International Water Management Institute

207

Working Paper

State of Water Quality Monitoring and Pollution Control in Africa: Towards Developing an African Water Quality Program (AWaQ)

Patience Mukuyu, Nilanthi Jayathilake, Moshood Tijani, Josiane Nikiema, Chris Dickens, Javier Mateo-Sagasta, Deborah V. Chapman and Stuart Warner

Working Papers

The publications in this series record the work and thinking of IWMI researchers, and knowledge that the Institute's scientific management feels is worthy of documenting. This series will ensure that scientific data and other information gathered or prepared as a part of the research work of the Institute are recorded and referenced. Working Papers could include project reports, case studies, conference or workshop proceedings, discussion papers or reports on progress of research, country-specific research reports, monographs, etc. Working Papers may be copublished, by IWMI and partner organizations. Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI staff. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

About IWMI

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 15 countries and a global network of scientists operating in more than 55 countries.

IWMI Working Paper 207

State of Water Quality Monitoring and Pollution Control in Africa: Towards Developing an African Water Quality Program (AWaQ)

Patience Mukuyu, Nilanthi Jayathilake, Moshood Tijani, Josiane Nikiema,
Chris Dickens, Javier Mateo-Sagasta, Deborah V. Chapman and Stuart Warner

International Water Management Institute (IWMI)
P. O. Box 2075, Colombo, Sri Lanka

The authors:
Patience Mukuyu was Researcher – Transboundary Water Management at the International Water Management Institute (IWMI), Pretoria, South Africa, at the time this study was conducted; Nilanthi Jayathilake is Researcher – Septage Management and Reuse at IWMI, Colombo, Sri Lanka; Moshood Tijani is Senior Policy Officer – Water Resources Management at African Ministers' Council on Water (AMCOW), Abuja, Nigeria; Josiane Nikiema is Professor in the Department of Construction Engineering at the University of Québec, Canada. She was Research Group Leader - Water Pollution and Circular Economy at IWMI, Accra, Ghana, at the time this research was conducted; Chris Dickens is Principal Researcher - Ecosystems at IWMI, Colombo, Sri Lanka; Javier Mateo-Sagasta is Senior Researcher and Coordinator – Water Quality at IWMI, Colombo, Sri Lanka; and Deborah V. Chapman and Stuart Warner are independent consultants based in Ireland.

Mukuyu, P.; Jayathilake, N.; Tijani, M.; Nikiema, J.; Dickens, C.; Mateo-Sagasta, J.; Chapman, D. V.; Warner, S. 2024. *State of water quality monitoring and pollution control in Africa: towards developing an African Water Quality Program (AWaQ)*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 44p. (IWMI Working Paper 207). doi: https://doi.org/10.5337/2023.216

/ water quality / monitoring / assessment / water pollution / pollution control / mitigation / capacity development / training / laboratories / wastewater treatment / water reuse / domestic wastes / industrial wastewater / agricultural pollution / groundwater / pollutants / water security / Sustainable Development Goals / Goal 6 Clean water and sanitation / water, sanitation and hygiene / regulations / policies / frameworks / surveys / Africa /

ISSN 2012-5763
e-ISSN 2478-1134
ISBN 978-92-9090-953-8

Please send inquiries and comments to IWMI-Publications@cgiar.org

A free copy of this publication can be downloaded at:
https://www.iwmi.org/publications/iwmi-working-papers/

Acknowledgments

The authors acknowledge funding from the CGIAR Initiative on NEXUS Gains for conducting this research study. Additional funding came from the World Water Quality Alliance (WWQA) of the United Nations Environment Programme (UNEP), which oversees the periodic World Water Quality Assessment and contributes to an understanding of emerging water quality issues around the world. Furthermore, the authors would like to thank the African Ministers' Council on Water (AMCOW) for their collaboration and guidance in the design of the framework for an African Water Quality Program (AWaQ). As the original survey was conducted in 2021, data might have changed since then.

Collaborators

International Water Management Institute (IWMI)

African Ministers' Council on Water (AMCOW), Abuja, Nigeria

Donors

This work was carried out under the CGIAR Research Program on Water, Land and Ecosystems (WLE) and finalized under the CGIAR Initiative on NEXUS Gains, which is grateful for the support of CGIAR Trust Fund contributors (https://www.cgiar.org/funders/).

World Water Quality Alliance (WWQA) of the United Nations Environment Programme (UNEP)

Contents

Acronyms and Abbreviations

AMCOW	African Ministers' Council on Water
APAGroP	AMCOW Pan-African Groundwater Program
AWaQ	African Water Quality Program
FAO	Food and Agriculture Organization of the United Nations
GEMS/Water	Global Environment Monitoring System for Freshwater
IIWQ	International Initiative on Water Quality
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme for Water Supply, Sanitation and Hygiene
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
WASSMO	Water and Sanitation Sector Monitoring and Reporting System
WHO	World Health Organization
WSP	Water safety plan
WWQA	World Water Quality Alliance

Summary

Responding to water pollution challenges on the African continent requires concerted efforts across various sectors and actors. The African Ministers' Council on Water (AMCOW) envisages an African Water Quality Program (AWaQ) to accelerate the continent's water security agenda. The design of this program, supported by the International Water Management Institute (IWMI), involves five phases taking place during the 2021-2022 period and resulting in the main output of a framework for AWaQ. This paper covers the first two of these five phases, which are designed to provide a baseline assessment of the status of water quality monitoring and assessment in Africa, including the capacities available across countries. This assessment considers various past and ongoing initiatives related to water quality monitoring and assessment, capacity development, and water pollution control and impact mitigation. While the initiatives presented here are not exhaustive, they do provide a starting point for understanding the state of water quality monitoring—the available capacities and the pollution control measures currently implemented—and how AWaQ can be designed to fill gaps and strengthen ongoing initiatives.

The findings discussed in this paper are based on literature reviews, remote interviews and a continent-wide survey (AMCOW-IWMI Africa-wide Survey) implemented to better understand the water quality situation in various countries. Although there are variations across countries in terms of the available capacities for water quality monitoring and assessment and pollution control, water pollution remains a critical challenge that provides an impetus for AWaQ. The survey was rolled out across Africa through the AMCOW network of African country representatives. Thirty-one out of 54 countries responded to the survey, offering their inputs on different water quality-related aspects.

The key findings from this survey are given below:

- There is an encouraging availability of national water testing laboratory facilities across African countries. Nonetheless, there are weaknesses that require attention to ensure effectiveness and sustainability.
- Regular and ongoing training is needed to keep up with laboratory testing methodologies. However, we observed a low trend in regular training, which does not augur well for keeping abreast of the best practices in water quality monitoring. In the context of emerging pollutants, training needs to be more regular than is currently experienced.
- Water quality monitoring and assessment capacities are patchy. Capacities related to staff training, laboratory infrastructure and monitoring program activities need strengthening.
- Pollution control mechanisms are facing challenges. Regulatory mechanisms and wastewater treatment technologies—the most widely deployed pollution control solutions—may benefit from more concerted investment and the political will and financing to boost their effectiveness.

We observed that several initiatives are currently being implemented at different scales: (i) global (e.g., Global Environment Monitoring System for Freshwater [GEMS/Water], World Water Quality Alliance [WWQA], Water Safety Plans [WSPs]); (ii) continental (e.g., AMCOW Pan-African Groundwater Program [APAGroP], Water and Sanitation Sector Monitoring and Reporting System [WASSMO]); (iii) transboundary (through basin organizations); and (iv) national programs. However, the coverage of these initiatives is not even and could benefit from greater regional coordination. There is scope for the envisaged AWaQ to fill the gaps seen in these monitoring initiatives by increasing coverage in participating countries and strengthening monitoring systems that generate water quality data.

State of Water Quality Monitoring and Pollution Control in Africa: Towards Developing an African Water Quality Program (AWaQ)

Patience Mukuyu, Nilanthi Jayathilake, Moshood Tijani, Josiane Nikiema, Chris Dickens, Javier Mateo-Sagasta, Deborah V. Chapman and Stuart Warner

Introduction

Background

In 2016, the United Nations Environment Programme (UNEP) presented a 'snapshot' of global water quality (UNEP 2016). Key findings from that report indicate an increasing threat to and observed deterioration in water quality across the world's rivers, including those in Africa. As the world's second-driest continent, having only about 9% of global freshwater resources while being home to about 15% of the world's population—which is expected to rise to 21.8% by 2050—the availability of and access to water are more crucial in Africa than they are almost anywhere else on Earth (UNEP 2010; UN DESA 2014). Coupled with anthropogenic pressures, most parts of Africa are projected to experience growing impacts of climate change on water quality associated with increased temperatures, prolonged drought periods and flash floods. It is now urgently necessary to strengthen water quality monitoring efforts in order to mitigate impacts such as increased pollutant concentrations when water flows decrease during drought periods as well as acceleration of chemical reactions in warmer waters, among other adverse impacts (Whitehead et al. 2009; IPCC 2021). While water quality, either directly or indirectly, is a key consideration for many of the 17 Sustainable Development Goals (SDGs) set by the United Nations, it has particular relevance to SDG 6: to ensure availability and sustainable management of water and sanitation for all. Further, SDG target 6.3 mainly aims at improving water quality, and indicator 6.3.2 measures whether and to what extent water quality management measures are contributing to improvement of water quality over time.[1] Having a clear grip on water quality monitoring and pollution control will enable the continent to achieve its developmental goals of improved access to clean water and sanitation.

However, sanitation systems in Africa do not adequately address waste containment, disposal and treatment so as to separate waste from human contact. This presents the risk of spreading disease to local communities as well as polluting groundwater and surface water resources (UNICEF and WHO 2020). As of 2017, close to 70% of the continent's population, mainly in sub-Saharan Africa (SSA), did not have access to basic sanitation services, a situation that poses a threat to water quality and, consequently, risks to human health (AfDB, UNEP and GRID-Arendal 2020). Most of the rural population in Africa is exposed to risk of disease from contaminated water due to direct dependence on untreated sources (e.g., rivers and streams). Recent estimates indicate that 7% of urban dwellers and 27% of rural people in SSA rely on unimproved water sources (WHO and UNICEF 2017). According to the United Nations Department of Economic and Social Affairs (UN DESA), there are 115 deaths every hour in Africa due to diseases linked to poor sanitation, poor hygiene and contaminated water (UN DESA 2014). It has been reported that "poor people in Africa spend at least a third of their incomes on treatment for water-related diseases such as malaria and diarrhea" (Sanctuary et al. 2007, 13). Up to 160 million people living in the rural areas of the continent are estimated to come into close contact with polluted water through daily activities such as bathing (UNEP 2016). In urban areas too, rapidly growing and urbanizing populations could overwhelm the capacity to provide wastewater treatment and sanitation services (AfDB, UNEP and Grid-Arendal 2020).

It is estimated that low- and middle-income countries—which include the majority of African countries—treat approximately 28% of their domestic and industrial wastewater. However, there are important disparities among subregions (WWAP 2017). Often, industrial wastewater treatment technologies fall short of achieving acceptable wastewater quality levels, which leads to the discharge of partially treated industrial water. Given the limited regulatory capacities, much of this pollution goes unregulated for prolonged periods. Diffuse pollution from agricultural return flows and runoff increases the nutrient load in water bodies, resulting in cases of eutrophication and anoxic conditions that hamper ecosystem functions (WWAP 2017).

Several interventions have been implemented with varying degrees of success to address the challenge of water pollution in Africa. Conventionally, at the national level, these have included regulatory mechanisms including licensing of polluters, environmental impact assessment of potentially harmful activities and wastewater treatment. However, water quality monitoring and pollution control measures have been constrained by the common challenges

[1] https://sdg.tracking-progress.org/indicator/6-3-2-proportion-of-bodies-of-water-with-good-ambient-water-quality/

of limited financial and human resource capacities (AfDB, UNEP and GRID-Arendal 2020). At the regional scale, such interventions have been implemented at the transboundary and subregional levels by various international actors. Indeed, there exists an opportunity to develop a continent-wide initiative cutting across the multiple aspects of monitoring water quality and mitigating pollution. Well-designed and robust ambient water quality monitoring programs can provide the basis for interventions and timely responses to emerging and existing pollution issues as well as informing long-term planning.

Against this background, we present here a paper on the status of water quality monitoring and pollution in Africa and discuss the foundations of a new African Ministers' Council on Water (AMCOW) African Water Quality Program (AWaQ). The first two phases of the project that IWMI has undertaken involve carrying out a situation analysis of water quality monitoring in Africa, describing the efforts thus far to manage deteriorating water quality. In the subsequent three phases of the project, research innovations that could be included to advance water quality management in Africa are presented. They will form part of the design of a new framework for the monitoring and management of water quality. The key output of this project will be a framework for developing AWaQ which will assist AMCOW in expanding and strengthening water quality monitoring and management across the continent.

The project's key outcomes will enable the establishment of a working program for monitoring and managing water quality that can be adopted by African countries, bringing them up to a similar level of water quality monitoring. The program will also enable Africa to participate meaningfully in the World Water Quality Alliance (WWQA) to scrutinize a multitude of water quality issues. Further, it will promote a continent-wide initiative to collect and provide data to larger repositories such as the Global Environment Monitoring System for Freshwater (GEMS/Water). Ultimately, an Africa-wide program will be initiated to manage water quality for the benefit of the environment and all of its inhabitants.

Towards the AWaQ Program

AWaQ aims to build on the rich experience gained and lessons learned from past and ongoing regional and subregional water quality initiatives taken up across Africa by different players including the African Union institutions and the broader members of the WWQA. For example, the new program is designed to build on existing AMCOW initiatives such as the Water and Sanitation Sector Monitoring and Reporting System (WASSMO). Among the WASSMO indicators, AWaQ addresses Indicator I-4.3(a-d)[2] (closely aligned to SDG Indicator 6.3.2)—'proportion of bodies of water with good ambient water quality'—and is based on data collected from AMCOW member states. AWaQ will also take into account other water quality initiatives, e.g., the AMCOW Pan-African Groundwater Program (APAGroP), in which the International Water Management Institute (IWMI) and other partners are strongly involved in support of AMCOW's groundwater management efforts.

It is important to review related initiatives to understand how a new program can be designed to add much-needed value and introduce complementarity in Africa's water quality management efforts. In addition, there is scope for linkages with ongoing initiatives and opportunities for identifying how other key institutions can contribute to different components of the program. Keeping that perspective in mind, this review is based on literature, secondary data and remote interviews conducted with key informants.

The work carried out under AWaQ has been conceptualized in five phases (Figure 1). The first two phases (this paper) assessed in 2021 past and existing initiatives and capacity for water quality monitoring and management in Africa. Phases 3 and 4 (Mukuyu et al. 2024a) analyzed in 2022 potential innovations in ambient water quality monitoring and management that AWaQ should consider. Finally, in phase 5, a framework for AWaQ was developed in 2023 and finalized in 2024 (Mukuyu et al. 2024b).

The water quality-related initiatives assessed include programs to monitor pollution loads, water quality degradation of both surface water and groundwater and associated impacts as well as programs put in place to control pollution and mitigate risks in alignment with the Drivers, Pressures, State, Impacts and Response (DPSIR) framework (Figure 2).

In this paper, we take a closer look at the African context, detailing initiatives undertaken to monitor water quality and pollution and to control and mitigate water pollution, including initiatives on wastewater reuse (phases 1 and 2 in Figure 1). Our aim is to map the status quo and identify areas of interest for a new African Water Quality Program (AWaQ) that can advance improved water quality monitoring and pollution control across Africa. A framework for AWaQ will allow for the formulation and rollout of a detailed operational program that will benefit African Union member states under the direction of AMCOW, and bring member states up to a shared state of readiness.

