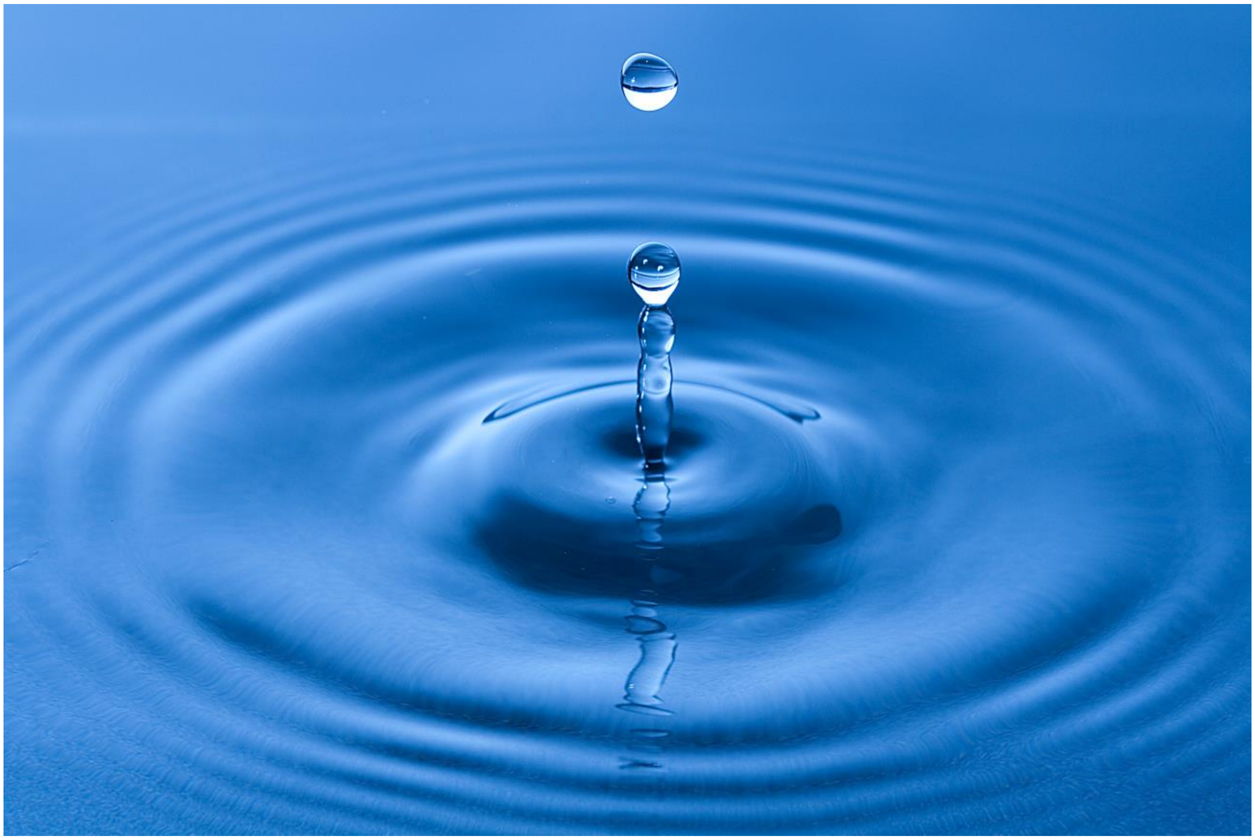
AMERICAN CHEMICAL SOCIETY



WHITE PAPER ON PROPOSED CAPACITY DEVELOPMENT FOR WATER QUALITY ASSESSMENT AND MANAGEMENT IN NIGERIA

A partnership between the American Chemical Society, University of Uyo (Nigeria), Chemical Society of Nigeria, and Hampton University (USA)

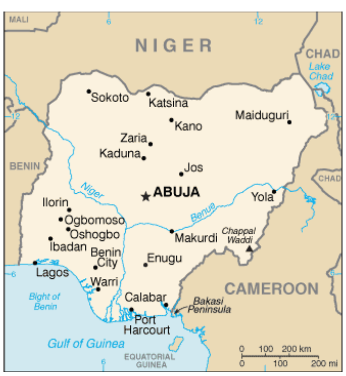
1.0: INTRODUCTION

The challenges that lie ahead as developing countries transition from agrarian to industry-based economies call for sound environmental practices. Water resources issues demand immediate and concerted attention. There are concerns over the reliability and safety of drinking water; source water protection; water distribution systems; quality assurance monitoring; wastewater handling and disposal; and sanitation. These vital water utilization processes, in turn, affect health, food security/safety, energy security, and economic prosperity.

Rural communities, particularly in African nations such as Nigeria, are especially hard-pressed for secure and safe water resources. Furthermore, trends in population demographics, such as population expansion, migration from rural to urban centers, and the transport of rural culture to urban centers will inevitably continue to exert strain on available water resources. Sustainability in water resources will require not only massive efforts to develop new and reliable sources, but effective management practices as well. The involvement of higher-education institutions is critical in this regard, as they will provide the expertise needed to train essential personnel; develop new technologies and strategies for transferring those technologies; and forge alliances with local organizations and service-providing groups to facilitate community-based initiatives.

Solutions to water and environmental health problems require approaches that emphasize partnerships to explore the links between water, health, public policy, technology, and poverty. Exposure and effective utilization of technological advances can have a catalytic effect in addressing water resource issues. Lastly, mechanisms are needed to facilitate the adoption and implementation of efforts and procedures that have proved to work elsewhere.

This white paper outlines plans to establish Nigeria’s first internationally accredited water-quality monitoring laboratory. This planned laboratory, in seeking to fill key knowledge gaps on Nigeria’s water pollution challenges, could provide a useful case study on the kinds of partnership- and technology-driven approaches that may prove pivotal to addressing future water challenges — not just in Nigeria, but elsewhere across the globe[1].



