How to implement a water quality testing programme

A step-by-step guide for WaSH professionals

Akvo.

Design, Capture, Understand, Act

#withAkvo

Contents

Why is water quality important?

Poor water quality is a serious problem, with diarrheal disease remaining among the top five diseases in reducing lifespan since 1990.[1] It is estimated that over 80% of wastewater worldwide is released into the environment without treatment,[2] while over 40% of the world's population face water scarcity and many are affected by E. coli, fluoride, arsenic, heavy metals, pesticides and other emerging contaminants.

Water quality testing is a crucial component of managing water. Regular monitoring of water quality helps to understand the water system in terms of seasonal influences, short term discharges, and long term trends, and data forms the backbone of monitoring. Governments, communities, and non governmental organisations (NGOs) can use monitoring to extract insights and make informed decisions to improve the management of water and water quality.

We have set ourselves a 2030 deadline with the Sustainable Development Goals (SDGs). But universal access to safe and affordable drinking water is still a challenge. Several governments have undertaken National Water Quality

1 Lancet 2020; 396: 1204–22
2 2017 UN World Water Development Report: Wastewater, the Untapped Resource.

Assessments and Water Safety Planning, which are important initiatives towards achieving the SDG6 goal. However, the lack of usable data remains a critical challenge in these endeavours. Despite the efforts made by the country governments, multilateral and bilateral agencies to bring safe water to the most vulnerable populations and to protect the environment, water quality testing has not been mainstreamed in the development sector.

Many development aid professionals and organisations are still hesitant to adopt water quality testing due to the technical and logistical challenges involved. As a result, many of the current guidelines and standards for safe water provisioning have developed workarounds in assessing water quality with the use of proxy indicators (i.e. diarrhea prevalence) and indirect parameters (i.e. smell, colour, etc.). These workarounds serve a critical purpose in allowing some degree of quality assurance, but they cannot compare with the certainty provided by direct measurement of the biological, chemical and physical constituents in the water.

In a positive development, the WHO/UNICEF Joint Monitoring Programme issued guidance on integrating water quality testing in household surveys in their 2020 report. The challenge moving forward is to develop sound approaches to correctly incorporating water quality data to existing guidelines and standards

Why this eBook?

This eBook provides a step-by-step guide on how to implement a water quality testing programme. Intended for international development professionals and government representatives, this eBook will help you to:

- Understand the technological challenges related to water quality testing
- Design your water quality programme for impact
- Capture reliable WASH and water quality data from the start
- Understand your data in order to generate important insights
- Act on your insights to improve your programme and drive change

This eBook will not cover every single water quality testing scenario. Our aim is to present a practical guide that applies the latest innovations in water quality testing and is applicable for a wide range of situations in the development sector. We follow Akvo's Data Journey approach to ensure success from implementation to impact.

1 | What is a Data Journey?

The Data Journey methodology consists of four phases: design, capture, understand and act. They form the starting point for organisations to ensure data is used to contribute to lasting and inclusive impact. These phases aren't always consecutive or prescriptive, there may be some overlap, and it may be necessary to go back to a previous phase due to findings at a later stage.

What does each Data Journey phase consist of?

Design

Gain clarity on the context of your programme, the problem you are trying to solve, the results you are trying to achieve, the partners you'll work with, the data you need to monitor progress, and the roles and responsibilities of each partner. The design phase should enable you to define your data needs and prepare for a smooth data capture process.

Questions to consider include:

- What is the context you are operating in? Who is involved and what is their role?

Design

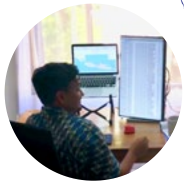
Gain clarity on the context of your programme, the problem you are trying to solve, the data you need, and the roles and responsibilities of each partner.

Capture

Capture reliable and high quality data from the start. Monitor your data collection to ensure accuracy and track progress.

Understand

Extract the insights that matter. Clean, analyse and visualise your data and turn it into valuable information and knowledge.



Act

Share insights with the relevant people, generate dialogue, encourage decision making and continuously improve your work.

- Which impact do you want to achieve and which outcomes will contribute to it?
- Which data will you need for which purpose, which data already exists and which do you still need to collect?
- What does the optimal survey design look like to ensure success?
- Which sampling plan fits best and is most cost-effective?

Capture

Collect relevant, high quality data from the start. Implement your data collection plan and track progress. Questions to consider include:

- Are the tools and skills and logistical plan in place to commence water quality data collection?
- Do you have the necessary hardware and software to accurately measure water quality in the field?
- How can you verify and ensure the quality of your data on the go?
- How best do you organise monitoring cycles of repeated data collection?

Understand

Clean, analyse and visualise your data and turn it into valuable information. Extract the insights that you can act upon. In the understand phase of your programme, you can generate information which can be interpreted to extract insights.

- What WASH and water quality data sources are you planning to combine? Is your data clean and ready for analysis?
- How will you visualise the waterpoint and water quality data to identify patterns and trends?
- How can you extract insights to enable you to make the right decisions?

Act

Share insights with the relevant people, generate dialogue, encourage decision making and continuously improve your work. In the act phase, you'll share your data to influence change.

- How will you share with the key audiences?
- Which systems does the data need to be stored in?
- How can you amplify your insights and create lasting impact?

For international development professionals, following this Data Journey will ensure smooth and successful implementation of your programme, allowing you to focus on capturing data that matters. In this eBook, we're focusing on the Data Journey for water quality testing.

Round out your Data Journey knowledge

Visit our knowledge library

2 | How to design your water quality testing programme

In the design phase, it's important to keep in mind which stakeholders will be involved and which problems and opportunities exist, at the start and throughout. It's an opportunity for you to understand what the objectives are, what the relevant actors and factors are, and which steps need to be taken to contribute to impact. Important questions to consider at the design phase of a water quality programme include:

- What is the context you are operating in?
- Which stakeholders are involved and what is their role?
- Who are the partners needing this data and who will be impacted?
- What are the goals and expectations of the partners involved?
- What will the water quality data be used for, how, and by whom?
- Is water quality currently tested/monitored and if so, how?

The answers to these questions provide the foundation to the entire programme, so it is crucial to document the answers in detail. Very often, only a portion of this information is shared by the lead partner at the start in order to move forward quickly. As a designer, you will need to hold back from progressing with the programme until the foundation is established. This will save resources in the long term and ensure the results of the programme are sustainable and effective.

