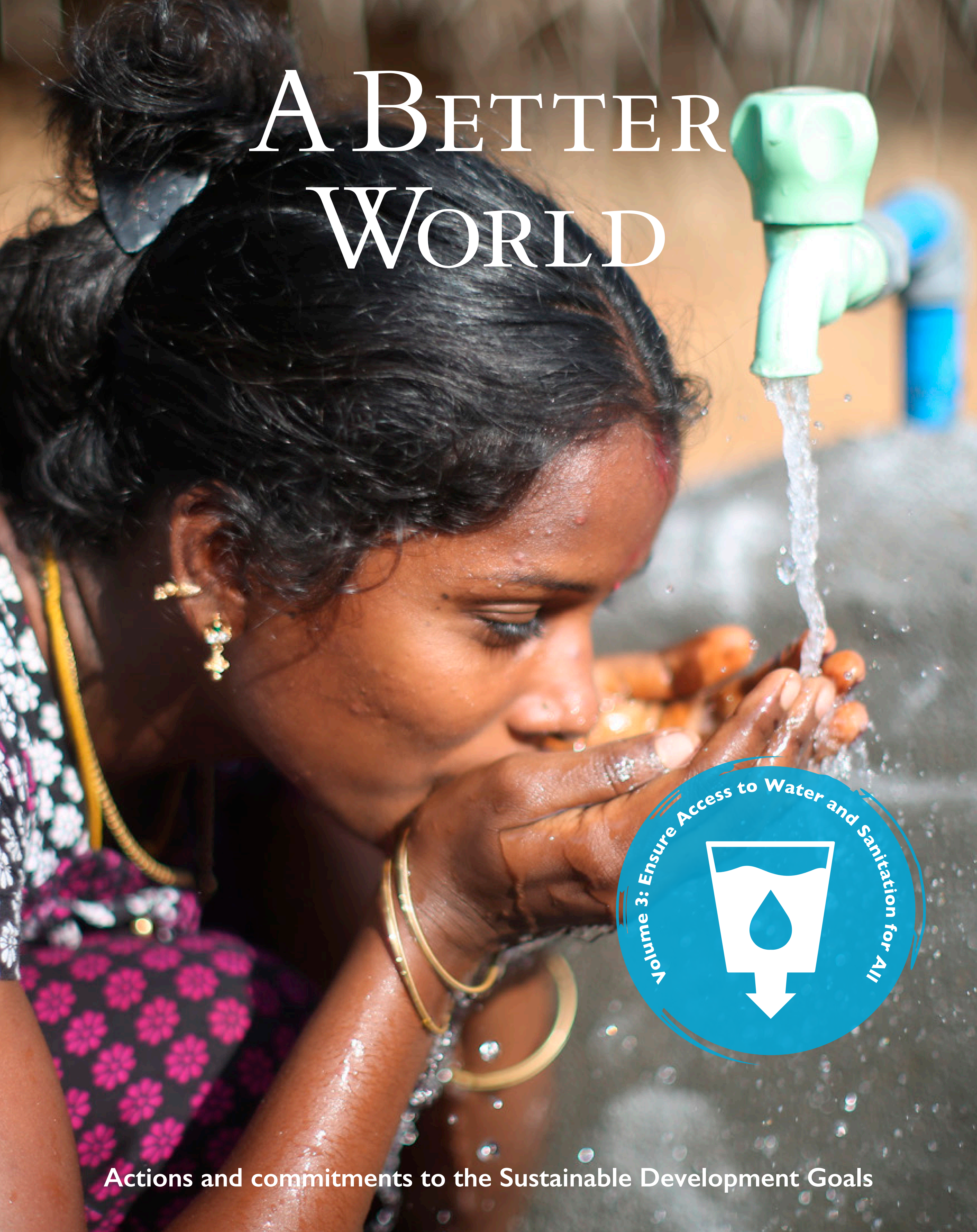
A Better World



Volume 3: Ensure Access to Water and Sanitation for All

Actions and commitments to the Sustainable Development Goals

A Better World

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ISBN 978-0-9956487-3-9
Original title: A Better World Volume 3

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Published in 2018 by Tudor Rose www.tudor-rose.co.uk

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Acknowledgements

Compiled by: Sean Nicklin, Ben Cornwell
Edited, designed and managed by: Leigh Trowbridge

Cover photo: Divya, in Pillayarkuppam village, India, drinks water from the safe water tap at her house. © Water.org

Printed in the UK by: Gomer Press Ltd.

With thanks to all the authors listed in the contents section for their support in making *A Better World* possible.

Academy of Sciences Malaysia (ASM)

African Development Bank (AfDB)

Asian Development Bank (ADB)

BRAC

China Institute of Water Resources and Hydropower Research (IWHR)

China Water Risk

Department of Irrigation and Drainage, Malaysia

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

General Water Authority, Libya

Institute of Technology Bandung

International Crops Research Institute for Semi Arid Tropics (ICRISAT)

International Hydrological Programme (IHP), United Nations Educational, Scientific and Cultural Organization (UNESCO)

Korea Water Forum (KWF)

Korea Water Resources Corporation (K-Water)

Malaysian Agricultural Research and Development Institute (MARDI)

MASHAV – Israel's Agency for International Cooperation

Mekong River Commission (MRC)

Ministry of Foreign Affairs and International Cooperation (MoFAIC), United Arab Emirates

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National Research Institute of Science and Technology for Environment and Agriculture, France

Oxyo Water

Prince Sultan Bin Abdulaziz International Prize for Water

River Engineering and Urban Drainage Research Centre (REDAC)

South Africa Department of Environmental Affairs

The International Institute for Water and Sanitation (ONEE)

UN Economic Commission for Africa (UNECA)

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Foreword

SEAN NICKLIN, GENERAL COORDINATOR OF THE HUMAN DEVELOPMENT FORUM FOR TUDOR ROSE

With the establishment of the Sustainable Development Goals (SDGs) in 2015, Tudor Rose and its Human Development Forum has accepted the challenge to expand its human development publishing with the creation of a series of volumes, each dedicated to one or more of the 17 SDGs. Entitled *A Better World*, this volume published in March 2018 covers Goal 6: Ensure access to water and sanitation for all. Clean, accessible water for all is an essential part of the world we want to live in. There is sufficient fresh water on the planet to achieve this. But due to bad economics or poor infrastructure, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene.

Water scarcity, poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families across the world. Drought afflicts some of the world's poorest countries, worsening hunger and malnutrition. By 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water. This volume reflects the progress and challenges in this essential topic, highlighting good practices in a wide variety of societies and disciplines. By focusing on the experiences and livelihoods of people, especially those in vulnerable human habitats, the book will show the benefits of best policy and practices, and how these may develop further as we come to terms with a changing and more turbulent world. This innovative endeavour is a striking example of sharing respective resources to engage the many official governmental, international organisations, institutional and professional interests in displaying the extent and variety of their efforts to make the world a better place.

Since 1999 Tudor Rose has published 28 books in partnership with the United Nations and its agencies, covering a diverse range of subjects from disaster reduction, water management and climate science to intercultural dialogue and humanitarian assistance. The books are read extensively by the human development sector and especially by community leaders in vulnerable regions around the globe. The books are close collaborations between individual UN agencies, UN member states and civil sector organisations, committed to a better future for the world. They have widened the knowledge of people in vulnerable communities and given them inspiration and knowledge to better their lives in a sustainable way.

Contents

Leading water cooperation worldwide to ensure water security for future generations

Aurélien Dumont, Renée Gift, Marina Rubio, Alice Aureli, Abou Amani, Blanca Jiménez-Cisneros, International Hydrological Programme (IHP), United Nations Educational, Scientific and Cultural Organization (UNESCO) – Division of Water Sciences

The Sustainable Development Goals (SDGs) embody a universal, ambitious, sustainable development agenda: an agenda "of the people, by the people and for the people," crafted with UNESCO's active involvement. The new 2030 Agenda for Sustainable Development represents a significant step forward in the recognition of the contribution of science to sustainable development. Through its natural sciences programmes, UNESCO is committed to the implementation of the SDGs by improving scientific knowledge, and providing policy assistance and support to developing countries in strengthening their scientific and technological capacities.


Image: charity:water / Jonna Davis

Groundwater: Filtering water in Cambodia

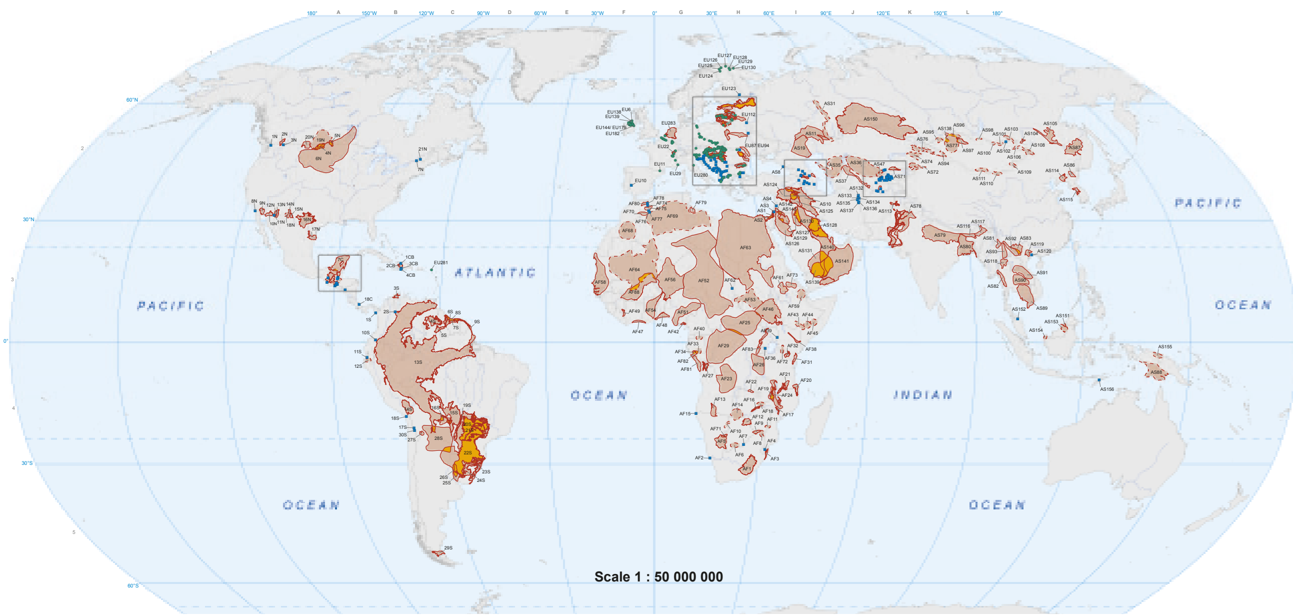
The recent recognition of the need to ensure availability and sustainable management of water and sanitation for all, at the level of a global goal, has prioritised international action around the fundamental subject of freshwater. Notwithstanding, UNESCO has advanced the international agenda for peace and sustainable development for more than 70 years, and has focused strategic action on water for more than 50 years through the establishment of its International Hydrological Programme (IHP).

IHP today remains the only intergovernmental programme of the United Nations (UN) system dedicated to science, knowledge and capacity building centred around freshwater. Guided since its inception by the simple message that water is indispensable to human life in all its aspects, IHP has evolved from an internationally coordinated hydrological research programme, to one with a holistic focus. Today, its scope reaches beyond the natural sciences to capture the social, economic, environmental, and cultural dimensions of water access, use and management. It achieves this through mobilizing international cooperation to produce and disseminate scientific knowledge; facilitating capacity building and education for strengthened water resource management; and bridging the science policy society interface to enhance water governance.

With the goal of achieving water security at its core, IHP implements projects and initiatives centred on water-related disasters and hydrological change, groundwater management, water scarcity and quality, water within human settlements, ecohydrology, and water education, through the implementation of its Strategic Plan known as the Eighth Phase (IHP-VIII: 2014–2021). Guided by its six thematic focal areas, IHP contributes both directly and indirectly to every target under SDG 6, emphasising the role of UNESCO with a clear mandate to address SDG 6.

As freshwater concerns are cross-cutting, IHP also concretely contributes to other goals. Its work on water-related disasters and hydrological changes directly addresses SDG 13 on climate action through advancing scientific knowledge on water sciences, reducing uncertainty, and improving planning to strengthen countries' resilience to the impacts of climate change. These activities, coupled with IHP's action to promote the supply of clean water and sanitation in cities and enhance urban water management, directly contribute to SDG 11 on inclusive, safe and resilient cities and human settlements.

Map of the transboundary aquifers of the world (edition 2015)



Source: IGRAC and UNESCO

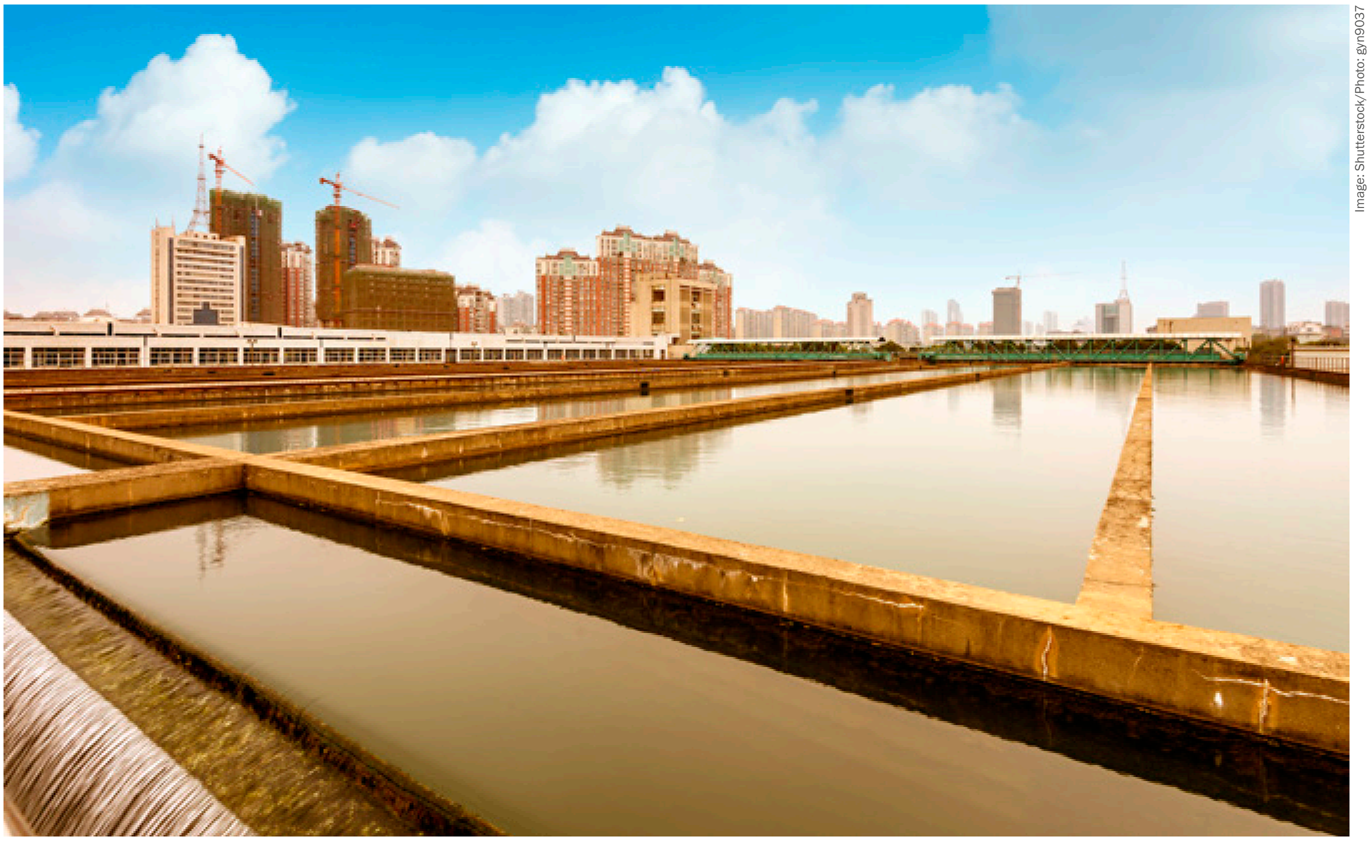
Efforts towards SDG 6 moreover enable interlinkages across all other SDGs, indirectly contributing to achieving several. IHP is providing knowledge and initiatives to improve livelihoods, and address food security, human health and well-being, education for sustainable development, and many others. For example, its thematic focus on water quality supports increased agricultural sustainability, improved water safety, strengthens scientific and technological knowledge for more sustainable patterns of consumption and production, and reduces marine pollution, thereby contributing to SDGs 2, 3, 12, and 14. IHP's work on ecohydrology aims to improve understanding of the connection between hydrological and biological process to ensure water security. Its work in this context addresses water pollution in coastal and urban environments, integrates ecosystem approaches to prepare for extreme hydrological events, and assesses the relationship between ecosystem functions and aquatic systems, contributing to SDGs 3, 11, 13, 14, and 15, among others. In providing water education and capacity building opportunities for youth and water professionals, IHP further impacts SDGs 8 and 16 by supporting education of youth and strengthening institutional governance. Overall, IHP's Strategy encompasses the three dimensions of sustainable development – social, environmental and economic.

Gender equality, which is represented by SDG 5, also represents one of UNESCO's global priorities. Recognising the importance of integrating gender considerations with formulating solutions for water access and management, UNESCO contributes to achieving SDG 5 through strengthening women's capacities in scientific domains and promoting effective participation of women in decision-making at all levels. The UNESCO World Water Assessment Programme (WWAP) developed a Gender and Water Toolkit to collect sex-disaggregated data aimed at producing scientific evidence on gender inequalities related to water and integrating these findings into the development and implementation of relevant policies. Better understanding the relationship between gender and water contributes to strengthening social inclusion, eradicating poverty and advancing environmental sustainability.

UNESCO's broad mandate, which extends across five sectors, uniquely positions IHP to benefit from multidisciplinary and transdisciplinary expertise and integrate a cross-sectoral approach towards achieving the SDGs. In addition, IHP's impact is multiplied through the contribution of the UNESCO Water Family, a unique network of institutions which comprise more than 3,000 professionals working in the field of water globally and supporting the implementation of IHP-VIII and UNESCO's overall strategic goals and priorities.

