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Chapter 5

Data collection

Yady Tatiana Solano-Correa, Rixia Zan, Maria Valasia Peppa and David Chaquea-Romero

Data gathering, the first step in generating knowledge, is a process that must proceed in line with communities' needs and peoples' practices. In this chapter, authors present case studies showing how technology can expedite data capture in Colombia and across the globe, as well as demonstrating how advanced methods can be transferred from other disciplines to provide meaningful knowledge in Colombia.

5.1 MULTITEMPORAL ANALYSIS FOR WATER MONITORING, MANAGEMENT, AND SECURITY FROM A REMOTE-SENSING PERSPECTIVE IN COLOMBIA

Yady Tatiana Solano-Correa

One of the most important external events to affect water in Colombia and the Upper Cauca River Basin (UCRB) is El Niño Southern Oscillation (ENSO) in its two variations: El Niño, characterised by high temperatures and extreme droughts (reducing water availability); and La Niña, characterised by low temperatures and extreme rain (increasing water levels, sedimentation, and risk of rivers overflowing). The effects of climate change have enhanced ENSO characteristics, causing widespread problems for Colombia in the past few decades. For instance, the La Niña period that occurred in 2010–11 led to considerable civil and economic losses and has been named one of the worst natural disasters in Colombian history (Vargas *et al.* (2018) and Hoyos *et al.* (2013).

Managing the consequences of ENSO events is of great relevance to both lives and livelihoods. It requires constant monitoring of water quantity and quality, and of land use surrounding different water sources. Such monitoring can be carried out in several ways, including through use of remote-sensing techniques. Remote sensing allows us to observe the Earth continuously, without coming into physical contact with it: remote sensors are located on aerial platforms and satellites, capturing information across the electromagnetic spectrum (optical and microwave) so that we can characterise the Earth's surface features and land cover.[1] This is possible thanks to the fact that everything in nature has its own distribution of reflected, absorbed, or emitted energy (Chuvieco, 1990).

Use of remote-sensing techniques makes it possible to obtain a detailed characterisation of water bodies without the need to embark on expensive, time-consuming and potentially dangerous field campaigns, where conflicts can make the collection of in-situ data difficult (Chawla *et al.*, 2020). Existing optical remote-sensing studies are commonly performed in areas with (i) ideal weather conditions that allow for high-frequency acquisitions of data (i.e. without much obstruction by clouds in the area) or (ii) with large extensions of water that are easier to analyse with freely available data (Du *et al.*, 2016). Nevertheless, these conditions are not fully satisfied for areas in Colombia, making the use of freely available optical remote-sensing data less common as a solution to water security problems. Therefore, there is a clear need to develop methodologies for optical and microwave satellite imagery that are able to work with freely available data and in areas with high cloud coverage.

Remote-sensing framework in the Upper Cauca River Basin

This case study presents a multitemporal image analysis of the surface area variations of two water bodies, correlated with water quality, located in the UCRB in Colombia (see Figure 5.1). The UCRB represents an important natural, cultural, social, and economic resource in Colombia, where water sources face continuous deterioration, which itself limits water use for human consumption (Sánchez Torres *et al.*, 2022).

The left panel of Figure 5.1 shows Salvajina Reservoir (SR) and the right panel shows Sonso Lake (SL). SR is located in the department of Cauca (right before the Cauca River crosses into the Valle del Cauca) and is a difficult-to-access area due to armed conflict. SR is used for various purposes, including to support (i) the Cauca River flow, (ii) dilution of pollutants, and (iii) production of electrical energy. SL, on the other hand, is located in Valle del Cauca (right after the Cauca River has passed through Cali), and is a wetland, decreed a nature reserve since 1978, that varies the distribution of its water mirror throughout the year due to aquatic plants. Each of these bodies of water is a good example of an area with a specific context that offers only limited options with regard to implementing an effective method to assess their water security directly. It is for this reason that they have been selected for the present analysis.

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[1] Optical remote sensing operates in red, green, blue, near-infrared, mid-infrared, and shortwave infrared wavelengths, while microwave remote sensing operates in microwave wavelengths, with the latter not being affected by atmospheric conditions (i.e. clouds, rain, fog, etc.).

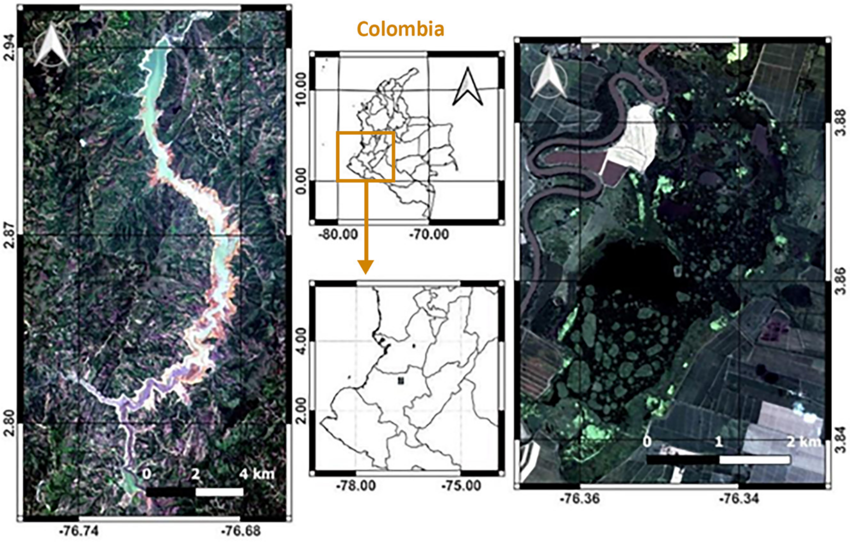

Figure 5.1 True colour satellite images of two water bodies in the UCRB: (left) Salvajina Reservoir; (right) Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