Step one: Define the programme objectives and the partners' expectations

Understanding the programme application

There are a number of different applications for a water quality testing programme - from safe water for domestic use to environmental protection. Each application presents a unique backdrop for designing a water quality testing programme and serves a critical purpose in the development sector. Here is a brief overview of the most common applications in order of increasing design complexity.

- **Drinking water source selection and confirmation:** The most prevalent use of WQ testing in the development sector is for the selection or confirmation of a specific water source to be used for safe drinking water. This generally does not require the use of statistical sampling methods or complex data analysis. Considerations include parameter selection and seasonal variations in water quality. We present a more comprehensive breakdown of parameter selection in step two.
- **Humanitarian and emergency responses:** In rapid needs assessments, the water quality data is used for the selection of emergency water sources and requires very little post-processing. The two main tools for decision making are the Rapid Assessment Tool (RAT) and Needs Severity Mapping. The RAT is meant to be conducted within three days of the onset of an emergency with the goal of implementing immediate response activities. The vast majority of the questionnaires are designed around the Sphere Standards. In the case of severity needs mapping or the investigation of disease outbreaks, additional knowledge and skills will be required.
- **Regional mapping of safe water access:** Another common use for water quality testing is in determining safe water availability and WASH-related health indicators. The main objectives for regional and national water quality mapping are to design suitable programmes and strategies to improve water services and to evaluate the performance of previous and ongoing initiatives. Before entering into a discussion on indicators, it is important to be clear on the entities or "objects" being assessed. Intuitively, one may assume that the object of study would always be "the water," but to avoid critical errors when applying statistical analyses, it is helpful to think of the objects as either water sources, people, or institutions, as presented in table 01.
- **Long term monitoring of water supply systems:** The aim of long term monitoring programmes is to ensure the sustainability and acceptability of a drinking water supply. This could be a hand pump, kiosk or full pipe network system. In any case, you should follow a Water Safety Plan approach for good quality assurance. This requires an understanding of water system design and hydrological principles, as well as a rigorous approach to designing a monitoring plan. The WHO and the International Water Association developed a detailed guideline using a risk assessment and risk management

Table 01: Object of study and associated indicators

Object of study	Common types	Example indicators
Water source	Water supply system	Number of safe drinking water systems in a district
People	Household, communities	% of households with access to safe water in a district
Institutions	School, health facility	% of schools with access to handwashing facilities in a district

approach described as a Water Safety Plan (WSP).

- **Assessment of ambient waters and effluents:** These assessments are done in the context of ecosystem health and consider impacts to aquatic life and agriculture, in addition to humans. This includes the testing of ambient waters, such as lakes, rivers, and groundwater, and effluents discharged from industrial, agricultural and urban processes such as wastewater treatment plants.

Understanding the programme objectives

The relevant WQ programme objective may sit within a larger hierarchy of objectives. We recommend that you identify the full hierarchy and then place boundaries around the WQ programme objectives for detailed design. The relevant objective would likely align with one of the categories described in the previous section. Table 02 shows a hierarchy of objectives and can be used to identify the most relevant objective for your programme.

It is good to know what the overall objectives are as stated in one and two, but the third tells us that this is essentially part of a performance monitoring programme. As follow up, you could ask if any WQ tests were done prior to rehabilitation, and what the other factors are for assessing performance.

Understanding the partners' expectations

In identifying the partners, it is important to keep in mind that the organisation of your main contact may not be the only one using the data. For example, a UN agency requests that water samples be collected and tested from every water source in District A. Upon further questioning, the UN agency may share that it is partnering with 10 other NGOs who will be the actual organisations implementing a water infrastructure rehabilitation programme. As for identifying who will be impacted, you may be told that it is for the communities in District A. However, with additional questioning, you may find out that the water points are managed by different entities, such as schools, private businesses, and community WASH committees. A full understanding of stakeholders is critical to developing a correct design and knowing what questions to ask next, and who else needs to be interviewed.

Step two: Select the water quality testing parameters

Roughly speaking, water quality can be divided into three domains:

- **Microbial contamination** refers to the presence of disease-causing (or pathogenic) microbes, which are generally introduced to water sources by contact with faecal material. Common examples include pathogenic strains of Escherichia coli (E. coli), and those that cause typhoid fever and cholera.
- **Chemical contamination** refers to metals, organic compounds and other chemicals that present potential health risks. Often they are a result of human activity like industrial waste disposal and agriculture, but also may be

Table 02: Hierarchy of objectives

Hierarchy of objectives		Most relevant WQ objective
1	Improve access to safe water services	
2	Rehabilitate contaminated hand dug wells	
3	Check the quality of rehabilitation done by the implementing partners	●
4	Test every hand dug well in District A	

naturally occurring such as the elevated arsenic levels observed in many parts of Bangladesh.

- **Physical contamination** refers to conditions relating to the water's physical condition, for example colour, odour, temperature and turbidity (cloudiness resulting from the presence of small particles like pieces of soil). Most of these present no direct health risk, but they can influence other factors (e.g. soil particles in turbid water can shelter bacteria) and sometimes make water unpleasant to drink.

In selecting parameters, there are several key factors in regards to water quality.

Local and international drinking water standards act as the primary reference for selecting testing parameters. Local standards may be obtained online from government websites, or by asking the relevant government department (i.e. Ministry of Water). As for international drinking water quality standards, the WHO guidelines are a good reference.[1]

1 "Safe drinking water does not have any significant risk to health over their lifetime. Safe drinking water has microbiological, chemical and physical characteristics that meet World Health Organization (WHO) guidelines or national standards for drinking water quality" (WHO/UNICEF, 2013).

Land and water usage in the zone of influence are also primary considerations for parameter selection. Agricultural, mining and other industries have their own typical Potential Contaminants of Concern (PCOC) that should be included in the testing.

There are a number of additional information areas that likely provide insight to potential water quality concerns. Below are some recommended by the Centre for Affordable Water and Sanitation Technology (CAWST, 2013).[2]

- **Health care data:** Community health centres or hospitals usually collect some level of information about the numbers of patients and types of illnesses that are treated. This information can indicate how illnesses are spreading throughout the area. The District Health Information Software 2 (DHIS2) is an open source, web-based health management system platform used in over 100 countries and can be used as a source for health care data.
- **Household and community data:** Indirect and direct questions related to water quality are typically asked in household and community surveys. This may include describing the physical attributes of their drinking water or whether people are getting sick from drinking the water.