Recently, UNESCO developed and launched a Water Information Network System (WINS), an open-access platform which compiles information on the water cycle from global information sources, including the UNESCO Water Family. The data collected by WINS will be critical in monitoring SDG 6 indicators and in supporting Member States in making informed decisions about water resource management.

As peace lies at the heart of UNESCO's mandate, IHP's Strategic Plan explores the fundamental nexus between water and peace. In this context, IHP has for many years been devoted to promoting water cooperation, and led the coordination of the UN International Year of Water Cooperation (IYWC) in 2013. In spite of public fears of "water wars", in reality, cooperation over shared water resources is more frequent than is conflict. The goal of IYWC was therefore to start paving the path for a more peaceful and sustainable future through finding a common purpose around freshwater amidst the diversity of interests and perspectives.



Modern urban wastewater treatment plant

As global demand for freshwater resources expands, governments have begun to focus their attention on groundwater resources. Groundwater is an extremely important source of freshwater on earth: around 98 % of the world's liquid freshwater is stored underground, which makes groundwater a unique buffer against prolonged drought. The importance of groundwater is evidenced by the fact that worldwide, 2.5 billion people depend solely on groundwater for their daily needs, it provides drinking water to at least 50% of the global population and accounts for 43% of all of the water used for irrigation. However, the global groundwater withdrawals rate has at least tripled over the last 50 years and still is increasing at an annual rate of between 1 and 2%.

The challenge of sustainable groundwater management is compounded by the fact that aquifers are located in the subsurface and as such there is often limited understanding of their boundaries and characteristics. In transboundary aquifers, borders complicate the acquisition of consistent information on the entire aquifer, and information gaps, conflicting interests and a lack of coordination across the boundaries easily lead to problems where collaborative approaches are not adopted.

Worldwide, more than 286 river basins are shared by at least two countries and almost 600 transboundary aquifers have been identified by UNESCO. SDG Target 6.5 calls for countries to "implement integrated water resources management (IWRM) at all levels, including through transboundary cooperation, as appropriate". This target explicitly recognises that safe and reliable water resources are not possible without transboundary cooperation.

UNESCO has been working for many years with its Member States to improve scientific knowledge on these transboundary waters and develop mechanisms for better cooperation through a number of initiatives and programmes. The International Shared Aquifer Resources Management Programme (ISARM) established by UNESCO Member States in 2000 is an example of an initiative which has fostered water cooperation for the sustainable management of groundwater resources through the compilation of a world inventory of transboundary aquifers, the development of best practices, case studies and guidance tools for decision making concerning shared groundwater resources management and the execution of regional and global projects. The contribution of UNESCO to the preparation of the International Law Commission's Draft Articles on the Law of Transboundary Aquifers, which recognise the importance of establishing agreements and joint institutional arrangements between States for their shared aquifers and aquifer systems, has been coordinated under the ISARM initiative. ISARM has catalysed the establishment of cooperative agreements in various regions of the world, like South America (case of Guarani Aquifer) and Southern Africa (case of Stampriet Aquifer, see page 14).

In 2000, UNESCO launched the Potential Conflict to Cooperation Potential (PCCP) initiative which aimed to highlight the benefits of peaceful cooperation between nations on the sharing of transboundary water resources. The development of capacities and skills formed a critical component of PCCP's focus. Tailored training material was developed and applied in Africa, Latin America, Asia, Europe and the

Middle East for water resource managers, decision-makers and journalists to enhance their negotiation skills as well as their understanding of transboundary issues. Through PCCP, UNESCO also undertook substantive research on best practices and lessons learned on cooperation over transboundary water and the causes of water conflicts, deepening knowledge and understanding of this complex issue. It also convened transboundary water experts and practitioners to promote dialogue, exchange experiences and enable networking.

These initiatives and achievements have been key in the designation of UNESCO as the co-custodian agency for SDG indicator 6.5.2, together with the United Nations Economic Commission for Europe (UNECE). Indicator 6.5.2 is defined as the "proportion of transboundary basin area with an operational arrangement for transboundary cooperation". In 2017, as part of the work on indicator 6.5.2, UNESCO and UNECE invited all countries with transboundary basins to track the progress on transboundary cooperation following a methodology developed by both organizations. This enables states to outline a complete picture of the status of cooperation over transboundary water and better establish their respective baselines. The information collected in tracking SDG indicator 6.5.2 will regularly feed into global reports and databases established at the UN level.

For the 286 transboundary river basins on the planet, 450 transboundary surface water treaties exist to this day, offering an important means to avoid or resolve disputes. However, existing transboundary water treaties and institutions are often weak in terms of their mandate, design, resources and enforcement mechanisms.

For the 600 transboundary aquifers identified so far, only very few agreements exist. The monitoring of the indicator 6.5.2 will therefore constitute an opportunity for UNESCO to work with its Member States to establish the conditions for transboundary cooperation on surface and groundwater resources by sharing principles, good practices and replicable experiences.

With its comprehensive approach to tackling water security established under IHP-VIII, UNESCO and its Water Family are prioritising programmes and initiatives to ensure the achievement of SDG 6. This has translated to concrete action not only on securing the availability and sustainable management of water and sanitation, but also on several goals which depend on the management of freshwater and related disasters for their success. IHP's WINS platform will be crucial in providing the data and information necessary to underpin Member States' efforts to implement and monitor the SDGs. Going forward, UNESCO will continue to use its strengths including its convening power, vast networks, multi-sectoral scope of expertise, and knowledge databases to support its Member States in achieving sustainable development.

Image: Shutterstock / Rawpixel.com

Save the Planet Sustainable Ecology Concept

From political commitments on transboundary water cooperation to on-ground actions in Southern Africa

Tales Carvalho-Resende, Alice Aureli, Blanca Jiménez-Cisneros, International Hydrological Programme (IHP), United Nations Educational, Scientific and Cultural Organization (UNESCO) – Division of Water Sciences

An African proverb says that "two footsteps do not make a path". This is particularly true for the field of water resources management as one of the main challenges for today's water managers is to take decisions that chart the way forward from committed obligations to concrete actions on the ground for the benefit of people, ecosystems and the biosphere. Such decisions are taken within a continuously evolving setting in which water is shared among various stakeholders and sectors that interact at several levels (local, national, regional and international). As water is a fluctuating resource that is difficult to measure in both time and space, the whole picture becomes even more complex. It is now recognized that an Integrated Water Resources Management (IWRM) approach is needed to consider all such factors and issues simultaneously in order to secure the equitable and sustainable management of freshwater.

Image: UN Photo/Evan Schneider

Clean drinking water runs from a tap in Senegal

IWRM: an integrated approach for water cooperation

The IWRM approach is a response to the much-criticized sector-by-sector perspective on water management (agriculture, energy, municipal water supply, etc.). It highlights instead the benefits that an integrated and holistic approach to water management at basin level can deliver. IWRM promotes not only cross-sectorial cooperation, but also the coordinated management and development of land, water (both surface and groundwater) and other related resources in order to optimize the resulting social and economic benefits in an equitable manner, without compromising ecosystem sustainability[1].

IWRM is primarily an on-ground and domestic level water management approach. However, without the inclusion of transboundary cooperation, basin-scale water management is limited, as national management is not able to cope effectively with the challenges originating in neighbouring basin countries[2], for instance over-abstraction and pollution. The implementation of the IWRM approach requires the development and strengthening of institutional structures at local and transboundary level in order to ensure that the resource (surface water and groundwater) becomes a catalyst for cooperation[3]. These institutions can take a variety of forms from mechanisms to joint bodies, such as river basin organizations. It is however noticeable that although groundwater is the major, and often only, source of drinking water in several regions of the world, it has often been neglected in IWRM planning, mainly because of its invisibility to the public eye and limited data.

Generating water cooperation at transboundary level

Generating water cooperation largely consists of promoting a process of building collaborative structures and institutions, and increased trust and confidence among stakeholders. This process is inevitably time-consuming and often means taking two steps forward and one step back[4]. This is especially so in a transboundary context. The complexity of interactions among countries can be seen in the limited number of transboundary governance arrangements. Worldwide, more than 286 river basins[5] and around 600 aquifers[6] cross sovereign borders. However, around 60% of transboundary river basins still lack any cooperative arrangement[7]. The situation

Image: UNESCO / Pius Gsponer, Namibia Nature Foundation

Borehole for irrigation in the Stampriet Transboundary Aquifer System

is notably more critical for transboundary aquifers where very few agreements exist. One of the reasons to explain this context is the fact that the promotion of transboundary water cooperation has generally been underfinanced within the international community, mainly because development partners have not been programmed to finance processes without a clear result and timeline[8].

Building a global foundation for IWRM implementation: SDG Target 6.5

By setting Target 6.5 in the Sustainable Development Goals (SDGs), Member States and the UN System have recognized the importance of the implementation of IWRM plans at basin scale at both national and transboundary level. This target will be of paramount importance to assist in interlinking the other water-related targets, and hence promote cooperation among the various stakeholders and sectors. It will also provide the missing roadmap and timeline that will facilitate investments on transboundary water cooperation. To reach Target 6.5, two indicators have been developed to assist in monitoring and assessing its implementation. Indicator 6.5.1 will assess the degree of IWRM implementation in order to assist countries in identifying policy, institutional, management tools and financing gaps and barriers, while indicator 6.5.2 is aimed at encouraging countries to develop operational frameworks for transboundary basins.

On-ground implementation of SDG Target 6.5 in Southern Africa

An example of the implementation of Target 6.5 in which political commitment has been translated into actions on the ground comes from Southern Africa. Water scarcity is a recognized norm in a large part of this very arid region that is subjected to high climatic variability and a highly unreliable rainfall regime which worsens the region's recurring droughts. The Orange-Senqu River Basin is one of the largest basins in Southern Africa and is home to numerous dams and complex transfer schemes used to manage and distribute water between primarily industrial users in the headwaters, and downstream agriculture. Given its importance, multiple initiatives have been carried out by local and international stakeholders to ensure the sustainable and equitable water resources management across the basin.

A major milestone for the promotion of transboundary water cooperation in the region was the establishment of the Orange-Senqu River Commission (ORASECOM) in 2000 by the Governments of Botswana, Lesotho, Namibia and South Africa. Its main objectives are to provide a forum for consultation and coordination between the riparian states to support IWRM. The roles and functions of ORASECOM are now shifting from planning to implementation of actions as part of its 10-year IWRM Plan (2015–2024) which is an expression of optimal use of all water resources, including groundwater, through joint actions of the riparian countries.

Groundwater: integrating the missing part of IWRM in the picture

The UNESCO International Hydrological Programme (IHP) was instrumental in making the IWRM picture complete by bringing to policy makers' attention the need to take due consideration of the importance of groundwater in the Orange-Senqu River Basin. As a result, ORASECOM was the first river basin in Southern Africa to establish a groundwater technical committee in 2007 to facilitate the dialogue between the countries on transboundary aquifer management. IHP also led the International Shared Aquifer Resources Management (ISARM) programme with the support of the Southern Africa Development Community (SADC) which mapped more than 20 transboundary aquifers in the region. Among these aquifers, the Stampriet Transboundary Aquifer System (STAS) was identified as one of the hotspots in the region.

Institutionalizing cooperation over transboundary aquifers in Southern Africa

The STAS is a large transboundary aquifer shared by Botswana, Namibia and South Africa that lies entirely within the Orange-Senqu River Basin. Its importance draws from the fact that it is the only permanent and dependable water resource in the area for drinking water and agriculture. From 2013 to 2015, the Governments of Botswana, Namibia and South Africa, jointly with IHP, undertook an in-depth assessment of the STAS which enabled the establishment of a shared science-based understanding of the resource. The technical results obtained were further consolidated with the support of IHP through capacity building activities on water diplomacy and groundwater governance to support the process of institutionalizing cooperation among the STAS countries.

On May 2017, the ORASECOM groundwater technical committee presented a proposal for the establishment of a joint governance mechanism for the STAS, nested in the ORASECOM structure. On August 2017, the Commissioners at Director General level that attended the ORASECOM Council meeting, supported the proposal made by the groundwater technical committee and decided to operationalize the mechanism – the first of its kind in Southern Africa.

The process that led to the establishment of the STAS joint governance mechanism is a breakthrough in many aspects. Firstly, it is the first agreement on transboundary aquifers since the SDGs were adopted in 2016. Prior to the decision to establish the mechanism, only six formal and two informal agreements had been documented worldwide. Secondly, it is the first operational governance mechanism to be nested in a river basin organization, thus fully capturing the IWRM approach and directly contributing to the implementation of Target 6.5 both at national and transboundary level. Thirdly, the mechanism will enable sustainable actions on the ground, as activities related to the STAS are part of ORASECOM's 10-year IWRM Plan (2015–2024). As such, the implementation and reporting of activities related to the STAS falls under ORASECOM's mandate and will be fully integrated therein with no additional costs to the STAS countries. Last but not least, what is striking in this process that led to institutionalizing cooperation over the STAS was its expeditiousness. This was possible mainly because of the existence of an on-going operational inter-state institutional arrangement such as ORASECOM. The institutional architecture of

Image: UNESCO

High-Level Representatives from Botswana, Namibia and South Africa greeting cooperation over the STAS (Paris, November 2016)

Image: UNESCO/Pius Gsponer, Namibia Nature Foundation

Field visit to an irrigation farm in the Stampriet Transboundary Aquifer System

ORASECOM, structured into a Council, a Secretariat, Task Teams and committees (for instance. the groundwater technical committee), has allowed the proposal made by the groundwater technical committee to be brought for the Council's consideration and decision in less than one year.

Conclusions

There is no clear roadmap and one-size-fits-all solution for institutionalizing and operationalizing cooperation over transboundary waters. The issues encountered in any basin will be unique and the steps taken to develop a cooperative approach reflect the individual concerns and priorities at play. However, the IWRM approach offers a baseline for the promotion of water cooperation at all levels (from local to transboundary) as it allows the existing socio-political environment in the basin and/or aquifer to be captured. Additionally, the IWRM approach offers the much needed flexibility to water managers to respond to changing conditions such as climate change.

The adoption of a dedicated target on IWRM implementation in the SDGs (Target 6.5) will provide a global foundation for development partners to encourage transboundary water cooperation by strengthening institutional capacities, and fill the current existing financial gap for this kind of initiative. The process that led to the establishment of the first joint mechanism for the governance of a transboundary aquifer in Southern Africa – the nesting of the STAS joint governance mechanism in the ORASECOM structure – should be considered by development partners as an example to be replicated and/or adapted to the socio-political environment in other basins.

Framing sustainable water resource management from the vantage point of climate-resilient infrastructure and a green economy

Denton F. Paulos, M. Amha, Y, UN Economic Commission for Africa

Natural resource management in Africa has been seen largely in binary terms, and often expressed metaphorically as a curse rather than a blessing. In the twenty first century, where development adversities range from climate change to rapid urbanization, with the latter often coupled with the absence of critical health, energy and water infrastructure, it is imperative to take advantage of this new momentum to frame the water challenge.

Water is a critical resource for Africa's development. For decades, though, the literature on water in Africa sees it as a 'problem' resource, one that underscores Africa's underdevelopment, and one that is gradually depleted, degraded and poorly managed. In transboundary terms, although water is viewed in terms of peace and co-operation, especially among riparian countries, water is also often perceived as a resource that has the ability to produce conflicts in stressed geopolitical environments. The management of the Nile Basin is a case in point.

Yet, Africa's water sector is a tale of several paradoxes. Close to 85 per cent of Africa's water resources comprise large river basins shared between several countries.[1] And Africa is blessed with abundant water resources. The region is home to roughly a third of the world's major international water basins greater than 100,00Okm^2, and boasts 17 rivers and approximately 160 lakes greater than 27 km^2 (UNECA/AU/AfDB, 2000). Most major African river basins are shared by 5 or more countries possessing a huge potential for energy production through hydropower – 1.4 million GWh per year.[2] Further, renewable fresh water on the continent accounted for 9 per cent of global water resources. Crucially, unleashing the full potential of such potentially vast water resources could stimulate economic development in water-dependent sectors such as agriculture, livestock, energy, manufacturing, fisheries and aquaculture, construction, retail and hospitality, and natural resources exploitation (including mining) thereby benefiting the African economy as a whole. But, most importantly water is a critical resource for life, sanitation and survival.

In this article, we suggest first, that given the pressures related to megatrends such as climate change, demographic bulge and rapid urbanization, there is an urgency to reframe the water challenge and to focus on the investment opportunity related to water resource management. Water is a renewable resource, but appears to be rapidly becoming a scarce resource in Africa. Without an urgent reframing of the water and development narrative, the momentum for Africa to achieve the implementation of the 2030 and 2063 agendas and to transition towards climate resilient infrastructure and green economies will be lost. The opposite argument is also true in that if water is not framed as a business case, then we could well witness a cascading set of devastating impacts as a result of water stress, resulting in economic hardship, disease outbreaks and negative impacts of extreme events on lives and livelihoods. Second, we argue that there is an imperative to move the recognition of a problem to an actualization of what needs to be done. In other words, we propose that a new momentum created as a result of climate change can be used to address the imperative for climate resilient infrastructure and the design of green infrastructure. Third, we argue that the Economic Commission for Africa (ECA), through support in the management of trans-boundary rivers in Africa, can work through partnerships to help frame a new water agenda and narrative for the continent, thus opening new avenues of entrepreneurial activities and new jobs for vulnerable women and men.

Understanding Africa's megatrends from a water perspective

The African region has delivered steady and remarkable rates of economic growth in recent years. This growth has been largely uneven across the continent, which has not managed to sever ties with poverty. Currently, millions of African youth have no real prospects outside the perceived allure of migration, partly due to drought/El Nino weather phenomena with induced economic hardship and other insidious forms of poverty. The irony is even more telling in a continent rich in water, yet thousands of its young people will see their lives claimed by scarcity of the very resource that could translate into decent jobs and economic prospects.

Today, the imperative to manage and use water sustainably, to provide safe drinking water and to increase access for sanitation as well as stimulate growth and create jobs is perhaps more important than ever. This is mainly because water is at the centre of several megatrends, not least climate change. Vital water resources in Africa are already under a great deal of stress. Even in the absence of climate change, current population trends and patterns of water use highlight that increasingly more countries will go beyond the limits of their economically usable land-based resources by 2025.