Source: CIA Factbook

2.0: NIGERIA’S WATER CHALLENGES

Nigeria is a prime example of a developing nation that is afflicted by water access and quality challenges. Africa’s most populous country, Nigeria has estimated population of about 177.5 million.[2] Although water pollution and access to clean water affect wide swaths of the country, they are particularly severe in the Niger Delta. Situated on the southern coast of Nigeria and bordered to the south by the Atlantic Ocean and to the East by Cameroon, the delta occupies a surface area of about 112,110 square kilometers. It represents about 12% of Nigeria's total surface area, and its estimated population exceeded 28 million in 2006[3].

[1] Dr. Isai Urasa contributed significantly to this segment.
[2] http://data.worldbank.org/indicator/SP.POP.TOTL
[3] http://www.nddc.gov.ng/NDRMP%20Chapter%201.pdf

Nigeria has long struggled to provide its residents with access to clean, treated drinking water. In 2000, the Nigerian government estimated that only 48% of inhabitants of the urban and semi-urban areas and 39% of inhabitants of the rural areas had access to potable water[4]. Many communities in Nigeria, as a result, rely on boreholes to extract untreated groundwater for drinking and household purposes[5]. Bottled water and sachet water, or "pure water," have also become more prevalent in Nigeria; although this water is not guaranteed to be treated, one reason it has become more popular is its greater perceived safety among the people[6].

Sources of water pollution in Nigeria:

Moreover, Nigeria (and in particular the Niger Delta region) serves as site to numerous agricultural and industrial activities that can pollute the water resources that the residents rely on for drinking and domestic purposes. Key among them is oil and gas exploration and extraction. The Niger Delta region suffers hundreds of oil spills per year, including at least 559 in 2014 alone[7]. Together, oil spills have introduced a cumulative total of at least 1.5 million barrels of oil into the environment since the early 1960s, an amount that almost doubles what spilled in the *Exxon Valdez* disaster in Alaska[8]. Oil pollution's impacts can be long-term; according to the United Nations (UN) Environment Programme, oil contamination in the Niger Delta could take three decades to clean up[9]. Key among oil and gas-related pollutants are total petroleum hydrocarbons (TPH), a class of dozens of compounds that can cause acute health issues such as headaches and dizziness as well as chronic diseases such as cancer and nerve pathology[10].

Other human-driven sources of pollution also afflict Nigeria. These include agricultural and urban runoff, and discharge from households and industrial activities — such as battery and aluminum manufacturing, pulp and paper manufacturing, and brewing[11]. Runoff often finds its way rivers and streams amid poor drainage systems, while household and industrial discharge sometimes gets dumped into waterbodies. These pollution sources contain a wide variety of toxic substances, from pesticides and nutrients in agricultural runoff to heavy metals in industrial discharge. The available literature on water quality suggests that levels of various pollutants — heavy metals, agricultural nutrients, pesticides, oil and polycyclic aromatic hydrocarbons, among others — in surface waters have increased as a result of these human activities[12].

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[4] Federal Government of Nigeria (2000). Annual report on Water Resources in Nigeria. Federal Ministry of Water Resources Press, Abuja, p. 54.

[5] Inam, E., et al (2014). Assessment of the Human Health Risk Associated with the Presence of Trace Metals in Groundwater Supplies in Akwa Ibom State, Nigeria. *World Journal of Applied Science and Technology*, 6(1), pgs. 55-65.

[6] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3161851/

[7] https://www.amnesty.org/en/latest/news/2015/03/hundreds-of-oil-spills-continue-to-blight-niger-delta/

[8] http://pakacademicsearch.com/pdf-files/eng/453/38-51%20Vol%202,%20No%203%20(2012).pdf

[9] http://postconflict.unep.ch/publications/OEA/UNEP_OEA.pdf

[10] http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=423&tid=75

[11] http://dx.doi.org/10.1002/cbdv.200690073/

[12] http://cdn.intechopen.com/pdfs/35057/InTech-Surface_water_quality_monitoring_in_nigeria_situational_analysis_and_future_management_strategy.pdf

Many Nigerians also lack access to sanitation services. Given that factor and the routine discharge of household waste into waterbodies, fecal contamination of water resources presents major risks in Nigeria, particularly to the poor[13]. Water afflicted by fecal contamination may bear a variety of pathogenic microorganisms. These include the following:

- Bacteria, such as *Vibrio cholera*, *Salmonella typhi*, *Salmonella paratyphi*, *Shigella dysenterie*, *Escherichia coli*, *Burkholderia pseudomallei*, *Cryptosporidium parvum*
- Mycotoxin-producing fungi, such as *Aspergillus ochraceus*, *Aspergillus flavus*, and *Penicillium* species;
- Parasites, such as *Giardia lamblia*;
- Viruses, such as *Norovirus*, *Eco-virus*, other enteric viruses.

Even global climate change may also hurt water quality, both globally and within Nigeria. As sea levels rise, salts from seawater will increasingly encroach upon coastal water resources[14][15]. In many places where saltwater intrusion has already occurred, mapping of the affected areas has yet to be conducted, making it difficult to identify which areas need deliveries of potable water[16].

Given this vast array of forms of contamination and ongoing struggles with access to clean drinking water, Nigerians face health risks associated with poor water quality and lack of access to potable water for drinking, household, and recreational activities. These challenges only promise to grow as Nigeria's population grows and its economy steadily shifts from an agrarian one toward a more industrialized one, in which polluting activities will expand.