[2] https://www.africawat-sanreports.org/Ui/core-indicators-table

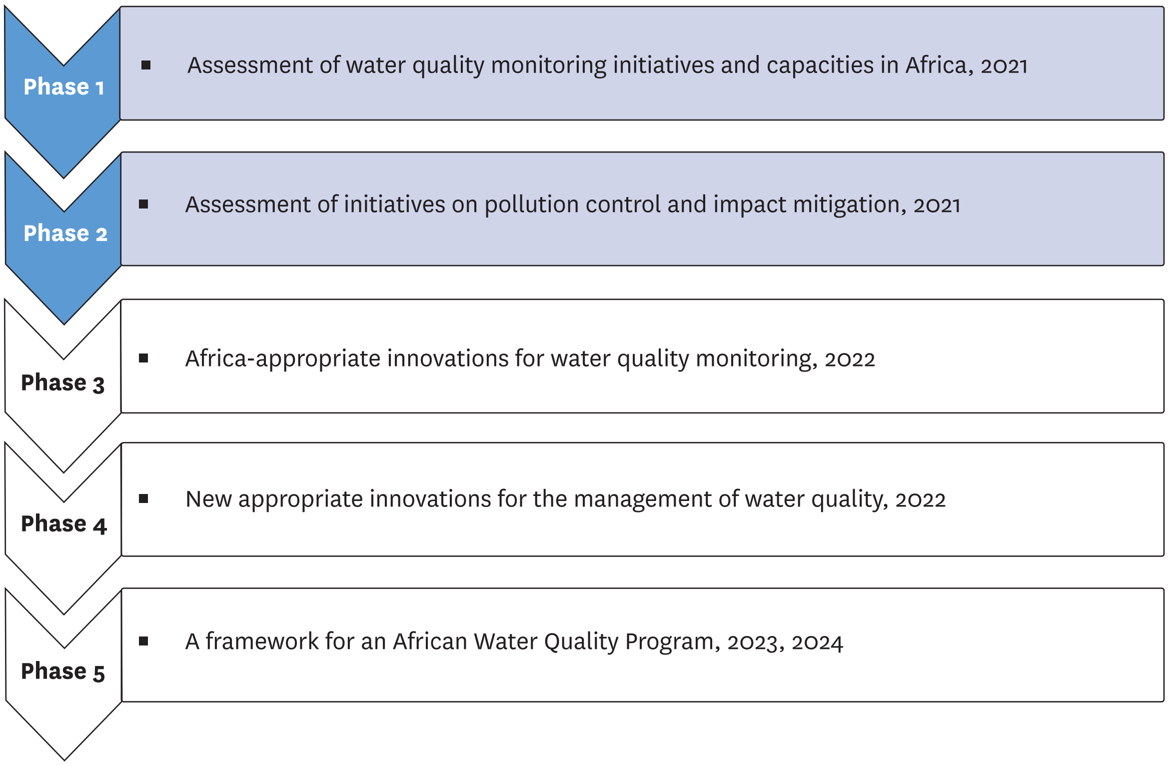


Figure 1. Five phases in the development of a framework for an African Water Quality Program.

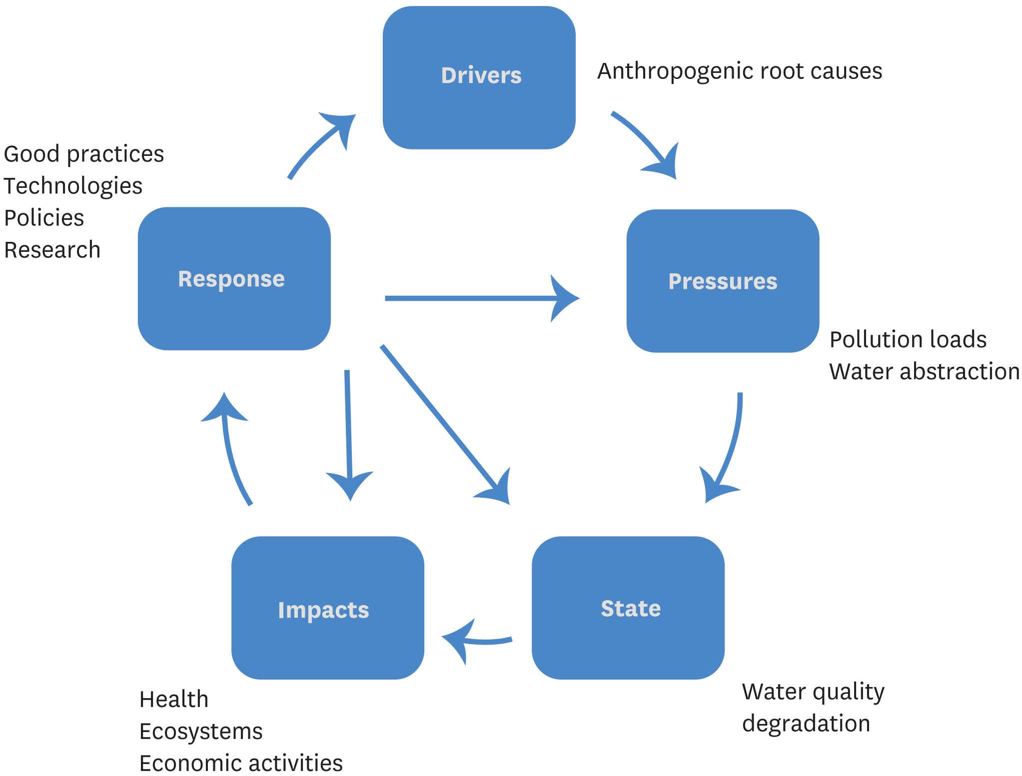


Figure 2. The DPSIR framework for the development of AWaQ.
Source: Mateo-Sagasta et al. 2018.

In subsequent sections of this paper, we present water quality monitoring initiatives operational at regional and subregional levels across the continent as well as examples from individual countries. The approach we used took four main forms:

- A review of the status of water quality monitoring and analytical capacities across African countries based on a continent-wide survey (Annex A).
- A desktop review of available literature at global, regional, transboundary and national scales with specific focus on water quality monitoring, pollution control and mitigation in Africa.
- An analysis of survey data to identify priority pollutants.
- A synthesis of country water quality profiles based on the data gathered and the literature reviewed (e.g., refer to Annex B for the water quality profile for Kenya).

Water Quality Monitoring and Assessment Capacity in Africa

As water is critical to human existence by supporting vital socioeconomic and ecological processes, monitoring its quality is essential to ensure the sustained functioning of these processes. Water quality monitoring provides the data needed to assess conditions and take informed decisions to mitigate impacts (Bartram and Ballance 1996). In more specific applications, information about water quality is essential to guide our efforts to reduce incidence of waterborne illnesses, identify high-risk water sources, determine effective water treatment methods, and contribute to the evaluation of water and sanitation improvement programs (Peletz et al. 2018). According to the International Organization for Standardization, water quality monitoring can be defined as the "programmed process of sampling, measurement and subsequent recording or signalling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives" (ISO 2021). The success of the envisioned AWaQ would require a solid foundation of water quality monitoring and assessment.

This section summarizes the water quality monitoring and assessment capacities available in African countries, in particular the critical components of water quality monitoring programs such as field sampling, laboratory testing and data interpretation. We draw upon past assessments and inputs from a continent-wide survey rolled out as part of this project.

AMCOW-IWMI Africa-wide Survey

The survey was designed to capture data on key contaminants, the water quality testing and monitoring capacities of African countries, and the existing pollution control mechanisms. The following sections summarize the results obtained across 31 countries.

Survey Dissemination

Between July and September 2021, the survey was disseminated through the AMCOW Secretariat to country representatives directly involved in water quality-related activities within national government departments. The same survey was also shared more broadly through network contacts and social media platforms specifically targeted at water quality practitioners. A French version was made available for dissemination in French-speaking African countries. There were 44 questions in the survey (see Annex A) to assess different aspects of water quality monitoring including human and technical capacities and testing facilities as well as key pollutants, sources and impacts.

Geography and Demographic Insights

Responses were received from different regions of the continent but there was little representation from island states such as the Comoros, Cape Verde, Madagascar and Seychelles. Overall, 31 countries took part in the survey (Table 1; Figure 3).

There was a greater proportion of males (84%) than females (16%) among the respondents. About 48% of the respondents were government officials; the remainder were distributed across private, academic and transboundary institutions. Registering government officials' perceptions in the survey was key in obtaining an informed national perspective on water quality.

Notes on Interpreting Survey Results. Some points to consider when interpreting the survey results:

- While responses were received from 31 (56.3%) of the 55 countries in Africa, the results do provide a good starting point for deducing the current status of water quality monitoring and management on the continent.
- There were multiple unique responses from 13 (42%) of the 31 countries that responded to the survey while the remainder had only one respondent each. Responses were averaged across respondents from the same country to generate a consolidated country perspective.

Table 1. Countries that participated in the AMCOW-IWMI Africa-wide survey.

Region	Participating countries
North Africa	Algeria, Egypt, Tunisia
East Africa	Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Tanzania, Uganda
West Africa	Benin, Cote d'Ivoire, Ghana, Liberia, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Gambia, Togo
Central Africa	Cameroon, Chad, Democratic Republic of Congo
Southern Africa	Botswana, Malawi, Mauritius, Mozambique, South Africa, Zambia, Zimbabwe

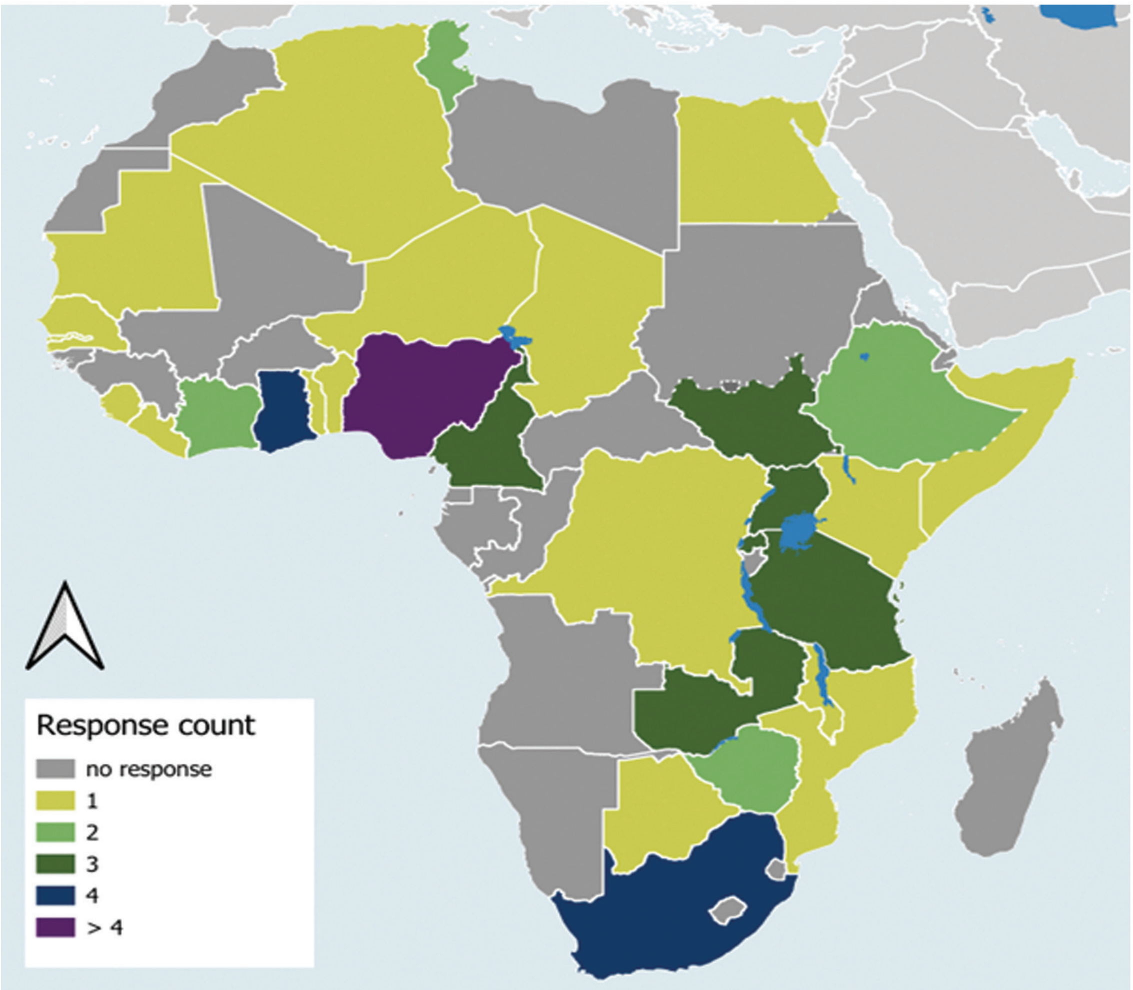


Figure 3. Number of responses received from participating countries.

Key Insights from the Survey

The survey revealed limitations in laboratory staff capacities, laboratory equipment and reagents, standardization and accreditation of laboratories, and proper mechanisms for data processing and interpretation. In addition, the survey identified proper coordination and cooperation among the relevant agencies, proper data management including establishing data sharing platforms and reporting mechanisms, and adequate funding as the most important needs in order to enhance water quality monitoring capacities. The following section provides some insights from the survey.

Capacity in water quality monitoring activities

The survey results showed that much of the training received by individuals engaged in water quality monitoring was related to field water sampling, water quality data processing and interpretation, laboratory water analysis and wastewater treatment (Figure 4). The majority of respondents (94%) said they received training as part of a university or college course, while 68% received it as part of a one-off certification program, and 58% indicated that they received ongoing regular training. It should be noted that some individuals received more than one type of training.

The survey also found that 55% of the countries that responded to the survey perceive the technical capacity of their laboratory personnel as adequate (Figure 5)—personnel able to carry out all roles satisfactorily—followed by 29% that described it as average—meaning that personnel are able to perform only some of the technical roles. Only 6% of the countries saw their staff as lacking the required capacities to conduct water quality monitoring-related activities such as field water sampling and laboratory testing.

Laboratory capacity

The survey found that water testing laboratory facilities were available in 90% of the participating countries with 68% of them stating that they were accredited laboratories. In 84% of the countries, some form of national-level registration was required to operate a laboratory. Some 48% said that their laboratories were equipped but not able to carry out all the analyses, while 23% indicated that their labs were underequipped for basic water quality analyses (Figure 6).

As for monitoring of water resources, the survey found that in 32% of the participating countries, institutions were underequipped for that task, while in 45%, institutions were equipped only for monitoring priority resources. Some 32% of the countries said they lack capacity, for example, in the form of vehicles and equipment to monitor water quality (Figure 7).

Some 19% of the participating countries reported that they have inadequate capacities to deal with the task of processing and interpreting water quality data in detail while 58% reported that they were able to process and interpret most water quality data. A further 23% reported above-average capacity and ability to interpret water quality data in detail.

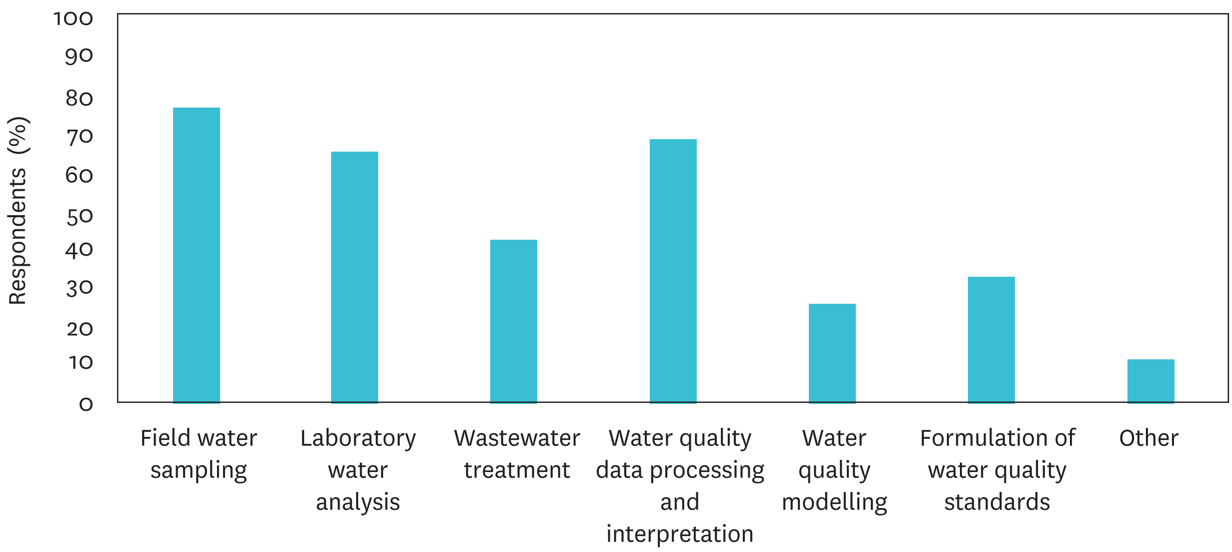


Figure 4. Summary of training received by survey respondents.