To overcome the existing remote-sensing challenges in the UCRB, a simple, yet effective, framework for monitoring water bodies through remote sensing is presented in Figure 5.2. The proposed method uses freely available data on the Google Earth Engine platform, which allows the researcher to clip out satellite images of the given area of interest (step 1). The framework's second step involves filtering the data, selecting only cloud-free images and/or those with the lowest percentage of clouds over the area of interest. Once data has been filtered out and downloaded, the third step sees the researcher extract radiometric indices and band ratios that help to better highlight water bodies.

Several satellite remote-sensing methods, such as image classification, linear unmixing, single-band thresholding, and water indexing, are available for the study of water bodies (Du *et al.*, 2014; Ji *et al.*, 2009). The Normalized Difference Water Index (NDWI) is one of the most used water indices to detect open surface water bodies. It was first created by the green (G) and near-infrared (NIR) spectral bands of Landsat TM (Özelkan, 2019), and benefits from the high reflectance in NIR of vegetation and soil features (Ko *et al.*, 2015). Other normalised indices exist to detect water bodies (such as the Modified NDWI); however, their results depend strongly on the colour, content, and depth of the water body under investigation, varying greatly from one region to another and therefore not allowing for a standardised comparison (Fisher *et al.*, 2016). For these and other reasons, the NDWI was used in this study to allow for the generic identification of water bodies.

With a proper feature extracted, the framework's fourth step segments the water bodies by three different methods: (i) Otsu's thresholding method

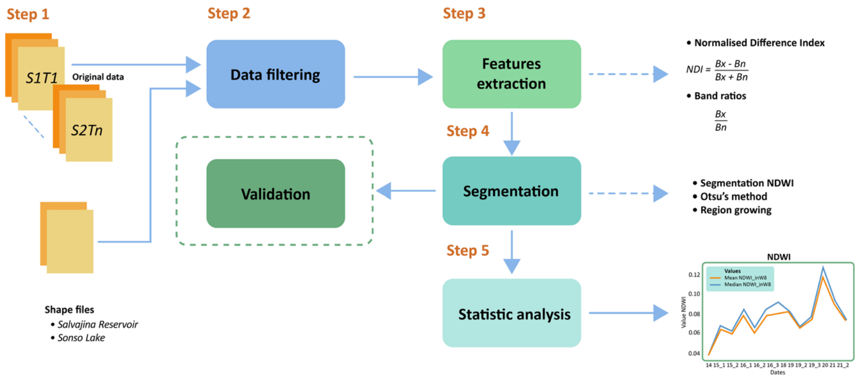

Figure 5.2 General block scheme of the proposed methodology for performing multitemporal analysis of water bodies. (Credit: rootsandwings.design).

(Yousefi, 2011), (ii) region growing (Fan & Lee, 2015), and (iii) segmentation by applying the physical meaning of the NDWI (Özelkan, 2019). These methods are applied to the NDWI images obtained for each water body. The fifth and final step performs a multitemporal statistical analysis of the images to correlate different variables such as area, water quality, and climate change variables. The analysis of these correlations should help decision-makers to better manage water bodies (see further explanation below).

Characterisation of two inland water bodies in the Upper Cauca River Basin

By making use of multitemporal information, it is possible to see how the water bodies' behaviour changes over different periods. Figure 5.3, for example, shows analysis of SR and SL over periods of seven and two

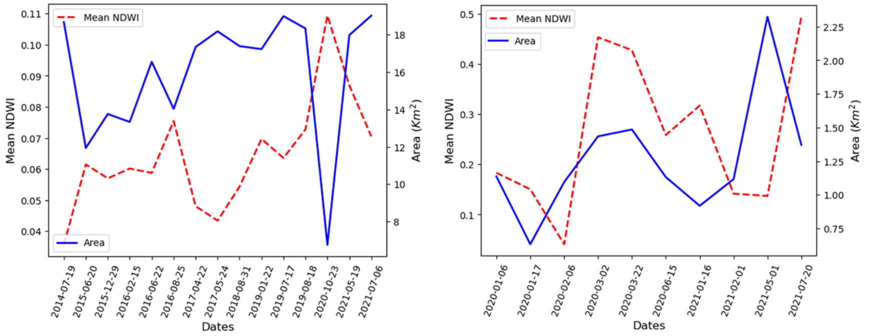

Figure 5.3 Characterisation of two inland water bodies in the UCRB: (a) Salvajina Reservoir; and (b) Sonso Lake: with regard to NDWI index and water body's area. (Credit: Yady Tatiana Solano-Correa).

years, respectively. Without the use of remote sensing, it would have been impossible to obtain such an analysis, since these areas generally do not use proper data acquisition protocols to keeps track of variables such as area/extension, contaminants, precipitation, or temperature, among others. Figure 5.3 shows the correlation between the temporal variable, the NDWI, and area/extension of SR and SL. An inverse correlation is found between these two values in SR (Figure 5.3a). This is because of the reflectance values of the water (Özelkan, 2019), which indicates the presence or absence of sediments and contaminants in the water body, with their proportion increasing when the water mirror (area) is smaller. A similar phenomenon occurs at SL (Figure 5.3b), but the inverse correlation is not as strong, perhaps because of aquatic plants on the water's surface (since this is a wetland). This information, together with meteorological data, can be used by decision-makers and communities to implement measurements about how to use the water for human consumption. Understanding if the increase/decrease of contaminants is related to climate conditions or human ones is also highly important for water security management.