2 CAWST (center for affordable water and sanitation technology), "Introduction to drinking water quality testing manual," 2013

- **Natural disasters:** Natural disasters such as flooding, earthquakes and landslides often contaminate water sources. Depending on the type and intensity of the natural disaster, you may need to consider microbiological contamination and high turbidity.
- **Geographic location:** Due to natural geological formations, some regions may be prone to arsenic, fluoride or other chemical contamination.
- **Secondary Information (WQ reports):** Government agencies, research centres or international organisations may carry out a national or regional survey and report on the surface and groundwater quality. This type of information provides a general idea of the local situation, which can help you to determine the water quality parameters required for the area.

The list of parameters in international standards is very long, and in the absence of any regional and site specific information, it can be a struggle to decide which parameters to select. If we could only choose one parameter, then it would be Total Coliforms and E. coli, due to their prevalence in the development context. In table 03, we provide an expanded list of parameters covering the typical contaminants of concern for safe drinking water. We recommend that this be considered the minimum in the absence of information from literature and secondary data.

Step three: Set up your sampling design, sampling frame and sampling plan

The technical design of a sampling plan is most dependent on the programme objectives and nature of the WASH indicators measured, as is evident when establishing the sampling frame. The sampling frame is defined as the target population in which the samples are taken, and identifying the

Table 03: Recommended minimum list of parameters for drinking water

WQ parameter	WHO limits	Comments
Physical		
PH	none	This is an operational water quality parameter and is important when disinfecting water with chlorine.
EC	none	Unusually high levels may suggest chemical contamination.
Turbidity		Turbidity could be an indication of surface runoff and may interfere with water treatment. What's more, bacteria and viruses can attach to suspended particles and cause health risks. High turbidity decreases water acceptability.
Chemical		
Fluoride	1.5 mg/l	Fluoride is a naturally-occurring form of the element fluorine, which is sometimes found in groundwater at levels that exceed safe levels. Too much fluoride can cause pitting and staining of tooth enamel. Long-term exposure to high levels could lead to bone issues in adults.
Nitrate and Nitrite	50 mg/l	These elements could occur due to the fertilisation of nearby farm fields or sanitation facilities located too close to the well. In most cases, these compounds aren't a serious health risk. They are harmful to infants, however, causing what's known as blue baby syndrome, which can be fatal.
Arsenic	10 µg/l	This element occurs naturally in rocks and soil, but it can also be an industrial waste byproduct, particularly from mining and coal burning. It can enter the groundwater from both natural deposits and pollution, so it could be an issue with well water. The EPA says studies link long-term exposure of arsenic to certain cancers as well as cardiovascular, neurological, and other conditions.
Chlorine	5 mg/l	This value is the health-based guideline. Chlorine is often used for water treatment.
Bacteriological		
Total coliform and E. coli	0MPN/100ml	Provided indication of contamination by fecal coliforms or other harmful bacteria. This is important because fecal pollution is the major cause of water-borne diseases in humans.

target population may not be as straightforward as it may seem. The key questions to ask are as follows:

- Is the objective to select a safe water source?
- Are the water quality results used to determine the status of WASH indicators, such as whether a community has access to safe water? If yes, is the object of those indicators a people group, school, health facility or water point?
- Are the water quality results used to evaluate the performance of a programme?

Based on these answers, you would first identify the nature of the target population, whether it be schools, health facilities, communities, or water points, and there could be more than one sampling frame depending on WASH indicators involved. Next would be to define the scope of the total population. For example, it could be all the schools within a geographical area, or only the schools that received assistance from NGOs.

Once the sampling frame is established, then you decide on the cross-sectional and longitudinal scope of the sampling. The overall scope of a water quality testing programme is a tradeoff between resources available and required water quality data. The higher the accuracy and coverage, the more resources are required. If and how much water quality testing is required in a programme should be based on available budget, capacity of the staff to conduct testing, availability of testing equipment and consumable items, logistics involved in sample collection and transportation, and the seasonality and variance of contamination in sources.[3]

Cross-sectional data is observations of different individuals at a single point in time. It is unlikely that a programme would have the resources to sample every individual in a population. Therefore, a sampling methodology is required to ensure that the sample you use to gather your data is representative of the population or group you are researching. If statistically significant results are needed, such as for calculating SDG indicators, then this would require a form of random sampling (i.e. simple, stratified, cluster, etc.). As a general rule of thumb, randomised surveys in the development sector aim for a confidence level of 95% and confidence interval of 5%. In the event of a rapid assessment for an emergency response, you would more likely use a convenience sampling approach because of logistical and time constraints.

Longitudinal data is observations of an individual at different points in time. In the case of Water Safety Plans, using fixed time intervals is advised because this will allow you to identify trends and outliers. Another consideration is to target specific times where you think contamination is at its worst. During the rainy seasons, especially near the start of a rain event, surface water sources may receive a gush of contaminated runoff. Alternatively, a water source that is impacted by chemical loading may show high concentrations of that chemical during the dry season because of the absence of diluting upgradient flows. For a detailed guide to creating your sampling strategy, check out our blog: How to choose your sampling strategy to guarantee relevant results.

3 World Health Organization (2012). Rapid Assessment of Drinking-Water Quality: A Handbook for Implementation. WHO, Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/publications/2012/rapid_assessment/en/index.html

Step four: Create an operational and logistics plan

Once the testing parameters and sampling strategy are clear, the next step is to create an operational plan and arrange logistics. An operational plan entails the activities and milestones to meet the programme objectives. It also includes the roles and responsibilities and timing and costs of the activities.

It is important to define roles and responsibilities in the beginning. Build a team that will be responsible for all different required activities and deliverables. A Gantt chart could be a very useful tool for defining the project schedule including roles and activities. For each activity/deliverable, other skills are required. For example, capturing water quality data requires, depending on the testing method, a water quality/chemistry background, while understanding data requires a data analysis background. Therefore, it is important to create an overview of who is in the team and who has the right skillset to perform certain parts of the Data Journey, from programme design and water quality testing to data analysis and report writing. It is also important to find out if there are gaps which can be complemented by finding staff outside the existing team.

