Africa's Water Quality

A Chemical Science Perspective

A report by the
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Advancing th

Contents

Background 4

Foreword by H.E. Joaquim Alberto Chissano 5

Key messages 6

1. Water, food and poverty: the context 7

2. Provision of water resources in Africa 8

3. Water and food production 10

4. Water quality: monitoring environmental health 12

5. Technologies to protect and improve water quality 14

6. Building scientific and human capacity 18

7. Building a sustainable water security system 19

8. References 21

BACKGROUND

On 26th - 29th August 2009 the Pan Africa Chemistry Network (PACN) held the [illegible], hosted by the University of Nairobi, Kenya, and sponsored by the RSC and Syngenta. The findings and recommendations contained within this report represent the views of the 180 scientists and practitioners that attended this conference from 14 different countries in Africa, as well as the UK, Switzerland, Colombia and Uruguay.

During this three-day meeting, delegates addressed the scientific issues surrounding sustainable water. The concluding open forum called for an increased understanding of the role of scientific research in finding solutions to issues relating to water, especially water quality, in Africa. It also called for an increased scientific voice within African Governments, together with a shift towards fostering a science-based water management culture.

This report is unique in that it summarises the conclusions and recommendations emerging from the [illegible], representing the opinions and knowledge of some of Africa's best scientists in the field of sustainable water research and development. It also includes the feedback received at the high level workshop organized at RSC headquarters in London, where experts on water and African issues were invited to discuss a draft of this report.

The report will be launched in Nairobi at the United Nations World Water Day 2010 "[illegible]", with the intention of alerting the governments of the African nations for which water quality remains an urgent issue. The document also serves as a roadmap for the numerous scientists in African academia, government and industry who will ultimately be tasked with undertaking the recommendations outlined herein.

The recommendations presented in this report specify '[illegible]' solutions for water wherever it is used: for drinking,

FOREWORD

Water is essential for life. Safe, abundant water is vital to our ability to prosper and to fulfil our potential. Without it, we face a continual decline in our well-being, poverty and hunger, and increasing levels of conflict.

Across Africa, a third of us have no access to clean water, and almost two thirds no access to clean sanitation, causing widespread suffering from malaria, typhoid, dysentery and many other diseases. Apart from this effect upon our health, the loss of productivity that results from water-related illnesses holds back our progress.

The population in many African countries is growing rapidly each year, averaging 2.5% across sub-Saharan African, but the lack of safe water and sanitation reduces our economic growth at twice that rate. And a growing population must be properly fed. We need to increase our food production by half in the next twenty years. How will we achieve this without reducing the amount and quality of the remaining water resources which we will need for drinking and sanitation? Clearly, the provision of sustainable, clean water for our people is of the highest priority.

The effects of climate change make the challenge of conserving our precious water resources even more difficult. The people of Africa that are responsible for less than 5% of the pollution which has changed the planet's atmosphere, will feel the worst of its impact in terms of increased flooding and drought. Climate change is a global problem, and it places the onus upon the global community to live up to their commitments to reduce by half the proportion of people without access to safe drinking water and basic sanitation.

Yet despite all the obstacles we face, I remain an optimist when it comes to Africa's agricultural development and to water sustainability.

The introduction of new forms of irrigation pioneered by African scientists and research institutions has the potential to transform the way staple foods are cultivated. Today, only 10% of Africa's cultivated land is irrigated. Imagine what we can do if this percentage is increased in a way which also does not overburden our water supplies.

We need to make more use of fertilizers to feed nutrient deficient soils, and of modern crop varieties and new farming techniques to improve yields. We can see already what can be achieved with determination, vision and partnership.

With the right policies and commitment, Africa has the chance to match, indeed better the Asian agricultural miracle of the last generation. Better because we can do so in an environmentally sustainable way, which takes fully into account the fact that 80% of Africans are dependent in some way on agriculture.

Sustainable supplies of water, its better management and protection are the key to this success – just as increased agricultural productivity holds the key to spreading prosperity and our other development goals.

This report relies upon the collective knowledge of scientists from across Africa, detailing how we can improve our capacity to tackle these challenges by establishing new centres of scientific excellence and by bringing together the best minds in science with governments to ensure water sustainability.

I have no doubt of the scale of the challenge, but I am also optimistic that with vision and will, we can encourage governments across Africa to adopt these solutions and put them into practice.