Conclusion

Information from optical remote-sensing experiments such as this can be used (and is used) by communities and decision-makers to improve quality of life in the studied regions, all while guaranteeing water security. Remote-sensing techniques inform proactive decisions (e.g. by offering real-time information on the water bodies' conditions, area, and water quality) to safeguard water supplies before a water security risk emerges, rather than forcing locals to react after an event has occurred. For example, if weather conditions are such that a flood might occur, analysing the water body will provide more detailed information on this possible event, allowing an informed decision to be made about evacuating the area. The opposite is also true: during an extended period without rain, multitemporal information will show when the water levels are decreasing (by a decrease in area/extension of the water body), signalling the need to conserve water to reduce the risk of drought. And while the analysis we have presented demonstrates the success of an optical remote-sensing approach, which relies on clear atmospheric conditions, similar analysis can, in fact, be provided with microwave remote-sensing techniques, which are not influenced by weather.

Remote sensing has the advantage of providing a broader view of a system in its entirety, thus providing complementary information (to in-situ data) for proactive management. Remote-sensing information is often seen as too technical, but researchers can easily teach users how to read the derived information (such as multitemporal statistical analysis), thus supporting them to make their own decisions while being proactive about the management of the territory. In this way, communities, not just experts, can take control and act when risks arise.

Click on the following images to see timelapses of chlorophyll and segmentation in both water bodies (Figures 5.4–5.7).

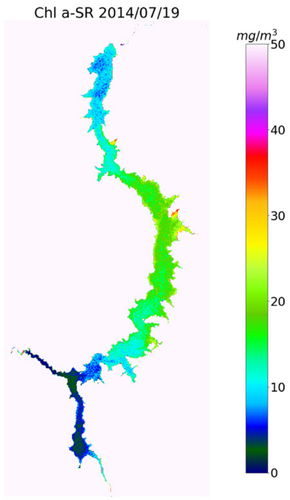

Figure 5.4 Chlorophyll in Salvajina Reservoir. (Credit: Yady Tatiana Solano-Correa).

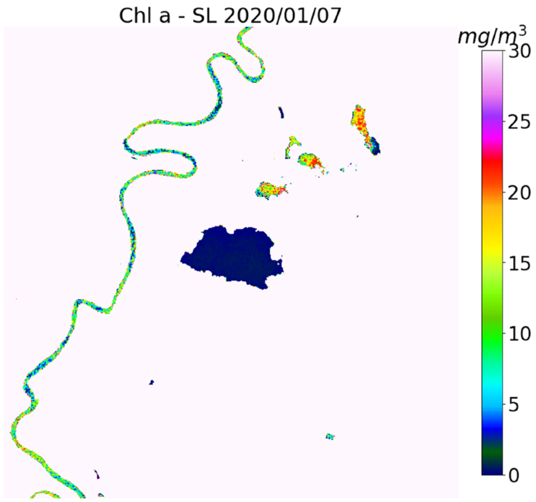

Figure 5.5 Chlorophyll in Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

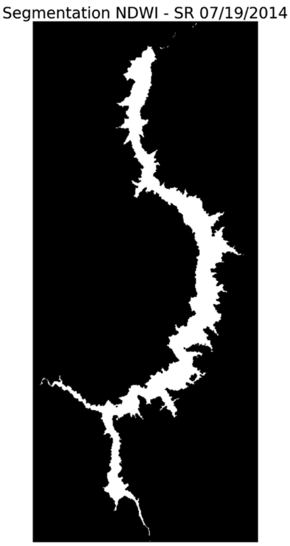

Figure 5.6 Segmentation in Salvajina Reservoir. (Credit: Yady Tatiana Solano-Correa).

Figure 5.7 Segmentation in Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

5.2 INNOVATIVE MOLECULAR MICROBIOLOGY METHOD FOR WATER QUALITY TESTING AND FAECAL POLLUTION SOURCE TRACKING: CASES FROM THE UK AND GLOBALLY

Rixia Zan and Maria Valasia Peppa

The COVID-19 pandemic has shown how powerful DNA/RNA-based diagnostics can be for hazard monitoring to protect public health (Diamond *et al.*, 2022). DNA/RNA-based diagnostics, also known as molecular diagnostics, examine sequences within the genetic code that can potentially serve as an indicator of specific diseases. Applying molecular microbiology to water quality monitoring could help with pollution source tracking and public health risk assessment. However, molecular microbiology-based methods usually are too expensive for low- to lower-middle-income countries. They also require a lot of investment in laboratory and professional skills. But it should be said that the problem of accessible water quality data is not unique to low- and lower-middle-income countries: for example, the UK sees high levels of sewage pollution in its rivers due to overflows and a lack of microbial water quality data. This challenge has become a top priority for the Environmental Audit Committee of the UK government (EAC, 2022).