Set roles and responsibilities

The RACI approach is a useful way to assign a list of activities to different team members and entails the following components (CAWST, 2013):

R Responsibility: This is the individual who is ultimately responsible for that activity being completed on time and on budget. Even if several other people will be working on that activity, only one person is ultimately responsible.

A Action: All the people who will need to take some action to complete that activity are assigned an 'A' in the RACI chart.

C Consult: This refers to those people who must be consulted in order to complete the activity.

I Inform: This refers to the people who will need to be informed of the activities, but won't need to provide any input.

In addition to the usual logistical considerations applicable to any country-scale data collection effort, for a water quality assessment additional logistics and planning issues are important, such as:

- Procurement of equipment for field testing or lab testing (e.g. sensors and/or photometers).
- Procurement of consumables in field tests, such as reagents and strip tests.
- Procurement of data collection hardware (e.g. mobile phones).
- Training of enumerators in following proper procedures for taking water samples and performing in-field tests.

For a thorough breakdown of this part of the Data Journey including how to conduct a Theory of Change and a factor and actor analysis, check out our Design eBook:
Akvo eBook: Design data-driven development programmes that deliver results effectively

3 | How to capture water quality data in the field

Step one: Consider the technical implications for water quality testing

In countries or areas with fewer laboratory facilities, resources, and technical capacity for testing water quality, sampling can be an issue. Some samples need to be tested within a specified time period, transported at controlled temperatures, and filtered or acidified. Especially in rural areas, a lack of resources can make it impossible to meet sampling requirements.

As a result, field water quality testing kits are commonly used especially by development aid organisations. Water quality testing is not difficult, but requires a degree of precision and strict adherence to step-by-step instructions in order to obtain accurate results. So, even with field kits, it is preferable to have certified technicians to do the testing. However, this is not practical in the development context. Even with thorough training, there still may be concerns with accuracy and reliability when carried out by field staff or citizens.

Precision is needed not only in conducting the actual test, but also in handling and processing water quality data. Transcription and labeling errors are common when conducting field tests because the recorded values need to be transferred from a field book to a computer, and often this does not occur until the completion of the fieldwork, which only increases the likelihood of error. This digitised data then needs to be sent to an individual with the necessary water chemistry and analytical skills to process and interpret water quality data, as well as storing it in a secure database. Being far from the field, the analyst may not be able to precisely trace the source of any discrepancies noticed in the data. Also, this extra layer of data handling can also introduce errors before data is entered into the database. In the next section, we will dive deeper into the latest innovations in field testing that have mitigated some of these challenges.

Field testing kits for water quality

Field testing kits are a cost effective alternative and supplement to laboratory testing. The ability to test at the sampling site mitigates the logistical challenges of storing and transporting water samples to a laboratory. This section presents the testing options linked to the Akvo Caddisfly app, which is connected to Akvo's data platform. These include colorimetry (photometer, Checkit Comparator, pool tester and test strips for various parameters), sensors (electrode sensors for pH and EC, optical luminescence sensor for Dissolved Oxygen), and microbiology (compartment bag Test for E. coli and Total Coliform). This selection of options covers a wide range of scenarios and takes into consideration the price/quality ratio and global availability. Table 04 gives an overview of all testing methods and parameters which are currently available in Caddisfly.

Table 04: Overview of testing methods and parameters in Akvo Caddisfly

No	Parameter	Photometer (colorimetry)	CHECKIT Comparator (colorimetry)	Test strips	Sensors (Electrochemistry)	Compartment bag test (microbiology)
1	Alkalinity	●	●	●		
2	Aluminium	●	●			
3	Ammonia	●	●	●		
4	Ammonium			●		
5	Arsenic			●		
6	Calcium Hardness	●				
7	Chloride	●		●		
8	Chlorine	●	●	●		
9	Chromium	●				
10	Copper	●	●			
11	Cyanide	●				
12	COD	●				
13	Dissolved Oxygen				●	
14	Electrical Conductivity				●	
15	E. coli					●
16	Fluoride	●	●			
17	Hardness (total)	●		●		
18	Iron	●	●	●		
19	Manganese	●	●			
20	Mercury			●		
21	Nickel	●				
22	Nitrate	●	●	●		
23	Nitrite	●	●	●		
24	pH	●	●		●	
25	Phosphate	●	●	●		

Table 04: Overview of testing methods and parameters in Akvo Caddisfly - continued

No	Parameter	Photometer (colorimetry)	CHECKIT Comparator (colorimetry)	Test strips	Sensors (Electrochemistry)	Compartment bag test (microbiology)
26	Potassium	●		●		
27	Sulphate	●				
28	Suspended Solids	●				
29	Temperature				●	
30	Turbidity	●				
31	Total Coliform					●
32	Zinc	●	●			

Colorimetry

Lovibond MD610 Photometer: For higher accuracy, the photometer can be used (2% FS). The colorimetric measurements use a reagent which is added to the water sample and causes a colour reaction. The intensity of the subsequent colour depends on the concentration of the parameter in the water sample. In the case of the photometer, a light source with a specific wavelength (LED) beams the complementary color through the water sample and a detector measures the amount of absorption (see figure 01).

Checkit Comparator: This method uses a calibrated colour disk and enables the data collector to compare the colour of the water sample with a reagent to the colour disk.

The Pool Tester: This uses a similar method, and the color interpretation can be added by selecting an interface in the Caddisfly app.

Figure 01: Caddisfly with Lovibond Photometer and bluetooth connection

Test Strips

Test strips follow the same principle as colorimetry. The reagent is attached to the paper strip. By dipping the reagent patch in the water sample, the colour of the reagent patch changes. The resulting colour change is interpreted by the human eye by comparing the colour to reference colours, mostly visualised on the original storage container. Test strips are cheaper and more simple than photometric tests. The accuracy of test strips is low and can be considered semi-quantitative. Test strips can be useful for screening large amounts of samples and to detect whether samples have roughly low-medium-high ranges.

Sensors

Electrode-based Sensors: pH and Electrical Conductivity can be measured accurately with handheld and easy to use Lovibond SD50 and SD70 sensors.

Optical sensor: The portable Lovibond SD 400 Oxi sensor is available to measure Dissolved Oxygen with high accuracy. It uses the optical luminescence technology with a range of 0 - 50 mg/l O2.

