not to drink the water, implying that is unclear. The respondent seemed to want to portray that KUKL was in control of the situation - “we are able to do everything” – and when asked if he personally thought KUKL were managing well, he replied “yes”. Some base-line information pertaining to the research that was gleaned from this interview was that the water is mostly supplied at night (as confirmed by customers), that there is no monitoring strategy, and that water quality is tested at the treatment plant and not at the point of delivery (which may explain the previous affirmation that the water supplied is clean). The respondent believes that customers do not care about the quality of the water, even though he describes customers coming to him in person with water samples to test for their quality. This personal mobilization suggests that customers do indeed care quite a lot about the water quality, which may encourage them to take up the tool - especially if it includes water quality - as a means of showing their level of engagement. The respondent was open

about KUKL staff also sitting on its management board, implying that in essence, KUKL answers to itself. This was reinforced by his alluding to the idea that KUKL could go “above the system of authority”. The respondent displayed an interest in issuing customer penalties, and in leading “police participation with people”, which may refer to a number of situations including attempting to curb the number of illegal connections to the water supply.

Main interview findings: KUKL.

The respondent had no information to offer and did not answer any questions about the technical aspects of the water supply. There was a sense of confusion about the current water supply situation. The respondent stated “the data we have is all on millions of papers, and are rough and not trustable, any Autocad maps we may have are crude and you would not be able to make anything in them. Actually if you need data [...] probably you won't be able to find any”.

Appendix D: Excerpts of personal communication with stakeholders

Excerpt from the 7th May 2020, from a KUKL representative: “your research has a contribution to these apps”.

Excerpt from the 30th Mar 2020, from a second KUKL representative: “your research will definitely help pursuing this mobile- app route”.

Excerpt from the 17th May 2020, a government representative: “your research act as a catalyst for KUKL and they developed such sort of application with immediate effect. [...] They also acknowledged the contribution of individual researcher in past for sharing the idea. I think you have done exceptional work on water sector of Kathmandu Valley. Kudos to your hard work and dedication”.