H.E. Joaquim Alberto Chissano
Former President of Mozambique
Chairperson, Africa Forum for Former African Heads of State and Government
Chairperson, Joaquim Chissano Foundation

KEY MESSAGES

1.

African heads of state joined the global consensus in agreeing to reduce by half the proportion of people "without sustainable access to safe drinking water" by 2015.[1] This is within the framework of the Millennium Development Goals 1 and 7 ("Eradicate extreme hunger and poverty" and "Ensure environmental sustainability", respectively). They further agreed, at the World Summit on Sustainable Development in Johannesburg, to reduce by half the proportion of people living without access to improved sanitation by 2015, compared to 1990 levels. The provision of water of suitable quality and in sufficient quantity forms the cornerstone for achieving these Millennium Development Goals.

In 2009, Africa's population exceeded 1 billion[2] and continues to increase at a rate of 2.4% annually. Of this population, 341 million lack access to clean drinking water,[3] and a further 589 million have no access to adequate sanitation.[4] In both cases, increases in coverage are not keeping pace with population growth, which means it will be unlikely that the 2015 Millennium Development Goals will be met.

It is estimated that around half of all patients occupying African hospital beds suffer from water-borne illnesses due to lack of access to clean water and sanitation. This is reducing the overall health and productivity of the adult workforce.[5] Water-borne diseases like typhoid, cholera and dysentery are among the major causes of mortality

2. PROVISION OF WATER RESOURCES IN AFRICA

2.1 Where is the water?

Africa as a continent appears to have an abundance of water; it has 17 rivers, each with catchments over 100,000 km^2, more than 160 lakes larger than 27 km^2, vast wetlands and limited, but widespread, groundwater. Rainfall similarly is plentiful, with Africa's annual average precipitation being at a level comparable to that of Europe and North America.[9] Withdrawals of water in Africa for its three main uses – agriculture, domestic, and industry – is low, estimated to be only 3.8% of total annual renewable water resources.[10]

However, Africa is a continent with large disparities in water availability between sub-regions. About 50% of Africa's total surface water is concentrated within a single basin – the Congo river basin – and 75% of total water resources are concentrated in just eight major river basins.[11] The countries with the highest available freshwater per capita include the Democratic Republic of Congo, with around 250,000 m^3 per capita per year. In contrast, Burundi and Kenya have only around 840 and 950 m^3 freshwater per capita per year, respectively.

Figure 1 shows the ex[illegible]

Food production comprises a large

4. WATER QUALITY: MONITORING ENVIRONMENTAL HEALTH

Environmental monitoring is essential if we are to identify sources of contaminants and build strategies to avoid these entering water resources that may be used for human consumption. Good environmental monitoring, operating within a robust legislative framework, is an essential prerequisite to achieve this. The first step is an assessment of the present status of the aquatic environment. Effort can then be focused on the restoration and protection of environmental health.

In order to build the capacity to protect environmental health, investment needs to be made in suitable hardware (technology that is fit for purpose including low technology options). However, the training of suitable personnel, together with the development of systems for data validation and quality assurance, are equally important. This requires people to operate and maintain the instrumentation and others to interpret the data, formulate policy and implement strategy. This is achievable through the identification and support of 'Centres of Excellence' within the region in question.

In determining a strategy for the protection of environmental health of the African continent, it is essential to involve and engage the communities who will benefit most from the rewards of a healthy environment. The equipment will need to be robust, low-cost and easy to maintain. The use of local or indigenous knowledge, where appropriate, will increase the probability of acceptance and success in the drive for the protection of the health of both humans and ecosystem in Africa.

4.1 Environmental monitoring networks

The establishment or improvement of monitoring networks should:

- ascertain where water quality and quantity is a problem;
- identify when remedial action is required;
- allow for short and long term planning and actions to take place.

4.2 Increasing analytical capacity in Africa

The increasing growth in the African population, combined with a lack of stringent environmental safeguards, has given rise to serious concern about water quality, and the associated threats to human health and the environment. If Africa and its research scientists are to embrace the recommendations of this report, increasing Africa's capabilities and capacity in analytical chemistry is imperative. In order to support chemical monitoring and management activities such as those discussed here, there is an urgent need for more personnel who are scientifically qualified and technically trained in relevant advanced analytical techniques. These include, for example, modern capillary gas chromatography (GC) methods incorporating detection either by electron capture (EC) or mass spectrometry (MS). Thus, it is essential to create and support centres of excellence in analytical chemistry, with a critical mass of experts, in African universities.