Bacteriological Testing

Compartment bag test: By simply filling a bag with the growth medium and water sample and allowing it to incubate at room temperature (25° or above), the test allows for the estimate of E. coli. concentrations (MPN/100mL). This allows for interventions to focus on water resources with the highest contamination risks first. This test complies with the 100 ml WHO norm criteria,[1] is affordable, and has a long shelf-life. Moreover, the test doesn't require a constant source of energy or any special equipment, such as an incubator, making the test more affordable and usable in different resource settings.

Benefits of using the Akvo Caddisfly app for water quality testing include paperless data collection, improved quality assurance, near-real time data visualisations, and remote quality control monitoring.

In the next steps, we'll focus on capturing water quality data digitally using the Akvo Caddisfly app.

Figure 02: Capturing the result of the compartment bag test to determine the presence of E. coli (0-100 MPN)

1 2017 World Health Organization Guidelines for Drinking-Water Quality

Step two: Prepare for the field

Before going to the field for water quality testing, it is advisable to create a checklist of items that need to be brought to the field. It is very inconvenient when equipment is missing once you are already testing in the field, usually resulting in incomplete data and wasted resources. The checklist can be categorised as follows.

Software

Make sure before you go to the field to:

- Charge your phone. Consider bringing an additional battery/power bank.
- Check if there is sufficient space available on the phone (at least 1.5 GB, but preferably more to store photos). Clean the phone if necessary.
- Check the GPS status of the phone and calibrate GPS.
- Make sure the correct and latest versions of the surveys are on the phone.
- Switch the phone to flight mode to save battery.

Equipment, reagents

Make a list of water quality testing equipment you need to bring to the field. Make sure sufficient consumables are brought (do not forget blanks and field duplicate samples if applicable).

Besides the phone, testing methods and consumables, the following equipment needs to be considered including in the checklist:

- Sample bottles (reusable).
- Pipette + pipette tips (if applicable).
- Distilled/deionised water (e.g. to clean photometer vials before and after measurement).
- Large empty bottle - for collecting waste disposal (used reagents).
- (Paper) towel - for cleaning the outside of the vials before placing in the cell chamber of a photometer.

Health and safety

Since there is a risk from (contaminated) water sources and chemicals used in testing, it is important to consider your own health and safety. Make sure to:

- Read the safety instructions for each test properly before using.
- Bring appropriate Personal Protective Equipment (PPE) such as gloves.
- In case of liquid chemicals: work in well-ventilated areas, prevent inhaling fumes from reagent and minimise volatilisation or aerosolisation of contaminants into the air.
- Avoid contact with the skin and eyes.
- Wash hands thoroughly during breaks and at the end of the work.
- Do not eat, drink or smoke when testing.
- Do not smell or taste the water sample.
- Tie back long hair.

Storage

When storing reagents, take account of the following:

- Store in a cool location.
- Protect from heat and direct sunlight.
- Protect from humidity and keep away from water.
- Store only in the original container.

Step three: Capture the water quality data

Mobile water quality testing can be done using the Akvo Caddisfly app. Akvo Caddisfly communicates with Akvo Flow and is part of an Akvo Flow survey. The water quality test results will be available on Akvo's data platform where data is organised, exported and visualised on interactive dashboards and maps.

Step-by-step instructions of the testing methods are included in the Caddisfly app. When a data collector goes into the field, he or she only needs to bring a charged smartphone and the testing equipment. In the field, the instructions guide the data collector through the tests and store the results instantly on the smartphone. The testing can be done offline and the results will be saved on the smartphone and automatically uploaded as soon as the smartphone connects to the Internet.

As an example of how the step-by-step water quality test instructions look in the Caddisfly app, the phone screenshots of the Aquagenx Compartment Bag Test to detect the Most Probable Number (MPN) of E. coli in a water sample are depicted in figure 03. This easy to use microbiological testing method gives a good indication of the degree of fecal contamination of the water sample by giving the range of 0-100 MPN.

Strip testing in the field

Akvo Caddisfly can read the results of a test strip by combining software, the camera of a smartphone and a very simple piece of hardware: the Colour Reference Card. The Colour Reference Card contains generic colours for which we know how they look in different types of light conditions. Therefore, the Colour Reference Card can be used to calibrate for the specific light conditions that occur while performing a strip test, since colours appear differently in different types of light. In this way, the human eye interpretation is taken out and