The health burden of poor access to clean water:

Water pollution and lack of access to clean water carry numerous health consequences in Nigeria. For instance, Nigeria faces a major burden of diseases and deaths, many of which result from fecal contamination of water resources. Diarrheal diseases are the fourth leading cause of death in Nigeria[17], and more than 97,000 children die every year from diarrhea caused by unsafe water and poor sanitation in Nigeria[18]. And as a result of poor sanitation alone, Nigeria loses 455 billion naira (U.S. $3 billion) per year, mostly in the form of health costs[19]. Overall, about 11% of global deaths among children under the age of 5 occur in Nigeria, with many of them resulting from unsafe water and lack of access to sanitation[20].

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[13] https://www.wsp.org/sites/wsp.org/files/publications/WSP-ESI-Nigeria-brochure.pdf
[14] http://www3.epa.gov/climatechange/impacts/water.html
[15] www.ajol.info/index.php/jasem/article/download/103925/94041
[16] http://olemiss.edu/sciencenet/saltnet/swica2/Oteri_ext.pdf
[17] http://www.cdc.gov/globalhealth?country/Nigeria/why/
[18] http://www.wateraid.org/ng
[19] http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/09/28/090224b0828d0b43/1_0/Rendered/PDF/Nigeria0loses00e0to0poor0sanitation.pdf
[20] http://www.unicef.org/media/media_68359.html

Some research has also suggested that cumulative exposure to heavy metals in groundwater supplies found in one state in Nigeria may be harmful to adults and children[21]. In another study of 240 Nigerians in Enugu state, unsafe levels of nickel, manganese, and chromium were detected in participants' blood. Poisoning incidents also are a regular occurrence in Nigeria. For instance, lead poisoning of water resources claimed the lives of more than 400 children in Nigeria's Zamfara state in just six months in 2010[22]. Meanwhile, global climate change-induced saltwater intrusion has boosted salt intake in individuals who drink from the affected waters to unhealthy levels in some countries, potentially boosting the risk of hypertension[23].

Factors underlying poor access to clean water in Nigeria:

Nigeria's chronic challenges with clean water access stem from a variety of policy-related and economic factors. Nigeria's Report of the Vision 2020 water and sanitation technical working group noted that the country "is endowed with abundant water resources to support agriculture, irrigation, transportation, energy and sustainable provision of water supply and adequate sanitation. Unfortunately, this enormous potential has remained largely untapped due to uncoordinated and haphazard implementation of policies and programmes"[24].

Within the Niger Delta region, water access problems are especially pronounced. The Niger Delta Regional Development Master Plan offers numerous explanations: "problems in the operation of the state water system, lack of effective urban planning, inadequate attention from government to the sector, and limited involvement of the private sector in water resources management and services provision"[25]. Similar problems afflict wastewater management and sanitation. The country lacks robust wastewater infrastructure in many areas, as well as sufficient wastewater-management regulations[26][27].

Fiscal issues also imperil Nigeria's ability to improve water access and water-quality monitoring. Earlier this decade, Nigeria was falling well short of the 215 billion naira that the country must invest in water supply annually[28] in order to meet water-related UN Millennium Development Goals. Much of this investment would need to go toward existing water infrastructure just to maintain and rehabilitate it[29].

Paucity of scientific capacity and data:

Nigeria's water pollution challenges present the potential for major health risks. However, scientists don't thoroughly understand how severe water pollution is across Nigeria or how

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[21] Inam, E., et al (2014). Assessment of the Human Health Risk Associated with the Presence of Trace Metals in Groundwater Supplies in Akwa Ibom State, Nigeria. *World Journal of Applied Science and Technology*, 6(1), pgs. 55-65.
[22] http://www.mcser.org/journal/index.php/ajis/article/viewFile/2307/2282
[23] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230389/pdf/ehp.1002804.pdf
[24] http://www.ibenaija.org/uploads/1/0/1/2/10128027/water__sanitation_ntwg_report.pdf
[25] http://www.nddc.gov.ng/NDRMP%20Chapter%201.pdf
[26] http://www.mcser.org/journal/index.php/ajis/article/viewFile/2307/2282
[27] http://isdsnet.com/ijds-v2n2-53.pdf
[28] http://www.ijser.org/researchpaper/WATER-AND-DEVELOPMENT-CHALLENGES-IN-NIGERIA.pdf
[29] *Ibid.*

severe the resulting health impacts might be. One key reason for this, according to Dr. Edu Inam, is that Nigeria appears to lack an independent, academically established water-quality monitoring laboratory that meets international standards for scientific reproducibility and reliability set by agencies such as the UN and the U.S. Environmental Protection Agency (EPA). Instead, water-quality monitoring in Nigeria has been done on a relatively localized, inconsistent basis.

One of the key consequences of a lack of scientific capacity is geospatially and temporally incomplete data on contaminant levels in water, sediments, and biota in Nigeria. Current water-quality monitoring efforts in Nigeria tend to emphasize conventional water-quality parameters such as pH and turbidity, while neglecting emerging contaminants of global concern, such as polycyclic aromatic hydrocarbons (PAHs), pharmaceutical and personal care products (PPCPs), radionuclides, and endocrine-disrupting compounds (EDCs). This is reflected in the fact that Nigerian government's drinking-water-quality standard specifies only 12 parameters for routine water-quality monitoring: taste, odor, color, turbidity, pH, conductivity, iron, nitrates, aluminum, residual chlorine, *E. coli*, and fluoride[30].

Scientists in Nigeria lack reliable data on background levels of key pollutants, according to Dr. Inam. Scientists need these "benchmarks" to serve as a baseline when evaluating the severity of a chemical or oil spill's environmental impact. Sufficient benchmarks and laboratories are lacking to measure total petroleum hydrocarbons (TPH) and total hydrocarbon content (THC) — key oil-related pollutants — in fish, plankton, benthos, sediments, mangroves, and soil, Dr. Alfred Itah said.