Water can be rapidly screened for potentially hazardous microorganisms anywhere in the world, thanks to the development of an innovative and affordable suitcase laboratory (Acharya *et al.*, 2020; Halla *et al.*, 2022; Hiruy *et al.*, 2022; Pantha *et al.*, 2021). Conventional culture-based methods require 18 to 24 hours of incubation to produce results. In addition, they cannot tell if the faecal pollution source is from warm-blooded animals or humans. But the innovative suitcase laboratory, developed by Newcastle University, can obtain results in just three hours and can also identify specifically human sewage in a water body (Zan *et al.*, 2022) – which is crucial for rapid decision-making. What's more, it simplifies traditional molecular microbiology methods: while it's usually difficult to interpret complicated bio-information, especially for non-specialists, the suitcase laboratory primarily consists of user-friendly tools and state-of-the-art handheld devices to facilitate ease of use. Not to mention the fact that it's cost-effective, which is particularly crucial for low- and lower-middle-income countries, where people still lack access to clean water and sanitation. In short, the suitcase laboratory allows any microbial hazards in water to be identified quickly, easily, and cheaply (see Figure 5.8).

How to assemble the suitcase laboratory

Conventional quantitative polymerase chain reaction (qPCR) machines for specific genetic quantification and the next-generation sequencing instruments for comprehensive characterisation of genetic material in water are heavy and expensive.[2] Instead, the suitcase laboratory includes a speaker-sized qPCR instrument from Quantabio (Beverly, USA) and a pocket-sized sequencing

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[2] qPCR is a molecular microbiology method to detect and measure specific genes.

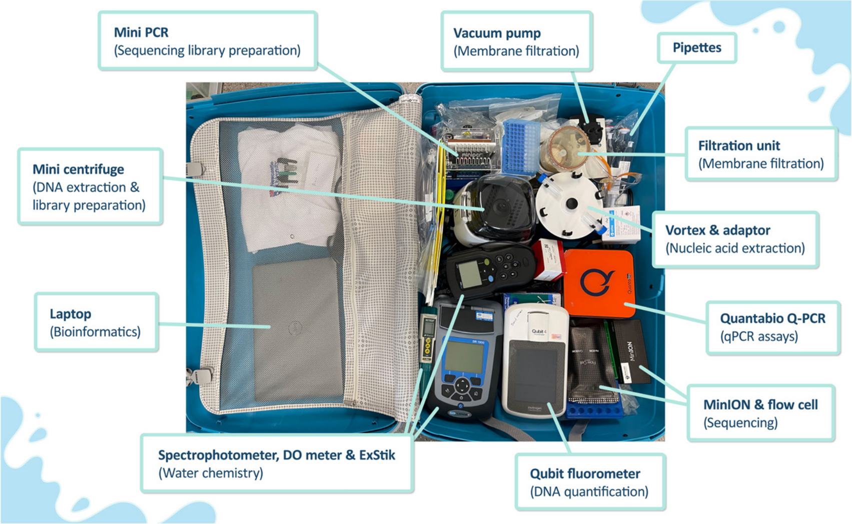


Figure 5.8 The latest edition of the suitcase laboratory. (Credit: Livia Douse).

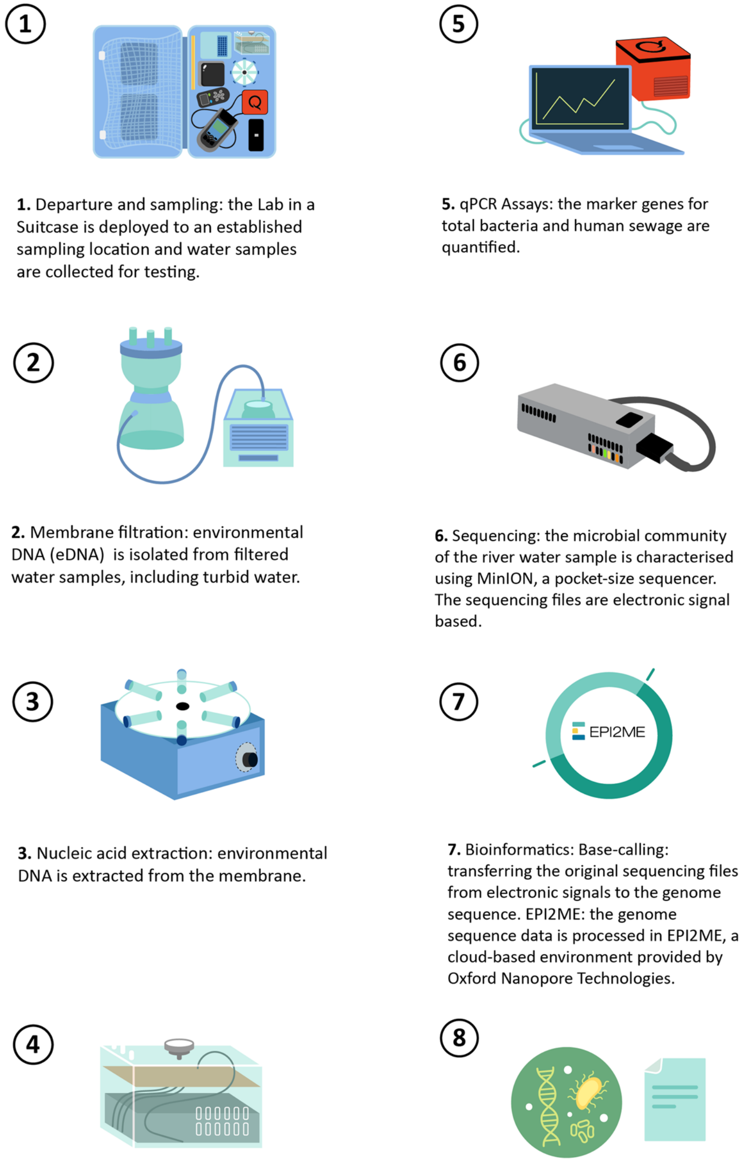
device, MinION, from Oxford Nanopore Technologies (Oxford, UK). Aside from these two equipment items, it includes all the portable equipment needed for environmental DNA extraction from water, quantification, and amplification. In addition, a powerful laptop for sequencing data analysis and interpretation is included. All these equipment items readily fit into checkable luggage (Figure 5.9).