Rapid urbanization and rising living standards will increase demand for water, energy and food. Africa is the fastest urbanizing region in the world. With increased urbanization will come the added pressures of demand for clean and safe water. Similarly, with climate change pressures and risks, there is an increased tendency for countries to move towards a low carbon development trajectory and green economies. These could spell new opportunities in sectors such as industries with the relevant infrastructural support. Africa's continued growth narrative is dependent on the ability of its economies to gain access to and efficiently manage water as a key asset in unleashing the job potential in sectors such as agriculture, energy, tourism industry and ecosystem management. The absence of insufficient and stable sources of water supplies will not only produce dysfunctional food systems and render erratic food supplies, it will considerably undermine Africa's ability to transition into green economy. Stable water supplies can increase Africa's capacity to generate hydropower electricity, which can increase revenue earnings for countries where the resource can be tapped, although some would argue that continually damming Africa's rivers, with concomitant reduced flows due to erratic rainfall, is the road to economic catastrophe and 'water wars.'

Small or large investments in the water sector – action required at all levels

Studies indicate that proper use and application of Climate Information Services (CIS) can improve the decision making process of managing water resources and help to build a climate change resilient economy, society and environment as well as increase the predictive capacities of farmers. The primary use of hydromet data is to support reservoir and water project operations, water management, and water supply forecasting for reservoir systems. Water use supported by hydromet include flood control, irrigation, power generation, water quality, water conservation, fish and wildlife management, research and recreation. Observational evidence demonstrates that many vital sources of water in Africa, including lakes, rivers, and underground water resources are under pressure due to climate change and climate variability. Therefore, the significance and urgency of upgrading hydromet services and climate-proofing our water infrastructure has never been more glaringly evident.

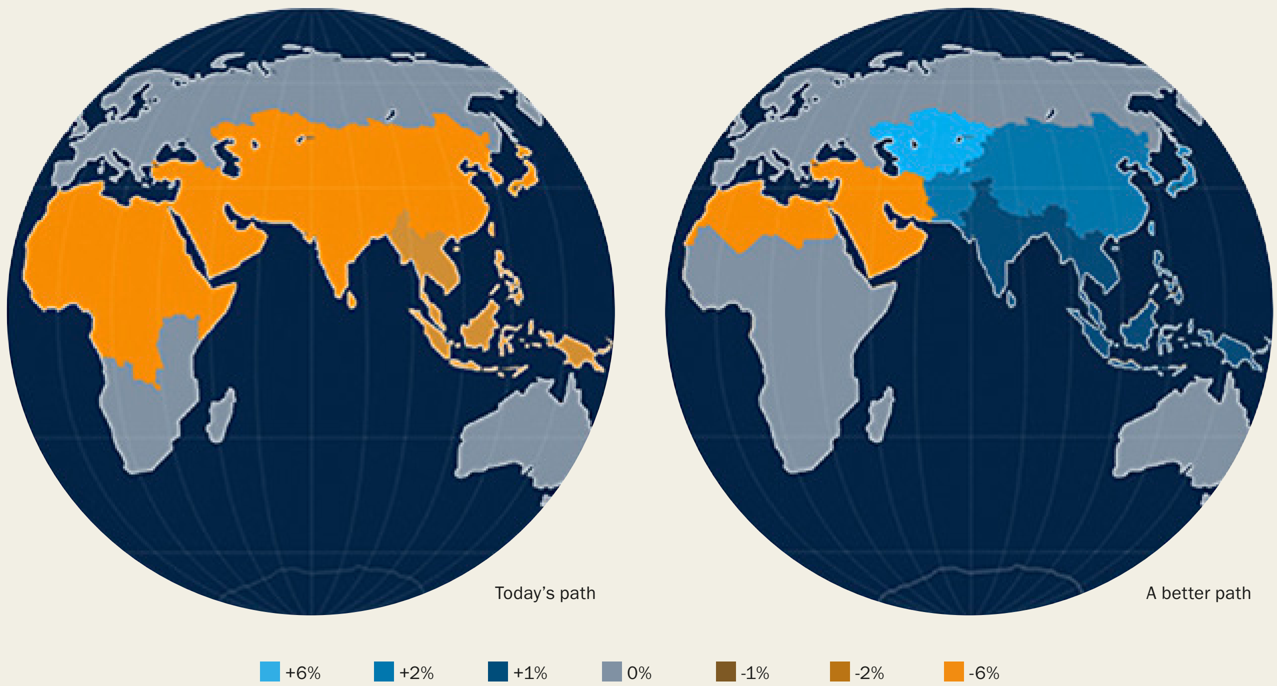
The opportunity here is to increase financing, enhance public-private partnerships, empower women who are disproportionately burdened by the domestic water supply, and target rural populations who are often the last served in extreme events. The major challenges of the water supply utilities under climate change include inadequacy of water storage, inadequate and poorly maintained supply networks, and vulnerability of the supply system to drought and flooding. In many countries, investments to harness water resources for development have tended to focus on built infrastructure such as large dams for irrigation and hydropower production. Yet, the question as to who truly benefits from these investments, and who pays their costs remains contentious. Investing in hydromet infrastructure, information networks and data sharing could help in water-related risk prevention and climate management strategies, such as early warning systems, and ensure climate resilient development.

According to a recent report, infrastructure investment commitments in Africa in 2015 totals US$83.4 billion, compared to US$74.5 billion in 2014[3]. Climate-proofing these substantial investments is essential as Africa stands to be impacted the most from the adverse effects of climate change even though the continent contributes less than 4 per cent of global greenhouse gas emissions. This is particularly so as most of the investments will support the construction of long-lived infrastructure such as dams, power stations, irrigation canals and transport corridors which may be vulnerable to changes in climatic patterns. For example, the water needed for hydropower generation or irrigation may not be available in the amounts needed or at the right time; roads may get washed away more frequently because of more frequent high rainfall events.

The limited existing infrastructure in Africa is already being severely impacted by extreme events associated with climate change. For instance, as a result of the unusual El Nino and La Nina events attributable to climate change in recent years, hydropower production from the Kariba Dam – which supplies most of the electricity consumed in Zimbabwe and Zambia – almost ceased in early 2016 when the volume of water in the reservoir dropped to about 12 per cent of capacity[4]. A 2015 study by the World Bank and the Economic Commission for Africa on Enhancing the Climate Resilience of Africa's Infrastructure (ECRAI)[5] found that failure to integrate climate change in the planning and design of power and water infrastructure could entail, in the driest climate scenarios, losses of hydropower revenues of between 5 and 60 per cent, depending on the basin.

To this effect, the ECA, the World Bank, the African Union Commission and the African Development Bank, with initial support from the Nordic Development Fund, have set up the Africa Climate Resilient Investment Facility (AFRI-RES). AFRI–RES is an Africa-based networked centre of technical competence and excellence, whose overall objective is

The impact of water scarcity on GDP



Source: World Bank Group, 2016

to strengthen the capacity of African institutions (including national Governments, river basin organizations, regional economic communities and power pools, among others), as well as the private sector (project developers and financiers), to plan, design and implement infrastructure investments that are resilient to climate variability and change in selected sectors.

In Africa, growth is strongly correlated to natural resources. Hence as Africa continues to grow, this will have a debilitating impact on natural capital. This growth has been accompanied by high energy and material intensities, as well as waste generation. Greening industrialization provides fresh new impetus for turning current supply chains linking natural resources to markets, into value chains that diversify Africa's economies and ensure that greater value is added. What is certain is that Africa's transition towards resource efficiency will require new skills but also stable sources of water to enable a low carbon development trajectory.

Water development frameworks – ECA's role in shaping a new narrative for water resource management

African Policy frameworks are many, and range from high-level declarations and resolutions to programmes of action on the development and use of the continent's water resources for socio-economic development, regional integration and the environment. These include the African Water Vision 2025 and its Framework of Action (UNECA/AU/AfDB, 2000), the African Union (AU) Extraordinary Summit on Water and Agriculture (Sirte Declaration) (AU, 2004), the AU Sharm El Sheikh Declaration on Water and Sanitation (AU, 2008), and most importantly, the Agenda 2063 – The Africa We Want (AU, 2014). These policy instruments are underpinned by strategies and programmes, including the New Partnership for African Development Programme (NEPAD), the Programme for Infrastructure Development in Africa (PIDA) and many others. However, regional commissions such as ECA have a role to play in reframing the narrative and supporting countries to move from an aspirational intent to the actualization of these frameworks.

Indeed, the UN Economic Commission for Africa (ECA) has been an active player in water resource management in Africa, particularly through activities geared towards catalyzing cooperation among African countries for the resolution of issues at national and river basin levels. Such activities include the provision of regional advisory services and technical assistance to the national governments and to intergovernmental organizations such as the River Basin Organizations, the River Economic Councils and the African Union. ECA continues to provide technical support and advisory services to member states, aimed at promoting rational utilization of natural resources in the context of climate change to ensure resilient development, and in supporting hydrological systems of river basins in order to improve their management.

ECA has a unique role in forming public-private partnerships and working closely with member states and river basin organizations that will result in framing a new urgency of dealing with the intersection between water and development. The old problems related to water use and management have not gone away – they have taken on a new impetus. Africa has a huge opportunity to turn the old problem of unsustainable management of water and other natural resources to new beginnings that will enable economic diversification, poverty reduction, job creation and the realization of Agenda 2030 and Agenda 2063 for Africa's transformational development.

Water and sanitation for all – bridging SDG 6 with other SDGs for sustainable development

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Water is a fundamental life-support system. Water cycles ensure clean air, food and the availability of drinking water, as well as sustaining sectors of the economy and the well-being of civilizations. If we could emulate natural water cycles in the management of the relationships between economies and water, there would be an energy-generating impact on those economies – society and nature would revitalize themselves. Also, learning from the cultural and historic practices of water management, especially prior to the era of industrialization, may provide insights and spawn new ideas to create technological solutions.

According to the ESCAP-ADB-UNDP[1] SDG data portal (2017), while access to improved water sources in the urban setting of the Asia-Pacific region is nearly universal, one in ten rural residents still live without access to clean drinking water (SDG 6.1). At the same time, a "silent disaster" is still evidenced by almost half of the regional population in having no access to safe sanitation (SDG 6.2) and by cities producing the greater volume of wastewater, with much of it left untreated (SDG 6.3). Lack of appropriate water and sanitation facilities puts millions of lives at risk. A lack of basic sanitation causes child deaths every year in developing countries as well as affecting the quality of education.

Along with positive trends and efforts towards creating integrated water resource management (SDG 6.5) to achieve SDGs at local, national and global levels, the prevailing approach of awareness generation and capacity building for improving water, sanitation and hygiene services is monotonous and lacks continuity. The strategic needs of communities through linear and silo based planning are not addressed in most cases, while the management and monitoring processes are focused on limited aspects such as triggering, hand washing and toilet construction. A complete WASH (Water, Sanitation and Hygiene) solution covers all key components such as location, supply, and governance in a coordinated manner but is not always replicated.

Challenges in achieving both water-efficiency indicators (SDG 6.3) and universal access to water and sanitation for all in a sustainable way could be addressed by a well-organised SDG 6 strategy with a package of policy and technology, and by incentivising collaborative frameworks. Household residents, industries, academia, the private sector and other stakeholders, policy makers and government decision makers should all be incentivised in managing their own future today, and maximising the social, environmental and economic benefits of efficient water resources management.

Integration in good and bad practices: the end-product of the economy ends up in the ocean

Water-related ecosystems, including forests, wetlands, rivers, aquifers and lakes are renewable and self-sustainable unless damaged by human activities. The planet's water composition makes it habitable but, like the air and climate, water is sometimes thought to be immune from human influence. According to ESCAP and ADB 2017, more that 70% of household and industrial wastewater is fed back into the ecosystem untreated, then carried to the oceans which accumulate the end-product of human activity. The oceans became the most threatened part of the environment as soon as humans began using them as a dump. Coastal regions face the challenge of under-utilised water resources due to a lack of technological know-how. Many coastal inhabitants are therefore disadvantaged, but it is also clear that many sustainable biotechnological products can be produced from farmed water and sea resources.

The productivity of oceans and inland water resources have been utilised for centuries to support basic human needs. Oceans provide sources of food, marine life and inorganic systems as well as providing connectivity and global transport routes. Oceans could hold the key to mitigating greenhouse gases, an idea which is pushing for greater exploration, especially with the focus drawn by SDG 14. Oceans are one of the last frontiers to present new challenges, requiring innovative technologies to deal with the dynamically changing physical and chemical conditions and the stresses imposed on ecology and biodiversity.

The exploitation of the oceans' biological resources is being realised through the Blue Economy[2] and biotechnology. The quest for alternatives to fossil fuels is pushing for the application of waves, wind and tide for the production of renewable energy, but one of the largest and almost unexploited resources is the cultivation of aquatic plants such as macroalgae.

The Terengganu School of Ocean Engineering, University of Malaysia, promotes seaweed farming throughout a large part of the ocean for various uses. Various macroalgae survive

Image: John Isaac

A man removes a plastic bottle from a river in Punakha, Bhutan. Pictured in the background is Punakha Dzong which houses Buddhist temples and the administrative offices of Punakha district

in different habitats. There are several species, and cultivating them in the sea can contribute to the replacement of the world's depleted biomass. Macroalgae is a multi-cellular plant that can be used for the development of many products, including energy from biofuel, healthy food, cosmetics, solar cells, pulp, fertilizer, batteries, preventive medicines, pharmaceuticals and nutraceuticals. A nature-based complex approach makes sea farming profitable.

Seaweed encourages systematic marine bioremediation and carbon sequestration, and neutralises acidification. Seaweed plantations reduce coast-bound wave forces, providing disaster risk reduction for coastal protection. Algae bloom can be neutralised through balancing the proportions of nitrate and phosphate.

An integrated technology for water resource exploration – inland, coastal, sea and ocean – should balance the search for renewable energy, food, textiles and bioplastics with the delicate ecological requirements upstream. Making better use of inland and coastal water systems would also help to improve the quality of life for needy communities. Accountability for this is best ensured through regulation, monitoring and evaluation. Advancing implementation of the 2030 Agenda, in particular accelerating the bridging of SDG 6 at the coastal zones with SDG 14 and other SDGs, is best done through awareness as well as efforts towards policy coherence at regional, national and local levels. Below are the most signifcant examples of policy levers impacting all dimensions of sustainable development.

Wastewater reuse, Saitama Shintoshin, Japan

Wastewater from households and commercial establishments in Saitama undergoes secondary treatment at the Saitama Sewage Treatment Center, using conventional activated sludge. To enable wastewater reuse, the treated wastewater is further treated at the Saitama Shintoshin purification plant using a combination of biofiltration and ozonating processes. Treated wastewater is then reused for various purposes, such as river restoration; irrigation for agriculture, parks and gardens; ground water recharge; augmentation of the streams and brooklets running through the town; recreational amenities and tourist venues. The reuse of treated wastewater has restored the ecological habitat and improved the town's natural environment with new water amenities (brooklets) created and parks revitalised. The system enables about 250,000 m^3 of freshwater to be saved yearly, amounting to ¥104 million (approximately $939,000) due to the provision of recycled wastewater. Pipes for the supply of reused wastewater have been installed under the main roads of Saitama Shintoshin, enabling all buildings to be supplied with treated wastewater.

Smart Cities Mission, India

The objective of the Smart Cities Mission is to promote the provision of core infrastructure, the application of environmentally 'smart' solutions, and the offer of a decent quality of life and a clean and sustainable environment. The mission also promotes inclusive development of water-efficient urban infrastructure, making a huge contribution to better water management and improving the efficiency of core services at a lower cost. The mission includes a comprehensive policy that defines smart cities as those that connect citizens, data, devices and other objects to a centralised infrastructure network that is utilized for urban planning as well as social and economic development. The financial framework includes input from the Ministry of Urban Development, Central Government, and the Special Purpose Vehicle (SPVs) revenue model, with low risk for lenders and investors. It is expected that a number of schemes in the smart city will be taken up on a public/private partnership basis, with the SPVs being central to this.

The smart city project has been developed to promote efficient infrastructures with optimum usage of natural resources. For instance, smart cities provide enhanced and sustainable public amenities, especially designed to cope with fluctuating numbers of visitors and a floating population. This includes the installation of e-toilets (electronic toilet systems) that are unmanned, automated and self-cleaning, with a remote monitoring facility to check usage and upkeep. These systems are solar powered and cloud connected, enabling remote tracking of water quality and of each pay-per-use transaction. Smart cities also provide waste water recycling and Supervisory Control And Data Acquisition (SCADA); smart metering; advanced leak detection; online quality monitoring; solid waste management; Radio Frequency Identification (RFID) for the tracking of vehicles; bio-methanation; waste to-energy technology; decentralised waste processing; and water ATMs which are automated water dispensing units, providing communities with 24/7 safe water access.

Water trading with the use of advanced remote sensing services, Australia

The programme of Water Trading and Economics in Australia provides a successful step towards water efficiency, being beneficial to various communities as water is distributed to everyone – agriculture, industry and domestic – by demand. Depending on the historical, political, legal, and economic context of a community, establishing a water market may be an appropriate solution for distributing scarce water resources to meet increasing demand. Water trading systems promote more efficient water allocation at a market-linked price, acting as an incentive for users to divert resources from low- to high-value activities. Under this system, a cap is established, representing the total amount of water available for consumption, consistent with sustainable levels of extraction. Individual users are then provided with an entitlement to a share of the total available. Water entitlements are tradable so that ownership can change over time, and price is determined by the value placed on water by many buyers and sellers. Since the method is resource efficient, the Australian government's buy-back programme represents a cost-effective means of acquiring water and transitioning the irrigation sector to more sustainable levels of extraction. It is a flexible method, implemented by many countries, and can be scaled up or down according to need and available resources.

Image: EEDS Bhopal

Field survey and interaction with the community, local leaders and officers in a small town in India, about water and sanitation conditions and facilities

CO_2 reduction potential due to water efficient infrastructure, Viet Nam

Viet Nam is implementing a water efficient infrastructure with potential to reduce CO_2 emissions. This includes the installation of water saving toilets and showers, measuring the water used, time of usage, temperature and electrical consumption of pumps, and establishing a model of energy reduction from the hot-water supply to a shower. The technology uses the default model of CO_2 reduction calculation for measurement, reporting and verification (MRV). A CO_2 reduction potential of approximately 16,000t CO_2 per year is expected by popularising the use of the latest water-saving toilet bowls.