Without access to high-quality, comprehensive data, policymakers and the public may struggle to make health- and environment-protective policies and lifestyle choices, respectively. In particular, the lack of an internationally accredited reference laboratory may imperil Nigeria's ability to meet its own water-quality guidelines and to achieve water-related goals laid out in the UN MDGs. The Nigerian government, in its Vision 2020 water and sanitation plan, suggested that Nigeria "institutionalize a performance monitoring and evaluation program for all stakeholders to ensure compliance with sector policies"[31]. To implement that goal, the document called for Nigeria to "establish an integrated water quality and sanitation reference laboratory network" across the nation's geopolitical regions "for monitoring quality of both raw water sources and treated water"[32].

3.0: VISION AND GOAL

Overall, given Nigeria's ongoing challenges with water contamination and access, Nigeria has an undeniable need for a water-quality monitoring laboratory that meets international standards. Such a laboratory could provide a useful source of scientific capacity and public information, as well as inspire new legislation and regulations to improve Nigeria's management of its water resources. Moreover, a laboratory in Nigeria could carry great benefits for other countries in West and North Africa that seek to learn more about their own water quality. It also could

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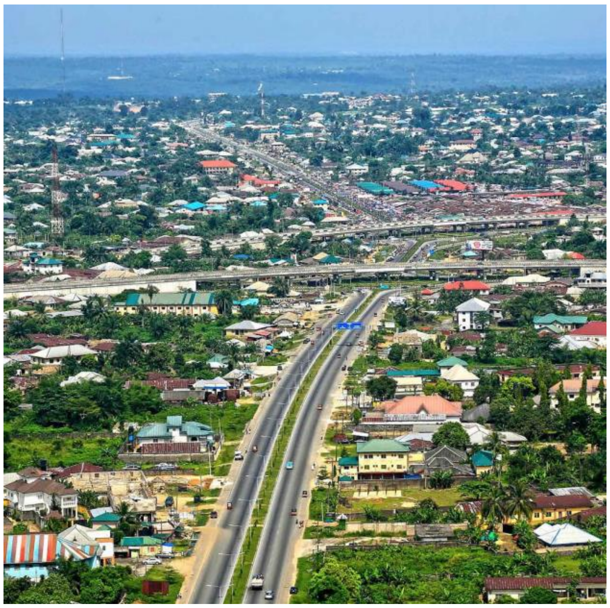
30 http://www.unicef.org/nigeria/ng_publications_Nigerian_Standard_for_Drinking_Water_Quality.pdf

31 http://www.ibenaija.org/uploads/1/0/1/2/10128027/water__sanitation_ntwg_report.pdf

32 *Ibid.*

provide ancillary benefits, such as job opportunities for laboratory technicians and training programs for students.

A team of Nigeria-based scientists has set out to establish such a laboratory. The scientists' goal is to open a water-quality monitoring laboratory that eventually receives international accreditation. A delegation of scientists visited the United States in the fall of 2015 to engage in networking, learn about opportunities for financial assistance, and acquire technical knowledge to help bring this laboratory to fruition. To the scientists' best understanding, the laboratory will be the first in Nigeria to meet U.S. EPA standards.



Aerial view of Uyo, Akwa Ibom state.

The University of Uyo (UNIUYO) will serve as the academic institution that houses the laboratory. The university was established in 1991 by the federal government of Nigeria, and is located in the heart of Uyo, the capital of Akwa Ibom state. More specifically, within UNIUYO, the laboratory will serve as part of a regional "centre of excellence" for Western Africa known as the International Centre for Energy and Environmental Sustainability Research (ICEESR). Beyond serving as a scientific facility, this laboratory will provide education, scientific training, and community services.

Although land is secured for the laboratory and groundbreaking on the facility has commenced, much work remains in order for it to become fully operational. In the ensuing sections, this document will describe the steps that will be needed to take the laboratory from concept to reality, with a preliminary goal of officially opening it in December 2017. The development of this roadmap was aided greatly by a series of meetings that the delegation had with government agencies, nonprofit organizations and scientific laboratories in Washington, DC and Virginia.

3.1: PARTNER INSTITUTIONS

A number of other organizations have played key roles in the delegation's visit, the drafting of this white paper, and the scientists' broader quest to establish the water-quality monitoring laboratory.

Global Innovation Imperatives (Gii) program, American Chemical Society (ACS):

The delegation's trip and the drafting of this white paper were sponsored by the Global Innovation Imperatives (Gii) program at the American Chemical Society (ACS). The purpose of the Gii program is to foster creative solutions to imperatives of global significance, such as clean water, food and health. The Gii program has carried out activities in India and Colombia to find local solutions for communities facing water challenges. ACS, meanwhile, is the world's largest scientific society and one of the world's leading sources of authoritative scientific information. A nonprofit organization chartered by Congress, ACS is at the forefront of the evolving worldwide chemistry enterprise and the premiere professional home for chemists, chemical engineers, and related professions around the world. ACS is dynamic and visionary, committed to "improving people's lives through the transforming power of chemistry"[33].

International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo:

The laboratory would be included in the International Centre for Energy and Environmental Sustainability Research (ICEESR) project. ICEESR is a newly created research and innovation center at UNIUYO that is dedicated to the generation and transfer of knowledge, and to strengthening individual and institutional capacities in furtherance of the mission and vision of UNIUYO. ICEESR is expected to play leading role in UNIUYO achieving overall research excellence as well as in becoming a regional "centre of excellence" for West Africa. The water-quality monitoring laboratory will be housed in the ICEESR Building, located at the permanent site campus of UNIUYO.

Among ICEESR's key objectives are industry-driven innovative research and training on science and technology for environmental sustainability; and capacity-building in areas such as environmental management, sustainable development, energy, and geoinformation. ICEESR already has strong linkages with renowned international research centers, such as the Massachusetts Institute of Technology's Media Laboratory, Georgia Institute of Technology's Strategic Energy Institute, and the International Environmental Research Centre at Gwangju Institute of Science and Technology in Korea[34]. For partnership and collaboration opportunities, please visit www.iceesr.org.ng.

