



Risk-Based Water Quality Management and Monitoring

A specialized training program designed to teach professionals how to plan, conduct, and analyze sanitary inspections and water assessment

Tess Brodie, *Technical Services Program Manager, Global Water Center*

CONTEXT

Developed in partnership with the World Health Organization (WHO), the Global Water Center offers an online course designed to equip participants with essential skills and knowledge for effective management and monitoring of water quality through a risk-based methodology. It offers a thorough foundation for planning and conducting sanitary inspections, performing water quality assessments, and analyzing data and creating action pathways to support the maintenance and enhancement of water safety in small drinking water supply systems.

This course is designed for two primary audiences involved in water quality management. The first group includes service providers such as water suppliers, NGOs, private utilities, surveillance agencies, and regulators who are implementing or planning water quality management programs using sanitary inspections and testing — particularly decision makers, managers, engineers, WASH specialists, and M&E staff. The second group encompasses government agencies, drinking-water and health stakeholders, and carbon credit stakeholders responsible for verifying and validating water quality data and driving progressive action.

RESULTS

A cohort of 222 individuals representing 58 countries and 110 organizations participated in the initial class, held from March to May 2026. Participants included 126 males, 47 women, and 49 preferred not to disclose their gender. Feedback from participants highlighted the value, direct applicability of the course content, and core idea that data-driven monitoring can positively influence and inform evidence-based decision making.



I found the Risk-Based Water Quality Management & Monitoring course very valuable to my work because it strengthened my understanding of risk-based approaches to water quality monitoring, sanitary inspections, and prioritizing high-risk areas for intervention. The course also helped me better understand how data-driven monitoring can improve decision-making and protect public health more effectively."

- PARTICIPANT FROM OROMIA, ETHIOPIA

LESSONS LEARNED

1. Data collection is the beginning, not the end

Across program contexts, the most consistent finding is that collecting data does not, by itself, create safer water. Impact depends on a full six-step cycle:

Collect → Manage → Interpret → Report → Act → Improve

Breakdowns at any point—poor data entry, reports that never reach decision-makers, actions not verified—can render even excellent monitoring data ineffective. Research confirms that in many countries, valuable data is gathered but not optimally used; ensuring priority data is well used may be as impactful as collecting more of it.

- Waterborne disease outbreaks have been directly linked not to absent data, but to data that was not acted upon in time.
- Coordination and clear handoffs across all six steps are essential—different people are often responsible for different parts of the chain.
- The “Improve” step closes the loop—verification of corrective actions feeds back into better data systems and program design over time.

2. A phased approach makes complex data use manageable

Once data is collected, analysis and corrective action unfold across three time horizons. Structuring program workflows around these phases helps teams prioritize and avoid being overwhelmed.

- Immediate (0–24 hours): Field test results and sanitary inspection findings drive urgent, site-level responses.
- Short-term (days to weeks): Laboratory results confirm or contextualize field findings; follow-up actions are assigned and verified.
- Medium to long-term (months): Patterns across systems inform strategic planning, resource allocation, and policy development. Integrating sanitary inspection data with water quality testing results provides a fuller picture than either alone.

3. Challenges are predictable—and that is an advantage

Most water quality monitoring programs encounter the same core challenges: logistics, parameter selection, resource constraints, and human capacity. Recognizing this allows programs to plan proactively rather than respond reactively.

- Challenges are interconnected—improving one area often relieves pressure on others (e.g., better parameter selection can stretch a limited budget).
- Context shapes priority: remote programs struggle primarily with logistics; programs in industrial areas face parameter selection as the lead challenge.
- Unaddressed challenges compound over time, leading to unreliable data, coverage gaps, and, ultimately, program collapse. Programs that anticipate barriers and plan accordingly show higher sustainability.

4. Organizational capacity is the infrastructure that sustains everything else

Technology and protocols only deliver results when the people running them have the right skills, clear roles, and sustained support. Capacity building is an investment, not a one-time cost.

- Effective programs require the right people in the right roles with adequate time—field technicians, data managers, laboratory staff, and coordination personnel all play distinct parts.
- Training must be comprehensive and ongoing: initial instruction, supervised practice, refresher courses, and peer learning—not a one-time workshop. Poor training leads to unreliable data, equipment damage, and missed problems that cost far more to remediate.
- Accountability structures matter: clear expectations, defined responsibilities, and follow-up systems—across water suppliers, surveillance agencies, and supporting organizations—are what turn monitoring data into shared action.
- Consider partnerships for specialized functions: contracted laboratory services or shared data management can be more sustainable than building all capacity in-house.