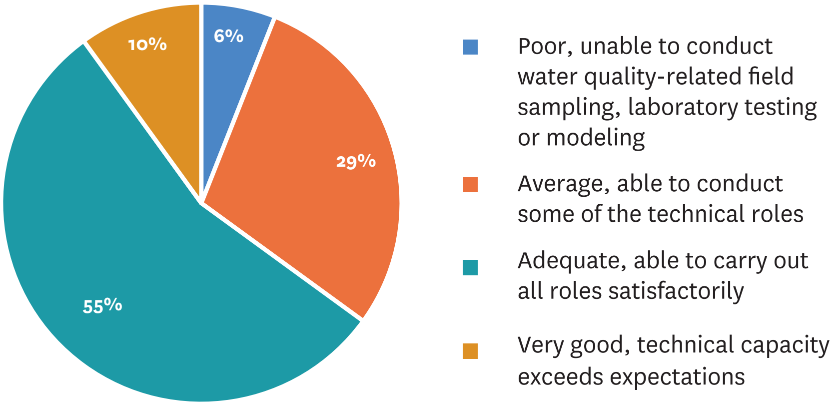


Figure 5. Technical capacities of laboratory staff.

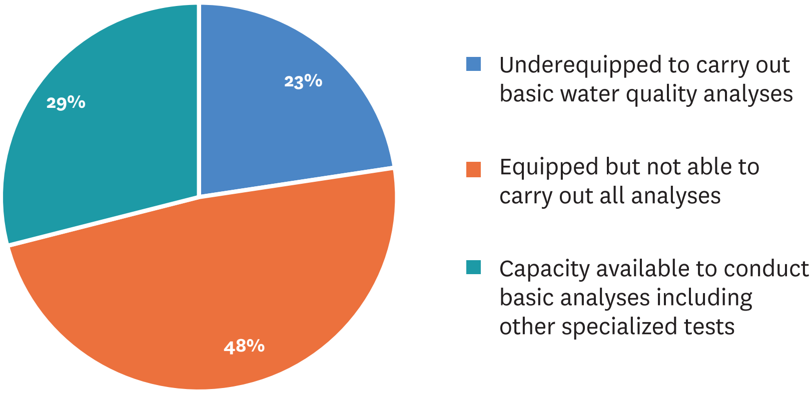


Figure 6. Laboratory testing capacity for water quality analyses.

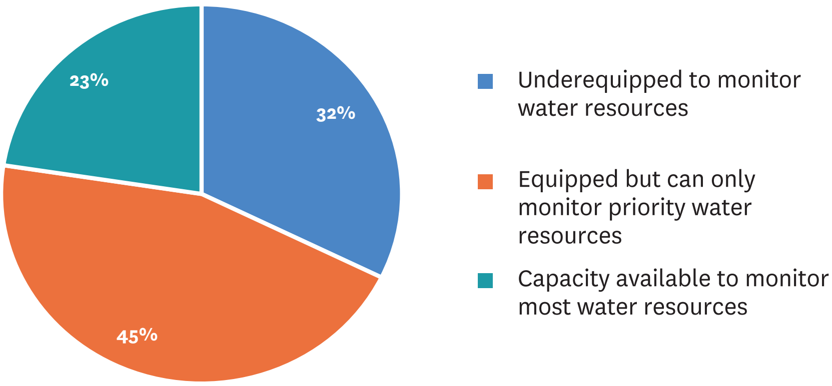


Figure 7. Technical capacities to monitor water quality.

GEMS/Water Capacity Development Centre Scoping Exercise

According to the capacity development scoping exercise conducted by GEMS/Water across 29 African countries, only two, South Africa and Rwanda, reported high scores on monitoring program design (UNEP GEMS/Water CDC 2020). Overall, across eight indicators for assessing technical capacities needed for water quality monitoring and assessment,[3] only South Africa, Kenya, Rwanda, Tanzania, Uganda and Nigeria scored more than 60%. These results highlight the capacity gaps that exist in Africa across different aspects of water quality monitoring such as water quality analysis, data management, quality control and field techniques.

The GEMS/Water global assessment of freshwater quality monitoring activities showed that although analytical capabilities were generally good, laboratories did not have sufficient financial or human resources to carry out activities such as quality assurance. Observations from the implementation of the global water quality program showed that there was:

- low confidence in monitoring program design;
- limited monitoring of groundwater resources;
- inadequate quality assurance;
- need for more capacity for data management and data assessment; and
- limited knowledge of alternative approaches to monitoring and assessment of water quality (UNEP GEMS/Water CDC 2020).

Summary of the State of Knowledge on Water Quality Degradation in Africa

Water quality issues are complex. Detailed knowledge of water quality is essential for allocating water to different types of use, and to adequately treat and prevent contamination of water sources. However, data scarcity is a major barrier to adequately address water quality challenges in Africa. It has been reported that the density of water quality measuring stations is one hundred times lower in Africa than elsewhere in the world (UNEP 2018). On the basis of the cost of data from 18 monitoring institutions in SSA, a study in 2017 revealed that monitoring the microbial quality of all improved drinking water sources in the region would cost USD 16 million per year, "which is minimal compared to the projected annual capital cost of achieving SDG 6.1 of safe water for all (USD 14.8 billion)" (Delaire et al. 2017). In spite of the relatively low cost, water quality testing levels in SSA remain unsatisfactory due to institutional, personnel and economic constraints (Delaire et al. 2017).

In the case of transboundary groundwater in Africa, conflicts are often attributed to the lack of information about the boundaries of the physical resource, resource capacity and conditions that impact water quality (AfDB, UNEP and GRID-Arendal 2020).

Key Pollutants and Sources

Mitigation of water pollution is of urgent importance in Africa, as suggested by the high levels of pollution currently being experienced on the continent. Poor sanitation, improper waste disposal practices, shortage of wastewater treatment facilities, malfunctioning of treatment plants, industrial activities, and urban and agricultural runoff are among the key causes of water pollution (see Box 1). Water quality degradation can occur due to different reasons in the urban areas compared to rural areas. While large quantities of pesticides, fertilizer and animal waste contaminate groundwater and surface water in farming areas, unsafe domestic wastes are a critical source of water pollution in the cities due to overcrowding, poverty and low sanitation in precarious neighborhoods (Pare and Bonzi-Coulibaly 2013).

In Africa, according to AfDB, UNEP and GRID-Arendal (2020), domestic, industrial, agricultural and stormwater runoff are the main wastewater streams and foremost in the contribution to pollution (Figure 8).

Data from the AMCOW-IWMI survey showed that petroleum products contribute the least to water pollution in 54% of the countries while sewage and dump sites were major contributors in 58% and 50% of the countries, respectively, followed by agriculture (45%) and industry (48%) (Figure 9).

[3] The indicators included monitoring program design, field techniques, analytical capability, quality assurance and quality control, data management, data assessment, groundwater monitoring and other approaches, e.g., biological (UNEP GEMS/Water CDC 2020).

Box 1. Water Pollution in Africa - A Snapshot.

- Up to a quarter (10-25%) of all river stretches in Africa are affected by severe pathogen pollution, one-seventh by severe organic pollution, and one-tenth by severe and moderate saline pollution.
- The largest source of pathogen and organic pollution is non-sewered sanitation.
- The largest anthropogenic source of saline pollution (load of total dissolved solids) is irrigated agriculture.
- Livestock are an important source of anthropogenic phosphorus seen in major lakes.
- Groundwater pollution has the following order of importance: (1) nitrate pollution, (2) pathogenic agents, (3) organic pollution, (4) salinization, and (5) acid mine drainage.

Sources: UNEP 2016; WWQA 2021.

Wastewater and fecal sludge	Agriculture	Industrial wastewater	Stormwater runoff
• Poor performance of wastewater treatment plants (WWTPs) due to increasing population and wastewater loads • Limited financial and technical capacities for operation and maintenance of WWTPs	• Animal waste, pesticide and nutrient-laden runoff from agriculture add to the pollutant load in surface water and groundwater • Use of wastewater for irrigation may add to the pollution of receiving waters	• Discharge of untreated wastewater directly into rivers and streams • Toxic contaminants from industry insufficiently treated before discharge	• Poor stormwater management practices • Limited regulatory framework for stormwater management

Figure 8. Main wastewater streams and challenges leading to water pollution.
Source: Adapted from AfDB, UNEP and GRID-Arendal 2020.

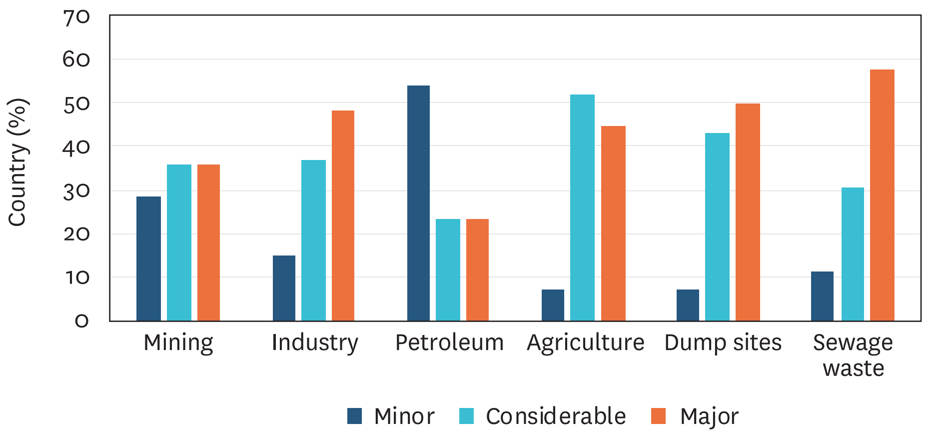


Figure 9. Contribution of various sectors to water pollution in Africa.

Domestic Waste

Data from the most recent World Health Organization (WHO)/United Nations Children's Fund (UNICEF)—Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) show that only 33% of the people in SSA—the lowest proportion compared to the other regions of the world—have at least basic sanitation facilities. Further, SSA has roughly one billion people lacking safely managed sanitation (WHO and UNICEF 2021a). Urban discharge of untreated or poorly treated effluents into water sources has been a major cause of surface water pollution in Africa (Fayiga et al. 2018). It has been estimated that 90% of untreated wastewater in Africa is released directly into rivers, lakes and oceans (WWAP 2017).

Most people in Africa rely on on-site sanitation facilities, which are, if not well-managed, potential sources of pathogens, organic matter and nutrients. It has been reported that only a small fraction of the collected sludge from on-site sanitation systems is treated and a greater percentage of it is indiscriminately disposed, inviting the risk of water pollution and posing a threat to public health.

Solid waste management is a massive challenge in Africa due to the lack of infrastructure for collection, transportation, treatment and disposal, proper solid waste management planning and sufficient financial resources, technical expertise and public awareness. Poorly managed solid waste and its decomposing byproducts find their way into wastewater and freshwater flows through runoff and other means (AfDB, UNEP and GRID-Arendal 2020).

Industrial Wastewater

In addition to domestic wastewater, industrial activity contributes significant amounts of chemical pollutants to Africa's water flows. The typical polluting industries include mining, pulp mills, tanneries, textiles, food and beverage factories, sugar refineries, oil and pharmaceutical production facilities (AfDB, UNEP and GRID-Arendal 2020). Industries contributing to water quality degradation vary from country to country. For example, in southwestern Ethiopia, industrial wastewater discharge from coffee refineries greatly contributes to the deterioration of river water quality (AfDB, UNEP and GRID-Arendal 2020) while in the Niger Delta, oil pollution from the petroleum industry is particularly prolific, with pollution visible in surface water and wetlands (Pare and Bonzi-Coulibaly 2013; Babatunde 2020).

Mining

Mining is one of the most important economic activities in African countries, particularly in Western and Southern Africa (Pare and Bonzi-Coulibaly 2013; Verlicchi and Grillini 2020). Mine water has a negative impact on water resources by increasing the levels of suspended solids, which leads to mobilization of elements such as iron, aluminum, cadmium, cobalt, manganese and zinc, and also a decrease in the pH of the receiving waters (Ochieng et al. 2010). In South Africa particularly, mining has been a major cause of water pollution for decades. For example, the Olifants and Vaal river systems have been severely affected by gold and coal mining. McCarthy (2011) concludes that new mines should probably not be permitted in the catchment areas of the Vaal and other rivers draining the eastern escarpment until economically viable methods are available to prevent pollution or to clean up the pollution that will inevitably be produced.

Agricultural Pollution

Agriculture is the main economic sector in Africa. However, when pesticide and fertilizer use exceeds the assimilation capacity of the agricultural system, it results in runoff with high pollution loads, which ultimately reaches water bodies by way of percolation to groundwater and surface and subsurface flows into streams, rivers and lakes. In addition, livestock production and aquaculture release nutrients too. Agricultural wastewater (from both crop cultivation and livestock production) can contain nutrients, pesticides, salts, sediments, organic matter, pathogens, metals and emerging pollutants (drug residues, hormones, feed additives) that pose a severe threat to water quality in rivers, lakes and aquifers (see Box 2). A case study conducted in three intensive agricultural areas in the Western Cape province of South Africa—Hex River Valley, Grabouw and Piketberg—revealed widespread pesticide contamination, mostly endosulfan, of groundwater, surface water and drinking water sources (AfDB, UNEP and GRID-Arendal 2020). Studies in Burkina Faso also indicated pesticide contamination of water, especially in the cotton-growing areas (Pare and Bonzi-Coulibaly 2013).

Main Impacts of Water Quality Degradation in Africa

Poor water quality has implications for the health of both humans and the environment at large in terms of socioeconomic conditions, ecosystem services and environmental impacts. Impaired access to clean water, impacts on food security and livelihoods, loss of biodiversity, increased water treatment costs and health effects associated with water-related infections are among the major impacts caused by water quality degradation. Table 2 presents a few selected examples from across Africa highlighting the impacts on health, ecosystems and economy associated with water quality degradation.

In addition to causing a variety of tropical diseases such as typhoid, cholera, dysentery and diarrhea, contamination of water sources leads to water scarcity which affects people in other ways. People, in particular women and girls, have to travel long distances to collect water for their households. This has implications for the education of girls. A study covering 24 countries in SSA estimated that 3.36 million children and 13.54 million women were responsible for household water collection requiring collection times greater than 30 minutes (Graham et al. 2016). Access to groundwater is also not without its problems and is often a cause of health issues to users (see Box 3).

Water quality degradation also leads to an increase in the cost of restoring water resources. Human-induced eutrophication is a scenario related to water quality degradation that is commonly observed across Africa. Eutrophication, which is the process of nutrient enrichment and associated excessive plant growth in water bodies, increases the cost of treatment of drinking water and puts pressure on the drinking water supply budgets of African countries (AfDB, UNEP and GRID-Arendal 2020).

The AMCOW-IWMI Africa-wide Survey showed that polluted water resources contribute to overall biodiversity loss in 87% of the countries in Africa followed by eutrophication in 77% and disease (health impacts) in 74% of the countries (Figure 10).

Box 2. **Emerging Pollutants.**

Emerging pollutants produced by pharmaceutical, personal care and household products, and industrial and agricultural chemicals as well as microplastics are known to present a significant challenge to water quality. Verlicchi and Grillini (2020) reported high concentrations of micropollutants such as pharmaceuticals in surface water in rural and peri-urban areas of South Africa and Mozambique. Concentrations of pharmaceuticals such as ibuprofen, acetylsalicylic acid, clozapine and estriol were found to be very high, some of which could be attributed to over-the-counter drugs obtainable without prescription.

An important point to note is that conventional wastewater treatment plants are often not equipped to treat these emerging pollutants; hence the treated effluent can still contain these pollutants. Haddaoui and Mateo-Sagasta (2021) reported that altogether 290 emerging pollutants were detected in different water matrices across the Middle East and North African (MENA) countries, stemming mainly from industrial effluents, agricultural practices and discharge or reuse of treated wastewater with pharmaceuticals, organic compounds and pesticides being the pollutant groups of great concern.

Box 3. **Groundwater Pollution.**

The aggregate volume of groundwater in Africa is estimated to be 20 times higher than the freshwater stored in rivers and lakes (MacDonald et al. 2012) and about 15% of the continent’s total renewable water resources. Close to 75% of Africa’s population relies on groundwater as the major drinking water source (UNEP 2010). However, the water in many shallow groundwater sources is contaminated due to untreated seepage from septic tanks and pit latrines, toxic chemicals from underground storage tanks, leachate from solid waste landfills and acid mine drainage, among others.

A groundwater pollution risk map developed by Ouedraogo et al. (2016) indicated that the northern, central and western parts of Africa are at high risk of pollution due to shallow groundwater systems and activities such as agriculture. Groundwater contamination by nitrates has been reported by recent studies across the African continent except a large part of the Sahara Desert. It has been estimated that 80 million people are affected by fluoride contamination in the East African rift region with more than 13 million people in Ethiopia living in areas with high fluoride risk (WWQA 2021).