Johkasou decentralised wastewater treatment system (DEWATS), Japan

As documented in 2009 by the Japan Education Center of Environmental Sanitation, a Johkasou is an onsite wastewater treatment system installed in the absence of a centralised public sewage plant. It offers primary, secondary and tertiary treatment, ensuring a biological oxygen demand (BOD) level of below 20 mg/l, while also eliminating pathogens. All household wastewater flows directly into a Johkasou with the aim of improving water and sanitation throughout the country as well as ensuring access to all, even in locations without a sewer line. A single unit provides service to an individual building housing from 5 to 5000 people. The wastewater is treated on site and can then be used for various purposes. Johkasou technology now boasts treatment performance equivalent to that of a centralised public sewage plant. Japan's Ministry of the Environment has a mandate to ensure regular desludging, effluent monitoring and the provision of a Johkasou facility to every household.

DEWATS leach pit sanitation technology, India

Leach pit decentralised wastewater treatment technology is one of the oldest and most efficient sanitation technologies available. It facilitates the infiltration of waste liquids and gases into the soil while retaining and digesting excreta. Construction is either of honeycomb brick or cement rings with holes. The pits hold solid faecal matter in the same

Image: University Malaysia Terengganu

Seaweed farming by a coastal community in Malaysia

way as a latrine, while allowing wastewater to percolate into the ground leaving behind only solid waste to be digested by natural phenomena. The life of the technology is 20–30 years, with a very low initial cost and almost no maintenance. The waste can be converted into compost for use in agriculture and for other purposes.

Call for policy coherence – aligning global with local levels
With the growth of population and industrialization, together with the rising cost of ecosystem services and stringent environmental restrictions, water and sanitation technology development is now focused on innovation. Water and ocean technology should be applying comprehensive structures to address complex solutions. The challenge is in attaining the sustainable development goals simultaneously and preparing a new generation of workforce to operate and manage SDG innovation, starting with introducing the SDGs into early curricula and allowing students to practice systems-thinking from primary to tertiary levels of education.

Farming water is unlike farming land because of the unique challenges of ecosystems and the need to implement a circular economy through strong, honest, selfless and reliable collaboration in engineering, biology, ecology, chemistry, economics, industry and academics to bring diverse knowledge, experience and best practice to a holistic system, delivering the next generation of technologies and creating jobs. Education needs courses that meet the challenges of developing new technologies pertinent to SDGs 6 and 14.

The United Nations central platform is the high level political forum (HLPF) for following up and reviewing the 2030 agenda for sustainable development, providing full and effective participation of all UN member states and specialised agencies. In 2018, the theme of the HLPF and the Asia-Pacific Forum on Sustainable Development will be "Transformation towards sustainable and resilient societies," where the goals will be reviewed, including SDG 17 – Partnerships; SDG 6 – Clean Water and Sanitation; SDG 7 – Clean Energy; SDG 11 – Sustainable Cities; SDG 12 – Responsible Production and Consumption; and SDG 15 – Life on Land. United Nations, regional development agencies and regional think-tanks are now actively creating the frameworks for policy coherence.

A better understanding of the links between the goals and the targets of water and sanitation-related SDGs, as proposed by recent publications of ESCAP (2017), has already been demonstrated by the national visionary strategic documents and aligned frameworks. For example, sustainable production and consumption patterns are best shown within the circular economy, self-sufficiency economy and 3R (reduce, reuse, recycle) economies, with integrated water resource management processes complying with the natural water cycles of member states.

ESCAP facilitates international cooperation and provides capacity building support to developing countries through analytical products and the promotion of intergovernmental platforms. This includes water- and sanitation-related initiatives and policy advocacy, focusing on linkages of science and technologies, for example, on rainwater harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse. In this regard, peer-learning on improving water and sanitation management may be achieved through incentivising partnerships and supporting the participation of local communities in decision making processes.

Utilization of solar and wind energy for rural water supply in Ethiopia

Osward Chanda, Acting Director for the Department of Water and Sanitation; Nancy Ogal, Senior Water and Sanitation Engineer; Franz Hollhuber, Principal Water and Sanitation Engineer, African Development Bank

A pilot project has been launched in Ethiopia with the objective of providing experience on the use of solar and wind energy for water pumping, to demonstrate how the systems should be best designed and implemented and to popularise the use of renewable systems within the sector and the communities. The business of water and sanitation in Ethiopia is included in the Growth and Transformation Plan-2, 2016–20, and one of the major strategies to implement water supply solutions is to increase the use of solar and wind energy technologies.

The project design focused on piloting and promoting the use of solar (photovoltaic) and wind energy for the purpose of water supply in the rural areas of Ethiopia, and initiating development of long term investment in these technologies under the government's Universal Access Programme (UAP). This was on the understanding that acquired know-how and confidence in solar and wind pumping technology would ensure an increased and sustained supply of water with a better economic, environmental and social value than small to medium sized fossil fuel powered pumping systems.

The African Development Bank's African Water Facility supported the pilot programme at a cost of Euro 1.99 million for the supply and installation of the pumps, comprising about 70 (40 solar and 30 wind) pumping systems, to be implemented in four regions within the Rural Water Supply and Sanitation Programme in Ethiopia, namely: Oromia, Amhara, SNNPR and Tigraye. Complementarity, implementation of pipe laying, reservoir construction and maintenance of public fountains were the responsibility of the government.

Development impact

Whereas it was expected that an estimated 130,000 people would be served by these water supply schemes, at completion a total of 67 (49 solar and 18 wind) pumping systems were contracted and completed in four regions, serving approximately 120,000 people, 50 per cent of which are women. The project has shown that solar and wind systems are a valid solution for pumping water in rural areas of Ethiopia. Solar systems, now a mature technology, have proven to function very well. The reported shortcomings were mainly due to a lack of exact data provided by the woredas (administrative divisions of Ethiopia) on the bore holes at the design stage, such as depth, static water level, drawdown, yield and water quality.

To ensure sustainable operation of the installed systems in the pilot project, 49 community members were trained for the installation, operation and maintenance of the system and 69 water committees were trained on revenue collection. Additionally, staff from regional, zonal and woreda offices participated in theoretical training sessions on solar and wind systems provided by the supervising consultants under the contract. The capacity building consisted of two sessions with 70 participants per session (3 per cent of whom were women) each running over six days. On-the-job training was also provided by the project contractors to regional, zonal and woreda water sector experts during the installation of the pumping systems, specifically one woreda technician and two community technicians for each site (40 per cent being women).

There is also increased involvement of the private sector in water services provision in rural areas. Two local private firms were contracted to design, deliver and install the solar and wind pumping systems. The capacity of the local contractors and their staff has strengthened considerably, given their involvement in the project implementation and it is expected that they will be able to operate independently in the sector.

The project created awareness in the broader water sector and within communities at all levels. Woreda staff confirmed to the Project Completion Reporting (PCR) mission that numerous communities had expressed a desire for installing solar pumping systems following successful operations of the completed systems located in their immediate neighbourhoods. A noteworthy multiplier effect resulting from participation of local firms is the upsurge of different NGOs installing solar-powered systems in the country through the private sector.

Benefits of the project

- Communities have opened their own small businesses
- Income-generating activities have been created such as growing crops in the water point areas
- Job opportunities have arisen
- Residents claim to have an improved income
- The government can now consider changing all diesel-driven pumps to solar and wind pumps where the sites are amenable
- The government has included the use of solar and wind pumps in the Growth and Transformation Plan-2
- Similar developments have been catalysed
- Other development partners and NGOs are considering the application of solar and wind energy pumps.

The project outputs included development of a strategy for implementation of solar and wind energy pilot works and a framework for long term implementation. In 2015, the supervising consultants recommended to the government that solar and wind energy should be incorporated in the UAP. An elaborate final framework report for up-scaling solar and wind systems has subsequently been presented to the government by the supervising consultant for consideration. The report includes numerous recommendations and proposals for rolling out solar and wind energy to communities and national level. The sustainability aspects together with the possibility for the financing of schemes by final beneficiaries without government or donor support have been considered.

Whereas the project aimed to implement solutions for water supply for domestic consumption, some communities will be able to sustain their livestock during unusual drought years by providing water that is available from the new facilities. Government and NGOs are also becoming highly interested in the use of solar technologies not only for community water supply but also for micro-irrigation developments and there is an increase in financial support from developmental partners for the wider use of solar technologies for water supply, micro-irrigation and rural electrification. Additionally, the government has developed a plan to replace most of the existing 10,000 diesel pumps for rural water supply with solar-powered systems in the next five to ten years.

Sustainability of installed systems

The full benefits (and consumer satisfaction) of solar and wind driven water supply systems can be achieved only if the necessary complementary investments are made, such as to ensure that reservoirs have a minimum of two days of water storage and that additional water points are installed. These requirements were predicated by the pilot scheme but, due to delays in implementation, the government has not yet finished installation of all of the planned reservoirs, water supply extensions and water points.

Water Supply Committees (WSCs) have been established to manage the water supply systems and it has been found that customers are generally willing to pay for water on a volume-based tariff system. In order to facilitate the WSCs to properly manage their water supply systems, there is need to install meters at every water point. The information from a bulk meter reading has to be collected and recorded daily, preferably in a standardised booklet, at least during the guarantee period. In the subsequent project phase, the same information can be recorded simultaneously as the water meters at water points and households are read and accounted for on a weekly basis.

Solar and wind pumps are just one element in a water supply system. As evident in other countries, communities are unable to differentiate problems in a supply system, they just know when there is a shortage. It is the responsibility

Image: AfDB

Water carrier waiting for load, near T'Uri, Tulu Bolo, Oromiya

Image: AfDB

Community members fetching water from a solar powered water supply source, Yirga Alem, SNNPR

of experts to determine the cause of a problem and rectify it quickly. Woreda Water Bureaus therefore provide an important sustainability support structure and should be given all necessary manpower, tools and training.

Based on interviews undertaken with stakeholders by the PCR mission, neither community members nor woreda staff have felt sufficiently prepared to intervene in case of system malfunction. However, at the time of writing, there is a guarantee period of about two years, and thus time available for further enhancing the technical capacities of the stakeholders.

Capacity-building under the project was successful but should be seen as a continuous process, considering the high turnover of personnel at woreda and zonal levels. It is worth recommending that cooperation with the country's more hands-on technical colleges and vocational training centres should be established so as to promote knowledge of solar and wind pumping systems and to improve familiarity with the role of the private sector with respect to maintaining the systems. This should be included in the curriculum of courses on mechanics and electrics. It would also promote private initiatives as well as sales of the systems.

Funding of further solar and wind pumping systems

The pilot project came at the right time. The government was ready to mitigate the water issues by the installation of diesel pumps, but prices for solar panels dropped dramatically throughout the implementation period. Without the use of solar and wind energy, the dramatic increase in power would not have been possible within the original time schedule. The numbers confirm the success of the project – studies have been made for 174 systems and tenders have been prepared by the project agency for at least 60 systems. The project results have therefore convinced the government to continue financing and installing photovoltaic and wind pumping systems.

As more systems are installed and used in the country, general knowledge will increase about solar and wind pumping as well as the services available from the private sector. The government could make it a requirement for all partners in the water sector that, for example, a lifecycle cost analysis has to be made up to a capacity of 30kW for each fossil fuel pumping system and, where an equal or better total cost of ownership is evident, a solar-powered system should to be chosen.

Image: AfDB

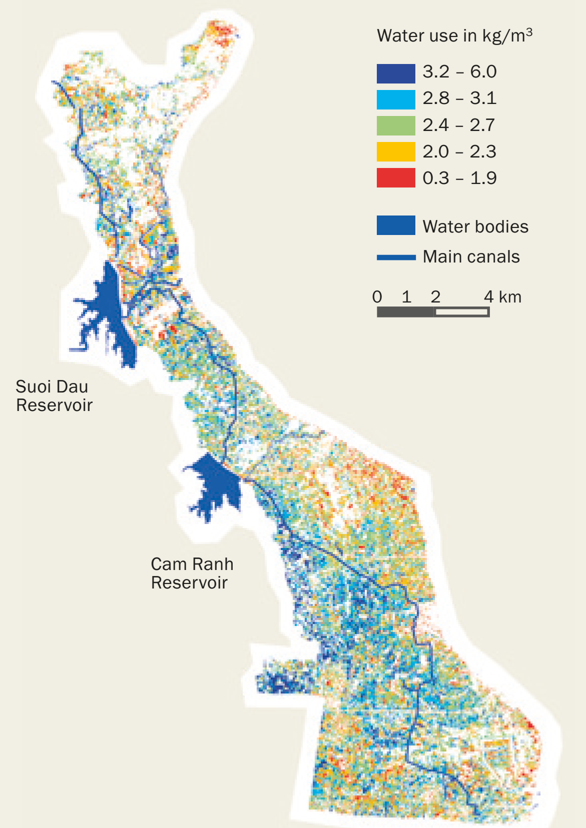
New solar panels replace a diesel generator, near Yirga Alem, SNNPR

New approaches to irrigation – measuring water use productivity using remote sensing

Yasmin Siddiqi, Principal Water Resources Specialist, Asian Development Bank; Wim Bastiaanssen, Professor in Global Water Accounting, IHE Delft, the UNESCO Institute for Water Education; Xueliang Cai, Senior Analyst Water Productivity, IHE Delft, the UNESCO Institute for Water Education

Water resources are becoming increasingly scarce in the Asia Pacific region. Rapid population growth – a predicted population of 5.2 billion by 2050 – will place increasing demands on finite resources.[1] About 80% of water is currently used by agriculture and, as the region urbanises, there will be more demand for usage in homes (including drinking), food production, and energy for homes and industries. By 2050, it is estimated that agriculture will need to produce 60% more food globally, and developing countries will have to double their food production to feed growing populations.[2]

Fig. 1: Water use in mango production, Khanh Hoa Province, Viet Nam



Source: Asian Development Bank, 2017

Climate change will exacerbate these circumstances, with increased variability in rainfall, temperature and the availability of water resources already evident across Asia. The recent, prolonged El Niño drought in South East Asia, placed further pressures on already scarce water resources in countries such as Cambodia and Viet Nam. The frequency and intensity of El Niños is expected to increase during this century, aggravated by higher temperatures and extreme weather due to climate change, further limiting water availability.[3]

By 2050, urban and industrial water demand will increase from 20% to 40% of the total regional demand. Water for use in irrigation (now about 80% of the total) must become more productive to meet future demands of other users.[4]

The advent of the post-2015 development agenda and the Sustainable Development Goal dedicated to water provides a platform and global focus for sustainable water management and sanitation. Target 6.4 for increasing water use efficiency across all sectors by 2030 is particularly relevant in the context of irrigated agriculture where the bulk of water resources are utilised but with low productivity.[5]

Water use efficiency and productivity

Estimates of irrigation system losses in Asia are up to 60%.[6] This is due to dilapidated irrigation infrastructure, weak management practices and a lack of incentives for water saving through pricing. Traditionally, irrigation performance has been based on system efficiencies, such as conveyance and field application and agricultural yield in terms of tons of crop produced per hectare. Measuring efficiency is a practical challenge as it is typically academic and research-based, and not a common undertaking for an irrigation agency. More commonly, irrigation system measurements are based on bulk diversions from the source, for instance water diverted from a river at a canal headworks and from a main canal to the distribution canal.

Recent technological advances in earth observation and remote sensing have introduced greater possibilities as to what measurements can be achieved. Traditional water productivity (WP) assessment focuses on consumed water, but irrigation systems, from source to plant, comprise a number of water conveyance and loss processes, like those of evaporation, deep percolation and water leakages from the canal. These may be exacerbated by poor on-farm land and

Image: ADB

Farmer Nguyen Tan Dan adjusts drip irrigation system he designed for dragon fruit in Binh Thuan Province, Viet Nam

water management practices like flood-irrigating fields rather than using furrows for row crops. Given these complexities, measurement has therefore been challenging, but WP assessment based on remote monitoring is now able to account for evapotranspiration – the sum of evaporation and plant transpiration from the land surface to the atmosphere – rendering a more accurate picture of efficiency.

With greater competing demands, climate change and increasing pressures on finite water resources, it is the output from a unit of water, including considerations such as income, jobs, and nutrition which become as critical as agricultural yield. The concepts of "crop per drop" or "cash per splash" encapsulate the need to maximise economic output from a unit of water rather than to focus on the efficiency of what is produced.

Technology revolutionising irrigation

Remote sensing to measure agricultural WP

Until now, neither farmers nor irrigation agencies have been able to measure the amount of water used to grow a kilogram of crop and how that production equation varies across an irrigation system. Remote sensing technology allows WP to be measured at the farm level, and can be mapped to demonstrate areas where champion farmers are producing more crop with the same volume of water.

Measurements are based on energy balance, considering crop evapotranspiration and biomass produced. Remote sensing data from satellites provides information on land use, crop type, soil moisture, and land surface temperature. Open source data from Landsat and Sentinel from the European Space Agency, and MODIS from NASA, provides suitable information with which to calculate how much water is consumed by a particular crop to grow a kilogram of biomass.

The technology does require field work for ground truthing crop types and understanding farmers' land and water management practices. But it also provides a significant advance in information availability concerning vast areas of irrigated land. Farmers and irrigation system operators and managers can, for the first time, see how water availability affects crop production.

It is not always the case that farmers with an abundance of water are doing better in terms of yield of crop produced. This is best illustrated by the pioneering application of remote sensing for WP in irrigation recently undertaken by

Harvesting mango in Khanh Hoa Province, Viet Nam

the Asian Development Bank (ADB), the Government of Viet Nam and IHE Delft. Measurements taken from five small-scale irrigation systems growing a variety of high value crops such as mango, coffee and dragon fruit have demonstrated the power of the new technology.

Fig. 1 shows the range of productivity achieved for mango growing in the Khanh Hoa Province, Viet Nam. The areas shaded in green indicate better productivity than those in red and it is worth noting that not all of the high productivity is at the top end of the flow system. The red plots alert farmers and irrigation system managers that there are improvements to be made – most likely in farmland and water management and other agronomic practices.

This availability of imagery showing overall irrigation system performance in terms of WP is the first step in the diagnosis of water use inefficiency. The future provision of this information via farmers' mobile phones could revolutionise how and when they irrigate to maximise the productive use of water.

The aim of ADB piloting this application in five Asian countries, including India, Indonesia, Pakistan, Sri Lanka and Viet Nam, is to contribute to SDG 6.4 using actual field measurements. In Viet Nam, preparatory field work for the Water Efficiency Improvements in Drought Affected Provinces initiative (proposed for financing by ADB) uses technology as a real-time indicator for monitoring the performance of irrigation investment, and is particularly crucial in regions at high risk of climate impact. The initiative is designed to raise awareness on using WP to benchmark agricultural water management and will ultimately contribute to the overall monitoring of SDG 6.4.