Further details on the program can be found here: <https://globalwatercenter.org/learn-with-us/courses/risk-based-water-quality-management-and-monitoring/>

Mobile-phone data collection as a drought early warning system

Brian McSorley, *Oxfam in Turkana, Kenya*

Contributed to the TWG on sensor-based drinking water quality monitoring

CONTEXT

Turkana County in northwestern Kenya is one of the most drought-prone regions in East Africa, where access to water can collapse rapidly when boreholes go down, fuel becomes scarce, or pastoral demand spikes. Oxfam piloted a mobile-phone-based data gathering project to give field teams and partners an early warning when conditions at community water points started to deteriorate, rather than waiting for a humanitarian crisis to become visible through household-level distress.

Rather than deploy new in-situ sensors, the project leveraged hardware that field staff and community members already carried. Operators and monitors used Nokia mobile phones to submit simple, structured reports from each water point on a regular cadence. Submissions were geo-tagged and aggregated into a single database that Oxfam used to track service indicators across a wide geography and over time.

TECHNOLOGY SPOTLIGHT

The system was deliberately low-cost and low-spec: Nokia feature phones running a structured data-collection app, a centralized spreadsheet/database back-end, and time-series visualizations of three core indicators per site — price of water per 20-litre jerry can (KES), daily pumping hours, and price of fuel per litre (KES). The same back-end was used to track operating conditions at diesel-generator and solar-powered borehole sites. The architecture is closer to a “smart” data-gathering workflow than to a continuous sensor network, but it generated higher-frequency operational data than periodic field assessments could provide, and it did so with no new hardware on the water point itself.

LESSONS LEARNED

1. Data and information systems

Even simple high-frequency indicators — water price, pumping hours, fuel price — produced an actionable signal of stress before it became a crisis. The principle generalizes directly to sensor-based water quality monitoring: continuous or near-continuous data on a small number of well-chosen parameters can outperform infrequent, more precise measurements when the goal is operational decision-making. The challenge in both cases is the same — connecting the data stream to the people and processes that act on it.

2. Capacity development

The data was only as good as the field routine behind it. Sustained reporting required dedicated staff time, clear roles, and ongoing follow-up; when reporting lapsed, the early warning value collapsed. Programs deploying chlorine, turbidity or microbial sensors should expect the same dynamic: hardware is the easy part, and the human layer — who interprets the data, who acts, how often — is what determines whether the investment pays off.

3. Governance

Oxfam used the data internally for programmatic decisions, but it was never formally integrated into Kenyan government early warning or compliance systems. This mirrors a recurring finding across NGO sensor pilots in low-resource settings: data that sits outside official channels rarely shifts policy or service delivery at scale. Future deployments of remote water quality monitoring will need to be designed from the outset with institutional pathways — who receives alerts, who is accountable, how digital evidence is treated — rather than retrofitted into government systems after the fact.



Solar-powered water point monitored under the Nokia data gathering project, Turkana, Kenya. *Credit: Oxfam.*



Nokia Data gathering project: early warning system. First experience using mobile technology in 2011-14. *Credit: Oxfam.*

24/7 remote monitoring of solar desalination units

Brian McSorley, *Oxfam humanitarian programmes*

Contributed to the TWG on sensor-based drinking water quality monitoring

CONTEXT

In arid and saline-affected contexts, Oxfam has deployed solar-powered reverse-osmosis desalination units to supply drinking water to displaced populations and host communities. Desalination plants are operationally complex — pressure regimes, membrane fouling, antiscalant dosing, and UV sterilization all have to stay within tight bands for the system to produce safe water reliably — and the consequences of a quiet failure are severe in humanitarian settings where alternatives are limited.

To manage that complexity from a distance, the units were instrumented with continuous, sensor-based operational monitoring transmitting to both a local control panel and a remote cloud dashboard accessible 24/7. Of all three Oxfam experiences shared with the TWG, this one sits closest to the kind of in-situ, continuous water quality monitoring described in the research agenda — and provides the clearest demonstration of what can go right.

TECHNOLOGY SPOTLIGHT

Each unit (Boreal Light SaltLab and similar) included an on-site PLC control panel with a graphical dashboard and a parallel online dashboard. Monitored parameters covered feed and booster pump voltage (~618 V), feed/booster temperature (47/52°C), frequency (44/40 Hz), motor current (27.9 A), system pressure (13.94 bar), electrical conductivity of permeate (78.9 µS/cm), and cumulative raw and clean water production (m³ and L). The dashboard included visual indicators and an alarm banner (“ALARM! Check pressure, EC or antiscalant”) that flagged out-of-range conditions in real time. EC monitoring on the permeate line is, in effect, a continuous water-quality measurement.