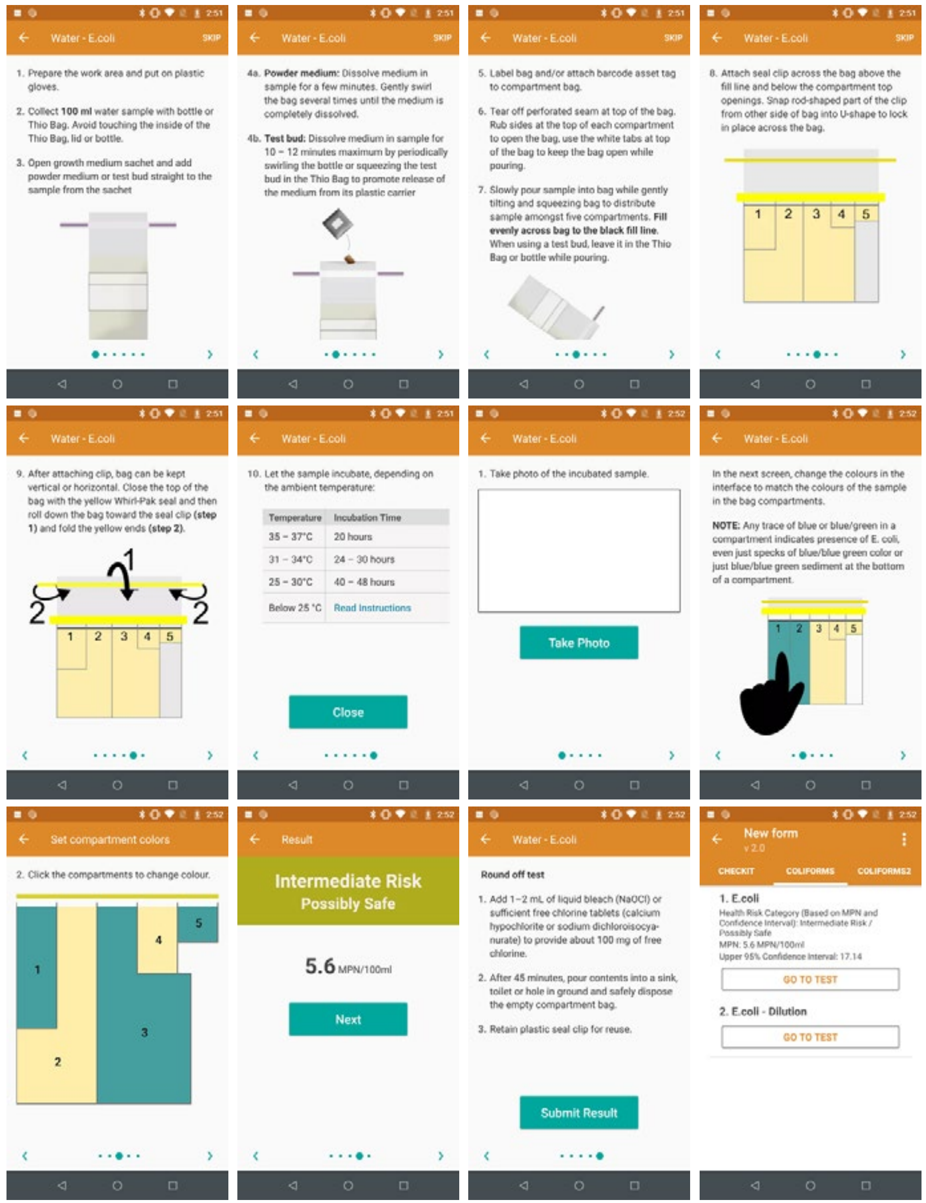


Figure 03: Akvo Caddisfly Compartment Bag Test screenshots

test strips become part of our data solution.

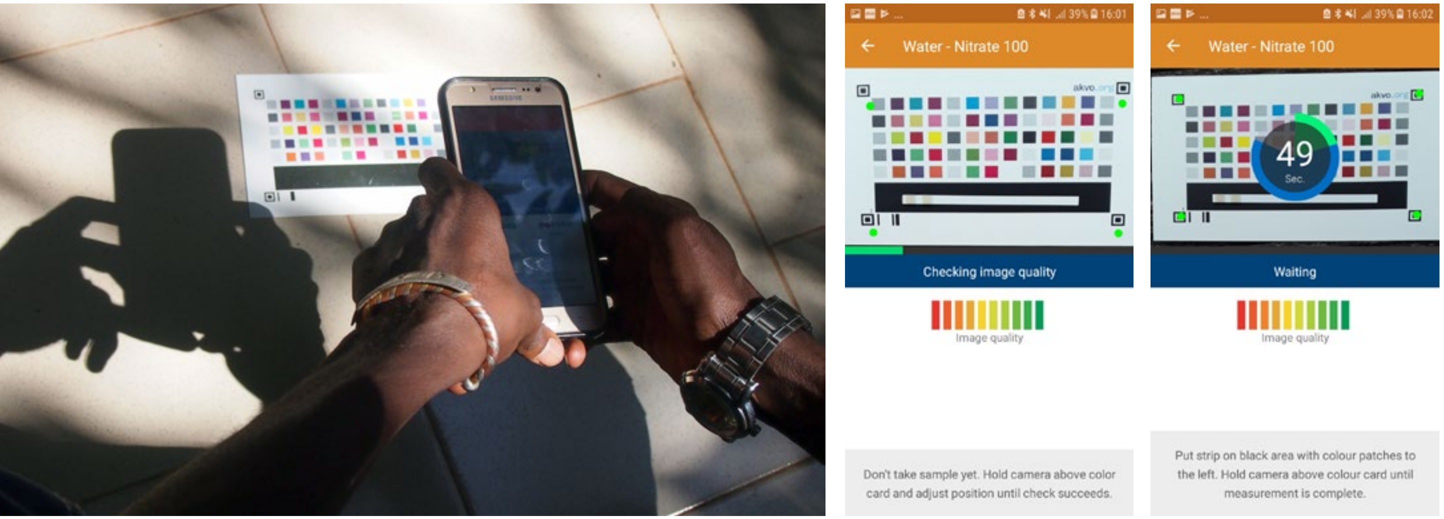
The general workflow for strip testing is:
Dip the test strip in your water sample.
Place the test strip on the Colour Reference Card.
Place your phone above the Colour Reference Card and the app will measure and calculate the result based on the colour change of the test strip patch.

Once finished with testing in the field, make sure to collect all liquid waste (such as reagents) in a big plastic bottle and bring to a proper waste disposal. Do not leave waste in the environment.

Step four: Ensure quality control during data collection

It is important to prevent secondary contamination. Make sure you have a good workspace; work on a good surface; on a table, your backpack or flat area, do not work on the ground and try to minimise the impact of wind (dust). When testing, make sure everything is cleaned properly and do not leave anything open while not used. Furthermore, do not touch the inside of sample containers such as petri dishes, lids or caps to prevent secondary contamination.

Figure 04: Akvo Caddisfly nitrate test strip recording and screenshots



Furthermore, to guarantee dependable outcomes, it is very important to use ample quality control processes, in different parts of the process. Options include:

- Using field blanks and field duplicate samples.
- Using a blind process, including blanks, duplicates and hidden standard solutions (to check the quality of the lab), when measurements are carried out by enumerators during training.
- Repeating measurements by multiple enumerators – at least on a random sample of tests performed.
- Having special enumerators that act as quality controllers by randomly validating field tests with lab tests.

To inform the quality assurance process, relevant experts of WHO and JMP could be involved as part of an advisory committee.

For a thorough breakdown of this part of the Data Journey, download our Capture eBook: Akvo eBook: Capture reliable data in the international development sector.

4 | How to understand your water quality testing data

In this section, we provide recommendations on data analysis and visualisation to enhance the interpretation of the collected and existing data.