Chemical Society of Nigeria:

With more than 1,000 members, the Chemical Society of Nigeria (CSN) is the major professional body representing and promoting the practice of chemistry in Nigeria. A nonpolitical and nonprofit organization founded in 1971, CSN is at the forefront of the evolving worldwide chemical enterprise and the premiere professional home for chemists, chemical engineers, and related professions in Nigeria and Africa at large[35]. Professor Gloria Obuzor, president of CSN, served as a member of the Nigerian delegation to the United States.

Hampton University

Hampton University is a historically black college located in Hampton, Virginia. Founded in 1868, Hampton University offers a range of degree programs for both undergraduate and graduate students across the liberal arts, business, engineering, and health. Hampton University chemistry professor Isai Urasa offered assistance to the delegation and office space for the drafting of an outline for this white paper.

3.2: THE DELEGATION'S VISIT

The Nigerian scientific delegation, which visited the United States on November 17-20, 2015, included the following scientists:

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[33] https://www.acs.org/content/acs/en/about/aboutacs.html
[34] http://www.iceesr.org.ng/about-iceesr-uniuyo/
[35] http://chemsociety.org.ng/about-us/

- Dr. Edu Inam, Department of Chemistry, University of Uyo
- Prof. Alfred Itah, Department of Microbiology, University of Uyo
- Dr. Valerie Solomon, Department of Agricultural Economics & Extension, University of Uyo
- Prof. Gloria Obuzor, Department of Chemistry, University of Port Harcourt; president of the Chemical Society of Nigeria

Additional individuals accompanied the delegation to its meetings:
- Lori Brown, ACS Office of International Activities
- Puneet Kollipara, science writer
- Prof. Isai Urasa, Department of Chemistry, Hampton University, who joined the group at some of the meetings and provided assistance in drafting the white paper.

Over the course of the delegation's visit, the delegation met with representatives of government agencies and nonprofit organizations in Washington, DC and toured two nearby laboratories that conduct water-quality testing. From these visits, the delegation received insights into water treatment, water-quality monitoring, scientific methodologies, and best practices for laboratory operations. Moreover, the meetings gave the team valuable contacts and potential sources of funding and technical assistance for the planned laboratory in Nigeria.

November 17:

The delegation spent the morning on a guided tour of the Dalecarlia Water Treatment Plant. Dalecarlia is one of two water treatment plants that provide drinking water to roughly 1 million people in Washington and Arlington, Virginia, who get their water from the Washington Aqueduct[36]. While on the tour, the delegation learned about the processes by which the water that enters the plant gets treated — from the sedimentation and filtration of solids and particles to disinfection with chlorine and ammonia[37].

Dalecarlia Water Treatment Plant

During the visit, the delegation also learned about some of the key contaminants of concern that the Dalecarlia facility monitors for regularly both to provide information to water customers and governments and ensure that water meets federal safety standards. These regularly monitored contaminants range from pathogens, such as *E. coli*, to chemical pollutants, such as volatile organic compounds and lead. The delegation also toured the facility's laboratories, which are staffed by chemists and microbiologists who analyze water samples for basic properties, such as alkalinity and pH, as well as for chemical and microbial contamination.

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[36] http://www.nab.usace.army.mil/Missions/WashingtonAqueduct.aspx
[37] http://www.nab.usace.army.mil/Missions/WashingtonAqueduct/TreatmentProcess.aspx

In the afternoon, the delegation met with representatives from the Africa bureau at the U.S. Agency for International Development (USAID). The USAID representatives offered suggestions to delegation members about potential networking opportunities and funding sources for the laboratory.

Finally, the delegation met at ACS headquarters with representatives from the Association of Public Health Laboratories (APHL) and the U.S. Water Partnership (USWP). APHL serves as a membership organization representing governmental laboratories that analyze environmental, food and clinical samples. Already, the Association of Public Health Laboratories (APHL) have worked with more than 30 countries to bring laboratory systems perspective to support public health[38]. Meanwhile, USWP is a coalition of more than 100 government agencies, nonprofit groups, universities, and companies that seek to address global water challenges. During the meeting, the delegation and the organizations discussed how they might collaborate to set up the laboratory. Joining the meeting by phone was Dan Hautman, a representative of the EPA Office of Ground Water and Drinking Water. Hautman outlined the procedures by which water-quality laboratories can be officially certified — a requirement under U.S. law if they wish to conduct compliance testing for public drinking-water systems[39].

November 18:

Delegation members met with representatives of EPA's Office of International Tribal Affairs, who told the delegation about the agency's international work, including in Africa. EPA representatives explained that the agency has helped nations develop water-quality enforcement regimes and water-safety plans and boost water-quality laboratory capacity. After this meeting, the delegation departed for Richmond, Virginia.

November 19:

The delegation paid an all-day visit to the Virginia Department of Consolidated Laboratory Services, an APHL-member laboratory in the state capital of Richmond. DCLS performs a variety of environmental and clinical testing for the Commonwealth of Virginia and other governmental bodies[40]. The laboratory performs about 7 million tests a year covering roughly 650 analytes, according to DCLS Deputy Director Angela Fritzinger. At DCLS, scientists and other staffers spoke to the delegation about the instruments and procedures they use, as well as their quality assurance procedures. Additionally, delegation members toured a microbiology lab and analytical chemistry labs at DCLS to see the laboratory's instrumentation and procedures up close.

November 20:

The delegation spent the day outlining the first draft of this white paper in office space provided by Professor Urasa at Hampton University's Department of Chemistry.

3.3: OUTCOME OF MEETINGS

During the delegation's visit, a number of key lessons and outcomes emerged. The first broad category of these lessons involved learning of potential networking and funding sources.