In South Africa in particular, it has been reported that groundwater in the mining district of Johannesburg is heavily contaminated by heavy metals (Ochieng et al. 2010). A study that investigated groundwater quality in 42 boreholes in rural and peri-urban South Africa found biological pollution with fecal contamination and high nitrate concentration in a majority of the samples, suggesting that on-site sanitation systems are grossly polluting aquifers (Masindi and Foteinis 2021). Lapworth et al. (2017) discussed cases of groundwater pollution in a number of African countries associated with sanitation (e.g., pit latrines) and non-sanitation (e.g., landfills, industrial) sources.

Table 2. Impacts of water pollution on health, ecosystems and the economy in Africa.

Impacts	Selected water pollution examples from Africa	Reference
Health	Between 100,000 and 200,000 cholera cases are officially reported each year in Africa. A total of 123,986 cases with 3,763 deaths were reported in 2002.	WWAP 2006
	In SSA, exposure to nitrate pollution emanating from upstream urban agglomerations lowers height-for-age scores and increases the likelihood of stunting in children younger than five years. More than 35% of children younger than five years are considered stunted in that region.	WBG 2019
	In some areas of Morocco, prevalence of the blue baby syndrome is higher among infants and children who drink well water with a nitrate concentration >50 mg/L.	AfDB, UNEP and GRID-Arendal 2020
	As pollution in the Akaki River worsened, using untreated wastewater for irrigation purposes increased prevalence of intestinal illnesses among farmers in Addis Ababa.	WWAP 2017; AfDB, UNEP and GRID-Arendal 2020
	Emerging pollutants can potentially cause endocrine disruption in humans and aquatic wildlife, affecting fertility and population survival. Also, they have the potential to cause cancerous tumors and development of bacterial pathogen resistance, including multi-drug resistance.	AfDB, UNEP and GRID-Arendal 2020
Ecosystems, biodiversity	Possible extinction of endemic species (e.g., Cichlid fish in Lake Victoria) due to severe eutrophication and dramatically low dissolved oxygen levels as a result of pollution caused by increased human activities such as discharge of wastes.	AfDB, UNEP and GRID-Arendal 2020
	Around Lake Naivasha in Kenya, biodiversity has been shrinking in recent years, possibly due to the deterioration of water quality caused by fertilizer and pesticide use by commercial rose plantations.	Wang et al. 2014
Economic	Due to the release of raw sewage into the Weija Reservoir, the Ghana Water Company, which operates the Weija drinking water treatment plant, spends close to GHS 40,000 per day (USD 2,000 at the 2011 exchange rate) to treat water drawn from the dam before it is supplied to consumers.	AfDB, UNEP and GRID-Arendal 2020

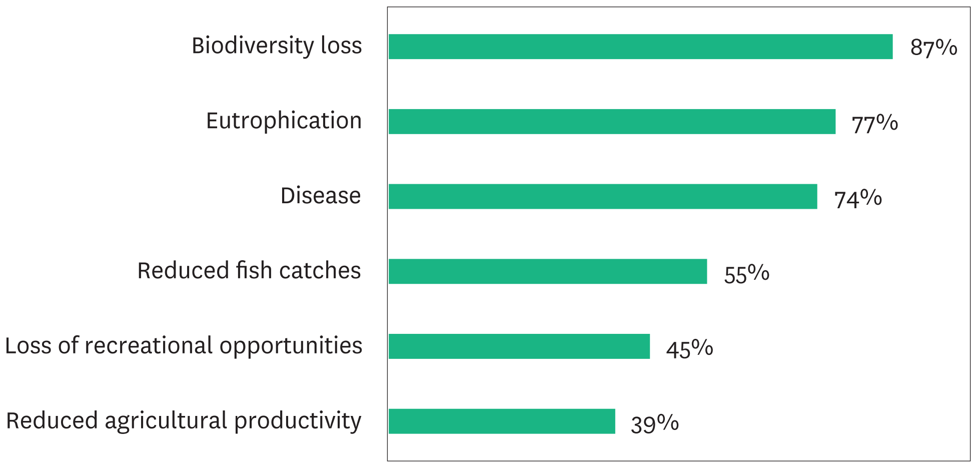


Figure 10. Main impacts of water pollution in African countries.

Continental Policy Framework for Water Quality Monitoring

Despite efforts and interventions introduced to address water and sanitation challenges in Africa, evidence suggests that continual improvement in policy actions and adequate implementation are still required to overcome water quality challenges. In that respect, there have been recent advances in water policies, strategies and institutional arrangements. These include greater awareness of and political commitment to Integrated Water Resources Management (IWRM), increasing commitment to water policy reform and a strong trend toward decentralization of water institutions (UNECA, AUC and AfDB 2003).

African Union

Under the African Union, the African continental policy framework comprises a number of advanced declarations and resolutions to develop and use water resources for socioeconomic advancement, regional integration and environmental sustainability (WWAP 2016). The African Union's Agenda 2063 spells out the aspirations of the continent: among them are prosperity and sustainable development through managing Africa's natural resource base including water (Table 3). Agenda 2063 is implemented through a series of ten-year implementation plans—the current plan covers the period 2013-2023 (AU 2015). It identifies five priority areas that are directly or indirectly linked to water quality: sustainable management of natural resources, ecosystem and biodiversity conservation, water security, sustainable consumption and production patterns, and climate resilience (AU 2015). In addition, the African Union's Africa Water Vision 2025 highlights the growing challenges of pollution across the continent and their impact on human health and ecosystem services (UNECA, AUC and AfDB 2003). This vision, articulated as "an Africa where there is an equitable and sustainable use and management of water resources for poverty alleviation, socio-economic development, regional cooperation, and the environment" (UNECA, AUC and AfDB 2003), demonstrates the continent's focus on continued socioeconomic development in a manner that can be environmentally sustained. One of the indicators in Africa Water Vision 2025 is the reform of water resource institutions to create an enabling environment for IWRM.

While regional, national, legal and institutional frameworks are needed to introduce instruments for economic governance (e.g., fees and taxes), capacity for compliance enforcement needs to be strengthened too. Other interventions such as promoting participatory approaches to include non-state actors, developing information and knowledge on water, and promoting research and capacity development of stakeholders to effectively integrate water quality would augment the current regulatory frameworks (IUCN-PACO n.d.).

National-level Policies

In addition to the continent-level vision outlined above, there are country-specific policies and regulations related to water resources management within which water quality monitoring is a part. Commitments to achieve SDGs have been a key driving force in shaping these policies to include the elements of water quality monitoring. While most countries have water quality management policy frameworks, some of them such as South Africa have a relatively more comprehensive framework. Similarly, African countries do have standards for effluent discharge into surface waters, but data on the extent to which these standards are being enforced are not available (Fayiga et al. 2018). Efforts on the SDG indicator related to tracking IWRM (Indicator 6.5.1) show that there are challenges being faced in terms of cross-sectoral coordination, outdated legal frameworks and unclear institutional mandates as well as challenges related to data and information collection and management (UNEP 2021a).

Table 3. African Union water-related provisions.

Continental policy and institutional response	Scope
Agenda 2063	Provides a collective vision and lays out a road map for development with a specific mention of access to safe water supply and sanitation.
Africa Water Vision 2025	Provides specific policy guidance to countries on developing and implementing programs aimed at strengthening governance of water resources; improving wise use of water; meeting urgent water needs; and strengthening the financial base for the desired water future.
African Ministers' Council on Water (AMCOW)	Provides the sectoral leadership needed to tackle the water challenges in Africa, having included sanitation as one of the strategic pillars in the AMCOW Strategy 2018-2030.
N'gor Declaration on Sanitation and Hygiene	Aims to accelerate the achievement of water and sanitation goals in Africa with commitments framed around issues such as inequalities in access and use; support to the sector at the highest political level; financing and human resource needs; waste management; and government-led monitoring and evaluation of national initiatives.

Source: AfDB, UNEP and GRID-Arendal 2020.

Water Quality Monitoring Initiatives in Africa

Taking stock of past and current efforts aimed at water quality monitoring and pollution control is important because such knowledge can help situate envisaged interventions at the most appropriate level of implementation and target the most critical areas and gaps.

Several initiatives have addressed water pollution challenges in Africa at the global, regional, transboundary and national levels, covering different aspects of water quality monitoring processes such as field sampling, laboratory analysis, data handling and processing as well as supporting activities such as capacity building and knowledge sharing among peer networks. For the purposes of this assessment, we identify some examples of such initiatives at the global, regional and subregional levels. Initiatives targeted at drinking water supplies are also included in this assessment. An analysis of these initiatives leads us to four categories based on their implementation focus:

- Sampling, analysis and data management.
- Coordination and reporting of water quality-related data.
- Capacity building.
- Scientific network, research and knowledge sharing.

Global Initiatives

SDG Indicator 6.3.2

The United Nations Environment Programme (UNEP) is the custodian of this global indicator which tracks the proportion of water bodies with good ambient water quality. The first reporting cycle was in 2017, and since then many more African countries have reported on progress. There has been good progress in countries such as Sierra Leone where, for example, capacity needs were identified in 2017 and since then a government department official has received training, designed a monitoring program, secured suitable field equipment, implemented the program and collected data (UNEP 2021b).

Global Environment Monitoring System for Freshwater (GEMS/Water)

The GEMS/Water initiative under UNEP is a long-standing initiative that seeks to bring together global data on surface water and groundwater quality. Member countries contribute data to the GEMStat Information System which has the aim of assessing the state and trend of global water quality. While the scope of the initiative is global, a number of countries in Africa are currently not contributing data to the database. GEMS/Water also supports the SDG Indicator 6.3.2 with data management, quality assurance, indicator calculation and capacity development (UNEP 2021b). GEMStat contains water quality data for close to 500 parameters including the SDG 6.3.2 core parameters: dissolved oxygen, nitrogen, phosphorus and pH. However, the availability of water quality data from African countries is non-existent, patchy or dated, as observed on the online global water quality database GEMStat[4] (Figure 11).

In addition to data collation, the GEMS/Water initiative carries out capacity development activities related to water quality monitoring. The GEMS/Water Capacity Development Centre, based at the Environmental Research Institute of the University College Cork in Ireland, was established in response to the lack of technical capacities in water quality monitoring. Activities carried out under this program since its inception in 2015 include raising awareness on water quality, conducting training workshops on water quality monitoring and assessment, and supporting efforts toward SDG Indicator 6.3.2 for ambient water quality. Training is offered in the form of short online continuous professional development courses and the longer-term postgraduate diploma and master's programs. The courses, delivered online, cover the practicalities of water quality monitoring and assessment, data handling and quality assurance. In addition to the short courses and graduate diplomas, workshops are held in different African countries. In 2018, a workshop was held in Dakar, Senegal, and attended by 13 African countries. At the time of writing this paper, there were seven students enrolled for the master's program.

World Water Quality Alliance (WWQA)

WWQA was established by UNEP and the Joint Research Centre of the European Commission in 2019 to provide water quality assessments and solutions to water quality challenges (UNEP 2019). Bringing together expertise from a wide range of sectors, it has formed a global consortium dedicated to responding to water quality challenges and offering demand-driven solutions. The alliance aims to raise awareness on water quality issues by reviewing the state of freshwater quality and potential impacts on human and ecosystem health and food security (UNEP 2019). In Africa, WWQA supports initiatives to improve water quality monitoring through citizen science and AWaQ.

Water Safety Plans

Water safety plans (WSPs) typically include a systems assessment of the operational monitoring and

[4] https://gemstat.org/

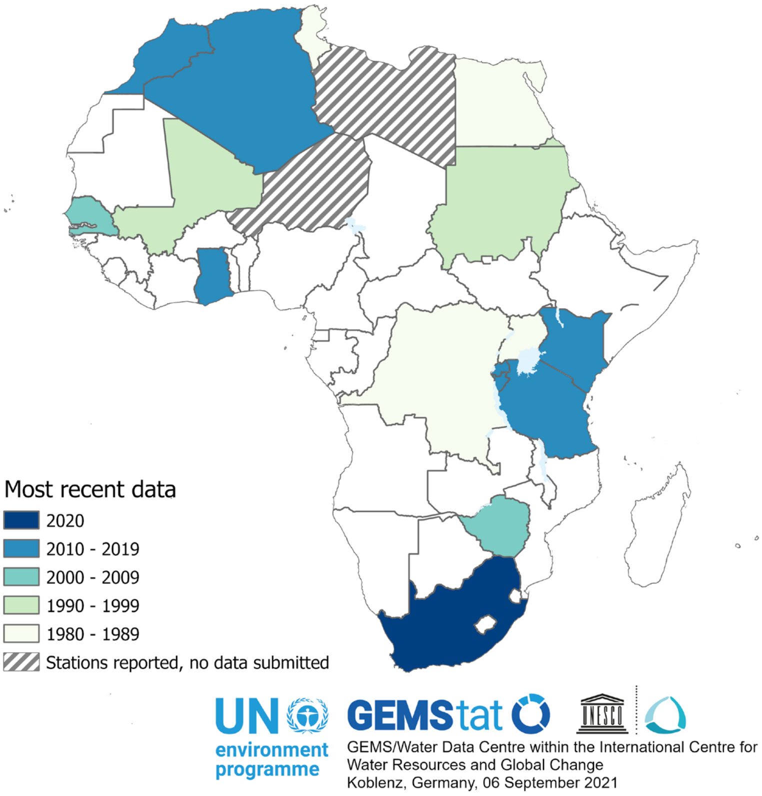


Figure 11. Availability of water quality data across African countries, as submitted to the GEMS/Water Global Freshwater Quality Database.

Source: https://statistics.gemstat.org/

management of water supply systems. Water safety planning has been promoted to support safe drinking water supplies and implemented in several countries across Africa including South Africa, Democratic Republic of the Congo, Egypt, Togo and Uganda (WHO 2017). However, only nine of these countries (Egypt, Ethiopia, Ghana, Morocco, Nigeria, South Africa, Togo, Tunisia and Uganda) have formally approved WSPs included in their national regulatory systems while others are yet to take this step (WHO 2017). Following the Covid-19 pandemic, the importance of water supply services has been receiving increasing attention and priority. When ambient water quality is adequately monitored, the treatment costs of domestic water supply decrease.

WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene

Established in 1990, the WHO/UNICEF JMP for Water Supply, Sanitation and Hygiene is a global initiative that monitors the status of drinking water and sanitation worldwide. The program also informs SDG indicators on drinking water and sanitation (WHO and UNICEF 2021b). In 2017, it produced the first global assessment of drinking water and sanitation services. Data on water, sanitation and hygiene (WASH) are managed through a global database.[5] Good ambient water quality is of critical importance where people are directly dependent on natural water sources, as in some parts of SSA (WHO and UNICEF 2017).

United Nations Educational, Scientific and Cultural Organization – Intergovernmental Hydrological Programme (UNESCO-IHP) International Initiative on Water Quality (IIWQ)

IIWQ is a scientific collaborative initiative which addresses water quality issues through joint research activities and knowledge sharing. It focuses on three main thematic areas: safe drinking water and sanitation, water quality management, and wastewater management and reuse. Within these broad themes, IIWQ addresses knowledge and capacity gaps and encourages scientific cooperation and exchange. The IIWQ expert advisory group comprises water quality specialists drawn from different governmental and nongovernmental entities who provide expert advice on water quality challenges (UNESCO 2015).

[5] https://washdata.org

Regional Initiatives

Continental Initiatives

At the continental level, the African Union[6] is the overarching institution that seeks mainly to promote unity and coordinate cooperation across its 55 member states. Through its various implementing arms, the organization provides strategic guidance on Africa's development issues including environmental impact. Within the African Union, AMCOW[7] holds the position of a Specialised Committee for Water and Sanitation that oversees water and sanitation-related issues. The activities of AU and AMCOW regarding water quality monitoring are central to our study.

Water and Sanitation Sector Monitoring and Reporting System (WASSMO)

WASSMO is an online reporting platform that captures water and sanitation data across African countries. AMCOW has been tasked with reporting the state of water resources on the continent. Country representatives are trained on the use of the platform to strengthen the quality of reporting. A total of 43 indicators are reported in seven key areas:

1. Water infrastructure for growth
2. Managing and protecting water resources
3. Water supply, sanitation, hygiene and wastewater
4. Climate change and disaster risk reduction
5. Governance and institutions
6. Financing
7. Information management and capacity development.

In 2021, sanitation policy guidelines were launched to guide the process of improving sanitation provision on the continent (AMCOW 2021). Given the contribution of sanitation provision to the status of water quality, coordinated efforts with water quality monitoring programs such as the envisaged AWaQ may yield positive results.