Managing water from above – use of drones

The act of monitoring with drones (or unmanned aerial vehicles) has taken place for decades but it is only more recently that these are being applied to improve irrigation practices.

The technology provides a higher spatial resolution (less than 1m) for monitoring farmers' fields, their physical infrastructure and irrigation system operation. For example, drones with hyperspectral, multispectral, or thermal sensors can identify which parts of a farmer's field requires irrigation, how well a crop has grown according to plant density, and the extent of agricultural water use. The drones can rapidly span the width and breadth of enormous fields to collect crop moisture data, and then sound an alarm whenever critically dry areas are identified. Drones enable farmers to identify areas at risk from pests or crops that are ready to harvest – and they can even deploy pesticides or water in that zone. Such technologies allow time and cost savings as well as increase water use efficiency by ensuring that the right amount of water is delivered at the right time.

Smart farming drones fitted with various kinds of remote sensing technology can be used to monitor crop health and provide timely responses. Such advancements are currently more visible in developed economies for intensive high value cropping, like vineyards in California, US. But small steps are being taken to bring these advances to developing economies, like Indonesia.

In 2017, the ADB approved the first performance-based lending for irrigation programme in Indonesia. The Integrated Participatory Development and Management of Irrigation Programme will improve irrigation system operation, maintenance, and water delivery to farmers to increase food production. The programme places specific value on the use of aerial surveys and drones to strengthen asset management and system operation and maintenance. It will also use remote sensor agriculture WP data to strengthen system delivery and performance monitoring.

Looking ahead – the future of efficient water management

Agriculture is the largest consumer of water, and remains wasteful in terms of output per unit of water. Feeding an ever-growing population and ensuring that sufficient supplies are available for cities, energy and our precious ecosystems will require increased crop production with less water. Climate change is already impacting on high risk environments where competing demands for water are placing farmers under more pressure.

Remote sensing and drone technologies will become useful tools to advance the understanding of water consumption by crops, identify champion farmers who have optimised efficient land and water management practices and, importantly, provide more responsive irrigation based on crop requirements. Watching farmers' fields and irrigation systems from above provides a more rapid mechanism for minding crop health and driving WP. If the technology is fully exploited, farmers might soon have real-time information available on mobile phones concerning when and how much water to use. For the first time, the region's most productive farmers will be identified and encouraged to share best practices with other farmers.

Technology provides a powerful tool to achieve the targets set under SDG 6.4 for improving water use efficiency. Being able to remotely measure WP on individual farmers' fields and understand how consumptive use of water varies across a system provides a simple benchmarking tool. The United Nations Food and Agriculture Organization is already taking steps to develop an open access database with near real-time data to allow monitoring of WP. This will revolutionise our understanding of irrigation performance and water use in agriculture.

Satellites, unmanned vehicles, robots, drones, mobile apps are transforming farming – providing us with more information and, importantly, empowering farmers for responsive decision making. Ultimately, technology will provide farmers with the power to improve water management on their fields. Building bridges with knowledge partners and the private sector is leading the way. The most critical challenge will be for irrigation agencies and ageing irrigation systems to adapt and modernise for greater flexibility in dealing with the changing supplies and demands.

Image: ADB

Grape vines with drip irrigation in Ninh Thuan, the driest province in Viet Nam

Mobilising community-led water supply, sanitation and hygiene improvements in Fijian villages

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Villages (koro) and settlements in rural and coastal areas of Fiji are gaining increased access to piped household water supplies and adopting the use of flush toilets. Inadequate systems for managing the resultant wastewater flows are a frequent cause of localized contamination and pollution of streams and rivers used for water supply, bathing, laundry and recreation, and nearby lagoons and beaches. Thus, apparent improvements in water supply and toilet facilities are unwittingly leading to increased health risks. The WASH Koro project is developing and demonstrating a range of sustainable community water supply and on-site wastewater treatment solutions for Fijian villages that protect public health and reduce contaminant loadings to surface and coastal waters. Social, scientific and engineering approaches have been integrated with local and indigenous knowledge, resources and construction techniques to engage the local community and build capacity at village level.

Water and sanitation in Fiji

Fiji is an archipelago of 332 tropical islands in the South Pacific, about 1,770km north of New Zealand. It has a population approaching 0.9m, of which about 85% live on the two main islands. Heavy rains (up to 3m or more annually) fall on the windward southeastern side of these mountainous islands, while the leeward north and western sides experiences annual rainfall of about 1.7m with distinct wet and dry seasons. This means that, except for seasonal periods of drought, the main islands are comparatively well endowed with freshwater resources.

About 46% of the Fijian population lives in rural villages and settlements, with indigenous iTaukei (predominantly Melanesian with a Polynesian admixture) comprising about 57% of the population. Traditional villages or koro are commonly sited near the coast or along inland rivers and streams. Tourist resorts along the coast provide jobs and income to supplement livelihoods based largely around agriculture, fishing and forestry.

According to WHO/UNICEF Joint Monitoring Programme (JMP) statistics for 2015, approximately 91% of the rural population of Fiji has an improved drinking water source and about 88% has access to improved sanitation facilities. This makes Fiji one of the few small island developing states (SIDS) in Oceania to have apparently achieved the Millennium Development Goals, placing it well ahead of other small island nations in Oceania, which report that, collectively, only 56% and 34% have access to improved water and sanitation facilities, respectively.

However, work over the last ten years in Fijian villages along the Coral Coast of Viti Levu, one of the more developed rural areas of the largest island, suggests that the WHO/UNICEF JMP estimates for rural areas are optimistic compared to on-the-ground reality. In particular, they fail to identify significant quantity and quality aspects of water supply and sanitation infrastructure and associated management, and the extent of associated water-related health and pollution issues.

Rural water supplies are most commonly from surface-water sources which are often compromised by catchment disturbances including cropping, farmed and feral animals, and forest harvest. Both continuity of service and quality of these water sources are vulnerable to impacts from heavy rainstorms and episodic cyclones or hurricanes, exacerbated by climate changes. Little or no treatment of such waters usually occurs. Some villages have access to wells or bores, and supplementary roof water harvesting has also been promoted in recent years. Overall, the capacity of water supplies to deliver water to villages is gradually increasing across the country, with many villages transitioning from communal standpipes to individually piped supplies to households. This commonly leads to installation of flush toilets and showers, and use of washing machines, creating a significant wastewater flow that needs management.

Lack of adequate wastewater management facilities, beyond small capacity septic tanks for blackwater, results in rapid clogging of soakage pits, particularly in the heavy clay soils common beyond the narrow coastal fringe of coral sands. This can lead to significant localized contamination and pollution of streams, rivers, lagoons and beaches used for bathing, laundry and recreation by villagers and tourists. Such wastewater impacts are exacerbated by leaking taps and toilet cisterns, poor septic tank construction practices and a general lack of maintenance, with most septic tanks operating while

Image: C.Tanner, NIWA

Constructing a sand filtration trench for land application of septic tank effluent in Bavu village, Fiji

full of accumulated sludge. Improvements in sanitation practices such as these have been proposed by The Expert Panel for the Reduction and Control of Typhoid Fever in Fiji (convened by the Fiji Ministry of Health in 2012) as a key action to reduce the high incidence of typhoid outbreaks in the country.

WASH Koro

WASH Koro is a collaborative project, funded by the New Zealand Aid programme of the Ministry of Foreign Affairs and Trade, that aims to provide self-help tools to mobilise communities to recognise and address their own water supply, sanitation, and associated health and hygiene needs. Working in close consultation with two partner villages along the Coral Coast of Fiji, WASH Koro is also developing and testing a range of practical low cost solutions for household wastewater management in the villages. Assessment of village water supply sites and soil characteristics has helped determine appropriate wastewater treatment approaches.

Working with villagers, and with assistance from an NGO (Rustic Pathways) at one of the sites, five septic tank and land application systems (LAS) for the treatment and disposal of household wastewater have been constructed to test and demonstrate their practical implementation and performance. Based on gravity-dosed sand-filter trenches, the LAS have been adapted to the local soil and climatic conditions, available materials and construction practices. Their primary aim is to reduce concentrations of organic and faecal microbiological contaminants to enable safe and sustainable soil infiltration and disposal. Monitoring is being undertaken to verify their effectiveness in real-world conditions.

Improved ventilated twin-pit latrines (EcoVIP2) have also been developed and constructed in two villages to demonstrate them as a waterless sanitation alternative to composting toilets. Leaf mulch, soil and ash is added to stimulate the activity of worms and insects, and enhance in-situ decomposition. Involvement of villagers in construction and operation of the demonstration systems has enabled hands-on training, and provided valuable information on local building methods and sources of appropriate materials, for example, filter sand. With input from the Fiji Water and Sewerage Department, the Ministry of Health and local NGOs, eight new KoroSan guidelines[1] have been produced covering both water-flushed and dry toilet options, and participatory approaches for engaging villages, and building knowledge and capacity.

Key lessons

There are strong interdependencies between village water supply and sanitation needs – piped household water creates wastewater flows which require management if health and environmental problems are to be avoided. Where water

Making visible the unseen

Water-borne gastro-intestinal diarrhoeal illnesses and secondary infection of cuts, grazes and skin lesions, for example from scabies and insect bites, are common health problems in Fijian villages. Because of the hot, high-humidity climate, Fijian villagers, especially the children, swim and bathe frequently in streams and lagoons around villages. Communal bathing and clothes washing are often also important social events in daily village life, and water from these sources may also be used for drinking and cooking during periods when piped or roof water supplies are unavailable.

Simple low-cost water quality testing was used alongside a variety of other participatory activities to help assess water-borne health risks in and around villages. With the involvement of women and members of water and health committees, relevant surface and drinking water quality sampling sites were identified, sampled, and microbiologically assessed using simplified faecal indicator testing methods – H2S paper strips, 3M Petrifilm™ or HyServe Compact Dry™ E.coli plate counts – and a field incubator. Feedback of results to the village the next day, after 24 hours incubation, showed significant faecal contamination of bathing areas and some surface water source around the villages. This could be traced back to discharges of blackwater from flushing toilets, and kitchen and bathroom greywater, without appropriate treatment and disposal systems or necessary maintenance. Small village pig enclosures also proved to be significant sources of faecal contamination. Such cross-contamination has the potential to substantially increase people's exposure to faecal microbes and related health and environmental risks.

Making visible the, otherwise unseen, microbiological state of waters within and around the village has increased understanding of wastewater sources and transmission pathways, and the potential health risks of different drinking water sources and bathing areas within villages. Direct visual assessment of the density of coloured blotches formed by growing E. coli bacterial colonies on the plates appeared to be more readily understood by villagers – and more influential – than showing numbers on a graph. This helped build a real world understanding of the links between water, sanitation and health.

supply capacity is limited, toilet flushing in some households in a village may compete with the basic drinking water needs of others. Improved waterless toilet options therefore need to be seriously considered where water supply capacity and financial resources are limited. Use of flushing toilets increases village water supply needs by 20–30%, and creates a blackwater waste stream with high potential health risks.

Provision of adequate treatment facilities to manage these sustainably is relatively costly for Fijian villagers and requires competent and experienced technicians, engineers and tradespeople who are able to effectively engage with villagers, and are suitably remunerated for their work. These skills are frequently unavailable in rural areas, and villagers are reluctant to pay for such services. An appropriate policy and regulatory framework is also necessary to promote uptake of appropriate technical solutions and ensure they are properly implemented.

Sustainable and effective village sanitation approaches must be tailored to the particular site and soil characteristics of a village or dwelling, and cognisant of the needs and financial resources of communities. Factors to consider include:

- Preferences of users, although this may shift with provision of improved knowledge and experience of alternatives
- Risk of contaminating surface and groundwater resources used for drinking, and areas where people bathe, wash, play, fish and gather shellfish, or may otherwise be exposed
- Surrounding population density, availability of suitable land and coordination between neighbouring households
- Strength of village leadership and governance, and capacity to operate and maintain systems
- Government policies and regulations.

A key finding from work carried out in Fiji has been the critical importance of participatory capacity-building, in tandem with technical approaches, to raise and embed the understanding of health and sanitation issues, enable appropriate choices to be made, and mobilise village-wide actions. These can be important drivers for the acceptance of village responsibilities, and the prioritisation and uptake of improved water and wastewater management systems and hygienic behaviours. Involvement of women, who tend to take primary responsibility for the health of their families, was especially important for promoting action across the whole WASH spectrum.

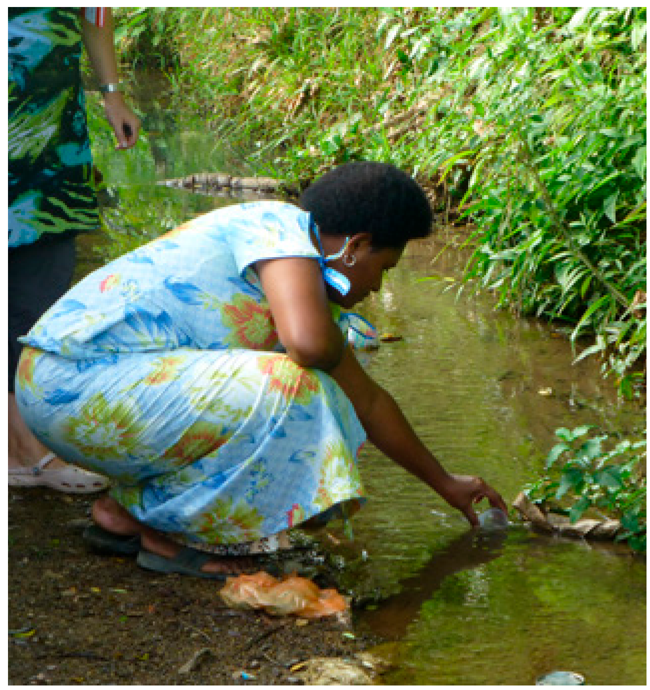

Image: C.Tanner, NIWA

Image: C.Tanner, NIWA

Involvement of villagers in site selection, sampling of water resources and testing the faecal microbiological status of those waters

Ensuring food security in Malaysia through technology and innovation in water and agriculture

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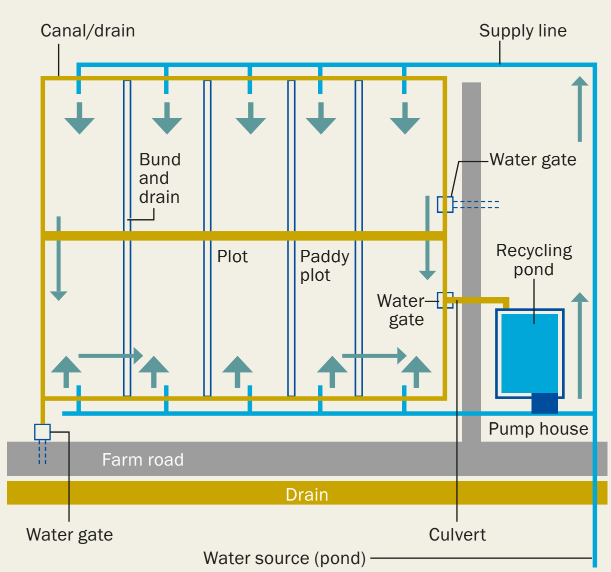
Malaysia's average annual rainfall is 2,940 mm. With a total land area of 33,080,000 ha, of which 7,585,000 ha is cultivated, Malaysia can be considered relatively water-rich compared to many other countries in the world. The volume of annual rainfall is 990 billion m^3, of which 360 billion m^3 (36%) is lost to evapotranspiration, 566 billion m^3 (57%) is the total annual surface run off, and 64 billion m^3 contributes to groundwater recharge. It is estimated that the total internal water resource is 580 billion m^3/year. Malaysia also has a total storage capacity of 460 million m^3, with 16 dams located across the country providing water for both irrigation and domestic use, while also fulfilling a flood mitigation and silt retention function.

It is estimated that the total water withdrawal for Malaysia is 13,210 million m^3, with 65% accounting for agricultural activities, out of which 90% is devoted to rice irrigation and the remainder utilised for vegetable, field crop and nursery plant production. Perennial crops such as oil palm, rubber, coconut and fruit trees are usually grown under rain-fed conditions. Of the remaining volume, 18% of annual water is used to serve municipalities and another 17% for industry.

Fig. 1: Layout of the tail water recovery research plot



Source: MARDI

In Malaysia, the water resources utilisation priorities are:

- Make the most efficient use of direct rainfall
- If rainfall is insufficient, utilise the uncontrolled river flow
- If that is insufficient, reuse drainage water or water release from the controlled reservoir to supplement irrigation
- If that is insufficient, use alternative resources such as underground water.

Irrigation in Malaysia

Surface irrigation is utilised mainly for rice production, even though only 48% of rice cultivation areas are provided with extensive irrigation and drainage facilities, with the remaining areas being rain fed. Rice is grown under level basin conditions in which the fields are flooded from planting to harvest. The seasonal water requirement for rice cultivation ranges from 1,100 to 1,300 mm. Of this, 52% of the total requirement is derived from direct rainfall, 20% is from uncontrolled surface runoff and 27% from dam storage. Currently, the recycling pumps contribute 17% of water released from the reservoirs without impacting the environment.

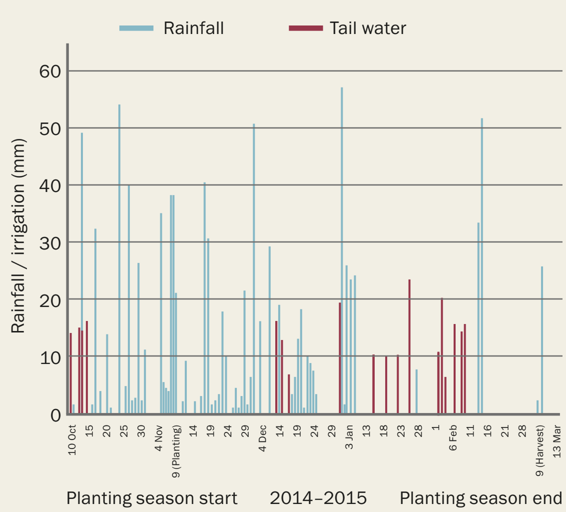
Furrow irrigation is used mainly for vegetables or short term crop cultivation in the small-scale planting of a few

Image: MARDI

Fig. 2: Storage pond and pump house used in a tail water recovery project

Image: MARDI

Fig 3: Rainfall distribution and irrigation events using tail water during main season 2014–15



Source: Malaysian government

Fig. 4: Construction and testing of a shallow tube well for a small scale irrigation project

acres only. The water is sourced either from a river or shallow ground water aquifer. Sprinkler irrigation, commonly found in sandy and hilly areas, is the method most popular with farmers for vegetable and field crop production. High value vegetable production typically uses fertigation techniques where liquid fertilizer is mixed into water during drip and micro jet irrigation. Micro jet irrigation is also used for nursery fields and orchards.