[38] http://www.aphl.org/globalhealth/
[39] http://www.epa.gov/dwlabcert/learn-about-laboratory-certification-drinking-water
[40] http://www.dgs.state.va.us/divisionofconsolidatedlaboratoryservices/tabid/453/default.aspx

Networking and funding opportunities

APHL expressed eagerness to assist the delegation. APHL Global Health Director Lucy Maryogo-Robinson noted that her group helps forge twinning arrangements between laboratories in different countries. In these multiyear arrangements, APHL matches two laboratories together, one of which is located in an underdeveloped nation, to share information and expertise with each other. While APHL representatives could not guarantee funding for such a twinning arrangement in this instance — the delegation may need to look to other agencies, such as USAID, for funding — she did suggest that twinning was a potential avenue for the delegation to pursue. APHL representatives also suggested that they could provide assistance with lab design, equipment and human-resources planning, and curriculum and training program development.

Representatives from USAID and EPA headquarters informed the delegation of several potentially useful sources of funding and networking opportunities with other institutions, both within Africa and across the globe. EPA representatives pointed to a couple of organizations in particular:

- The International Institute for Water and Environmental Engineering (2iE) in Burkina Faso, which offers training and conducts research into a range of issues including water pollution and treatment.
- The Water Research Institute of Ghana, which conducts research into water resources, also could serve as a networking source for the delegation.

USAID itself offers its own funding for development projects. Representatives of USAID said that the agency's region- or country-level missions control most of the agency's funds for water-related projects. The USAID representatives suggested that the delegation contact the agency's mission in Nigeria and a separate, regional mission for West Africa based in Accra, Ghana. USAID representatives provided a number of other suggestions for potential funding and networking opportunities:

- Rotary International, a civil society organization with heavy operations in Nigeria. USAID representatives explained that water and sanitation projects comprise one of Rotary's largest funding areas.
- The Coca-Cola Company Foundation, which provides funding to advance several social causes, one of which is water access/conservation.
- The African Water Association (AfWA), a water-issues professional organization based in Abidjan, Côte d'Ivoire.
- The Aquaya Institute, a nonprofit research and consulting organization with offices in California and Nairobi, Kenya. Aquaya engages in research and development and provides consulting services with the aim of promoting access to safe water.

Scientific and technical lessons

But funding and networking opportunities were just one major component of what the delegation learned. The delegation also acquired a finer-grained sense of the scientific tools, techniques, procedures and other elements — both tangible and intangible — that go into the operation of a water-quality monitoring laboratory. The tours of the Dalecarlia water treatment plant and the Virginia DCLS were particularly insightful in this sense. As staff scientists at the facilities walked the delegation through their laboratories, they presented a wide variety of scientific instruments and techniques that they routinely use to analyze water samples for various pollutants.

Dalecarlia and DCLS scientists explained that these instruments must be operated in a specific way to ensure that the public and policymakers can trust the data produced with these tools. The laboratories use highly standardized, rigorously vetted techniques, or protocols, that have received official recognition from an authoritative body such as the U.S. EPA[41]. For water-quality data to be used in a policymaking context — such as compliance with drinking-water regulations — the data must usually be generated via approved protocols. These protocols cover not just the instruments' operation, but also all other phases of the scientific process, stretching back to the collection, holding, and transport of samples.

Scientists offered the delegation some examples of EPA protocols — each of which is assigned a number — that serve as widely accepted methods to analyze water samples for specific contaminants[42][43]. For instance:

- Method 200.8: Uses inductively coupled plasma-mass spectrometry (ICP-MS) to detect trace metals in drinking water.
- Method 525.2: Pairs solid-phase extraction with gas chromatography-mass spectrometry (GC-MS) to detect semi-volatile organic compounds in drinking water. According to Robert Glowacky of DCLS, this method can be used on compounds such as polycyclic aromatic hydrocarbons, nitrogen- and phosphorous-based pesticides, chlorinated pesticides, phthalates, and polychlorinated biphenyls.

Glowacky suggested that the delegation determine which instruments to acquire based primarily on which EPA-approved protocols the scientists want to use, as well as based on the instruments' ability to measure various water-related media and the limit of detection that the scientists wish to achieve. He also suggested that the delegation place high weight on purchasing from a vendor that places a high priority on post-purchase customer service and support.

DCLS staff scientists emphasized the importance of implementing a robust quality management system (QMS) in ensuring that protocols are carried out correctly and, thus, ensuring the trustworthiness of the data that is generated. A well-designed QMS includes a number of components. Among them is quality assurance, which refers to the set of operating principles that, when performed properly during sample collection and the experiment, will yield defensible, trustworthy data. Having a dedicated quality assurance officer or division that is separate from other parts to the laboratory can help ensure that quality assurance matters are carried out objectively. Other important QMS components range from the presence of up-to-date safety manuals and personal protective equipment, to thorough logging of every action taken in

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[41] https://www.gpo.gov/fdsys/pkg/CFR-2014-title40-vol23/xml/CFR-2014-title40-vol23-sec136-3.xml

[42] http://www.ecfr.gov/cgi-bin/text-idx?SID=ef7cb0def9282229378675db04643bf5&mc=true&node=se40.23.136_13&rgn=div8

[43] http://www.ecfr.gov/cgi-bin/text-idx?SID=827ada984a3fca23999ea970adc93fc2&mc=true&node=sp40.23.141.c&rgn=div6

the lab, to the internal and external audits that laboratories routinely undergo, to corrective responses and preventive measures.