Step one: Conduct primary data analysis

Here, we cover suggestions for presenting the raw data, which are the numerical results for each WQ parameter. Sometimes, people are tempted to skip this step and jump straight to visualising the WASH indicators (i.e. access to safe water), but this could lead to errors. What's more, visualising the raw numbers improves transparency by allowing the reader to see how the WASH indicators were derived.

pH, Electrical Conductivity data and Turbidity

pH, EC and turbidity are called physical parameters, because they provide bulk indications on the nature of the water quality. pH describes the acidity or basicity of the water. EC describes the total amount of dissolved solids in the water. Turbidity describes the amount of suspended solids in the water.

pH and EC are useful for describing the general characteristics of the water and should be plotted geographically and stratified according to surface or groundwater. Stratification is important because each has its own general ranges. For example, surface water tends to have lower pH and lower EC than groundwater. Visualising in this way can help to identify errors in testing or

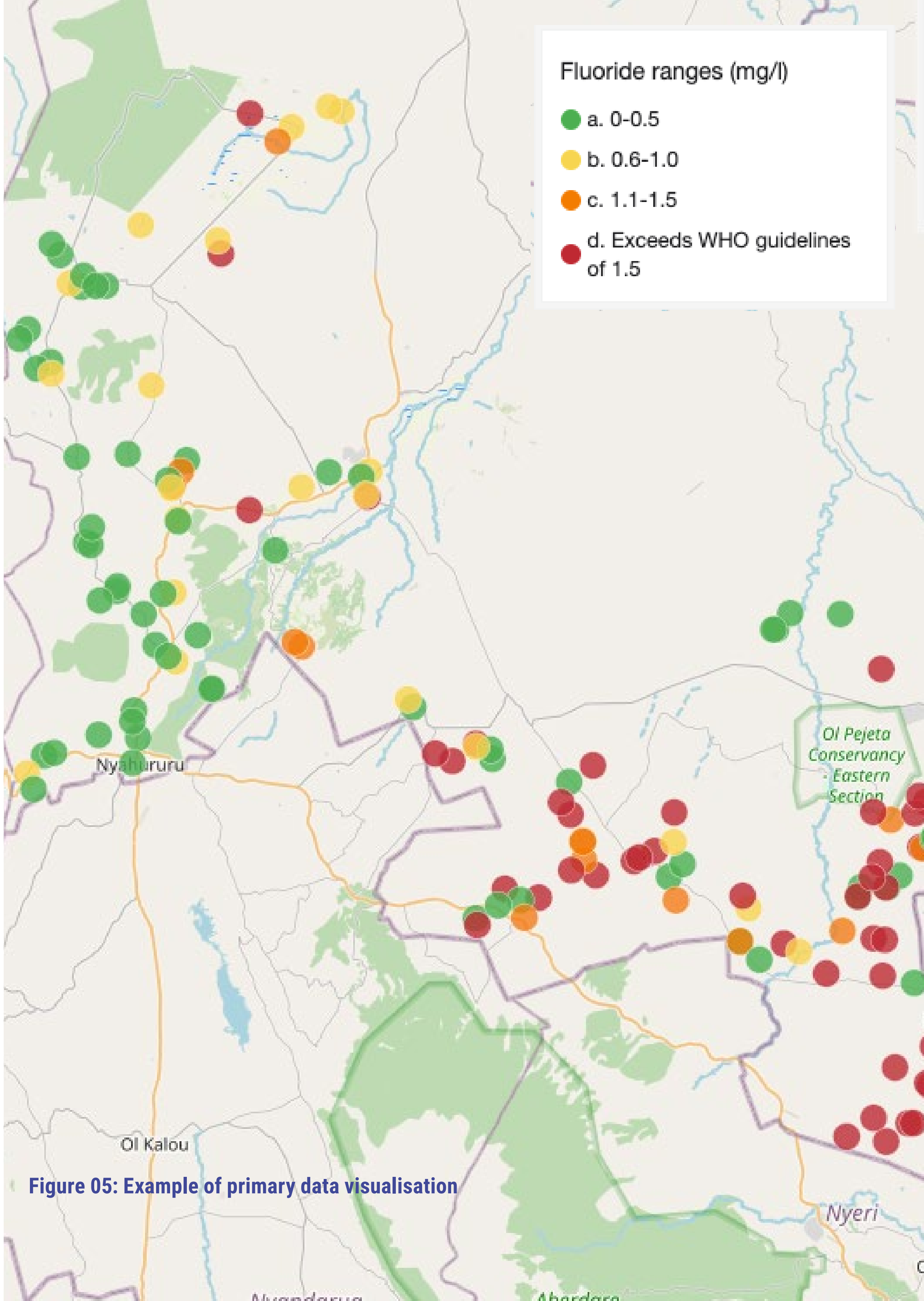


Figure 05: Example of primary data visualisation

potential contamination.

Turbidity is useful when interpreted with the specific context of the sample. For example, groundwater samples should not be turbid, so any detection of turbidity suggests issues with the well screen. Knowing the turbidity is also important for designing water treatment systems.

Comparison with standard limits/ranges

Concentration limits and ranges established for potentially harmful substances are essential references for water quality, so these should be shown when presenting testing results. For example, when creating a bar chart for Nitrate/Nitrite, one should always include a line at 50 mg/L showing the WHO limit. When creating a map, one should include this limit in the legend, and highlight the samples exceeding this limit with a special shading or colour as shown in figure 05.

Identifying outliers and trends

Besides regulatory and recommended standards, it is useful to develop graphs and visualisations that identify outliers and trends, especially for longitudinal data. One reason is that these may point to future exceedances even though the data at the moment are within safe limits. Secondly, they may point to exceedances as a result of parameters not tested. For example, the EPA limit for sulphate is 250 mg/L set mainly for aesthetic purposes. However, sulphate is often associated with acid mine drainage, which represent a wide range of potential heavy metal contaminants. The bottom line is that any trends or outliers detected in the data should trigger further assessment to understand the underlying cause and any reason for WQ safety concerns.

Step two: Conduct secondary data analysis

In the humanitarian and development sector, water quality data often goes through further processing and calculations to arrive at other indicators and parameters. This includes SDG indicators such as access to safe water, and needs severity ratings. Very often, organisations report only on the calculated indicators which have potential impacts to correct interpretation, and future analysis of the results. For instance, if you show a map of % of households with access to safe water and no other information, the reader would not know whether the determination of “safe” was through direct water quality testing or a proxy observation of the water source type. This is important because water safety indicators that incorporate direct water quality testing are inherently more reliable. Within this context, we suggest the following.

- Practically all secondary analysis involves either a rubric and/or calculation formula, so these should be clearly documented and easily accessible. For example, if your determination of a safe water source is a) no detectable Total Coliforms/E. coli, and b) arsenic levels < 0.01 mg/L, then that should be noted in the report or online dashboard.
- When presenting the results of secondary data analysis, you should show the primary data in the same location of the report, or point to the location of the corresponding primary data, such as in an annex.