Increasing water supply and reducing water demand

Research is being conducted into fully utilising the available water resources for crop production through increasing the water supply and reducing water demand.

The first phase of water management typically focuses on increasing water supply. This involves the construction of dams and barrages across a river. Alternative options for the increasing of water supplies include agricultural water recycling and re-use, groundwater exploration, and increased on-farm water storage. For the reduction of water demand,

Table 1: Water saving in tail water recovery system

Description	Off-season May–Aug 2014	Main-season Nov–Mar 2014/2015	Off-season May–Aug 2015
Rainfall during growth period (mm)	768	940	798
Direct pumping from storage pond (mm)	322	247	264
Total water supply (mm)	1,090	1,187	1,062
Water saved by recycling (%)	29.5	20.8	24.8
Net withdrawal from storage pond (m^3)	793	1092	293
Estimated energy cost			
Total amount of water pumped (m^3)	27,270	20,940	22,300
Total amount of diesel used (L)	330	235	300
Total cost of diesel (RM) (RM 2.20/L)	726	517	660
Energy cost per ha (RM)	85.80	61.10	78.0

Ratio of cultivated area to storage pond: 10:1
Currency conversion: US$1 to RM 4.2

Source: Malaysian government

the options are to improve cultural practices that reduce on-farm water losses, and to increase the efficiency of crop consumptive water use and improve irrigation efficiency.

Other measures that indirectly contribute to water saving include irrigation scheduling based on rainfall patterns; crop performance evaluation to identify critical water-stress-sensitive growth stages; the incorporation of ICT and a geographic information system (GIS) to improve water delivery services in irrigation through better water control; land levelling to improve water management; and the improvement of rain-fed agriculture through terracing and on-farm water conservation.

The tail water recovery system for rice cultivation

A tail water recovery system is designed to collect, store and distribute irrigation or rain water runoff from a farm for reuse (see figures 1 and 2). If the runoff water is not utilised, it will eventually flow into the sea. The captured water is pumped and delivered effectively into a supply system before reuse.

A tail water recovery research project conducted at MARDI, Seberang Perai has shown that the total amount of water saved from rice cultivation ranged from 20 to 30% (see table 1). The ratio of cultivated area to storage pond was 10 to 1. During the planting season, the captured tail water from excess rainfall was sufficient to supplement rainwater in order to meet the seasonal water requirement (see figure 3). Since the implementation of the project, no additional irrigation water has been needed for rice cultivation in the research plot, showing improved irrigation efficiency and water saving. Additionally, the residues from chemical applications were found to be localised to the application areas in the field rather than distributed to non-target areas such as collection drains or a storage pond.

Improving the water productivity index

In most cases, the single most important avenue for managing water demand in agriculture is through increasing agricultural productivity with respect to water. Increase in crop yields, i.e. production per unit of land, is the most important indication of improved crop water productivity. Yield increases are made possible through a combination of improved water control, land management, diversity and agronomic practices. Managing overall demand by focusing on water productivity is more important than concentrating on the technical efficiency of water use alone.

Breeding crop varieties with higher water-use efficiency is seen as providing part of the solution to reduce water demand. For instance, in a rice crop breeding programme, two key processes have been exploited to achieve higher water-use efficiency:

- Reduction in growth duration while maintaining or even improving crop yield
- Synthesizing more biomass in exchange for water transpired by the crop, i.e. improving crop transpiration efficiency and planting drought-tolerant varieties.

Table 2 lists some of the improved rice varieties with a short maturation period and high yield.

Shallow groundwater / tube well

The exploitation of shallow tube-wells for irrigation is suitable for short-term crops such as vegetables and field crops and commonly found near lowland and coastal areas and used profitably by small farms (see figure 4). During agricul-

Table 2: Increased water productivity through reduced growth duration and increased yield

Varieties	Maturation* main season – off season	Potential yield (mt/ha)
Bajong/Biris	160–170	3
Bario/Mamut/Bubuk	140–160	3
Malinja	137–147	4
Setanjung	135–142	5
Mahsuri	134 –138	5
MR 84	124–137	7
MR 127	120–128	7
MR 211	99–100	8
MR 185	112–119	8
MR 219/ MR220	105–120	10
MR 253/MR263	104–110	10
MR 220 CL1 & CL2	97–113	10
MR 284	105–110	10
MR 297	100–110	10

*Maturation measured in number of days after sowing

Source: Malaysian government

tural drought, when the surface water from storage ponds or rivers is insufficient to complement rainwater to meet crop water requirements, shallow tube well irrigation is a suitable choice. However, shallow underground water, especially in the eastern region of the Malaysian peninsular, contains high levels of iron and is unsuitable, particularly for leafy vegetables. This problem has been overcome with the integration of sawdust cartridge filtration into the irrigation system. Sawdust has been found to be able to absorb up to 95% of iron content from underground water. With a construction cost of no more than RM2,000, this system is economical yet highly efficient and easily operated by farmers.

Scheduling the planting

To fully exploit rainwater and achieve yield potential for short term crops, planting dates should be timed to coincide with the rainfall pattern. The optimum time to start sowing is at the onset of the rainy season, with harvesting scheduled for the dry period. Figure 5 shows the planting schedule based on the long term average monthly rainfall pattern for rice cultivation in the northern state of the Malaysian peninsular. The planting schedule can change over time as a result of climate change as well as changes in technological and socio-economic factors. Thus, it is necessary to regularly update the average rainfall and climatic data for each specific agro-climatic zone planting schedule in order to reduce the impact of climate change.

Land levelling

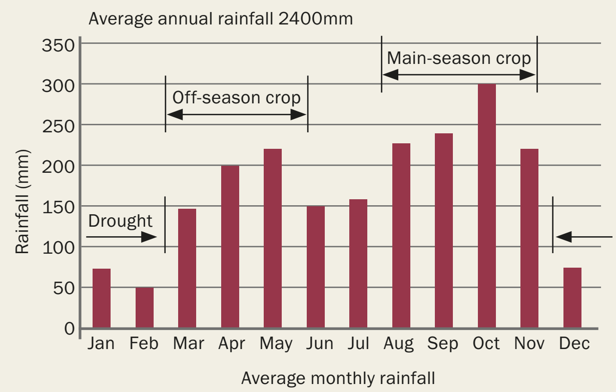
Particularly important for paddy fields, a well levelled surface will increase the efficiency of water use, improve crop establishment, reduce input, improve machine efficiency and reduce the need for a more intensive on-farm irrigation and drainage system. The availability of laser controlled land levelling equipment (see figure 6) and ICT technology has marked one of the most significant recent advances in surface irrigation technology. Now, the cut and fill operations in land levelling are guided by a receiver attached to the motor grader, based on a treatment map using the GPS system. The improvement of land levelling technologies has reduced standing water in rice fields from 10–15 cm to 5–10 cm. This has improved field water use significantly by reducing seepage and deep percolation.

ICT water management

ICT is making significant impact on agriculture and agricultural water management. Farmers now have access to a wealth of online information on crop prices, weather forecasts for irrigation and water management, and plant diseases, to influence planting decisions.

Together with GIS technology, new ways of supporting water management are available. The telemetric system integrated with GIS enables irrigators to operate water gates and pumping systems, monitor dam water levels and supply canals from a remote office (see figure 7). This helps the operator to supply the right amount of water to the right place at the right time, improving conveyance efficiency and significantly reducing water wastage. The technology also acts as an effective early flood warning system.

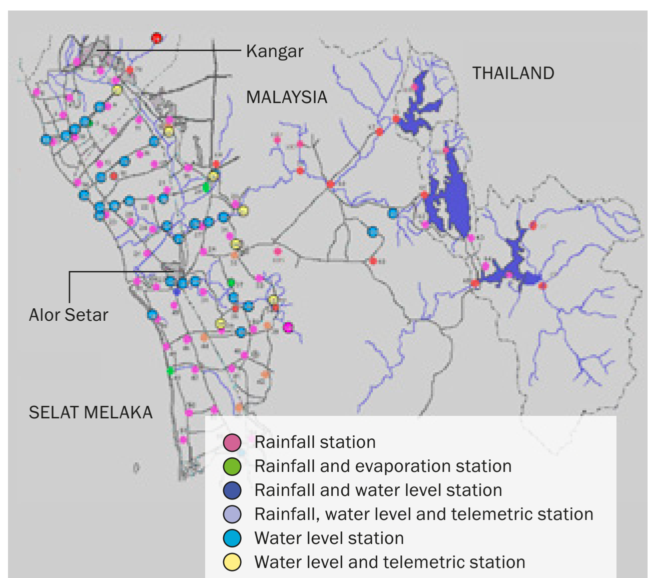
Fig 5: Rice planting schedule based on long-term average rainfall pattern



Source: Malaysian government

Image: MARDI

Fig. 6: Laser-guided land levelling technology has improved surface irrigation, particularly in rice basin areas



Source: Malaysian government

Fig. 7: The use of a telemetric system in the Muda Agriculture Development Authority area to control and monitor irrigation water supply from reservoirs to rice fields

Strategic collaboration, networking, awareness and succession planning for capacity building towards water security in Malaysia

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Our forefathers understood and appreciated the balance of natural systems and of the environment. The devastation caused by carelessness, greed and irresponsibility was brought to international prominence in Rachel Carson's 1962 book *The Silent Spring* in which she urges the global community to recognise its proper responsibility for the environment. This idea is endorsed in the Brundtland Report[1] which promotes socially inclusive and environmentally sustainable economic growth, encompassing economic and social development as well as environmental protection beyond local, intergenerational frameworks to better focus on the common interest of mankind.

Some Malaysian organisations that adhere to the Sustainable Development Goals (SDGs) have compiled key sustainability-focused publications and translated them for use in primary education. The International Science, Technology and Innovation Centre for South-South Cooperation (ISTIC), has also been instrumental in translating valuable documents to further sustainability education in Malaysia. This emphasis on education is of primary importance.

However, in achieving the SDGs, Malaysia needs to move at a faster pace towards addressing water resource challenges and attaining a secure water system. An inadequate supply of water, both in quantity and quality, limits the capacity to alleviate poverty and boost economic recovery, resulting in poor health, low productivity and food insecurity. Thus, water security is at the heart of SDG 6, whereby the improvement of water resources is recognised as a catalyst for environmental well-being and the national development of environmental sustainability.

The Malaysian Department of Irrigation and Drainage (DID), acting under the auspice of the Ministry of Natural Resources and Environment, has been given a mandate to manage national water resources and to meet the SDG 6 target by 2030. DID Malaysia has begun to undertake a comprehensive and integrated approach in addressing the issues in a sustainable and equitable manner. This includes strengthening Integrated Water Resources Management (IWRM) implementation, improving water security, addressing water quality and pollution and enhancing collaboration, networking, awareness and capacity-building at national and international levels.

Enhancement of strategic collaboration and networking

Stakeholder inclusiveness and collaboration are essential in ensuring the security and sustainability of water resources as well as in achieving the common goal of managing multiple water sources. This applies beyond the country's border where scientific collaboration in the development of water networks should be reinforced and enhanced. DID has made this possible via the Malaysia International Hydrological Programme (MIHP) together with the Regional Humid Tropics Hydrology and Water Resources Centre for Southeast Asia and the Pacific, also known as the Humid Tropics Centre, Kuala Lumpur (HTC KL).

HTC KL, in its capacity as a UNESCO Water Centre, Category 2 (UNESCO-WC2) organisation, has been instrumental in encouraging regional and international collaboration such as jointly organising a training workshop, in 2009, on Flash Flood Risk Assessment and Mitigation Strategies with the International Centre for Water Hazard and Risk Management (ICHARM) and the Regional Centre on Urban Water Management, Tehran. In 2016, HTC KL also collaborated with UNESCO's Jakarta office and Malaysia's local universities network in conducting the International Workshop on Comparative Studies of Applying Ecohydrology and Integrated Water Resources Management for Upscaling Water Security in Asia and Africa. The workshop stands as a contribution to South-South Cooperation through the UNESCO International Hydrological Programme (IHP) as it involved three of the Least Developing Countries (LDCs) – Nigeria, Sudan and Ethiopia; and three of the developing countries – Malaysia, Indonesia and Iran.

HTC KL also facilitated UNESCO's visionary flagship programme, Sustainable Water Management Improves Tomorrow's Cities' Health (SWITCH-in-Asia), that addresses the non-sustainability of current water management practices in cities, and sets the scene for the development of solutions in managing water for the city of the future.

The showcase project, Integrated Stormwater Management Ecohydrology (MSMA-ISME), was launched at HTC KL in May 2013 by Irina Bokova, Director General of UNESCO. MSMA-ISME covers all aspects of integrated urban water cycle management which comprises a rainwater harvesting system; green roof system; bio-retention system; porous pavement; greywater reuse system and constructed wetland.

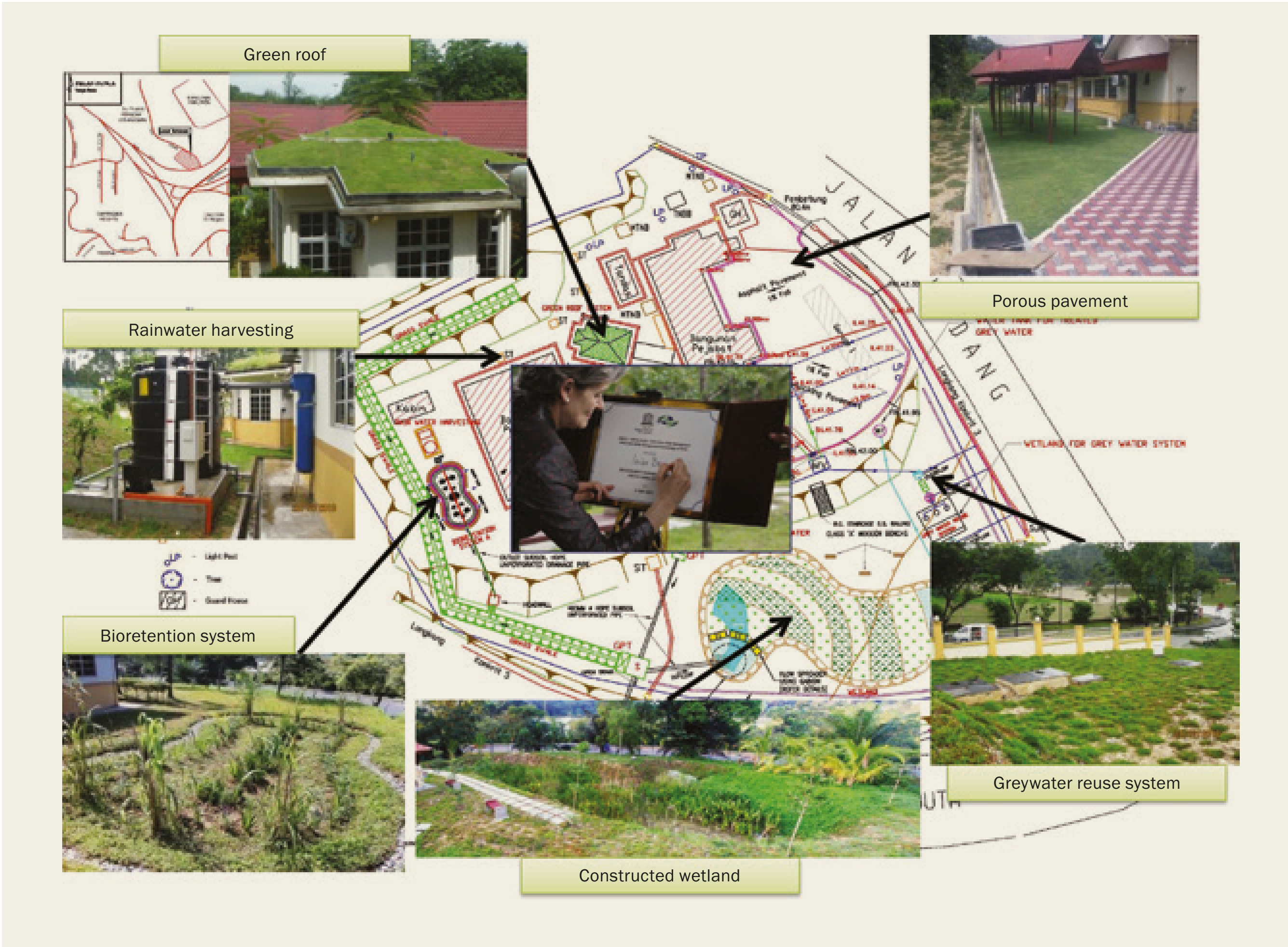


Illustration showing the diversity of the MSMA-Integrated Stormwater Management Ecohydrology showcase project at HTC KL compound

In line with its UNESCO-WC2 functions, HTC KL has created a platform for scientific collaboration and the exchange of technical, scientific and policy information between Asian and African Category 2 Water Centres. This has been achieved with the Malaysia Fund-in Trust (MFiT), together with partners from UNESCO Jakarta office, the Asia Pacific Centre for Ecohydrology, Indonesia (APCE), Regional Centre for Integrated River Basin Management, Nigeria (RC-IRBM), and local universities. This collaboration has resulted in the project: Comparative Studies of Applying Ecohydrology and Integrated Water Resources Management (IWRM) for Upscaling Water Security in Asia and Africa. This focuses on developing modular curricula for water education and strategies in water management through various activities, and applying ecohydrology, IWRM and science education for sustainable development.

The availability of water education as identified in SDG 6 and UNESCO IHP VIII: Water Security – Addressing Local, Regional and Global Challenges, is one of the areas that will benefit through strategic collaboration and networking. As stated by the Malaysian education minister, Datuk Seri Mahdzir Khalid during his speech in London in 2017: "Malaysia, as a UNESCO executive board member, is committed in achieving the Sustainable Development Goals of the United Nations in its 2030 agenda which calls for all children to have access to quality education…" SDGs will then also form the link between the country's blueprint for education and the 2050 National Transformation (TN50).[2]

Also, as one of the functions of the MIHP is to promote sustainable development through integrated water resources management, the MIHP and DID have instated two annual events: a national World Water Day and a UNESCO Day.