AMCOW Pan-African Groundwater Program (APAGroP)

APAGroP was established to strengthen the exchange of knowledge on groundwater management in Africa. The core vision of this program is to improve groundwater policy and practice so as to ensure sustainable and equitable use of groundwater to support lives and livelihoods. As part of this program, development of country support tools will enable individual countries to develop plans that will ensure sustainable use of groundwater. For example, Namibia is piloting the process of developing such a country support tool (Tijani 2020).

In addition, within the framework of short- and medium-term action plans, AMCOW is collaborating with partners in this flagship groundwater program in six thematic focus areas:

1. Policy, governance and institutional systems strengthening
2. Groundwater country support management tools and measures
3. Capacity strengthening and drilling professionalism
4. Groundwater knowledge and information sharing platform/hub
5. Groundwater resources assessment and mapping
6. Unlocking private and public investments in the groundwater sector

Transboundary Basin Initiatives

According to the Transboundary Waters Assessment Programme (TWAP) database, about 20% of the world's 286 known transboundary basins are in Africa, and close to 70% of the continent's total area falls within a shared basin. A large proportion of Africa's water resources are, therefore, highly interconnected and interdependent. This makes transboundary initiatives especially relevant for water pollution mitigation efforts, particularly in the context of externalization of pollution. Some examples of basins with ongoing transboundary initiatives include the Orange-Senqu and Okavango in Southern Africa, Lake Tanganyika in Central/East Africa, and the Senegal in West Africa (Table 4). In some basins, the focus of such initiatives has been on strengthening shared monitoring systems by setting up monitoring stations and developing information systems. Some success has been reported in developing targeted monitoring systems in the Nile Basin's Regional Hydro-Meteorological Network (Box 4).

[6] https://au.int/en/overview
[7] https://amcow-online.org/

Table 4. Examples of transboundary initiatives on water quality monitoring and management.

Transboundary basin	Initiative	Outputs	References
Orange-Senqu Basin	A Framework for Monitoring Water Resource Quality in the Orange-Senqu River Basin	Water resource quality monitoring framework	ORASECOM 2009
Okavango Basin	Water Quality Monitoring in the Okavango Delta and Chobe River System	Automated monitoring network for water quality and quantity	OKACOM 2021
	Environmental Monitoring Framework	Aquatic ecological monitoring, water quality, hydrological flows, sediment transport and groundwater	
	Support to the Cubango-Okavango River Basin Strategic Action Programme Implementation (2017-2022)	Joint basin-wide surveys which established the baseline status of selected physiochemical and chemical parameters including pH, turbidity, electrical conductivity, dissolved oxygen, temperature, nitrates and phosphates	
	Strategic Action Programme for the Sustainable Development and Management of the Cubango-Okavango Basin (2011)	Established the development of surface water and groundwater quality monitoring systems	
Senegal River Basin	Support to operationalize the Senegal River quality network by setting up a durable, interoperable information system	Improved knowledge and monitoring of water quality in the Senegal River Basin by promoting data management	INBO and RIOB 2022
Nile Basin Initiative	Nile Basin Initiative Water Quality Monitoring Programme	Nile Basin Regional Hydro-Meteorological Network	NBI 2019
Zambezi River Authority	Environmental Monitoring Programme (ongoing)	Monthly, quarterly and bi-annual sampling of the Zambezi River and its tributaries	ZRA n.d.
Lake Victoria Basin	Promotion of Resource Efficient and Cleaner Production (RECP) in small-scale mining plants in the Lake Victoria Basin (2017-2019)	Catalyzing private sector investment in cleaner and more efficient industrial production and supply chains throughout the Lake Victoria Basin	UNIDO 2019
Lake Victoria Basin	Environmental Management Project -Phase 1 (1997-2005) -Phase II (2009-2017)	Watershed management and land rehabilitation -Monitoring and control of water hyacinth, rehabilitation, sanitation and wastewater treatment facilities, and working with private companies to reduce industrial pollution -Reducing environmental stress in targeted pollution hotspots and selected degraded subcatchments to improve the livelihoods of communities depending on the natural resources of the basin	United Republic of Tanzania n.d .

(Continued)

Table 4. Examples of transboundary initiatives on water quality monitoring and management.(Continued)

Transboundary basin	Initiative	Outputs	References
Lake Tanganyika	Lake Tanganyika Water Management (LATAWANA) Project. Funded by the European Union and implemented by Enabel (2019-2023)	A key outcome of the project is the establishment of the Lake Tanganyika Water Monitoring Network. The monitoring network will involve laboratories from neighboring countries. The project will finance their compliance, the purchase of sampling and analytical equipment and reagents in order to monitor the various sampling sites. The quality tracking data will be fed into a database and a WebGis (Lake Tanganyika Water Portal) accessible to different audiences.	LATAWAMA 2022

Box 4. Nile Basin Regional Hydro-Meteorological Network.

The Nile Basin Initiative consists of 10 African countries—Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda—all sharing the Nile River. The entire basin has 949 meteorological and 427 hydrological stations which measure rainfall and temperature, although water quality monitoring is still in its infancy. About 80 hydrological and 323 meteorological monitoring stations make up the Nile Basin Regional HydroMet System which is linked to upgraded water quality laboratories within the participating countries. This system ensures the availability of reliable data and improves water resources planning and management in the basin.

Source: NBI 2019.

State of Pollution Control and Impact Mitigation in Africa

Wastewater Treatment

Countries in Africa generate, mainly within their cities, large amounts of solid and liquid waste, which is mostly discharged untreated into water bodies (AfDB, UNEP and GRID-Arendal 2020). This makes the water bodies heavily polluted, posing a threat to human health, ecosystems and economic activities. The sanitation challenges highlighted in the earlier sections of this paper are prolific sources of pollution. Against this backdrop, the need to attain SDG Target 6.3—"by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and at least doubling recycling and safe reuse globally"—is most urgent. However, wastewater treatment efficiency falls far short of the desired level in most African cities (Omosa et al. 2012). Untreated wastewater, identified as one of the key contributors to water pollution across Africa's urban areas, is not sufficiently treated for discharge (Nikiema et al. 2013; AfDB, UNEP and GRID-Arendal 2020).

The most commonly used wastewater treatment technologies in Africa are waste stabilization ponds and, in some cases, activated sludge and trickling filter technologies (Omosa et al. 2012; Wang et al. 2014). However, treatment plants are overloaded and subject to other challenges such as power cuts and poor operation and maintenance, leading to the production of poor quality effluent with high nutrient and heavy metal loads (Nikiema et al. 2013; Wang et al. 2014). The AQUASTAT database of the Food and Agriculture Organization of the United Nations (FAO) provides data on produced and treated wastewater, among other variables. However, data on collected wastewater are scanty for most African countries (Table 5). As per FAO AQUASTAT data, Tunisia has the highest treatment rate (79%) based on collected wastewater compared to produced wastewater.

Table 5. Percentage of treated wastewater in some African countries (2017 data).

Country	Produced municipal wastewater (10^9 m³/year)	Collected wastewater (10^9 m³/year)	Treated municipal wastewater (10^9 m³/year)	Treated wastewater (%) based on produced volume	Treated wastewater (%) based on collected volume
Algeria	1.5	0.705	0.4	27	57
Botswana	0.011	-	0.008	73	-
Burkina Faso	0.0487	0.0024	0.0014	3	58
Egypt	7.078	6.497	4.282	60	66
Eswatini	0.0132	-	0.009	68	
Ghana	0.28	0.028	0.022	8	79
Kenya	0.0805	-	0.0424	53	-
Mauritania	0.0214	-	0.0007	3	-
Morocco	0.7	-	0.166	24	-
Namibia	0.0195	-	0.006	31	-
Senegal	0.0696		0.0112	16	-
South Africa	3.542	2.769	1.919	54	69
Tunisia	0.287	0.241	0.226	79	94
Zimbabwe	0.194		0.095	49	-

Source: FAO 2021.

Note: Data for other African countries were not available at the time of writing.

Regulatory Tools for Water Pollution Control

Regulations to control pollution of water resources have been instituted in African countries with varying degrees of success. They have the underlying goals of protecting public and ecological health as well as safeguarding the economy. Water quality regulations can also have a strong human rights mandate by seeking to ensure that citizens are kept safe from harmful pollutants. For example, in South Africa, water quality regulations are rooted in the country's Constitution and Bill of Rights. Typical regulatory instruments include wastewater discharge licenses or permits, water pollution guidelines and standards for drinking water, fisheries, wastewater, on-site sanitation, environmental impact assessment and adoption of best practices such as sustainable agricultural practices (Mateo-Sagasta et al. 2018).

It is important to note that water quality monitoring and pollution control activities are managed across several sectors including health, water supply and sanitation services, environment, agriculture and industry with regulatory frameworks applicable to each (UN-Water 2015). Regulatory instruments are therefore often developed based on the type of water use: for example, the setting of standards for (i) effluent discharge, (ii) ecological functions, (iii) drinking water, and (iv) wastewater reuse, among others. Licenses or permits are also common instruments used to regulate water quality. Several African countries have adopted the Polluter Pays Principle to manage pollution by passing the cost of pollution to the polluter through fines and taxes, for example, in Botswana, Kenya, Nigeria, South Africa and Zimbabwe (GoB 2016; GoZ 2012; Ojo 2021). According to Mateo-Sagasta et al. (2018), the principle is less effective in managing diffuse pollution such as that from agricultural runoff. The successes and failures of this principle are largely associated with the capacity to enforce measures punitive enough such that the cost of pollution deters polluters (Olaniyan 2015).

Enforcement of water quality regulations and ensuring compliance is a complex process. It is marked by shortcomings and inefficiencies which impact the effectiveness of the regulations as a water pollution control tool. Coupled with limited resources, the enforcement-compliance relationship presents complex dynamics even in well-resourced environments. A study by Peletz et al. (2018) highlighted that in countries with a weak regulatory environment, the success of monitoring programs is dependent on staff motivation and incentives for meeting monitoring targets.

Andarge and Lichtenberg (2020) showed that the lower the likelihood of enforcement, the lesser the compliance. In addition, the cost of enforcing pollution regulations in poor environments can be a challenge too, as observed by Weststrate et al. (2019) who found that compliance with on-site sanitation regulations for pit latrine design and fecal sludge management in poor communities was very low in the absence of enforcement. Their study further highlighted the weak regulatory framework available to safely manage fecal sludge in African countries. Recent efforts by AMCOW through the African Sanitation Policy Guidelines are important in strengthening the sanitation regulatory framework with direct implications for water quality when implemented (AMCOW 2021).

At the transboundary level, national and transnational water quality management frameworks converge to manage the water quality of shared resources. Harmonization of policies is therefore critical in ensuring coordinated efforts toward managing water quality. Transboundary agreements such as the Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC) promotes regional policy coherence.

Water Pollution Control Strategies – Survey Insights

According to the results of the AMCOW-IWMI Africa-wide Survey, pollution control solutions that show interesting potential for impact include the following:

Regulatory solutions
- Polluter Pays Principles, regulating industrial effluent
- Environmental impact assessments
- Fines, e.g., criminalizing alluvial mining
-

Management approaches
- Catchment management
- Buffer zone protection and restoration
- Water quality monitoring programs

Civic and private sector movements
- Pressure groups, national clean-up campaigns

Technologies and innovation
- Arsenic removal
- Wastewater treatment
- Countrywide implementation of fecal sludge treatment plants
- Use of resource efficiency and cleaner production approaches

Pollution control regulations were the most popularly employed strategy in 74% of the countries surveyed (Figure 12), followed by nature-based solutions (65%). Least applied were wastewater reuse technologies (29%).

Results from the survey showed mixed sentiments on the effectiveness of different treatment technologies, nonetheless, showing the limitations of such technologies in successfully mitigating pollution. Wastewater treatment, adoption of good agricultural practices and pollution control regulations were perceived to have the least impact compared to other available options for water pollution control (Figure 13).

Regarding government prioritization of water quality, 29% of the countries indicated that their governments gave water quality issues low priority while 45% and 16% of the countries indicated moderate and high priority, respectively. Government prioritization is critical in ensuring water quality receives the attention and support required to mitigate adverse impacts.

Investments in Pollution Control and Mitigation Initiatives

Investments by several donors and organizations including the African Development Bank (AfDB) have directed funding toward the rehabilitation and expansion of wastewater treatment plants in Kenya and Egypt (AfDB 2017, 2018). Similarly, the World Bank has supported several initiatives in Africa related to water pollution control: for example, a USD 115 million grant was awarded to Mozambique in 2019 for improving sanitation and wastewater treatment (WBG 2019).

Other project-based initiatives implemented include research projects and the piloting of innovations in water quality monitoring and pollution control: for example, the European Union's Horizon 2020 funded project in Egypt, Morocco and Tunisia for wastewater treatment technologies as well as the project piloting the CabECO® membrane electrolytic technology for water treatment (European Commission 2020). The United States Environmental Protection Agency (USEPA) is implementing the West Africa Drinking Water Laboratory Capacity Program, albeit currently only in Ghana (USEPA 2021). The Aquaya Institute has implemented a water monitoring project in Ethiopia, Guinea, Kenya, Senegal, Uganda and Zambia and produced data on microbial water quality through analyses of water samples (Aquaya Institute 2020). Similarly, IWMI has implemented research projects in North Africa, adding knowledge on the safe reuse of wastewater (Ng 2018).

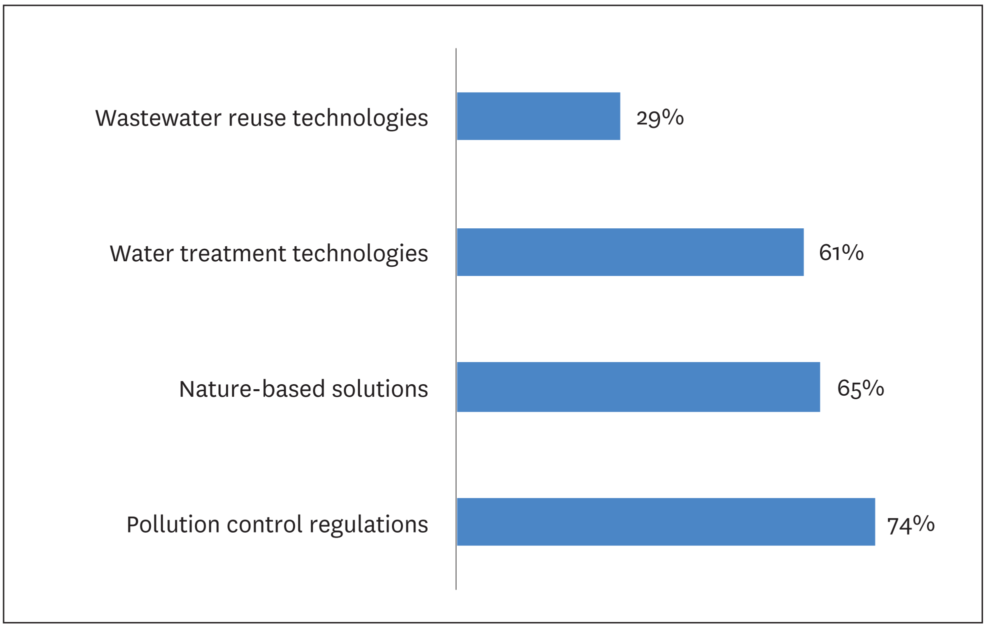


Figure 12. Use of water pollution control strategies across African countries.

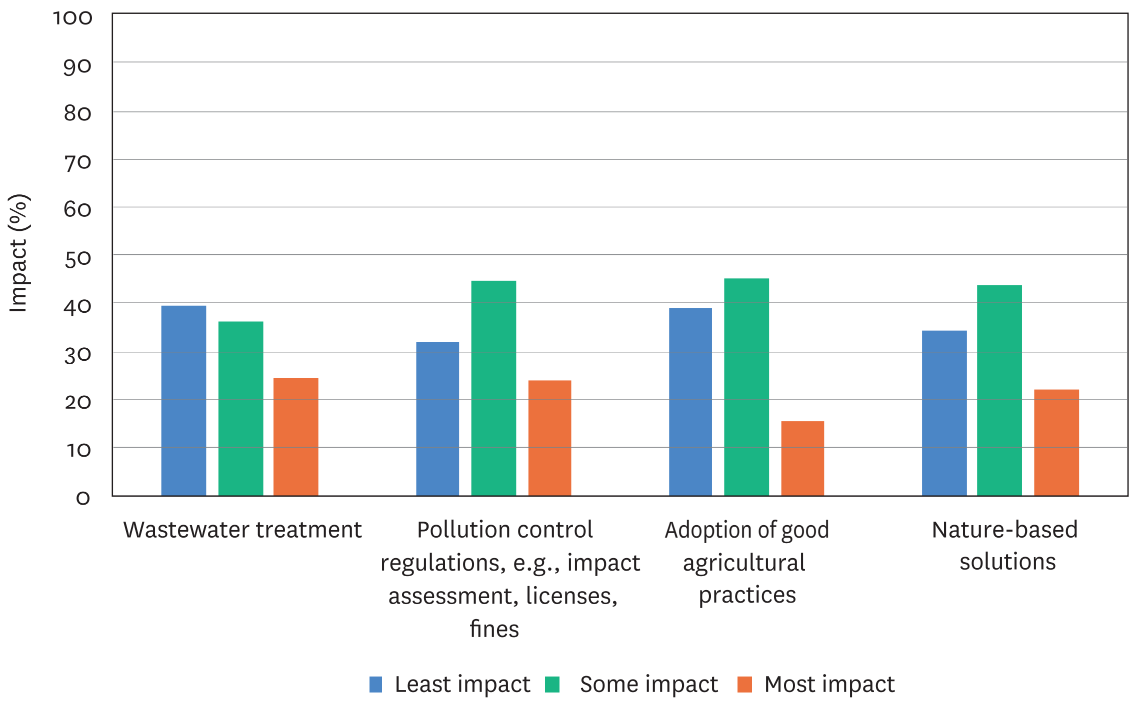


Figure 13. Effectiveness of water pollution control strategies.