A suitcase laboratory for sequencing and water chemistry costs about $13 000; adding a qPCR machine to the mix brings the cost to $26 000, according to 2024 prices. Overall, this portable equipment allows for an 87% reduction in weight and an 85% reduction in cost.

What's more, while molecular microbiology is 2.6 times costlier than conventional microbiology, it provides detailed pollution source identification and helps with risk assessment and decision-making (Zan *et al.*, 2023). Although using the suitcase laboratory would require some knowledge of molecular microbiology, undergraduate students and local researchers can be trained in its application with a one-week training workshop. The main challenge is to get molecular microbiology consumables supplied to low-resource settings.

Case study

In our recent UK-based study (Zan *et al.*, 2022), we validated a methodology with portable laboratory equipment items that produced results which closely tallied with those obtained with conventional laboratory equipment items. We were able to identify human host-associated *bacteroides* in storm drain effluents and the Ouseburn River by using the portable instruments on site (in the back of a van) within three hours of sampling. The comprehensive



1. Departure and sampling: the Lab in a Suitcase is deployed to an established sampling location and water samples are collected for testing.

2. Membrane filtration: environmental DNA (eDNA) is isolated from filtered water samples, including turbid water.

3. Nucleic acid extraction: environmental DNA is extracted from the membrane.

4. Sequencing library preparation (PCR): amplifying the target gene (16S rRNA gene for total bacteria) for sequencing.

5. qPCR Assays: the marker genes for total bacteria and human sewage are quantified.

6. Sequencing: the microbial community of the river water sample is characterised using MinION, a pocket-size sequencer. The sequencing files are electronic signal based.

7. Bioinformatics: Base-calling: transferring the original sequencing files from electronic signals to the genome sequence. EPI2ME: the genome sequence data is processed in EPI2ME, a cloud-based environment provided by Oxford Nanopore Technologies.

8. Analysis and results: the qPCR assay and sequencing data is interpreted and visualised to determine what kind of bacteria is present.

Figure 5.9 The process for assembling the suitcase laboratory. (Credit: rootsandwings.design).

Figure 5.10 Photographs of sampling along the Ouseburn River. (Credit: David Werner).

physicochemical and microbial water quality data showed faecal pollution from misconnections in the discharge of a surface water drain. The data also showed how stormwater retention in a pond produced effluent characteristics, like those seen in receiving river water, when compared with the water quality of discharges from two storm drains (Figure 5.10).

Global impact

The innovative suitcase laboratory for molecular microbiology water quality diagnostics enables faecal pollution source tracking and quantitative microbial risk assessment (Halla *et al.*, 2022; Zan *et al.*, 2023). This technology can also be applied to identify organisms such as protozoa (giardia and crypto) and antimicrobial resistance traits.

The application of the suitcase laboratory does require certain skills. But, as this video shows, we can train less experienced local researchers in applying state-of-the-art microbiology and related risk assessment methods with the help of the suitcase laboratory. Through this hands-on practice, participants learn about the importance of environmental monitoring, and wastewater collection and treatment.

Figure 5.11 Portable molecular diagnostics for on-site water quality monitoring workshops: (a) Kality Wastewater Treatment Plant, Addis Abba, Ethiopia; (b and c) Kung Krabaen Bay Royal Development Study Centre, Chanthaburi Province, Thailand; and (d) Mamiraua Institute for Sustainable Development, Amazon, Brazil. (Credit: Rixia Zan).

So far, we have used the suitcase laboratory in the UK, Brazil, Thailand, Cambodia, Malaysia, Ethiopia, and Tanzania. Trainees from Thailand, Brazil, and Ethiopia have applied the technology to their research (Figure 5.11). And since we started delivering the water quality workshops in 2021, over 150 researchers and water professionals have been trained in how to use the suitcase laboratory. We have built relationships with universities and institutions in Africa, Southeast Asia, and South America. We have also helped less experienced researchers develop their own microbiology laboratories and have collected comprehensive water quality data from all over the world. These workshops have allowed us to transfer our skills to others.