2017 marks another successful DID commitment through the MIHP, in which the ASEAN Working Group on Water Resources Management (AGWRM) meeting was held to provide a platform for promoting cooperation between ASEAN members and to facilitate involvement in the IWRM Programme, in which the exchange of technological knowledge and planning for capacity building has increased awareness among targeted stakeholders of ASEAN members.

Through local networks and the enhancement of international cooperation, DID will be able to train, develop and equip stakeholders, particularly those in government, to manage water resources in their entirety as directed by the Malaysia National Water Resources Policy (MNWRP). There is also a crucial need to enhance the knowledge and application of water resources management, where investments must be made to encourage continuous research, development and innovation, as well as forge partnerships with institutions of higher education, research based institutions and non-governmental organisations. These platforms could be used to further refine alignment in managing water resources and to gain first hand information from the developed countries for adoption in Malaysia.

Awareness and capacity building

Efforts to secure and sustain water resources as well as to engage stakeholders requires continued focus. Working together among stakeholders to nurture a sense of belonging among communities is the key to achieving sustainable results. This is captured in the MNWRP where capacity building and awareness is one of the main concerns.

Good practical models introduced by the River of Life (RoL)[3] project's Public Outreach Program (POP) have prepared the way for a new awareness platform in the Klang Valley area. RoL and sewerage are water-related projects given priority as high impact Entry Point Projects (EPPs) in the Tenth Malaysia Plan which will enable Kuala Lumpur to become a top twenty Most Livable City.

The Government Transformation Program (GTP) and Economic Transformation Program (ETP) were created to make Malaysia into a fully developed nation by 2020. This EPP project spans four ministries: Ministry of Federal Territory (KWP); Ministry of Energy, Green Technology and Water (KETTHA); Ministry of Urban Wellbeing, Housing and Local Government (KPKT); and Ministry of Natural Resources and Environment (NRE).

There are ten key approaches in RoL POP, namely Smart partnership; Integrated approach; Civic science approach; Active consultation process; Pollution prevention at source; Working with ongoing activities; Participatory and practical approach; Involving the mainstream and social media; Stimulating stakeholder contributions and co-financing; and Sustaining the activities beyond the project period (exit strategy). These key approaches have created strategies that reconnect six target groups – local communities; institutions; industries; cooperation and developers; food establishments; workshops and wet markets – with nature. The RoL POP has been conducted over only 10.7% of the total RoL area of 551 km^2, comprising RoL POP 1 – upper Sg Klang (40.4 km^2) – and RoL POP 2 – Sg Bunus catchment (18.3 km^2). A case study conducted by HTC KL and its partners concludes that the annual average wet load of the Sg Kerayong catchment (area without POP) is higher than that of Upper Sg Klang (area with POP) due to the successful Public Outreach Programme conducted at Sg Klang. The result is that the difference in annual gross pollutant load between Upper Sungai Klang and Sungai Kerayong catchment is around 57%.

As Malaysia celebrated 60 years as an independent nation in 2017, the prime minister launched the 2050 National Transformation (TN50) roadmap, which is an initiative to plan for the future of the country, specifically in the period 2020 to 2050. In order to achieve the five TN50 "Circles of the Future" – Work and value creation; Living and wellbeing; Governance; Society; and Lifestyle – we need the diversity and inclusiveness of all parties. Awareness and capacity building will prioritise the promotion of urban gardening, sustainable cities, accessible infrastructure and the reduction of the carbon footprint.

To empower capacity building, DID has a succession plan to expand knowledge and awareness of water security. This follows the seminars, workshops, and training conducted at national and international level in recent decades, i.e. International Conference on Urban Drainage (ICUD); Asia Water Resources Expo and Forum (AWARE); International Conference on Water Resources; National Water Watch Programme for Young Leaders; and a one-off capacity building event curated by the DID. The network and linkage activities have included the 7th World Water Forum 2015; Joint University of Canberra-UNESCO International Forum on Sustainable Landscape; Inter-Regional Workshop on South-South Cooperation for Upscaling Integrated Water Resources Management and Ecohydrology as Tools for Achieving Water Security in Africa; International Workshop on Capacity Building of Journalist Educators on Climate Change and Water Management using UNESCO Model Curricular in Tehran; and The Workshop for Capacity Building on Climate Change Impact Assessments and Adaptation Planning in the Asia-Pacific Region, in Manila.

Conclusion

Sustainable development must be put in place now as a legacy. Its future is fragile until the IWRM ambitions are met. In line with the SDG theme "The Future We Want" as adopted in the UN General Assembly Resolution 66/288 on 27th July 2012, all countries should work towards the achievement of the sustainable development goals by 2030. The realisation of these goals requires collective and collaborative partnership efforts including resource mobilisation, innovation and knowledge sharing, as well as active partnerships among the government, private sector, non-governmental organisations, civil society, universities and research institutions. Thus, DID, with its enhancement of strategic collaboration and networking, awareness, and a continuous succession plan for capacity building, is on track to support SDG 6, particularly theme 6.6a: Expand international cooperation and capacity-building, and theme 6.6b: Support and strengthening of participation of local communities in improving water and sanitation management.

Image: DID, Malaysia

The International Workshop on Comparative Studies of Applying Ecohydrology and Integrated Water Resources Management for Upscaling Water Security in Asia and Africa, organised through UNESCO Water Centre Category 2, Kuala Lumpur, 2016

The SuSanA platform and the Shit Flow Diagram – tools to achieve more sustainable sanitation for all

Arne Panesar, Dirk Walther, Thomas Kauter-Eby, Susanne Bieker, Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH; Suresh Rohilla, Centre for Science and Environment (CSE); Regina Dube, Ministry of Environment and Energy of the City of Hamburg; Kim Augustin, HamburgWasser; Roland Schertenleib, formerly Swiss Federal Institute of Aquatic Science and Technology (EAWAG)

Daniela Krahl of the German Federal Ministry for Economic Development and Cooperation (BMZ) has said that: "The water strategy of our Ministry is seen as a model because it addresses the spirit of the SDGs in a holistic manner, thus going beyond SDG 6. That is what we need today and that is why I like the excreta flow diagram. It brings people from different spheres together to understand a challenge that they can only solve together. A platform – the Sustainable Sanitation Alliance (SuSanA) – has been formed to allow for discussion on sanitation at all levels, particularly with an inter-sectoral outlook, and with the aim to find equitable and sustainable solutions. That is why the Ministry is supporting cooperation in German development expertise on this platform, and is proud to see its positive impact."

Human excreta can pollute water and settlements, spreading deadly pathogens and emitting methane that contributes to global warming. They can also provide a safe fertiliser to help build a world without hunger, and create energy for a circular economy. Solving the sanitation crisis is therefore a challenge and opportunity in need of cross-sectoral communication, and facilitating such communication requires a new language and new communication tools.

The SuSanA is a platform built for developing and enabling communication for this purpose.[1,2] One of the tools used to inform stakeholders from a range of backgrounds on city-wide sanitation conditions is known colloquially as the Shit Flow Diagram (SFD), which often forms a crucial basis for discussion among a wide range of urban agencies on future steps towards better urban sanitation for all.

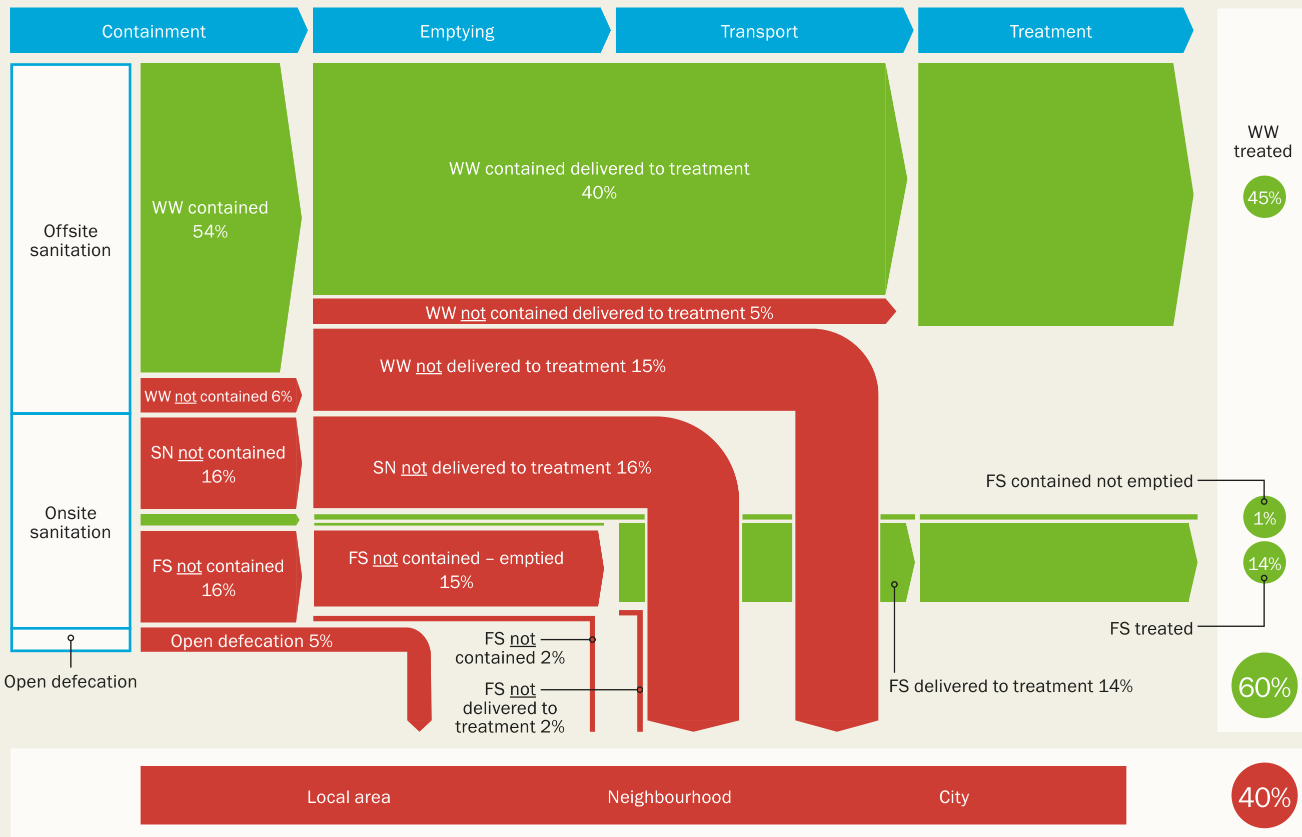
There are three key concepts that link sanitation to the Sustainable Development Goals as a whole – the systems approach to sanitation; viewing sanitation as part of a circular economy; and the use of SFDs. These crucial elements are brought together on the SuSanA platform with the aim of addressing the SDGs holistically.

Image: Press Trust of India (PTI)

Image: Arne Panesar

A Shit Flow Diagram (SFD) is an advocacy and decision support tool that summarises and presents in a concise report what happens to excreta in urban areas. When Bill Gates met India's prime minister, Narendra Modi in 2016, he used an SFD graphic to begin an exchange on the urban sanitation crisis and where efforts might be focused to address it efficiently

Fig 1: A typical Shit Flow Diagram



Source: SFD Promotion Initiative

The graphic from the SFD report on Tiruchirappalli (Trichy), India,[3] shows that 60% of the population is dependent on offsite sanitation systems and 35% is connected to a sewer line. Finally, 5% of the population practices open defecation. It can be concluded that the excreta of 60% of the population is managed safely and 40% of excreta is discharged into the environment untreated. The potential of SFDs as a tool to communicate sanitation gaps is widely recognised in the sector

The power of iconography to reach SDG 6 and more

When Bill Gates met India's prime minister Narendra Modi in 2016, he used a graphic to begin discussions on the nature of the sanitation crisis and where efforts should be focused to overcome it. The graphic was an SFD depicting the sanitation conditions of the Indian city of Trichy, and allowed for a highly structured discussion by visually emphasising the challenges and possible action fields for improving sanitation management on a city-wide level. It also underlined the importance of safe faecal sludge management in cities.

It became apparent that the power of SFD graphics lay in the idea that they:

- Present both central and decentral systems in one image, overcoming a breakdown in discourse on how to solve the urban sanitation crisis that has existed for too long.
- Are inclusive, as they show the journey of the excreta of all humans in a city.
- Use a systems approach to sanitation (see below), as they follow the journey of excreta along the sanitation chain, from containment, via transport to treatment and beyond.
- Establish a direct link to the viewer, especially if that person lives in the city depicted in the graphic and is curious as to the safety of excreta management.
- Establish a direct link to the viewer's work, even if that person does not work in the field of sanitation. SFDs are helpful to a range of sectors in a city, for instance to the health sector where the SFD shows to what extent mismanaged or missing sanitation systems become a health concern; to the environmental sector where it shows to what extent unsafely managed excreta reach the environment; to reuse concepts where it shows which sanitation system components produce what kind of excreta flows (information useful for biogas or fertiliser production, if safely managed).
- Can be linked to infrastructure considerations, and indicate where to prioritise investment into urban sanitation.

The SFD as a prompt for expert discussion and action

The graphic itself does not solve, but discussion prompted by the graphic among experts from various sectors has the potential to do so. When Prof. Barbara Evans, one of the first to visualise excreta management in cities and towns, presented an SFD graphic of Dhaka to the city's mayor, he was alarmed. It showed that, while open defecation was at only 1%, around 98% of the city's excreta were unsafely managed.[4] This made it immediately clear that further discussion with a broader group of stakeholders was required to improve management.

SFD reports contribute to better diagnostics and more targeted intervention at city level. For the report to be of most value, it must comprise the graphic together with a detailed set of critical information on the sanitation service delivery context of a city and a transparent reference to all data sources used, otherwise sustainable solutions cannot be achieved. For example, there are cities that have received funds for more than one large wastewater treatment plant which became dysfunctional after a few months. Investment in a large plant is a bad idea if skilled personal are not in place to run and maintain it, or if the appropriate policy environment to finance the operational and maintenance costs is missing.

Presenting an SFD graphic to a key decision maker often sets the appropriate tone for productive discourse, initiating it by providing a clear and common ground. There are various backgrounds against which such discussion can take place. For instance, in Moshi, Tanzania, four key stakeholders of urban sanitation used the city's SFD[5] as a starting point to help develop a joint understanding of the status quo and to inform discussion on possible futures for the city. In India, the SFD has been integrated in the ministry's toolkit for implementing the already effective National Urban Sanitation Policy, strengthening communication among experts as well as providing information for the public.

In summary, an SFD not only presents relevant information visually to more than one sector but, by doing so, brings together the various sectors and their respective agendas. Thus, various stakeholders are linked in communication that otherwise would have remained within their own field of discourse. The SFD is therefore responsible for shaping a new, more encompassing conversation on sanitation.

Two other strong visual concepts required for SFDs

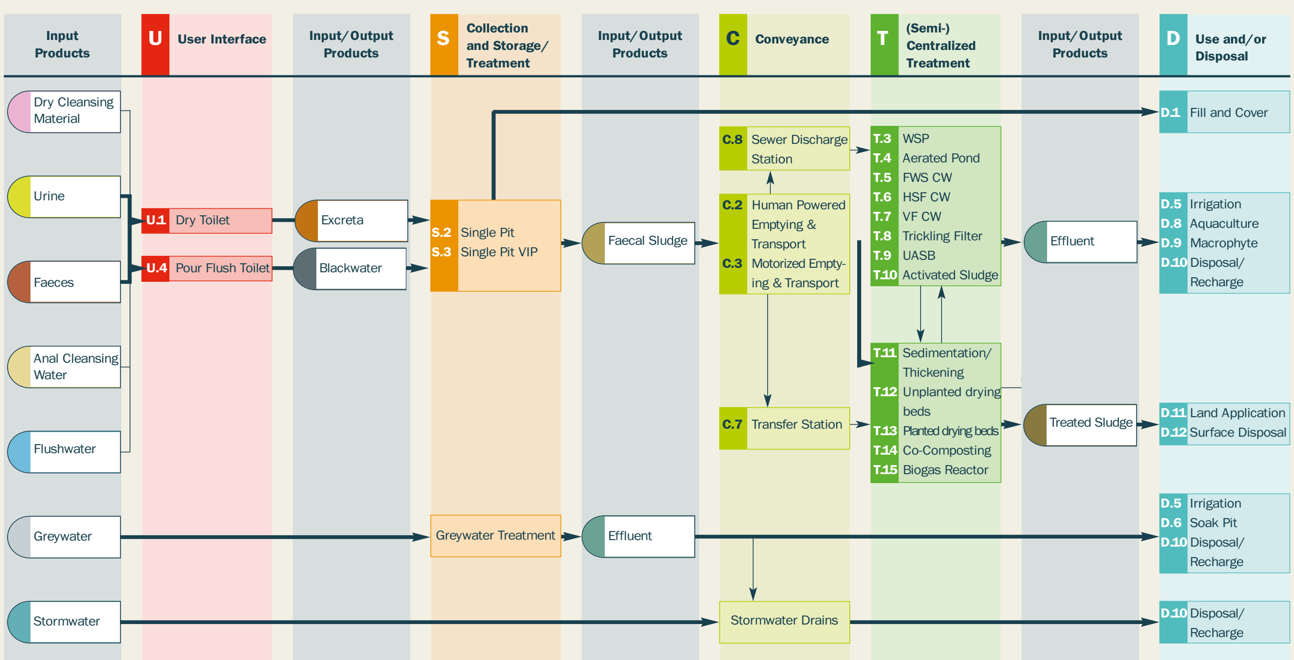
While the idea of the graphic quickly emerged in discussions between experts, the underlying thinking was predicated on two main pillars[6,7] that also evolved around iconography.

One is the systems approach to sanitation that defines the components forming a typical system and produces a set of examples. The other is the idea of sanitation as part of a circular economy. It is possible close the loop on sanitation, linking excreta management with broader resource efficiency and sustainability discussions and hence with a range of SDGs.[8] Both approaches connect sanitation with matter flow analysis and are discussed below.