Concluding Remarks

The aim of this review was to highlight the need for an African Water Quality Program (AWaQ) within the context of past and existing water quality monitoring and pollution control initiatives. Based on literature reviews and a survey conducted in 31 countries by AMCOW and IWMI, and a preliminary review of the current initiatives, it can be said that there is scope for AWaQ to make an impact by building upon past and present initiatives, strengthening synergies and filling existing gaps.

Water quality profiles were prepared for the countries that responded to the Africa-wide survey. As an example, the water quality profile for Kenya is given in Annex B.

Key Messages

The main findings of this review include the following:

1. While several initiatives are currently being implemented at continental, transboundary basin and national scales, coverage remains patchy. Not all African countries were found to be participating in some of the initiatives, even the global ones such as those led by GEMS/Water and the WHO Water Safety Plans. This may point to the potential for AWaQ to broaden the reach of existing initiatives.

2. There is a synergistic overlap between efforts directed at ambient water quality monitoring and water supply and sanitation-directed initiatives. Further exploration on how they can be better streamlined in line with AWaQ is needed.

3. There is a need to strengthen initiatives focusing on the data generation element of water quality monitoring, e.g., through laboratory infrastructure and testing equipment.

4. Different implementation scales may provide various entry points for AWaQ.

5. An analysis of the results of the Africa-wide survey shows the following:

    a. There is an encouraging availability of national water testing laboratory facilities across African countries. Nonetheless, capacity-related weaknesses require attention to ensure functionality and sustainability.
    b. Water quality monitoring and assessment capacities are patchy. Weakness in capacities related to staff training, laboratory infrastructure as well as monitoring program activities was indicated.
    c. Pollution control mechanisms require strengthening, particularly regulatory mechanisms and wastewater treatment technologies, which are the most widely deployed pollution control solutions. These mechanisms may benefit from more concerted investment and political will to boost their effectiveness.
    d. Ongoing regular training is essential to keep up with laboratory testing methodologies. The observed low trend in regular training may not augur well for keeping abreast of developments in water quality monitoring best practices, especially in view of emerging pollutants.

Next Steps

Ongoing efforts in this project will focus on assessing water quality monitoring and management innovations and how these innovations can be better leveraged to yield results at scale on the African continent. In the final phase of this project, the framework for AWaQ will be developed based on findings from phases 1-4, incorporating inputs received from stakeholders through the survey and other consultation fora such as the Africa Water Week (Annex C).

References

AfDB (African Development Bank). 2017. *Egypt—sustainable development of Abu Rawash Wastewater Treatment Plant (Abu-Rawash-WWTP)—appraisal report*. Abidjan, Côte d'Ivoire: African Development Bank Group (AfDB). 30p. Available at https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Egypt_-_Sustainable_Development_of_Abu_Rawash_Wastewater_Treatment_Plant__Abu-Rawash-WWTP_.pdf (accessed on March 30, 2023).

AfDB. 2018. *Nairobi Rivers Basin Rehabilitation and Restoration Program: Sewerage Improvement project phase II— Country: Republic of Kenya—Project appraisal report*. Abidjan, Côte d'Ivoire: AfDB. 39p. Available at https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/KENYA_-__AR__-_Nairobi_Rivers_Basin_Rehabilitation_and_restoration_Program.pdf (accessed on March 30, 2023).

AfDB; UNEP (United Nations Environment Programme); GRID-Arendal. 2020. *Sanitation and wastewater atlas of Africa*. Abidjan, Côte d'Ivoire: African Development Bank Group (AfDB); Nairobi, Kenya: United Nations Environment Programme (UNEP); and Arendal, Norway: GRID-Arendal.

AMCOW (African Ministers' Council on Water). 2021. *African sanitation policy guidelines (ASPG)*. Abuja, Nigeria: African Ministers' Council on Water (AMCOW). 211p. Available at https://knowledgehub.amcow-online.org/resource/african-sanitation-policy-guidelines-(aspg) (accessed on March 30, 2023).

AU (African Union). 2015. *Agenda 2063: The Africa we want. First ten-year implementation plan*. Addis Ababa, Ethiopia: African Union Commission. 24p. Available at https://au.int/sites/default/files/documents/33126-doc-11_an_overview_of_agenda.pdf (accessed on March 30, 2023).

Andarge, T.; Lichtenberg, E. 2020. Regulatory compliance under enforcement gaps. *Journal of Regulatory Economics* 57(3): 181–202. https://doi.org/10.1007/s11149-020-09405-0

Aquaya Institute. 2020. *From data to decisions: Water quality monitoring programs in Sub-Saharan Africa*. Nairobi, Kenya: Aquaya Institute. 5p. Available at https://reachwater.org.uk/wp-content/uploads/2020/09/WQMonitoringPrograms-SubSaharanAfrica_oneSheeter_v5.pdf (accessed on March 30, 2023).

Babatunde, A.O. 2020. Oil pollution and water conflicts in the riverine communities in Nigeria's Niger Delta region: Challenges for and elements of problem-solving strategies. *Journal of Contemporary African Studies* 38(2): 274–293. https://doi.org/10.1080/02589001.2020.1730310

Bartram, J.; Ballance, R. (Eds.) 1996. *Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. London, UK: CRC Press. 400p. https://doi.org/10.1201/9781003062110

Delaire, C.; Peletz, R.; Kumpel, E.; Kisiangani, J.; Bain, R.; Khush, R. 2017. How much will it cost to monitor microbial drinking water quality in Sub-Saharan Africa?. *Environmental Science and Technology* 51(11): 5869–5878. https://doi.org/10.1021/acs.est.6b06442

Döll, P.; Kaspar, F.; Lehner, B. 2003. A global hydrological model for deriving water availability indicators: Model tuning and validation. *Journal of Hydrology* 270(1–2): 105–134. https://doi.org/10.1016/S0022-1694(02)00283-4

European Commission. 2020. *Tackling water and sanitation challenges to contribute to a green transition: Results from 7 Horizon 2020 projects that foster scientific and technological cooperation with Africa*. News. October 12, 2020. Available at https://ec.europa.eu/newsroom/intpa/items/690203/en (accessed on March 30, 2023).

Fayiga, A.O.; Ipinmoroti, M.O.; Chirenje, T. 2018. Environmental pollution in Africa. *Environment, Development and Sustainability* 20: 41–73. https://doi.org/10.1007/s10668-016-9894-4

FAO (Food and Agriculture Organization of the United Nations). 2021. AQUASTAT – FAO's global information system on water and agriculture. Rome: FAO. Available at https://tableau.apps.fao.org/views/ReviewDashboard-v1/country_dashboard?%3Aembed=y&%3AisGuestRedirectFromVizportal=y (accessed on May 30, 2023).

Githinji, M.W.; Mwaura, F.; Wamalwa, J. 2019. Land use and water pollution along the altitudinal gradient of the Likii River, Laikipia County, Kenya. *Journal of Environment Pollution and Human Health* 7(1): 39–52. Available at http://www.sciepub.com/portal/downloads?doi=10.12691/jephh-7-1-6&filename=jephh-7-1-6.pdf (accessed on March 28, 2023).

GoB (Government of Botswana). 2016. *National water policy*. Republic of Botswana, Government Paper. Gaborone, Botswana: Ministry Minerals, Energy and Water Resources.

GoZ (Government of Zimbabwe). 2012. *National water policy*. Harare, Zimbabwe: Ministry of Water Resources Development and Management, Government of Zimbabwe. 40p.

Graham, J.P.; Hirai, M.; Kim, S-S. 2016. An analysis of water collection labor among women and children in 24 Sub-Saharan African countries. *PLoS ONE* 11(6): e0155981. https://doi.org/10.1371/journal.pone.0155981

Haddaoui, I.; Mateo-Sagasta, J. 2021. A review on occurrence of emerging pollutants in waters of the MENA region. *Environmental Science and Pollution Research* 28:68090–68110. https://doi.org/10.1007/s11356-021-16558-8

IPCC (Intergovernmental Panel on Climate Change). 2021. *Regional fact sheet – Africa*. Sixth Assessment Report of Working Group on the Physical Science Basis. Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC). 2p. Available at https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Africa.pdf (accessed on March 30, 2023).

INBO (International Network of Basin Organizations); RIOB (Le Réseau International des Organismes de Bassin). 2022. *Support to operationalise the Senegal River Quality Network by setting up a durable, interoperable information system*. Africa : 100 water and climate projects. Available at https://www.riob.org/en/incubation/Interoperable-Information-System-Senegal-river (accessed on March 30, 2023).

ISO (International Organization for Standardization). 2021. *ISO 6107:2021: Water quality — vocabulary*. Geneva, Switzerland: International Organization for Standardization (ISO). Available at https://www.iso.org/obp/ui/#iso:std:iso:6107:ed-1:v1:en (accessed on March 30, 2023).

IUCN-PACO (International Union for Conservation of Nature-Central and West Africa Programme). n.d. *West Africa water resources policy (WAWRP)*. Ouagadougou, Burkina Faso: Central and West Africa Programme, International Union for Conservation of Nature (IUCN). Available at https://doczz.fr/download/2399662 (accessed on March 29, 2023).

Kithiia, S.M. 2012. Water quality degradation trends in Kenya over the last decade. In: Voudouris, K.; Voutsa D. (eds.) *Water quality: Monitoring and assessment*. London, UK: IntechOpen. pp.509—526. https://doi.org/10.5772/32010

LATAWAMA (Lake Tanganyika Water Management). 2022. *Project description*. Available at https://latawama.org/en/project-description/?lang=en (accessed on March 30, 2023).

Lapworth, D.J.; Nkhuwa, D.C.W.; Okotto-Okotto, J.; Pedley, S.; Stuart, M.E.; Tijani, M.N.; Wright, J.J.H.J. 2017. Urban groundwater quality in sub-Saharan Africa: Current status and implications for water security and public health. *Hydrogeology Journal* 25(4): 1093–1116. https://doi.org/10.1007/s10040-016-1516-6

MacDonald, A.M.; Bonsor, H.C.; Dochartaigh, B.É.Ó.; Taylor, R.G. 2012. Quantitative maps of groundwater resources in Africa. *Environmental Research Letters* 7(2): 024009. https://doi.org/10.1088/1748-9326/7/2/024009

Masindi, V.; Foteinis, S. 2021. Groundwater contamination in sub-Saharan Africa: Implications for groundwater protection in developing countries. *Cleaner Engineering and Technology* 2:100038. https://doi.org/10.1016/j.clet.2020.100038

Mateo-Sagasta, J.; Zadeh, S.M.; Turral, H. (Eds.) 2018. *More people, more food, worse water? A global review of water pollution from agriculture*. Colombo, Sri Lanka: International Water Management Institute (IWMI); Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). 224p. Available at http://www.iwmi.cgiar.org/Publications/Books/PDF/more-people-more-food-worse-water.pdf (accessed on March 30, 2023).

McCarthy, T.S. 2011. The impact of acid mine drainage in South Africa. *South Africa Journal of Science* 107(5/6): 7p. http://doi.org/10.4102/sajs.v107i5/6.712

MWI (Ministry of Water and Irrigation). 2007. *The National Water Services Strategy (NWSS): 2007-2015*. Nairobi, Kenya: Ministry of Water and Irrigation, Republic of Kenya. Available at https://wasreb.go.ke/downloads/NWSS.pdf (accessed on March 29, 2023).

Mukuyu, P.; Warner, S.; Chapman, D. V.; Jayathilake, N.; Dickens, C.; Mateo-Sagasta, J. 2024a. *Innovations in water quality monitoring and management in Africa: towards developing an African Water Quality Program (AWaQ)*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 52p. (IWMI Working Paper 208). doi: https://doi.org/10.5337/2023.217

Mukuyu, P.; Dickens, C.; Jayathilake, N.; Tijani, M.; Chapman, D. V.; Warner, S. 2024b. *A framework for an African Water Quality Program (AWaQ)*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 22p. (IWMI Working Paper 209). https://doi.org/10.5337/2024.202

Musyoki, A.M.; Abednego, M.; Sileiman, M.A.; Mbithi, J.N.; Maingi, J. M. 2013. Water-borne bacterial pathogens in surface waters of Nairobi River and health implication to communities downstream Athi River. *International Journal of Life Science and Pharma Research* 3 (1): L4–L10. Available at https://www.ijlpr.com/index.php/journal/article/view/303/209 (accessed on March 28, 2023).

Ndungu, J.N. 2014. *Assessing water quality in Lake Naivasha*. PhD dissertation. Enschede, The Netherlands: University of Twente. 174p. http://doi.org/10.3990/1.9789036537001

Ng, M. 2018. Launch of a major project on water reuse at Cairo Water Week. Giving water a second life. *International Water Management Institute (IWMI)*, October 17, 2018. Available at https://www.iwmi.cgiar.org/2018/10/giving-water-a-second-life/ (accessed on March 29, 2023).

Nikiema, J.; Figoli, A.; Weissenbacher, N.; Langergraber, G.; Marrot, B.; Moulin, P. 2013. Wastewater treatment practices in Africa–experiences from seven countries. *Sustainable Sanitation Practice* 14: 26–34. Available at http://www.ecosan.at/ssp/selected-contributions-from-the-1st-waterbiotech-conference-9-11-oct-2012-cairo-egypt/SSP-14_Jan2013.pdf (accessed on March 28, 2023).

NBI (Nile Basin Initiative). 2019. *Nile basin regional hydro-meteorological network*. Entebbe, Uganda: Nile Basin Initiative (NBI). 12p. Available at https://www.nilebasin.org/images/docs/Hydromet_Success_Story.pdf (accessed on March 30, 2023).

Njoroge, L.W.; Wahab A.A.; Tracey S.A.; Oting, W.K.A. 2018. Water resource in Kenya: Impact of climate change/urbanization. *International Journal of Scientific and Research Publications* 8(4): 30–35. http://dx.doi.org/10.29322/IJSRP.8.4.2018.p7606

Ochieng, G.M.; Seanego, E.S.; Nkwonta, O.I. 2010. Impacts of mining on water resources in South Africa: A review. *Scientific Research and Essays* 5(22): 3351–3357. Available at https://academicjournals.org/journal/SRE/article-full-text-pdf/E1F28F718891#:~:text=Acid%20generation%20and%20metals%20dissolution,referred%20as%20acid%20mine%20drainage (accessed on March 28, 2023).

Ojo, O.O. 2021. Polluter pays principle under Nigerian environmental law. *Environmental Liability – Law, Policy and Practice* 26(3): 91–105. Available at http://dspace.jgu.edu.in:8080/jspui/bitstream/10739/4867/1/02a-EL26-3%20Article-01%20OLYINKA%20OJO%20%28091-105%29%20%282%29.pdf (accessed on March 28, 2023).

Olaniyan, A. 2015. The multi-agency response approach to the management of oil spill incidents: Legal framework for effective implementation in Nigeria. *The Journal of Sustainable Development Law and Policy* 6(1): 109–128. http://doi.org/10.4314/jsdlp.v6i1.5

Omosa, I.B.; Wang, H.; Cheng, S.; Li, F. 2012. Sustainable tertiary wastewater treatment is required for water resources pollution control in Africa. *Environmental Science and Technology* 46(13): 7065–7066. http://doi.org/10.1021/es3022254

ORASECOM (Orange-Senqu River Commission). 2009. *A framework for monitoring water resource quality in the Orange-Senqu river basin*. Centurion, Gauteng, South Africa: Orange-Senqu River Commission (ORASECOM). 88p. Available at https://orasecom.org/wp-content/uploads/2020/05/661Water-Quality-Monitoring-Framework-.pdf (accessed on March 29, 2023).