For example, our trainees from Newcastle University Medicine (NUMed) Malaysia attended a water quality workshop in August 2022. Then, they successfully helped us to deliver hands-on training in Ethiopia and Thailand in 2023. They also independently delivered the training to their own partner organisations in Cambodia, Thailand, and Indonesia. The attendees in Ethiopia are now using the suitcase laboratory to investigate bacterial hazards in the Akaki catchment (Hiruy *et al.*, 2022). Since several of our trainees have now become academics, they can pass on the skills they have gained to others. In Thailand, we provided hands-on training to the staff in Kung Karabean Bay Royal Development Study Centre in Chanthaburi province. Ten researchers from the study centre attended the practical lab session, while researchers from Thai universities and the Department of Fisheries in Chanthaburi attended the discussion session, after which a participant said, ‘we can now better understand how the microorganisms affect the fishery products throughout the molecular microbiology technologies we learnt from this workshop.’ Currently, NUMed (Malaysia), Addis Ababa Water and Sewage Authority (Ethiopia), King Mongkut's University of Technology Thonburi (Thailand), and Federal University of Minas Gerais (Brazil) are all using the suitcase laboratory. This year, we will deliver more workshops to colleagues from Colombia and Ukraine, increasing our global impact (Figure 5.11).

Conclusion

Water quality can be assessed via different approaches that are complementary to each other; we've mentioned just two of them in this spotlight.

Firstly, technological development makes water monitoring more efficient, allowing for the detection of microbial indicators of faecal contamination and bacteria resistant to antibiotics.

We have also, however, highlighted the importance of the social aspect, as democratising access to information and knowledge promotes community and participatory water quality data management (including collection, processing, and analysis). This helps to strengthen social cohesion and facilitate more informed decision-making to promote water security.

We also assert that the role of the academic institutions in these case studies is fundamental. For this reason, continuing to promote universities' social function, capacity building, and knowledge generation (especially in issues related to water security) is key to incorporating these concerns into political agendas and inter-institutional work.

Finally, it is essential to empower communities through the development of varied methodologies, tools, and socio-technical innovations. Decisions should not just be made by rulers or experts with a top-down approach, whereby communities are reduced to an object of study or response variable; even the most vulnerable communities can contribute to follow-up, monitoring, and generating new solutions for water security with a bottom-up approach.

5.3 EXPLORATORY MIXED METHODS DESIGN IN PRACTICE-CENTRED RESEARCH: SHOWERING IN CALI, COLOMBIA

David Chaquea-Romero

Residential water demand is connected to various aspects of water utility operations, such as pricing strategies, conservation initiatives, and customer engagement programmes. By analysing residential water demand trends, utility companies can implement targeted conservation efforts and incentivise efficient water use among consumers. Residential water demand research is mainly rooted in psychological and economic studies into the water consumption phenomenon (Darnton *et al.*, 2011; Shove, 2010, 2012). This approach is grounded in a positivist and causal understanding of household water consumption, where people are considered to be rational decision-makers whose behaviour is based on informed choices (Browne *et al.*, 2015; Shove, 2010; Sofoulis, 2011). As such, domestic water management focuses on providing knowledge and promoting water and/or pro-environmental values to encourage individuals to choose 'better' behaviours (Watson, 2012). This has created a top-down dynamic when it comes to determining 'best practices' for

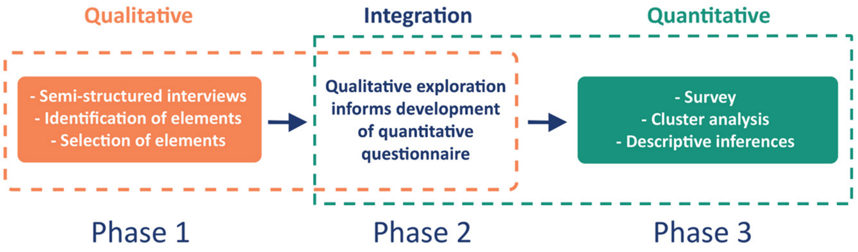


Figure 5.12 Scheme of the exploratory mixed methods design. Adapted from Plano Clark *et al.* (2008). (Credit: rootsandwings.design).

water users, where politicians, academics, water utilities, and water experts dictate how people should utilise water in their homes (Sofoulis, 2011: 805).

In contrast, when taken from the sociological perspective of practice theory (PT), visions of residential water demand are derived from the practices carried out by people in their everyday life (Browne *et al.*, 2015; Rinkinen *et al.*, 2021). Practices are what people actually do – like eating, sleeping, driving, working, or studying. They represent ‘correct’, ‘appropriate’, or ‘acceptable’ ways to behave under certain circumstances, which are socially accepted and do not need fully conscious or rational evaluation (Reckwitz, 2002; Shove *et al.*, 2012). As an outcome of practices, water demand is constantly and actively reproduced through people’s performances (Rinkinen *et al.*, 2021); therefore, changing current consumption patterns lies in a better understanding of the configuration of water use practices (Figure 5.12).

Practice-centred research: mixed methodologies

Practice-centred approaches should play a crucial role in informing alternative water demand management, but they are underrepresented in the current policymaking framework (Hampton & Adams, 2018; Shove, 2010). While behavioural perspectives are predominant in domestic water consumption research and management, the translation of PT into intervention strategies is a work in progress (Kurz *et al.*, 2015: 123).

PT is not currently well represented in policymaking, because of the difficulty associated with characterising water use practices in large populations and scaling up their results (Hampton & Adams, 2018). Qualitative methods focusing on a small number of cases have traditionally been used in practice-centred research; quantitative methods, meanwhile, have been sidelined (Gram-Hanssen, 2015; Spaargaren *et al.*, 2016). However, quantitative methods can be used to address the situated and context-dependent characteristics and dynamics of practices, since they do not only evidence causality but also describe social phenomena (Browne *et al.*, 2014).