LESSONS LEARNED

1. Technology and service innovations

Continuous operational telemetry detected anomalies — pressure shifts, conductivity excursions, low antiscalant — before they degraded output water quality or damaged the membranes. This is a direct, in-field demonstration of the value that the global research agenda hypothesizes for low-cost chlorine and microbial sensors in low-resource settings: sensors that are cheap relative to the cost of a failure pay for themselves when they catch problems early, even if the cost-effectiveness frame is still under-evidenced in the literature.

2. Data and information systems

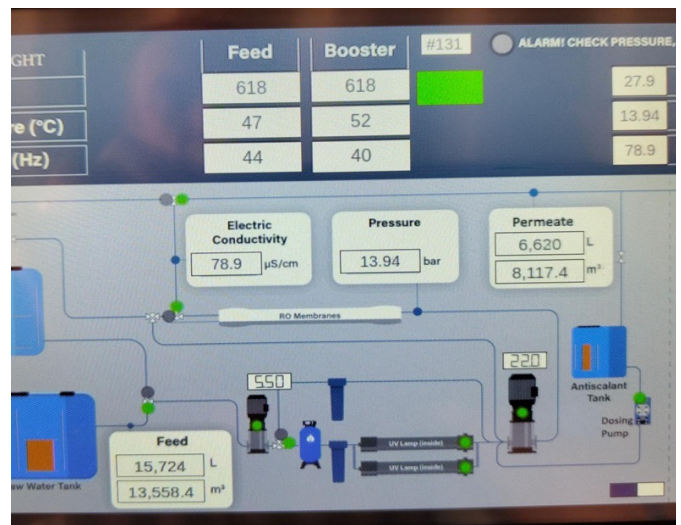
A two-tier architecture — operator-facing local control panel plus a remote/online dashboard — let local staff act on real-time data while managers and engineering advisors retained portfolio-wide oversight. This is a useful architectural pattern for the rural water sector: a single dashboard rarely meets the needs of both operators and regulators, and treating local action and central oversight as two distinct interfaces avoids the trap of building a dashboard that no one uses.

3. Capacity development

Even with rich data, Oxfam found that analyzing it and acting on it required significant staff time, and that a realistic time horizon was needed to introduce, test and institutionalize new technology. The “technology will never be a substitute for getting the basics right” framing from the broader Oxfam experience applies here too: continuous monitoring of desalination units delivered value because there was a maintenance regime, an operator workflow, and an engineering team to escalate to. Sensor-based water quality monitoring programs should plan for that same supporting cast from the start.



Reverse-osmosis desalination skid inside a containerized unit, with pre-filtration, RO membranes, pumps and dosing equipment. *Credit: Oxfam.*



Boreal Light control panel dashboard showing feed/booster voltage and temperature, frequency, current, pressure, permeate conductivity, and cumulative production volumes. *Credit: Oxfam.*



Installation is Just the Beginning

Lessons from Remote Monitoring Drinking Water Systems Across Seven Countries

Derek Chitwood, *Water Mission*

CONTEXT

Water Mission was contracted by UNICEF to install approximately 50 remote monitoring systems in seven countries: Madagascar, Iraq, Chad, Uganda, Rwanda, Mauritania, and Malawi. The sensors attached to the remote monitors included water meters to measure water production from boreholes, groundwater level sensors to assist in estimating changes in aquifer capacity and measure drawdown during pumping, and conductivity meters to monitor changes in the mineral content of the aquifer. Installations were carried out in 2022 and 2023. In each country, Water Mission staff traveled to a few sites and worked alongside contractors to complete the initial installations, with the goal of training them to complete the remaining installations, make necessary repairs, and visualize and download data.

TECHNOLOGY SPOTLIGHT

The remote monitoring systems used were version 3 of the SonSet Link system, which internally Water Mission called the SatWater Communicator. The SatWater Communicator had one pulse water meter input and three 4 – 20 mA sensor inputs. In all installations except in Iraq, the groundwater level sensor used was the OTT PLS with 4-20mA output. The PLS has a pressure-compensating capillary tube. This venting allows accurate measurements with changes in barometric pressure. Except for the installations in Chad, the PLS was installed in production wells directly above the pump, allowing measurement of both the static water level, recorded automatically at night when the solar pumps were off and the water level returned to the initial water table, and the dynamic water level, recording the lowest groundwater level throughout pumping of the borehole during the day. In Iraq, because of the extreme depth to groundwater, the groundwater level sensor used was an Eno Scientific

Well Watch 670, which uses sound waves to accurately measure the depth to groundwater. The conductivity sensor used was a GF Signet 2850. This was installed in series with the water meter at each site. Initially, the data for all our remote monitoring systems was on a proprietary platform, but now this and all of Water Mission's remote monitoring systems are integrated into mWater.