Ouedraogo, I.; Defourny, P.; Vanclooster, M. 2016. Mapping the groundwater vulnerability for pollution at the pan African scale. *Science of the Total Environment* 544: 939–953. https://doi.org/10.1016/j.scitotenv.2015.11.135

Pare, S.; Bonzi-Coulibaly, Y. 2013. Water quality issues in West and Central Africa: present status and future challenges. In: *Understanding freshwater quality problems in a changing world: Proceedings of H04, the IAHS-IAPSO-IASPEI Joint 37th Scientific Assembly, July 22-26, 2013, Gothenburg, Sweden*. pp. 87–95. Available at https://iahs.info/uploads/dms/15573.14-87-95-361-24-H04-Pare-Bonzi_April_2013CORR.pdf (accessed on March 29, 2023).

Peletz, R.; Kisiangani, J; Bonham, M.; Ronoh, P.; Delaire, C.; Kumpel, E.; Marks, S.; Khush, R. 2018. Why do water quality monitoring programmes succeed or fail? A qualitative comparative analysis of regulated testing systems in sub-Saharan Africa. *International Journal of Hygiene and Environmental Health* 221(6): 907–920. https://doi.org/10.1016/j.ijheh.2018.05.010

Sanctuary, M.; Tropp, H.; Haller, L. 2007. *Making water a part of economic development: The economic benefits of improved water management and services*. Stockholm, Sweden: Stockholm International Water Institute (SIWI). 48p. Available at https://siwi.org/wp-content/uploads/2015/09/waterandmacroecon.pdf (accessed on March 30, 2023).

OKACOM (The Permanent Okavango River Basin Water Commission). 2021. *Current projects*. Available at https://www.okacom.org/current-projects (accessed on March 29, 2023).

Tijani, M. 2020. *AMCOW Pan-African Groundwater Program (APAGroP): A new AMCOW agenda to improve capacities and education on groundwater resources in Africa*. Abuja, Nigeria: African Ministers' Council on Water (AMCOW). 13p. Available at https://iwra.org/member/congress/resource/PPT10b1Tijani.pdf (accessed on March 30, 2023).

UN-Water. 2015. *Compendium of water quality regulatory frameworks: Which water for which use?* Geneva, Switzerland: UN-Water. Available at www.iwa-network.org/which-water-for-which-use (accessed on May 31, 2023).

UNICEF (United Nations Children's Fund); WHO (World Health Organization). 2020. *State of the world's sanitation: An urgent call to transform sanitation for better health, environments, economies and societies*. New York: United Nations Children's Fund and World Health Organization. 94p. Available at https://www.who.int/publications/i/item/9789240014473 (accessed on March 29, 2023).

UN DESA (United Nations Department of Economic and Social Affairs). 2014. International decade for action 'water for life' 2005-2015: Africa. Available at https://www.un.org/waterforlifedecade/africa.shtml (accessed on May 31, 2023).

UNECA (United Nations Economic Commission for Africa); AUC (African Union Commission); AfDB (African Development Bank). 2003. *Africa Water Vision for 2025: Equitable and sustainable use of water for socioeconomic development*. Addis Ababa, Ethiopia: United Nations Economic Commission for Africa. 71p. https://hdl.handle.net/10855/5488

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2015. *International initiative on water quality: Promoting scientific research, knowledge sharing, effective technology and policy approaches to improve water quality for sustainable development*. Paris, France: United Nations Educational, Scientific Cultural Organization. 26p. Available at https://unesdoc.unesco.org/ark:/48223/pf0000243651 (accessed on March 29, 2023).

UNEP (United Nations Environment Programme). 2010. *Africa water atlas*. Nairobi, Kenya: Division of Early Warning and Assessment (DEWA), United Nations Environment Programme (UNEP). 326p. Available at https://na.unep.net/atlas/africaWater/downloads/africa_water_atlas.pdf (accessed on May 31, 2023).

UNEP. 2016. *A snapshot of the world's water quality: Towards a global assessment*. Nairobi, Kenya: United Nations Environment Programme (UNEP). 162p. Available at https://wesr.unep.org/media/docs/assessments/unep_wwqa_report_web.pdf (accessed on March 29, 2023).

UNEP. 2018. *Progress on ambient water quality: Piloting the monitoring methodology and initial findings for SDG indicator 6.3.2*. Nairobi, Kenya: United Nations Environment Programme (UNEP). 60p. Available at https://www.unep.org/resources/report/progress-ambient-water-quality-piloting-monitoring-methodology-and-initial-2 (accessed on March 30, 2023).

UNEP. 2019. *World Water Quality Alliance launched to tackle global water crisis*. Press release, September 19, 2019. Available at https://www.unep.org/news-and-stories/press-release/world-water-quality-alliance-launched-tackle-global-water-crisis#:~:text=Ispra%2C%2019%20September%202019%20%2D%20With,quality%20science%2C%20technology%20innovation%2C%20governance (accessed on March 30, 2023).

UNEP. 2021a. *Progress on integrated water resources management. Tracking SDG 6 series: Global indicator 6.5.1 updates and acceleration needs*. Nairobi, Kenya: United Nations Environment Programme. 110p. Available at https://www.unwater.org/sites/default/files/app/uploads/2021/09/SDG6_Indicator_Report_651_Progress-on-Integrated-Water-Resources-Management_2021_EN.pdf (accessed on March 30, 2023).

UNEP. 2021b. *Progress on ambient water quality. Tracking SDG 6 series: Global indicator 6.3.2 updates and acceleration needs*. Nairobi, Kenya: United Nations Environment Programme. 82p. Available at https://www.unwater.org/sites/default/files/app/uploads/2021/09/SDG6_Indicator_Report_632_Progress-on-Ambient-Water-Quality_2021_EN.pdf (accessed on March 30, 2023).

UNEP GEMS/Water CDC (Capacity Development Centre of the Global Environment Monitoring System for freshwater for the United Nations Environment Programme). 2020. *Water quality monitoring capacity scoping for Africa: Summary report 2020*. Cork, Ireland: UNEP GEMS/Water Capacity Development Centre (CDC), Environmental Research Institute, University College Cork.

UNIDO (United Nations Industrial Development Organization). 2019. *Health and pollution action plan: United Republic of Tanzania*. Vienna, Austria: United Nations Industrial Development Organization. 152p. Available at https://www.unido.org/sites/default/files/files/2019-10/Tanzania%20HPAP.English_2.pdf (accessed on March 30, 2023).

United Republic of Tanzania. n.d. *Short brief on Lake Victoria Environmental Management Project (LVEMP)*. Dodoma, Tanzania: Ministry of Water, United Republic of Tanzania. 9p. Available at https://www.maji.go.tz/uploads/publications/sw1549607182-LVEMP%20Brief%20Summary%202-%20MoWI.pdf (accessed on March 30, 2023).

USEPA (United States Environmental Protection Agency). 2021. *West Africa drinking water laboratory capacity program*. EPA Collaboration with Sub-Saharan Africa. Available at https://www.epa.gov/international-cooperation/epa-collaboration-sub-saharan-africa#DW (accessed on March 30, 2023).

Verlicchi, P.; Grillini, V. 2020. Surface water and groundwater quality in South Africa and Mozambique— analysis of the most critical pollutants for drinking purposes and challenges in water treatment selection: *Water* 12(1): 305. https://doi.org/10.3390/w12010305

Wang, H.; Wang, T.; Zhang, B.; Li, F.; Toure, B.; Omosa, I.B.; Chiramba, T.; Abdel-Monem, M.; Pradhan, M. 2014. Water and wastewater treatment in Africa— Current practices and challenges. *Clean Soil Air Water* 42(8): 1029–1035. https://doi.org/10.1002/clen.201300208

Weststrate, J.; Gianoli, A.; Eshuis, J.; Dijkstra, G.; Cossa, I.J.; Rusca, M. 2019. The regulation of onsite sanitation in Maputo, Mozambique. *Utilities Policy* 61: 100968. https://doi.org/10.1016/j.jup.2019.100968

Whitehead, P.G.; Wilby, R.L.; Battarbee, R.W.; Kernan, M.; Wade, A.J. 2009. A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal* 54(1): 101–123. https://doi.org/10.1623/hysj.54.1.101

WBG (World Bank Group). 2019. *Mozambique receives $115 million in grants to increase access to sanitation*. Press release. May 22, 2019. Available at https://www.worldbank.org/en/news/press-release/2019/05/22/mozambique-receives-115-million-in-grants-to-increase-access-to-sanitation (accessed on March 30, 2023).

WHO (World Health Organization). 2017. *Global status report on water safety plans: A review of proactive risk assessment and risk management practices to ensure the safety of drinking-water*. Geneva, Switzerland: World Health Organization (WHO). 44p. Available at https://www.who.int/publications/i/item/WHO-FWC-WSH-17.03 (accessed on March 30, 2023).

WHO; United Nations Children's Fund (UNICEF). 2017. *Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines*. Geneva, Switzerland: WHO; New York, USA: UNICEF. 116p. Available at https://www.who.int/publications/i/item/9789241512893 (accessed on March 30, 2023).

WHO; UNICEF. 2021a. *Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs*. Geneva, Switzerland: World Health Organization (WHO); New York, USA: United Nations Children's Fund (UNICEF). 164p. Available at https://data.unicef.org/resources/progress-on-household-drinking-water-sanitation-and-hygiene-2000-2020/ (accessed on March 30, 2023).

WHO; UNICEF. 2021b. *Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP)*. Available at https://washdata.org/data/downloads#KEN (accessed on March 30, 2023).

WWAP (World Water Assessment Programme). 2006. *Water: a shared responsibility. The United Nations World Water Development Report 2*. Paris, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). 601p. Available at https://unesdoc.unesco.org/ark:/48223/pf0000145405 (accessed on March 30, 2023).

WWAP. 2016. *The United Nations world water development report 2016: Water and jobs*. Paris, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). 164p. Available athttps://unesdoc.unesco.org/ark:/48223/pf0000243938 (accessed on March 30, 2023).

WWAP. 2017. *The United Nations World Water Development Report 2017: Wastewater—the untapped resource*. Paris, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). Available at https://unesdoc.unesco.org/ark:/48223/pf0000247153 (accessed on March 30, 2023).

WWQA (World Water Quality Alliance). 2021. *World water quality assessment: First global display of a water quality baseline*. A consortium effort by the World Water Quality Alliance—towards a full global assessment. Information Document Annex for display at the 5th session of the United Nations Environment Assembly, Nairobi, Kenya, 2021. Available at https://pure.iiasa.ac.at/id/eprint/17645/ (accessed on March 30, 2023).

ZRA (Zambezi River Authority). n.d. *Environmental monitoring programme*. Available at http://www.zambezira.org/environmental-monitoring/environmental-monitoring-programme (accessed on March 30, 2023).

Annex A. AMCOW-IWMI Africa-wide Survey.

Survey Questions

No.	Question
1.	Please enter your full name
2.	Please provide your contact information (e.g., email address/WhatsApp)
3.	What is your gender?
4.	In which country are you currently based?
5.	Which country are you representing in your responses to this survey? (Please indicate only one country)
6.	What is the name of your organization?
7.	In which sector does your organization work?
8.	What is your job title?
9.	How long have you worked in this role?
10.	What is your area of specialization?
11.	Have you received any training related to the following areas? (You can select multiple options) o Field water sampling o Laboratory water analysis o Water quality data processing and interpretation o Water quality modeling o Wastewater treatment o Formulation of water quality standards o None of the above
12.	Please indicate the format in which training was received o Part of a university or college course o Part of a one-off training certification o One-day workshop o Ongoing regular training
13.	How would you rate the technical capacity of individuals in your country's water testing laboratories to carry out their roles with respect to field sampling, laboratory water analysis, and interpretation of water quality data? o Poor, unable to conduct water quality-related field sampling, laboratory testing or modeling o Average, able to conduct some of the technical roles o Adequate, able to carry out all roles satisfactorily o Very good, technical capacity exceeds expectations o Do not know
14.	Are there any government environmental (ambient) water quality monitoring programs in your country? o Yes o No o Do not know
15.	If the answer to Q 14 is 'no', how is water quality monitoring conducted in your country? (You can select multiple options) o Project-based monitoring by researchers, nongovernmental organizations (NGOs), international organizations, etc. o Private entities (e.g., industry, academia, etc.)
16.	Which type of water bodies are monitored in your country? (You can select multiple options) o Aquifers (groundwater) o Rivers and streams o Lakes and reservoirs o Wetlands o Estuaries o Transboundary waters

Continued...

No.	Question
17.	Who coordinates national/regional water quality monitoring activities in your country? (You can select multiple options) o National institutions o Provincial institutions o Regional organizations o International organizations/NGOs o Private entities o Do not know
18.	Are there any government national/central/regional water testing laboratories in your country? o Yes o No o Do not know
19.	How many water testing laboratories are currently operational in your country?
20.	Are there any accredited laboratories in your country (e.g., ISO 17025)? o Yes o No o Do not know
21.	Do water testing laboratories require national-level registration? o Yes o No o Do not know
22.	Please indicate the water quality parameters currently analyzed in national water testing laboratories. o Physical parameters (color, temperature, turbidity, odor, etc.) o Major chemical parameters (pH, electrical conductivity, total dissolved solids, etc.) o Major cations (calcium, magnesium, sodium, potassium, etc.) o Major anions (carbonates, bicarbonates, fluorides, chlorides, sulfates, etc.) o Oxygen (dissolved oxygen, biological oxygen demand, chemical oxygen demand, etc.) o Nutrients – Nitrate compounds (nitrates, nitrites, total nitrogen, ammonia, etc.) o Nutrients – Phosphate compounds (phosphates, total phosphorus, etc.) o Heavy metals (copper, cadmium, zinc, iron, lead, mercury, etc.) o Radioactive elements (alpha- and beta- emitter parameters) o Pesticides (organo-chlorine group, organo-phosphorus group, etc.) o Biological parameters (zooplankton and phytoplankton (chlorophyll a)) o Emerging contaminants (pharmaceutical compounds, personal care products (PCPs), endocrine-disrupting compounds (EDCs), microplastics, etc.) o Microbiological parameters (fecal coliforms, *E. coli*, etc.) o Emerging pathogens (antimicrobial resistant bacteria, viruses, protozoa
23.	Which laboratory equipment is used in national water testing laboratories in your country? o Portable meters (e.g., pH, conductivity, dissolved oxygen) o Benchtop meters (e.g., pH, conductivity, dissolved oxygen) o Spectrophotometer o Gas chromatograph (GC) o High-performance liquid chromatograph (HPLC) o Atomic emission spectrometer (AES) o Mass spectrometer (MS) o Inductively coupled plasma (ICP) o Flame photometer

Continued...

No.	Question
24.	How often is this equipment serviced and maintained? o Never o When they malfunction o Regular servicing and maintenance o Do not know
25.	How would you rate the technical capacities for water quality monitoring in your country? 1 = Underequipped to monitor water resources (e.g., conduct field sampling) 2 = Equipped, but can only monitor priority water resources 3 = Capacity available to monitor most water resources o 1 o 2 o 3
26.	How would you rate the laboratory technical capacities for water testing in your country? 1 = Underequipped to carry out basic water quality analysis 2 = Equipped but not able to carry out all analyses 3 = Capacity available to conduct basic analysis and other specialized tests o 1 o 2 o 3
27.	Please explain your rating choice in Q 27 and Q 28.
28.	How would you rate the technical capacities to process and interpret water quality data in your country? 1 = Underequipped to process and interpret basic water quality data 2 = Equipped to process and interpret most water quality data 3 = Able to process and interpret all water quality data in detail o 1 o 2 o 3
29.	What happens to the water quality data generated? o Data are stored in laboratory databases without further processing. o Data are stored, processed and used to inform operational decisions. o Data are stored and released as requested by external users. o Data sharing is coordinated across different government agencies or departments.
30.	What would you say are the three most important laboratory testing capacity needs?
31.	What would you say are the three most important water quality monitoring capacity needs?
32.	Which of the following are the most critical pollutants in your country? (Please select all that apply) o Physical parameters (color, temperature, turbidity, odor, etc.) o Major chemical parameters (pH, electrical conductivity, total dissolved solids, etc.) o Major cations (calcium, magnesium, sodium, potassium, etc.) o Major anions (carbonates, bicarbonates, fluorides, chlorides, sulfates, etc.) o Oxygen (dissolved oxygen, biological oxygen demand, chemical oxygen demand, etc.) o Nutrients – Nitrate compounds (nitrates, nitrites, total nitrogen, ammonia, etc.) o Nutrients – Phosphate compounds (phosphates, total phosphorus, etc.) o Heavy metals (copper, cadmium, zinc, iron, lead, mercury, etc.) o Radioactive elements (alpha- and beta- emitter parameters) o Pesticides (organo-chlorine group, organo-phosphorus group, etc.) o Biological parameters (zooplankton and phytoplankton (chlorophyll a)) o Emerging contaminants (pharmaceutical compounds, personal care products (PCPs), endocrine-disrupting compounds (EDCs), microplastics, etc.) o Microbiological parameters (fecal coliforms, *E. coli*, etc.) o Emerging pathogens (antimicrobial resistant bacteria, viruses, protozoa, etc.)