Some authors have claimed that quantitative approaches could be mistakenly applied in studying practices if they are used in the absence of a qualitative counterpart (e.g. Schatzki, 2012; Sofoulis, 2011). Consequently, mixed methods have been applied to characterise use practices (e.g. Eon *et al.*, 2018; Gram-Hanssen *et al.*, 2020; Pullinger *et al.*, 2013; van Tienoven *et al.*, 2017). These mixed methods have been mainly *explanatory*, where quantitative data is collected first and qualitative data is subsequently used to explain the findings (Creswell & Plano Clark, 2018). Here, it is assumed that the researchers are already very familiar with the object of study.

However, in cases like the one presented here, a lack of knowledge about what showering is (or means), demanded the implementation of an *exploratory* mixed methods design. We carried out a qualitative stage first to understand what made sense for people when they shower (Røpke, 2009). This prevented top-down impositions of researchers' preconceptions that did not necessarily align with people's actual ways of showering. Then, based on qualitative findings, a 'substantive, relevant, and culturally sensitive' questionnaire was designed (Creswell & Plano Clark, 2018: 86), which was capable of capturing the fuzzy composition of showering; finally, this was implemented quantitatively so that its findings could be scaled up to a larger population.

Practice-centred research: the case of showering in Cali

The research was conducted in Cali, the third-largest city in Colombia with a population of approximately 2.3 million people, and certainly the most important city in the Pacific region. It is culturally diverse because it has historically been a focus of migration from rural areas and other cities of the country. The city has the highest urban water demand in the UCRB, and its residential water demand is tackled through traditional, punitive economic measures and environmental education.

The three phases of the applied exploratory mixed methods design to characterise showering practice are presented below:

- Phase 1: We conducted 91 semi-structured interviews with people from 31 households in different parts of Cali, to identify the elements of showering based on the classification proposed by Shove *et al.* (2012): materials, competences, and meanings (Figure 5.13).[3]
- Phase 2: In the integration stage, the questionnaire was designed to collect data on the composition of people's performances in a larger sample, by measuring the presence or absence of the elements of the practice.[4] Even though showering is a 'habitual' practice (Shove, 2012), it is not performed in the same way every time: some elements are either integrated or not integrated in certain performances. Therefore, the measurement was carried out through four degrees of recurrence: 'always', 'most of the time', 'rarely', and 'never' (Figure 5.14).
- Phase 3: In the quantitative stage, we carried out the Domestic Water Use Practices Survey in a representative sample at the city level of 245 households; 597 people participated overall. Subsequent statistical

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[3] Shove *et al.*'s three elements have been widely applied in empirical studies of practices.

[4] Here the concept of measuring does not represent the reduction of the practice to numerical values. Rather, it is used as 'the process of linking abstract concepts to empirical indicators' (Hernández Sampieri *et al.*, 2010: 199).

Figure 5.13 The elements of practice. Based on Shove *et al.* (2012) and Spurling *et al.* (2013). (Credit: rootsandwings.design).

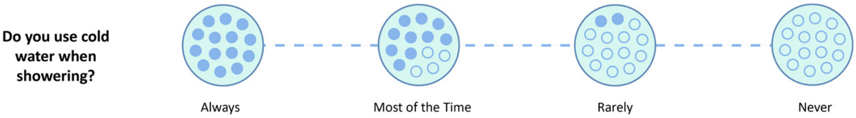
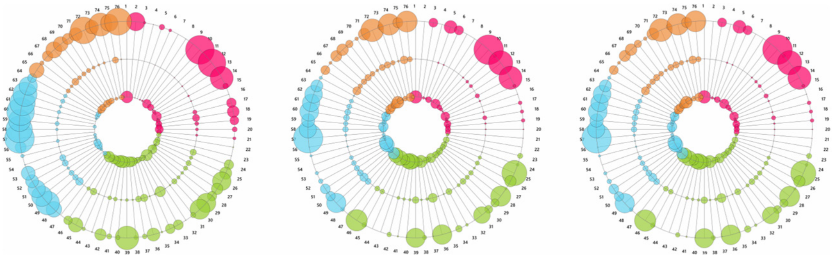


Figure 5.14 Example of the measurement of recurrence, using cold water in showering. (Credit: David Chaquea-Romero).

analysis consisted of the application of the k-means clustering method to identify patterns of response across the survey participants, by grouping cases whose content was as similar as it was different from other groups (Xu & Wunsch, 2009). Clusters or 'variants' of showering practice were identified based on the elements that people integrate always, most of the time, rarely, or never in their performances.

The variants of showering practice in Cali

The variants were named based on their characteristic elements: 'restoration showering', 'mixed simple showering', and 'simple readiness showering'. Each of them represents a particular understanding of the 'appropriate' way to perform the showering (Figure 5.15).



Restoration Showering
(27.8%)

Mixed Simple Showering
(40.36%)

Simple Readiness Showering
(31.82%)

Figure 5.15 The practice of showering represented through an RRD. (Credit: David Chaquea-Romero).