The status of instrumentation in African Higher Education institutions is a grave problem which urgently requires addressing. Governments need to provide funds to enable universities to [illegible]

5. TECHNOLOGIES TO PROTECT AND IMPROVE WATER QUALITY

Water quality is defined by its chemical, physical, and biological characteristics and needs to be considered in the context of whether it is [illegible]. This will depend on its intended use. Key processes that impact on water quality include:

- Eutrophication, i.e. elevated nutrient concentrations leading to excessive algal growth and deoxygenation due to diffuse run-off from agricultural land and point source discharges from wastewater treatment plants;
- Diffuse and point source discharges/drainage from mining activities;
- Localised discharges of organic micropollutants and metals from specific industries and domestic wastewater;
- Saline intrusion into groundwater in coastal areas;
- Erosion and sedimentation from, for example, deforestation, rainfall events (which are temporally and spatially highly variable) and engineering projects.

5.1 Clean drinking water

Methods to produce clean drinking water differ across the globe but, in general, involve the removal of suspended solids and bulk organics by coagulation, sedimentation and filtration, followed by chemical disinfection where necessary.

Many rural communities in Africa use ground-, surface- or rain-water for drinking. Many cannot afford the expensive chemicals required to disinfect water, so they have to take it as it is, or simply leave it to settle to remove sediments. It is therefore essential to provide low-cost methods for testing water quality.

Problems associated with drinking untreated water include:

- contamination of surface water by bio-organisms;
- contamination of groundwater by fluoride, arsenic, nitrate, iron and of more recently, chromium from natural geological sources or agricultural and industrial activities;
- excess salinity due to sea water infiltration.

For communities connected to a water supply network, it is the responsibility of the service provider to produce water that is suitable for drinking when it reaches the consumer; it is essential that governments set up monitoring systems to ensure this is the case. However,

Case Study 1 – EPA Compact Water Plants utilised in Africa for small and remote communities

EPA (Estación Potabilizadora de Agua) Compact Water Plants use a conventional treatment system (coagulation, flocculation, sedimentation, rapid filtration and disinfection process) with no need of pumps; instead they use hydraulic flocculation, a settling tank and rapid sand filters. Erection of the plant, training and the necessary intake and distribution works are standardized, achieving a whole product solution. Operation of the plant requires only a low energy input (. . 4 hp - EPA 20, delivering 20 m^3/hr), when compared with other conventional solutions or more sophisticated technologies. In addition, operation of the plant is straightforward and can be carried out by one person. Local personnel can easily be trained to operate the plant and take charge of its maintenance.

In the case of four communities served by EPA Compact Water Plants, it was noted that they developed a feeling of "ownership". They agreed to charge a fixed sum of money per litre of treated water, assuring the funding for proper operation of the plant. Anticipating the needs of remote communities without access to an electricity supply or other fuel source, a new model of the Compact Water Plant has recently been introduced. This new model includes a solar panel which covers all the energy requirements (1 hp), while delivering half the flow rate of the original model (10 m^3/hr). Erection of this model for many smaller, poor or rural African communities, no drinking water supply network is available. In these cases, technologies that produce water suitable for drinking need to be cheap, easy to use, robust and suitable for maintenance by the local population. They should produce water that is free from suspended particles and, most importantly, microbial contaminants, without the need for monitoring water quality output.

5.1.1 Point of entry treatment

Point of entry treatment refers to water treatment carried out at the source of distribution. It is economical, convenient and suitable for urban or small rural communities where the costs of water supply can be shared (see Case Study 1). This type of project has shown itself to be successful when water is seen as a valued commodity by the local population.

(5) biological treatment and (6) filtration. The majority of the processes work through the application of a physical force and are collectively known as physical processes.