Another message that emerged during the delegation's tour was the benefits of having robust systems for storing, managing, and analyzing data. Dalecarlia and DCLS both make use of laboratory information management systems (LIMS), software-based systems that serve as a central repository for performing a range of data-related tasks. These include tracking samples, inputting experimental data, conducting quality control, and performing data analyses. Robert Hoffa of the Dalecarlia Water Treatment Plant informed the scientists that the facility has benefited immensely from its LIMS, which enables them to perform on-demand analyses quickly for their customers — a crucial benefit given the public-health implications. Glowacky of DCLS, meanwhile, advised the delegation on purchasing a LIMS that would be reasonably user-friendly and fit-for-purpose. Glowacky noted that some LIMS are designed specifically for environmental applications, and some even come with built-in quality-control tools.

Finally, the delegation learned what achieving official certification and accreditation for the laboratory might entail. As an example, Hautman of the EPA's Office of Ground Water and Drinking Water outlined how the laboratories can obtain certification — from EPA itself or a state certifier — in order to conduct compliance testing for drinking water in public water systems in the U.S. Not only must laboratories follow approved protocols to the letter of the law and have sufficient, properly trained staff. They must also pass regular audits, which include on-site evaluations and "proficiency tests" for each analyte they study and each method they use. In these tests, laboratories must measure a contaminant's level in a "proficiency sample" within a certain range of the actual value.

Virginia DCLS's Cathy Westerman also noted the existence of the National Environmental Laboratory Accreditation Program (NELAP)[44], which can often be used to substitute for drinking-water compliance-testing certification from EPA[45]. This accreditation program also assesses laboratories for non-drinking-water-related matters. Accreditation can take about nine months to receive from the time a laboratory applies for it, Westerman said.

The terms "accreditation and "certification" are often used interchangeably, though in many cases accreditation programs are more rigorous than certification programs, Westerman said. Whereas many certification programs merely assess laboratories' compliance with basic rules and procedures, an accreditation program also assesses their technical competence to perform specific tests, Westerman said. She explained that laboratories can obtain NELAP accreditation from DCLS by passing semiannual proficiency testing, setting up rigorous QMSes, and keeping detailed records that attest to the traceability and defensibility of their results.

4.0: LABORATORY DESCRIPTION AND OBJECTIVES

With the knowledge obtained during their visit in hand, the delegation members aim to open the laboratory by December 2017. The water-quality monitoring laboratory is envisioned to have instrumentation to carry out chemical and microbiology analysis for a wide range of parameters, specifically contaminants of global concern that aren't routinely measured in Nigeria. These

[44] http://nelac-institute.org/content/NELAP/index.php
[45] http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30006MXP.txt

include chemicals such as chlorination and other disinfection byproducts, endocrine-disrupting chemicals, pharmaceutical and personal care products, pesticides, bromates, trace metals, among others, according to Dr. Inam.

In addition to conducting water-quality analysis, the laboratory would create a highly credible water-quality database, a resource that could serve the university and its researchers, the government, other research institutions, industries, and the general public, Dr. Inam said. This laboratory project will generate data that Nigeria's government agencies could use for better management of water resources. Other research institutions and public water utilities could look to the laboratory for technical guidance or information to improve their own water-quality analyses or to identify areas for improvement in water quality.

Additionally, the delegation believes that the laboratory's findings could help foster additional research and public outreach. Researchers both within and outside the laboratory's host university could use the data generated there to publish research papers and communiqués. The university could produce press releases and educational materials highlighting key findings of the laboratory's work.

4.1: IMPLEMENTATION STRATEGY

Already, some funding, land and other resources for the laboratory have been secured. UNIUYO has allocated 1.7 hectares of land space on its permanent site campus for the project. Dr. Inam said the project has received 10 million naira in funding toward the construction of the building that will house the facility, which will consist of multiple laboratories devoted to separate aspects of water quality. An additional 30 million naira (almost US$100,000) are needed, she said. The expected completion date of the building is December 2016.

Dr. Inam said that the facility will have access to basic infrastructure within the university campus and will be supported by relevant stakeholders, from water utilities to the Nigerian government, which will benefit from the services provided by the laboratory. Meanwhile, the university receives funding from the federal government of Nigeria, as well as from other government agencies, such as the Tertiary Education Trust Fund and the Petroleum Technology Development Fund, and from international oil companies operating in Nigeria, such as ExxonMobil, Shell, and Elf, according to Dr. Inam.

The overall strategy to ensure the success and sustainability of this laboratory project lies in the building of strong partnerships locally, nationally, and internationally, according to Dr. Inam. As a starting point, this report is prepared in partnership with ACS, CSN, Hampton University, and UNIUYO. These partners will seek additional financial and material resources for setting up the laboratory, student and faculty exchange programs, and collaborative research. The university, working in conjunction with nearby communities, will also help identify the best candidates to fill job vacancies at the laboratory.

The second part of the strategy involves seeking partnerships with stakeholders, many of which will benefit directly. Government agencies from the state to the federal level, as well as private-sector water operators in Nigeria, will be consulted on issues such as their biggest areas of need and on candidates for training. Local community organizations will also prove pivotal in building trust and spreading word about the laboratory among residents. Additional partnerships and collaborations may be sought with the following stakeholder institutions, according to Dr. Inam. In exchange for providing funding, the partners will have access to the building's facilities, she said:

- Federal Ministry of Water Resources, Nigeria
- Department of Petroleum Resources, Nigeria
- Niger Delta Development Corporation (NDDC), Nigeria
- WaterAid

Additional financial assistance will also be sought from development agencies operating in Nigeria with previous records of intervening in the country's water challenges. These include Japan's development agency (JICA), South Korea's development agency (KOICA), and USAID. Additional technical advice and financial assistance could be sought from the other organizations that USAID and EPA representatives noted during the delegation's visit — ranging from Rotary International to the Coca-Cola Company Foundation to the African Water Association.