For a thorough breakdown of this part of the Data Journey, download our Understand eBook: [Akvo eBook: Understand your data and extract insights that matter].

5 | How to act upon your water quality data to contribute to impact

Step one: Enhance the usability of the data

To set the context, table 05 shows some typical ways in which water quality results lead to specific outcomes and impacts.

At this stage, we have assumed that all of the primary and secondary analyses were completed and the necessary visualisations and graphs were produced to support the resulting actions listed above. We have a few practical suggestions that can enhance the impact of the data.

1. Firstly, produce a standalone report that contains all of the collected data. Often the data sits in an annex of a larger report (i.e. five year WASH strategy) or hidden in someone's hard drive. By producing a standalone report, this makes data available for multiple purposes. Also, it provides transparency and the opportunity for others to check the quality of your work. This is a powerful way to improve the legitimacy of your numbers.
2. Secondly, widely share your data through your own online portal similar to Mali, or open data platforms such as WPDx. This allows others to use your data for other programmes and research leading to further outcomes and impacts.
3. Thirdly, include a date and geo-identifier to every data point and calculated indicator. This may seem redundant because this metadata is usually

Table 05: Examples of outcomes and impacts

WQ testing objectives	Examples of impact
Testing water sources for selecting or confirming a water supply	Results used to do advocacy work for improving water service.
Long-term monitoring of water supply systems	Water supply systems provided safe water evidenced by the data collected.
Investigation of WASH-related disease outbreaks	A contaminated water source is rehabilitated. Households are trained in safe water handling.
Needs Severity Mapping	A WASH programme is implemented in the five districts with the worst severity.
Performance monitoring of WASH interventions	A follow up WASH programme is conducted to fill gaps and fix areas that did not perform as expected.
Regional assessment of water service levels	Results used to develop a five year strategy to meet SDG goals.
Regional water infrastructure inventory	Results used to create a financial plan for infrastructure expansion
Regional ambient water resource inventory	Results used to develop environmental policies governing industries.

automatically logged, especially when using digital collection apps. However, the data that goes into annexes or shared in online platforms is often not the raw data but rather has gone through some processing. If the date and geo-identifier are dropped, then it may be difficult to compare this with other data sets.

Step two: Adaptive management and post-programme impact evaluations

In this final section, we would like to emphasise two programme implementation (Act) concepts to consider when implementing a water quality testing programme.

Adaptive management

The idea of adaptive management is to focus on increasing the likelihood of achieving the results rather than simply measuring them. The Data Journey approach is cyclical and interconnected in nature - if you notice something unexpected in the Understand phase, for example, you may need to go back to the Design phase to make sure that you're still on the right track and the assumptions you made at the start of the programme are still correct. This could lead to changes in your Theory of Change, for example, which would alter the underpinnings of a Monitoring and Evaluation (M&E) plan. To learn more about adaptive management, please check this excellent resource provided by USAID: Discussion Note: Adaptive Management | USAID Learning Lab. Practically, we stress that in order for adaptive management to be possible, there needs to be a high frequency of data collected, and the processing needs to be fast in order for the decision-makers to enact changes while a programme is implemented. For water quality testing, this points to field kits, digital data collection, and advanced data analytic tools for fast processing.

Impact evaluations

As for impact evaluations, we need to think beyond water quality testing. Referring back to table five, the impacts are often related to improved health and infrastructure as well as the development of policies and strategies, etc. Impact indicators are usually measured at the end of a programme. We encourage you to measure these indicators at the start of your programme as well so that you have a baseline with which to measure change. When designing a water quality testing plan or programme, it is good practice to consider what the post-programme impact evaluation will look like, and then incorporate the necessary indicators into the WQ plan. For example, when testing the water source, you may consider collecting additional data and information on household diarrhea rates, water service levels, and district strategies. By thinking ahead and collecting this additional data, you can significantly improve the impact evaluation conducted at the end of a programme.

Conclusion

Water quality testing is essential to achieving Sustainable Development Goal 6 (SDG6). Regular monitoring of water quality helps to understand the water system in terms of seasonal influences, short term discharges, and long term trends, and data forms the backbone of monitoring. Governments, communities, and non governmental organisations (NGOs) can use monitoring to extract insights and make informed decisions to improve the management of water and water quality.

By following the steps in the eBook and bringing a robust water quality testing element into your development programmes, we can expedite our efforts to achieve SDG6, protect the environment, and bring safe water to the most vulnerable populations. The Data Journey provides a comprehensive approach to water quality testing programmes, allowing practitioners to boost the impact of their development work in a sustainable, inclusive and effective way. Good luck!

About Akvo

We believe in equal access to public services, reliable infrastructure and a safer environment for everyone. We are convinced that this will happen faster if governments and non-governmental organisations become more effective, accountable and collaborative.

Since 2008, we've worked with over 20 governments and 200 organisations in more than 70 countries to improve the way they implement development projects and make decisions using data. We call them partners.

With our combination of tools, services, local expertise and sector knowledge, our partners improve the management of water, sanitation and agriculture, with a strong commitment to accelerating the progress of the sustainable development goals.

With our unique approach to development, we help our partners design their projects so that they can capture and understand reliable data which they can act upon.

Visit us at www.akvo.org to learn more.

Credits

Authors

Franky Li, Mert Blommestijn, Ayan Biswas

Editor

Georgia Walker

Art direction / graphic design

Linda Leunissen

Photograph and image credits

P04 Enabel. P05 Kopernik by Ima Puspita Sari. P06 (from left) Stefan Kraus, Tiipaalga, Greencoffee by Lissy van Noort, Oxfam. P07 WWF Guyana by Mert Blommestijn. P09 UNICEF Sierra Leone by Mert Blommestijn. P18 UNICEF Sierra Leone by Ibrahim Sorie Conteh. P19 UNICEF Sierra Leone by Mert Blommestijn. P22 Lars Heemskerk. P24 Akvo Lumen map by Watershed Kenya. P27 WWF Guyana by Mert Blommestijn. P29 Kopernik by Stefan Kraus (RGB Collective).

The Akvo Caddisfly app was developed with the support of Cisco.


Looking to unlock the power
of data for sustainable change?
Embark on a Data Journey
#withAkvo and amplify the impact
of your development work
Akvo.
Get in touch now