Restoration showering

This pattern of performance revolves around restoring an individual's ideal physical and mental state. In this variant, the reasons and expectations of the practice are complementary. People always carry out the practice because:

- they feel cold or hot – and want to refresh themselves;
- they feel sweaty or they feel their body or hair is dirty – and want to feel clean;
- they feel odourful – and want to smell good;
- they feel tired or painful – and want to feel relaxed and energised, or to improve their mood.

The rings of recurrence diagram (RRD)

The RRD visualises differences between variants of showering practice. It consists of three rings: outer (representing the recurrence: 'always'), middle (representing the recurrence: 'most of the time'), and inner (representing the recurrence: 'rarely'). The recurrence 'never' is not included.

The RRD also visualises the types of elements in showering practice. It consists of four colours: red represents materials, green represents competences, blue represents meanings, and orange represents positions (i.e. actions before or after the practice is performed).

Participants' responses are distributed across the diagram in the intersection between a vector (element) and ring (recurrence). When the responses of two or more participants happen in an intersection (e.g. 'cold water' and 'always'), they are added to each other, and this value is represented by the diameter of the circle whose centre is in the respective intersection. Circle size therefore correlates to the number of coincidences in participants' responses.

Restoration showering has two faces in this pattern of performance: recovery and readiness. Recovery is related to performing the practice after activities that require physical activity (sports or household chores). Restoration showering is also carried out after returning home, and as such relates to feelings of weariness, the sensation of warmth, or ridding oneself of environmental pollution. On the other hand, readiness implies returning the body to a neutral state, in advance of activities to be carried out in the immediate future: before breakfast, leaving home, working or studying at home, being visited by someone, or dating at night.

It is not surprising that the daily frequency of restoration showering is twice a day, occasionally increasing to three, or decreasing to one (e.g. on weekends). Here, the distinction between body and hair is also crucial, which is reflected in using different consumables and in rinsing twice or more times. Because of this composition, people who carry out restoration showering frequently consider the practice to be of long duration.

Mixed simple showering

The mixed simple showering variant is configured on the minimum conditions that deem the performance appropriate around three main meanings: comfort, cleanliness, and care. This variant is considered ‘mixed’ because people’s performances are more flexible in this variant compared with restoration showering, which means that, depending on the circumstances, they could adopt a relaxing, smelling good, or caring for the body/hair configuration. This variant is labelled as ‘simple’ because its composing elements are not essential but frequent; therefore, the standards of comfort, cleanliness, and care are not as meticulous as in restoration showering. Time spent showering is considered short, which could be associated with the fact that this pattern is often carried out in households with only one bathroom. Long showers are taken rarely, which could be related to the fact that people performing this type of showering are often in a hurry (e.g. before work on a weekday).

Simple readiness showering

While mixed simple showering is still strongly tied to comfort, cleanliness, and care, simple readiness showering is characterised by the position it occupies in relation to other practices. This pattern of performance is usually a prerequisite for other activities: showering is performed before leaving home, before working or studying at home, and before dating at night. These positions are not essential, but they are frequently integrated into showering performances. Simple readiness showering could be considered the minimum standard to achieve before leaving home or carrying out practices that are traditionally associated with leaving it but are carried out inside (working or studying). In contrast to mixed simple showering, people who carry out this variant often live in households with two or more bathrooms; nonetheless, the practice is usually performed in the ‘family bathroom’.

Conclusion

The variants of showering were consistent with the meanings of showering found by Hand *et al.* (2005) and Shove (2003) in their qualitative historical analysis of the practice, as well as with the variants of showering identified by Pullinger *et al*. (2013) in their explanatory mixed methods design applied to characterise water use practices in southern England. This proves that the implementation of an exploratory mixed methods approach is suitable for studying water use practices and (cautiously) scaling up their results. Methodological designs like the one outlined above challenge the traditional top-down approach to water consumption, by enabling people to speak about what makes sense for them in domestic water use from a bottom-up, culturally sensitive perspective.

The implementation of mixed methods – and particularly exploratory designs – could also boost the inclusion of practice-centred approaches in the policymaking arena, since descriptive inferences can be drawn in larger populations. This opens up a wider spectrum of intervention possibilities from within practices, rather than from external impositions (Jack, 2013).

In the specific case of showering in Cali, the identification of three variants provided evidence that materials, competences, and meanings are arranged and bound together through a routinised and daily reproduction, not from people's rational choices (Shove, 2010). Therefore, changes in peoples' water use cannot only be achieved through increased water prices, information campaigns, or environmental awareness. Research in local communities in Australia (Allon & Sofoulis, 2006; Fam *et al*., 2015; Fam & Mellick Lopes, 2015) shows that interventions centred on practices can be more effective, emerging from and fitting in current ways of water use. Findings in the presented spotlight contest the effectiveness of the one-size-fits-all strategies that are traditionally implemented in water demand management: such strategies neglect the fact that water is entangled in practices that are internally differentiated (i.e. variants of practice), which must be addressed and targeted from a holistic perspective.

To the knowledge of the author, practice-centred approaches are almost entirely unknown in residential water demand research and management at the local and national levels, which rely mainly on punitive economic measures, environmental education, or metering improvements. Further involvement of PT in residential water demand policymaking requires more research into the relationship between water consumption and the constitution of practices – which represents a further avenue to explore and improve for the approach presented here. Based on this, domestic water consumption could be addressed as a complex social phenomenon, beyond the exclusive engineering, economic, and psychological domains.

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