Continued...

No.	Question
33.	How would you rate the contribution of these sources to water pollution in your country?

	Minor Contribution	Considerable Contribution	Major Contribution
Mining	○	○	○
Industry	○	○	○
Petroleum	○	○	○
Urban	○	○	○
Agriculture	○	○	○
Dump sites	○	○	○
Sewage waste	○	○	○

34. Please name the most polluted water bodies in your country.

35. What activities are dependent on each of the water bodies mentioned in Q 35? (e.g., domestic water supply, ecological significance, recreation and tourism)

36. What have been the 3 main impacts of water pollution in your country or region? (Please select up to a maximum of three options)
- o Disease
- o Biodiversity loss
- o Loss of recreational opportunities
- o Eutrophication
- o Reduced agriculture productivity
- o Reduced fish catch
- o Reduced tourism

37. How is water pollution controlled in your country?
- o Water treatment technologies
- o Pollution control regulations (e.g., impact assessment, licenses, fines)
- o Wastewater reuse technologies
- o Nature-based solutions

38. Which of these pollution control/management tools has had the most impact in addressing pollution issues in your country?

	Least impact	Some impact	Most impact
Wastewater treatment	○	○	○
Pollution control regulations (e.g., impact assessment, licenses, fines)	○	○	○
Adoption of good agricultural practices	○	○	○
Nature-based solutions	○	○	○
Other	○	○	○

Continued...

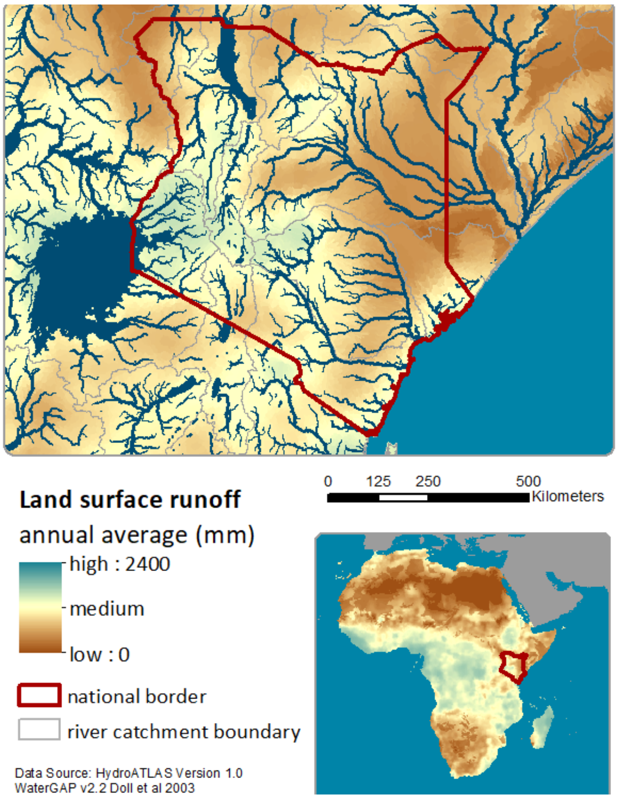
No.	Question
39.	Please name any inter-country water quality program that your country has taken part in, in the past.
40.	Please name up to 5 organizations/institutions that you have collaborated with on water pollution control, monitoring and analysis (including private institutions and academia). Please specify with names.
41.	How would you rate the government's attention to interventions on water quality and monitoring issues in your country? o Low priority to water quality and monitoring issues o Moderate attention to water quality and monitoring issues o High priority and proactive actions on water quality and monitoring issues
42.	What are some water pollution control solutions being implemented in your country that show interesting potential for impact?
43.	How would you rate the level of awareness of nongovernment actors (communities, NGOs, etc.) regarding water quality issues in your country? o Poorly informed and unaware of the potential dangers of water quality issues o Moderately informed and aware of the potential dangers of water quality issues o Well informed and are proactive in engaging the authority for actions
44.	Please provide any relevant links to water quality-related data and information pertaining to your country.

Annex B. Example of a Water Quality Profile for One Country.

Kenya

Background

- **Population**: 47.2 million
- **Water Supply**: National water coverage – 71.2%; Rural – 63.3%; Urban – 91.3% (WHO and UNICEF 2021b)
- **Sanitation**: National coverage – 58.2%; Rural –48.1%; Urban – 84%; National open defecation –8.5%; Rural – 11.3%; Urban – 1.3% (WHO and UNICEF 2021b)
- **Major water bodies**: Lake Victoria, Athi-Galana-Sabaki River, Tana River, Turkwel, Kerio, Athi-Galana, Northern and Southern Ewaso Ng'iro.
  Lakes — Magadi, Naivasha, Turkana, Elementaita, Nakuru, Bogoria and Baringo.
- **SDG 6.3.2. score (2020)** – 86.52 (UNEP 2021b)



Pollutants, Sources and Impact

Kenya is classified as a water-scarce country with many people living in rural areas with limited access to quality water. In addition, water resources are under pressure from agricultural chemicals (fertilizer and herbicides) and urban and industrial wastes, as well as from use for hydroelectric power (Kithiia 2012). Past studies have pointed out raw sewage overflowing from blocked or collapsed sewers, filled-up septic tanks and pit latrines in urban areas such as Nairobi as a major source of water pollution. On the other hand, in the rural areas, locating wells in close proximity to pit latrines increases the likelihood of microorganism contamination (Njoroge et al. 2018).

Major Pollution Categories and Examples of Their Occurrence in Kenya

Major categories	Example	References
Organic pollutants	Lake Naivasha – Water quality in the northern parts of the Lake is influenced by agricultural activities whereas the northeastern parts are dominated by domestic effluent. Water in the Likii River is not safe for human consumption because of pesticide residues	Ndungu 2014 Githinji et al. 2019
Pathogens	Microbiological contamination of the Nairobi and Athi rivers is high by Kenya standards and WHO guidelines for drinking water and agricultural use. The waters were found to be highly contaminated with human pathogenic bacteria, dominated by *E. coli*.	Musyoki et al. 2013
Inorganic pollutants (salts and metals)	The Ngong River at Embakasi indicates high values for most polluting substances including manganese, lead and mercury as a result of upstream industrial activity.	Kithiia 2012

Policies and Institutions: Stakeholders and Their Responsibilities

Stakeholders	Main responsibilities/duties
Ministry of Water and Irrigation	Responsible for the water sector in Kenya. Formulation of policy and strategy for water and sewerage services, sector coordination and monitoring of other water services institutions.
Water Services Regulatory Board	Regulation and monitoring of urban and rural water services
National Environment Management Authority	Promotes integration of environmental considerations into government policies, plans, programs and projects. Formulates water quality regulations
Water Services Boards	Water Services Boards are responsible for asset management, that is, for the development and rehabilitation of water and sewerage facilities. There are eight regional Water Service Boards.
Water Appeals Board	To settle water-related disputes and conflicts

Source: MWI 2007.

Water Pollution Monitoring and Control: Policies and Regulatory Environment

Policies, act, regulations	Description
Water Act (2002)	Provides for the management, conservation, use and control of water resources; regulation of the right to use water; regulation and management of water supply and sewerage services
Environmental Management and Coordination (Water Quality) Regulations, 2006 (Cap. 387).	Frames rules relating to the use and discharge of water for different purposes; makes provision for the protection of water resources from pollution; and defines water quality standards.
Guidelines on Drinking Water Quality and Effluent Monitoring, 2008	Focuses on drinking water quality and industrial effluents. Provides guidelines to water service providers to determine effluent quality, check on the operational efficiency of the wastewater treatment system; and monitor industrial effluent in their areas

Water Quality Monitoring and Pollution Control Initiatives

Program	Status/ Year	Objective	Scope	Funded by
GEMS/Water Quality Monitoring Program UNEP GEMS/Water CDC 2020)	Active	Extensive ambient water quality monitoring of surface water and groundwater	Collects data from surface water and groundwater 2-4 times per year	UNEP GEMS/ Water Capacity Development Centre
Aquaya Institute's Monitoring for Safe Water (MfSW) research program (Ethiopia, Guinea, Kenya, Senegal, Uganda and Zambia)	(2012-2016)	To build capacities for monitoring of water safety in sub-Saharan Africa	The program has collected qualitative and quantitative data on microbial water quality monitoring activities among the engaged monitoring institutions in six countries	UK Aid from the UK Foreign, Commonwealth and Development Office (FCDO)
Nairobi Rivers Basin Rehabilitation and Restoration Program: Sewerage Improvement project Phase II (NaRSIP-II)	2021	Access to improved sanitation services in Nairobi; improving the quality of rivers within the Nairobi metropolis	Water quality assessment of Nairobi and its satellite towns and rivers and, subsequently, quarterly surface water/ groundwater quality monitoring	African Development Bank, Government of Kenya

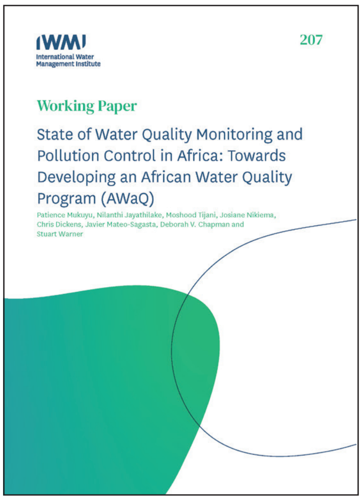
Laboratory Facilities and Capacity

The main Water Resources Authority (WRA) laboratory in Nairobi has the ability to analyze an extensive range of parameters and is staffed by a well-trained team. The laboratory works in line to ISO 17025 standards, and is certified by the Kenya Bureau of Standards. There is an extensive ambient water quality monitoring program that collects data from surface water and groundwater sources 2-4 times a year. Several regional laboratories support the central laboratory, together analyzing over 3,000 samples per year (UNEP GEMS/Water CDC 2020).

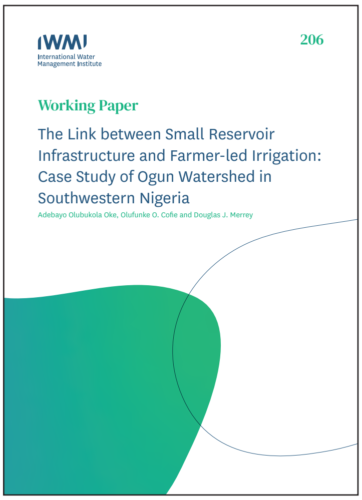
Annex C. Session Notes: Africa Water Week (November 24, 2021)

Challenges	Solutions
Low availability of *in situ* water quality data: • Not enough water quality stations, not even in critical control points • Scarcity of qualified staff for sampling and lab analysis • Insufficient laboratory capacities for some parameters, including emerging pollutants	Complement *in situ* data with modeled data and *ex situ* (remote sensing) data. Explore the role of citizen science, not only to involve citizens in data collection and sharing but also as a way to raise the awareness of local communities on pollution issues and form a coalition for action, policy and investment in pollution control.
Low accessibility of existing water quality data: • Data frequently stored on paper, CDs, etc., which makes it difficult to share and process • Unwillingness to share data. Fear of the consequences of making data public.	Harmonizing data collection and processing protocols and methodologies across countries and stakeholders Promote MoUs for water quality data sharing between institutions
Different parameters, methods and units used by different stakeholders and countries, which limits comparability, data aggregation and analysis	Build a water quality data platform for data storage and processing where different organizations can upload data
Weak or nonexistent data management systems and limited capacities to operate such systems	Capacity development and training. This will require targeted training for specific staff in institutions. The required capacity for effective monitoring goes beyond improved knowledge and skills of a few individuals; it requires these individuals to operate within effective institutions and different institutions to collaborate effectively on data collection and sharing. Facilitating inter-institutional coordination through country dialogues, workshops or other methods is thus necessary.
Low awareness about the linkage between water quality degradation and broader environmental and health impacts	Motivating funding and stimulate investments by making the best use of existing data to generate awareness stories.
Low investment in water quality monitoring, data processing and data use and communication	Credible water data can stimulate investment, support advocacy, stimulate political commitment, inform policy and monitor effectiveness in time. Sensitizing countries about these benefits will provide an incentive for countries to allocate appropriate financial and human resources. Cooperation to have a shared diagnosis on hotspots to be able to prioritize limited investments

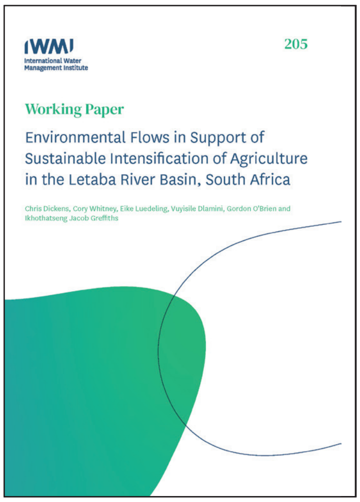
IWMI Working Paper Series



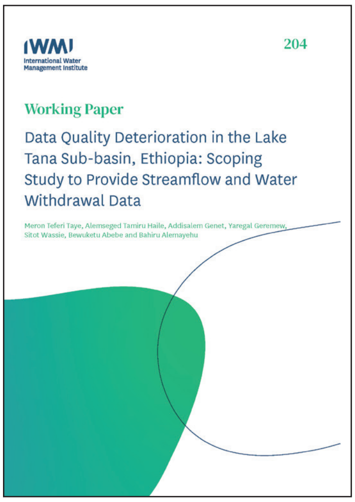
207 State of Water Quality Monitoring and Pollution Control in Africa: Towards Developing an African Water Quality Program (AWaQ)
https://doi.org/10.5337/2023.216



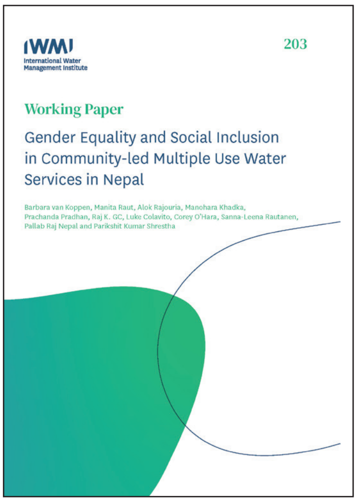
206 The Link between Small Reservoir Infrastructure and Farmer-led Irrigation: Case Study of Ogun Watershed in Southwestern Nigeria
https://doi.org/10.5337/2022.229



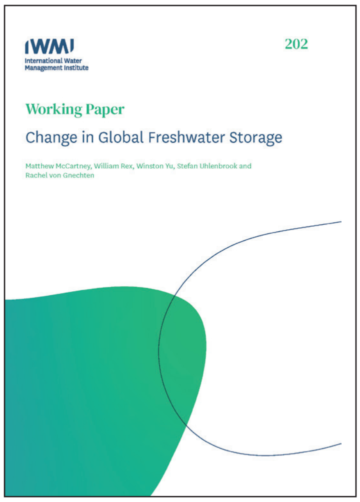
205 Environmental Flows in Support of Sustainable Intensification of Agriculture in the Letaba River Basin, South Africa
https://doi.org/10.5337/2022.226



204 Data Quality Deterioration in the Lake Tana Sub-basin, Ethiopia: Scoping Study to Provide Streamflow and Water Withdrawal Data
https://doi.org/10.5337/2022.208



203 Gender Equality and Social Inclusion in Community-led Multiple Use Water Services in Nepal
https://doi.org/10.5337/2022.200



202 Change in Global Freshwater Storage
https://doi.org/10.5337/2022.204

For access to all IWMI publications, visit: www.iwmi.org/publications/

Headquarters
127 Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Mailing address
P. O. Box 2075
Colombo
Sri Lanka

Telephone
+94 11 2880000

Fax
+94 11 2786854

Email
iwmi@cgiar.org

Website
www.iwmi.org

International Water Management Institute
CGIAR

IWMI is a CGIAR Research Center

ISSN 2012-5763
e-ISSN 2478-1134
ISBN 978-92-9090-953-8