LESSONS LEARNED

1. Installation to Operation and Maintenance

One of the key takeaways from the installations is clarity about the need for maintenance and repairs to be expected and included in the budget. Remote Monitoring systems are complex and, like any equipment, they must be installed correctly and maintained over the years of operation. Many of the systems installed by the contractors never worked, and others have failed, sometimes simply because the batteries in the SatWater Communicator died and need to be replaced, but have not been.

2. Ongoing Operations and Maintenance

Another lesson is that, whether working with large organizations or through our own offices, there needs to be a person in each office whose responsibility is to maintain the remote monitoring system, and funding must be available for maintenance. We found some UNICEF staff very engaged and even doing repairs themselves, while others did not have time to follow up after the consultants completed the initial installations, leading to several remote monitoring systems never working properly.



After installing our first system in Madagascar. Credit: Derek Chitwood.



After the first installation, training the local UNICEF staff about its operations and maintenance. Credit: Derek Chitwood.

3. Groundwater Level Sensors

One final takeaway is that groundwater level sensors in contact with water need regular maintenance or simpler systems need to be installed. While vented pressure level systems make installation relatively simple, due to a lack of maintenance, most of the capillary tubes have come to be plugged, making the data inaccurate. An alternative system would include a non-vent pressure level sensor and a second pressure sensor installed at the surface to measure changes in barometric pressure. Of course, an even better system for groundwater measurements is to use a well sounder such as Eno Scientific's Well Watch.

This has no contact with the water, and it will not experience the same scaling issues seen on the PLS. That said, regular maintenance, at a minimum of every six months, must be conducted to verify that the instrument is working properly and providing accurate values.



Water ATMs

Smart dispensing as a governance and service-delivery tool

Brian McSorley, *Oxfam in Uganda, Kenya, Zimbabwe and South Sudan*
Contributed to the TWG on sensor-based drinking water quality monitoring

CONTEXT

Across humanitarian and urban-poor contexts, Oxfam has deployed prepaid Water ATMs — RFID or token-activated dispensers fitted to community tap stands — to bring digital metering, fairer pricing, and a sustainable revenue stream to communities that have historically relied on either free, unmetered water or unregulated vendor markets. Sites have included the Kyaka II refugee settlement in Uganda, informal settlements in Nairobi, urban Harare, and Juba in South Sudan, each with markedly different water systems, payment behaviors, and operator capacity.

The promise of the technology was twofold: tighter governance of who consumes water and at what price, and a continuous digital data stream on dispense events that could underpin tariff setting, leak detection, and accountability to users. The reality, captured in Oxfam's 2023 internal performance review of Water ATMs and smart water devices, has been more uneven, and offers some of the most directly transferable lessons in the deck for the TWG's research agenda on sensor-based water quality monitoring.

TECHNOLOGY SPOTLIGHT

Sites used a mix of vendor systems — Susteq RFID/keycard dispensers and Lorentz-branded smart taps among them — typically integrated with solar power, prepaid cards or tokens, and back-end software for tariff configuration and event logging. Hardware ranged from purpose-built outdoor cabinets at single tap stands to multi-tap manifolds serving busy collection points. Capital costs per unit were modest, but lifetime costs — spare parts, calibration, vandalism repair, software licenses, and staff time — were not consistently tracked across sites.

1. Technology and service innovations

Oxfam's performance review documented uneven outcomes: units that worked well at some sites, broken or stockpiled devices at others, and installations that were eventually abandoned. The technology worked in principle but did not always work in practice, and the gap was usually about product fit and post-installation support rather than the sensor or controller itself. The directly transferable lesson for low-cost chlorine and microbial sensors is that pilot-stage performance is a poor predictor of scaled performance unless a maintenance and spare-parts pathway is built in from day one.

2. Capacity development

Where Water ATMs were sustained, user, community and institutional buy-in mattered more than the device specification. Communities that understood the tariff logic, trusted the water source, and had local champions or operators continued to use the system. Those communities that did not share this understanding, did not use the system. This suggests that future water quality sensor deployments should treat community engagement and operator training as core line items in the budget, not as add-ons.

3. Governance and financing

The use of multiple vendor platforms across sites made it effectively impossible to consolidate data into a single view of performance, cost-per-litre, or revenue across the portfolio. Total cost of ownership was rarely tracked over the device lifetime. Both findings echo gaps named in the global research agenda: donor-driven technology fragmentation that undermines interoperability, and a near-complete absence of total-cost-of-ownership evidence for sensor-based monitoring in low-resource settings.

Further detail in Oxfam's public performance review: oxfamwash.org/performance-review-of-water-atms-and-smart-water-devices-in-oxfam-programmes



Community tap stand Water ATM, Kyaka II refugee settlement, Uganda (Nov. 2019). *Credit: Oxfam.*



Bank of Water ATMs at a community collection point in Harare, Zimbabwe. *Credit: Oxfam.*