There is a vibrant field of research developing within the African scientific community investigating emerging water treatment technologies that utilise locally available biomaterials and resources. Promising bioresource candidates, including examples presented at the PACN Sustainable Water conference, include:

- Seeds of the [illegible] tree, and roots from the [illegible], can be used as flocculating agents (see Case Study 2).
- [illegible]: recent comparisons of the maximum sorption capacity of several untreated biomaterial based residues showed that African water hyacinth ([illegible]) is a suitable candidate for use as biosorbent in the removal of heavy metal ions from aqueous solutions in water distribution systems in Kenya and Ethiopia.[28]
- [illegible]: water treatment using activated carbon made from locally grown agricultural waste (maize, cobs, bagasse, coconut shells, macadamia nut shells, coffee husks, sawdust) is an emerging field of sustainable remediation under examination in Kenya.[29]
- [illegible]: the adsorption of Pb from Nairobi river using multi-layer fishbone beds is emerging as a useful candidate for future development by the University of Nairobi, Kenya.[30]
- [illegible] (maize), [illegible] (tropical spiderwort), [illegible] (sunflower) and [illegible] (amaranthus) have been the subject of much study for their ability to bioaccumulate the metals Pb, Cu, Cd and Zn and have promising potential for removal metals from wastewater.[31 32 33]
- [illegible]: the University of Fort Hare in South Africa is taking a leading role in the development of PMMA-grafted lignocellulose/clay nano-composites for the removal of heavy metals and chlorinated organics from water.[34]
- [illegible]: the removal of fluoride contamination from ground water using raw bauxite is being examined by a group from Botswana, with promising early results.[35]

Case Study 3 – Development of a household water de-fluoridation process for developing countries

High levels of fluoride in groundwater has been reported parts of in Ethiopia, Malawi, Kenya and Tanzania and can lead to health problems including dental fluorosis, osteosclerosis, thyroid problems, growth retardation and even kidney failure. Most of the methods currently available for the removal of fluoride from drinking water are either too expensive, are technically unfeasible for household use or change the water quality. In this study, the removal of fluoride from water using aluminium hydroxide has been investigated and a household defluoridation unit (HDU) has been designed and tested.

Top lid
Removable perforated distribution plate
Activated Alumina
Micro filter
Rubber washer
1.5mm diameter orifice for water drip
Treated water collecting chamber

The surface area and pore volume of the prepared adsorbent were 110 m^2/g and 0.29 cm^3/g, respectively.

A series of batch adsorption tests were carried out to evaluate the effects of operational parameters such as contact time, adsorbent dose, thermal treatment of adsorbent, initial fluoride concentration, pH and other ions which commonly exist in groundwater. Results showed that fluoride removal efficiency exceeding 90% was achieved within 1 hour contact time at an optimum adsorbent dose of 1.6 g/L, treating water containing an initial fluoride concentration of 20 mg/L.

A HDU packed with 0.9 kg of adsorbent with 28.3 cm bed depth resulted in a specific safe water yield of 823.79 L under the optimum operating conditions used in this study. Regeneration of the exhausted media using 1% NaOH and 0.1 M HCl showed that the adsorbent could be reused. The estimated running cost of the unit was 28 USD/m^3 of treated water, which can be minimized further. Hence, it is concluded that this proposed method is simple and has superior performance for the treatment of fluoride-contaminated water with potential application in both household and community water treatment systems.

Z. F[illegible], E. M[illegible], A. A[illegible] B. [illegible]
C[illegible]

Other processes operate through a biological reaction, coupled to an adsorption step. In these cases, microorganisms utilise water components as part of their growth cycle, converting dissolved organic components into solids for removal in downstream physical processes.

For communities serviced with a sewerage system, it

For Africa to achieve its potential it should invest in human capital and reduce its dependence on increasingly vulnerable natural resources. It should develop a common vision with science, technology and innovation indicators for the continent and integrate these into decision making and policy spheres and increase substantially the investment in Africa from influential bodies.

It is essential that scientific networks are created with common agendas and investment is made in infrastructure. These networks will help to focus higher education and research and will create a culture of science. However, Africa should not emulate existing foreign models but invent ones that will work in Africa and foster research that goes beyond research ***ab*** Africa to research *f* Africa and ***b*** Africans.

6.1 A vision of scientific excellence

AEGfcEGcW

Water is needed for domestic use, in businesses and industry, and for agriculture, and it is also key to ensuring a healthy and diverse natural environment. Too much water is a threat to national security and property, and too little water affects a country's prosperity, and can be a threat to the health of its citizens and to its natural

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