Research partnerships will also help improve the quality of the laboratory's work and give laboratory staff additional opportunities for training. ICEESR has already entered into a formal memorandum of understanding that includes collaboration on water-quality research with the following institutions:

- International Environmental Research Centre, Gwangju Institute of Science and Technology, South Korea
- Lancaster Environment Centre, Lancaster University, United Kingdom
- Georgia Institute of Technology
- Abuja Water Board, Abuja, Nigeria
- Akwa Ibom Water Company Limited

The laboratory will also receive mentorship via already-established linkages with APHL, USWP, and the Dalecarlia water-treatment plant to ensure professionalism, continuous capacity-building development, and staff adherence to U.S. EPA protocols. Once the laboratory is fully operational — with December 2017 as the target date — staff will work towards acquiring U.S. EPA accreditation.

4.2: EQUIPMENT NEEDS

The water-quality monitoring laboratory will require a variety of scientific equipment in order to function. Already, the delegation has identified a number of instruments that the water-chemistry and microbiological laboratories within the facility will need.

The water-chemistry laboratory will need instruments that enable it to perform analytical methods such as liquid chromatography-mass spectrometry (LC-MS), gas chromatography-mass spectrometry (GC-MS), inductively coupled plasma optical emission spectrophotometry (ICP-OES), and LC-MS/MS. Moreover, basic water-chemistry equipment needs have been identified; these include evaporators, filtration apparatuses, shakers, fume hoods, furnaces, ovens, vacuum pumps, refrigerators, water baths, balances, pneumatic trough, solid-phase extraction and water-purification systems, Soxhlet extractors, heating mantle controllers, extraction thimbles, flasks, and desiccators.

The microbiological laboratory will use a variety of techniques to identify and quantify microbes in water samples. Specific equipment needs include microscopes, transilluminators, laminar flow hoods, a PCR system, magnetic stirrers, lyophilizers, grab samplers, incubators, autoclaves, a GC-flame ionization detector, dry-air and microwave ovens, high-speed refrigerated centrifuges, colony counters, and digital cameras.

Dr. Inam explained that the laboratory is likely to install a LIMS. However, she said this step likely represents a longer-term goal that will occur after the laboratory has acquired the appropriate computer and software systems.

4.3: PROJECT AVAILABILITY AND ACCESSIBILITY

The water-quality monitoring laboratory will be available to all relevant stakeholders in the region. Once, fully operational, the laboratory will attract and help both the students and academic staff of UNIUYO. The university will improve and expand its water-related study programs, either by enhancing currently available courses or by enabling the creation of new courses. The laboratory will also provide short trainings, internships, seminars, and workshops to people involved in water-quality assessment and management.

The laboratory will fill another major void, this one in the university's postgraduate curriculum, by giving postgraduate chemistry students who have interest in specializing in analytical chemistry the opportunity to use modern analytical instruments. Currently, postgraduate students in the Department of Chemistry deliver their samples to private laboratories across the country for analysis. Without the opportunity to perform the measurements themselves, the students may never get fully trained in operating the analytical instruments, and they may not understand certain nuances of the subject matter. The new laboratory will finally give these students the facilities and instruments that have long eluded them.

4.4: MANAGEMENT AND STAFFING PLAN

The laboratory staff will include a laboratory manager, a quality-assurance officer, and at least two laboratory technicians. Decision-making in the laboratory will follow a collaborative approach whereby key personnel equally participate in program development.

The laboratory manager will report to the director of ICEESR. This laboratory manager will be in charge of coordinating, managing, and organizing the day-to-day activities and operations of the laboratory; supervising staff; seeking and managing grant funds; and initiating and carrying out laboratory programs, research collaborations, and agency-community partnerships.

Below the laboratory manager will be the quality-assurance officer, who will be charged with setting up and administer a quality-assurance program. This officer will develop the laboratory's quality-assurance policies and a quality-assurance manual. Additionally, the officer will conduct periodic reviews of the laboratory to ensure compliance with established quality standards, and ensure good recordkeeping and inventories.

Also below the manager will be two laboratory technicians. The technicians will be in charge of the day-to-day operation and upkeep of the laboratory and its equipment, sample analysis, and the safe use and management of chemicals and reagents.

The laboratory will also have external measures in place to ensure that the project is being delivered in its intended manner. First, a coordination committee — comprising partners from UNIUYO, ACS, CSN, and Hampton University — will oversee implementation and provide follow-up oversight. The second measure involves the mentoring services provided to laboratory staff by APHL, USWP, and other partners.

5.0: OUTCOMES AND IMPACTS OF THE LABORATORY

Primary outcomes:

By the end of the first full year of operations, the laboratory will:

- Produce data on the quality of drinking water resources in Akwa Ibom state;
- Conduct training for no fewer than 50 individuals involved in water-quality monitoring in the 36 local government areas of Akwa Ibom state;
- Help develop a new curriculum for the training of water-quality professionals in the state;
- Develop new policy for drinking-water safety in Akwa Ibom state.

Long-term impacts:

Beyond year one, the laboratory will produce a variety of benefits, both for the university and for society at large. These impacts are economic, social, and environmental in nature.

1. Economic:
   - Job creation: The laboratory will create additional new jobs both within UNIUYO and Akwa Ibom state in general.
   - Boosting the university's stature: The laboratory will increase the number of national and international grants to the university. This will increase the ranking of the university and, in turn, attract more quality students, including international students.
2. Social:
   - Policy and legislation: With the information the laboratory produces, policymakers could develop new national legislation on drinking water similar to the U.S. Clean Water Act. Federal agencies also will have better information with which to enforce existing laws and regulations.
   - Community awareness: The laboratory, by publishing research communiqués, press releases, educational materials and public databases, will increase community awareness on water quality.
3. Environmental and health:
   - Improved public and environmental health: By providing better water-quality information and enabling policymakers to enact better water-protection measures, the laboratory has the potential to benefit public health, as well as the health of ecosystems and waterbodies.
   - Environmental technology development: The laboratory's research findings could help promote the development of water-treatment kits and simple clean-up technologies.