Image: SuSanA/GIZ

Roland Schertenleib, former director of the Swiss Institute for Water Research, was a key figure to argue for a global systems approach to sanitation

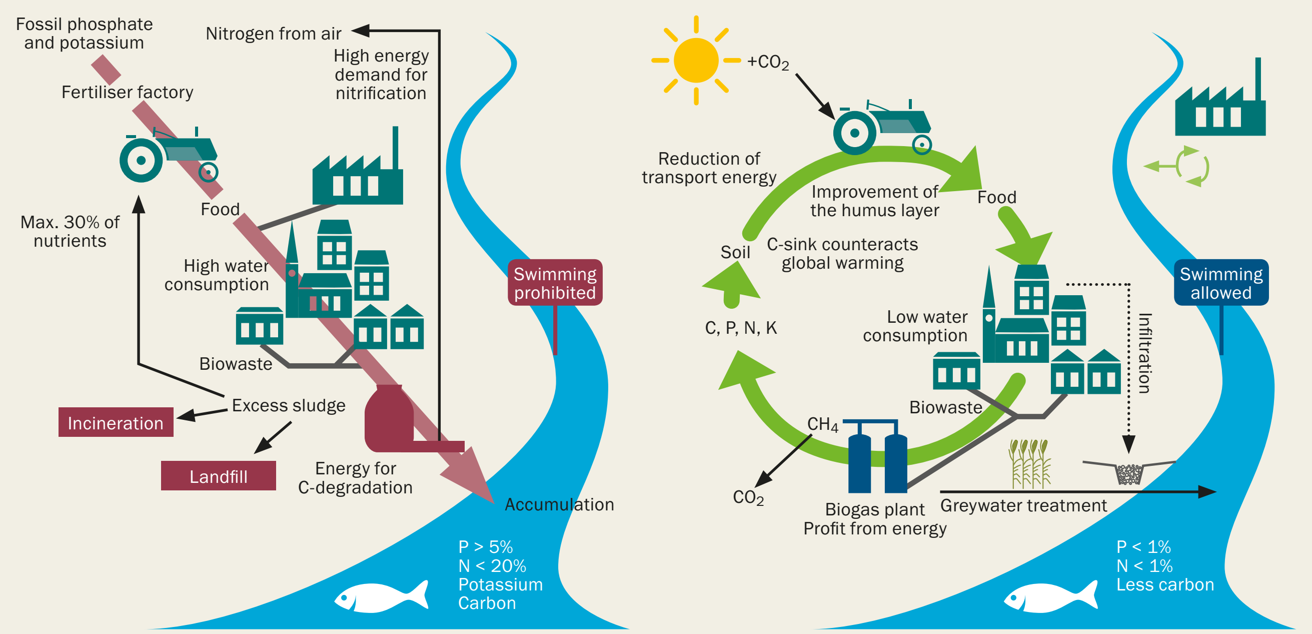
Fig 2: Combining sanitation system components to form sets of systems along a sanitation chain



See reference 12: Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C., & Schertenleib, R., 2008. Compendium of Sanitation Systems and Technologies. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland

The systems approach to sustainable sanitation for a single pit system. This method has found widespread acceptance in the sector

Fig. 3: Comparison of linear- and reuse-oriented approaches to sanitation



Source: adapted from reference 15: Lange, J., & Otterpohl, R. (1996). Abwasser-Handbuch zu einer zukunftsfähigen Wasserwirtschaft

Iconography used to describe closed loop systems by Lange et al. 1996. It compares a linear to a reuse oriented approach to sanitation

The SuSanA-network – moving to a systems approach

Sunita Narain, director of Centre for Science and Environment, New Delhi, India, reports that: "The biggest ever sanitation programme, the Clean India Campaign (Swachh Bharat), instigated by Indian prime minister Narendra Modi, has broadened its focus from ODF (open defecation-free) to ODF++ (including waste water, septage, greywater and faecal sludge management)."[9,10,11] The mission of the Indian government and an engaged community of experts had originally begun with the slogan "Toilets before Temples," yet this was the first step in an extended mission. Now, with ODF++, the focus has moved beyond the toilet to include various other elements of the sanitation chain and particularly an approach to sanitation from a systems perspective.

For many years, sanitation improvement was often focused on the construction of latrines without considering aspects of operation, maintenance and services. However, there has been increasing awareness globally that building latrines alone and neglecting the entire sanitation service chain does not improve public health conditions, and could even be a cause of environmental deterioration.

This increased awareness was one of the main reasons for creating the Sustainable Sanitation Alliance, just before the International Year of Sanitation in 2008,[12] experts having been concerned that the Year would be oriented towards infrastructure, thereby potentially worsening the situation. The alliance was, among other activities, actively involved in the development of a key publication, spearheaded by the Swiss Water Research Institute EAWAG, entitled *The Compendium of Sanitation Systems and Technologies.*[13] A crucial ingredient of the publication was its provision of iconography to depict sanitation chains and the ways in which elements could be linked to the chain using a number of exemplary systems.

Sanitation in the circular economy – closing the loop

The global endorsement of the SDGs calls for a radical re-thinking of the conventional, accepted approaches to urban infrastructure in general, and to sanitation in particular.

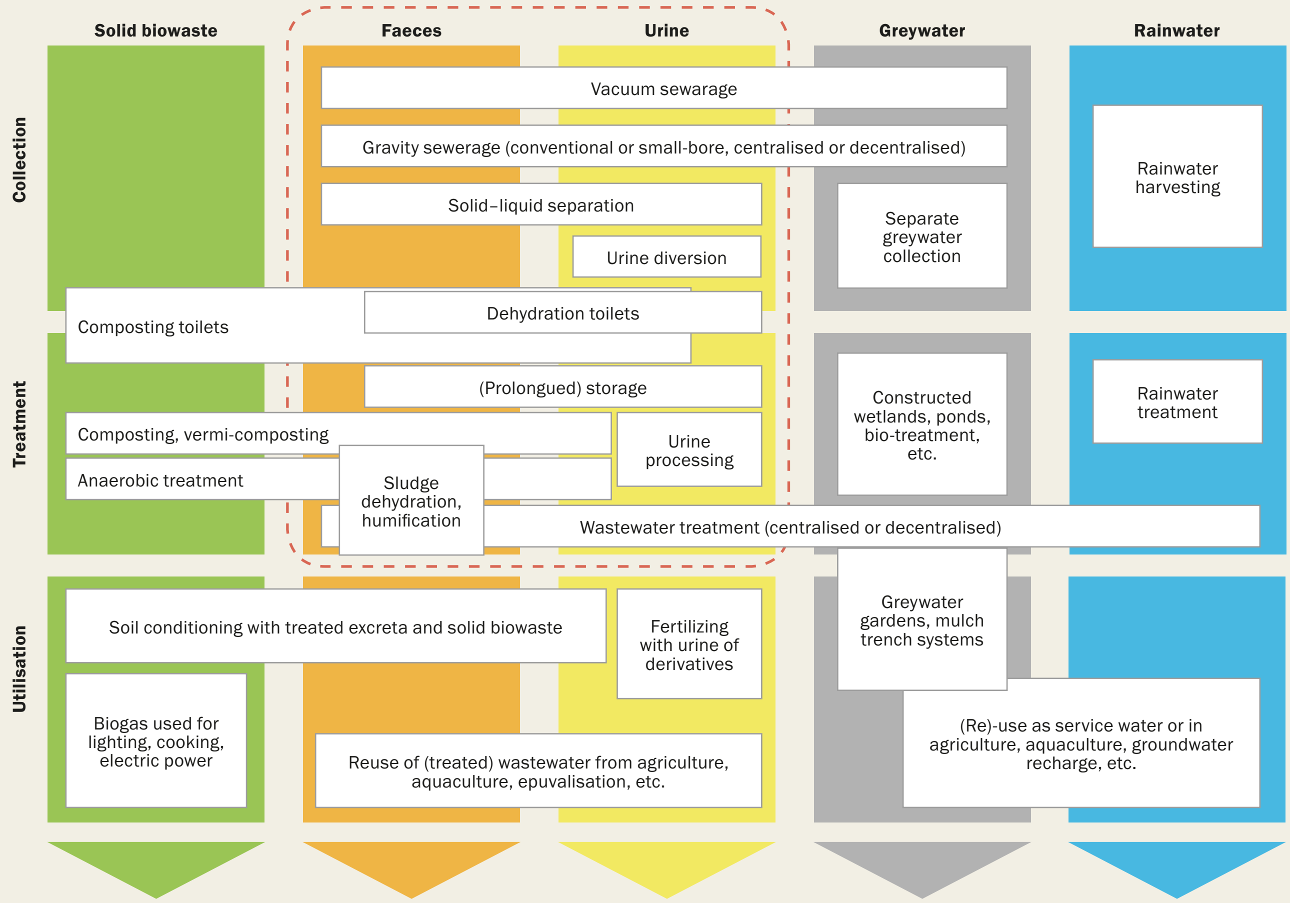
Changing the basic paradigm from linear flow streams and disposal towards a cycle-oriented management of renewable resources has the potential to deliver the kind of change, and the degree of change, that the SDGs demand.[14,15,16,17] Discussions began at the start of the millennium by Swedish and German organisations as to the importance of non-renewable resources like phosphorous and nitrogen as well as efficient use and recycling (see Fig. 3).

While the new thinking is partly in place for implementing change in solid waste management, energy, and agriculture (among many sectors spearheading the changes), the paradigm shift in sanitation is still embryonic. This lag is exposed by the fact that forward-looking engineers proposed the shift from linear to circular systems of managing water and wastewater (including excreta, and rainwater) in the 1970s.[18] Today, over 40 years later, the circular approach remains the exception.

Some progress has been made, for instance in the understanding of urban-rural sanitation value chains, or of sanitation in the circular economy, hence the idea of using wastewater and excreta in the safe production of energy, fertiliser or irrigation water is much more broadly accepted in the sector today than ten years ago. However, as such improvements need cross and inter-sectoral communication, progress is much slower than that which is necessary to reach the SDGs holistically.

However, forward-looking projects built on more holistically sustainable sanitation systems do address these concerns. In the context of German development cooperation, such projects receive an additional push from the German Federal Ministry for Economic Cooperation and

Fig 4: Essential technological components used in reuse-oriented sanitation systems



Source: adapted from reference 16: UNESCO/IHP & GTZ (2006). Capacity Building for Ecological Sanitation – Concepts for ecologically sustainable sanitation in formal and continuing education

In 2004, Florian Klingel, as advisor in the GTZ Ecosan Programme, developed an iconography to describe matter fluxes and technologies relevant to closing-the-loop sanitation approaches. The system's borders are broad and include many sectors. The SFD however, restricts its focus to the area outlined in red above

Development (BMZ)'s water strategy, endorsed in 2017. The strategy places water sector activities in the context of the BMZ's overall contribution to implementing the 2030 Agenda, the Paris Agreement and other global agreements such as those on human rights. Beyond calling for holistic management of water and related resources, key interfaces and areas of activity involving adjacent sectors are, or will be described in separate strategy documents. These links between sectors typically occur in the following SDG constellations:

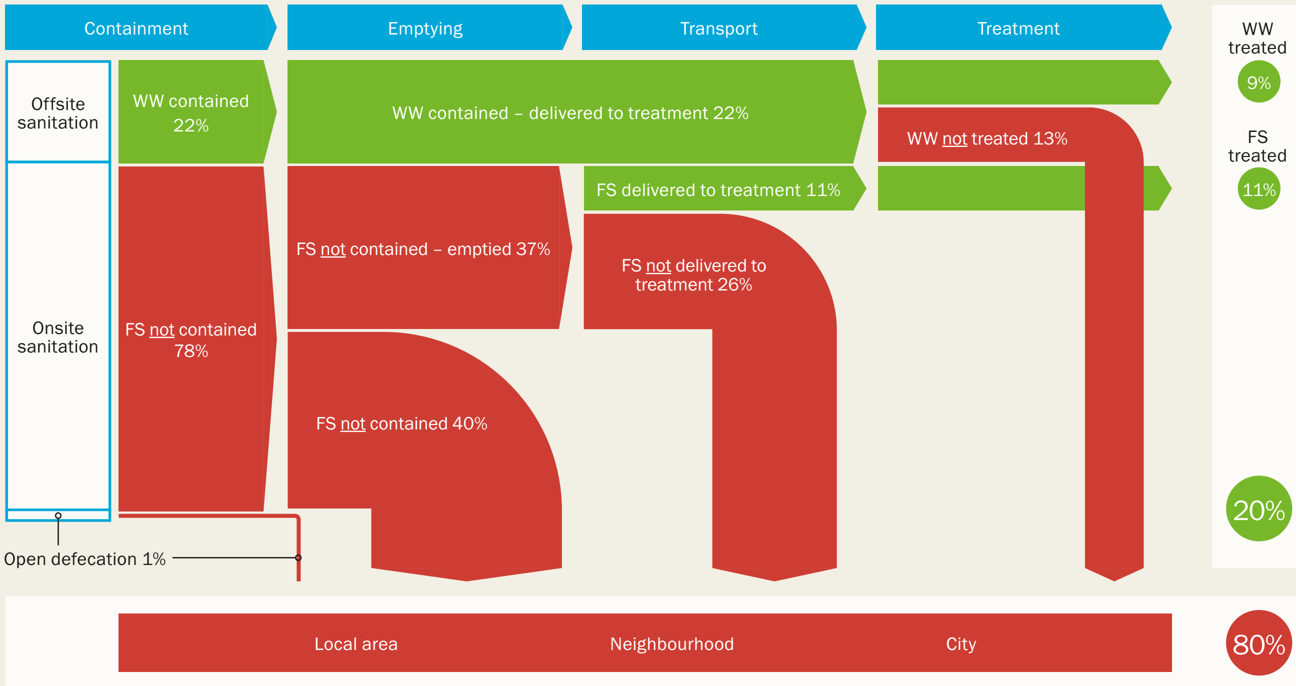
- Water education, health, and food and nutrition
- Water, sustainable economic development
- Employment and vocational training
- Water, agriculture and energy
- Water, environment and climate change
- Water, good governance, urban development
- Water, population growth and migration.[19]

Case history 1: Nashik, India

The city of Nashik is outstanding in its endeavour to become an exemplar of sustainability through liquid and solid waste management over a range of projects. Nashik ranked 42nd out of 423 Indian cities when evaluated in a sanitation ranking exercise carried out under the mandate of the National Urban Sanitation Policy, through the Ministry of Urban Development, government of India.

As a further development, one of the innovative projects undertaken by Nashik is the Waste to Energy programme, implemented with the support of Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) as an activity under German development cooperation. The project involves combining the waste streams of organic kitchen waste and septage from public and community toilets and converting it into electrical energy through co-fermentation. The sources of waste are ring-fenced, owing to a bylaw which dictates that the city takes ownership of the waste from hotel kitchens. A two barrier system of septage pasteurisation and biomethanisation enables the operator to use the residue for soil enhancement at agricultural sites. Field trials are currently ongoing in the Dhule district to the South of Nashik. With this approach, complete reuse of input waste is maintained, and nutrients as well as organic carbon are recirculated. The operation is completely financed through the business model, with an estimated 15–30% of the capital investment to be refinanced.[20]

Fig 5: SFD from Kochi, India



Source: SFD Promotion Initiative

Among others, the graphic shows that 22% of the population is directly connected to (offsite) sewer systems, and 78% relies on onsite sanitation systems. Overall, the excreta of only 20% of the population is managed safely and 80% of excreta is discharged into the environment untreated[21]

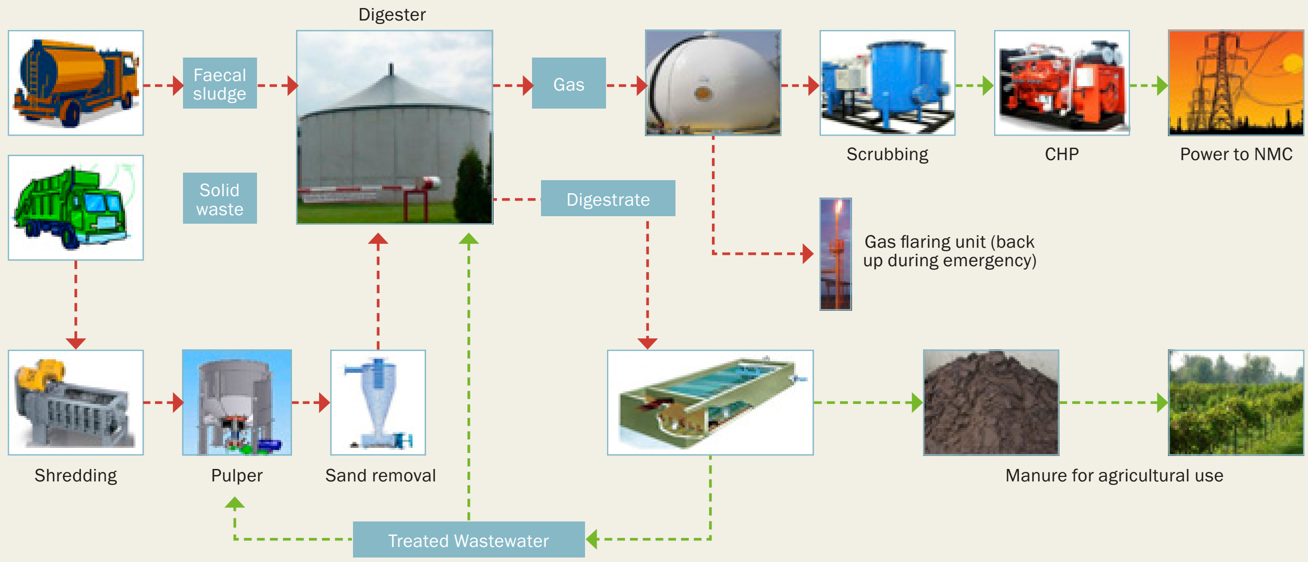
Fig 6: Action areas identified by the City Sanitation Plan for Nashik, India

1 Open defecation / urination
2 Solid waste not segregated at source
3 Pollution at the Godavari River due to open drains
4 Treated wastewater neither used nor recycled
5 Possibility of ground water pollution due to septic tanks

Source: GIZ Support to National Urban Sanitation Policy

A city sanitation plan is preceded by an assessment of the sanitary conditions in the city. The plan then addresses the current concerns and plans for future sanitary requirements through a participatory and holistic approach. The Nashik city sanitation plan was developed by the city with support from GIZ (Deutsche Gesellschaft fuer Internationale Zusammenarbeit GmbH) with funds from the German Ministry for Economic Cooperation and Development. The city's Waste to Energy programme now works in the direction suggested by the plan [see 20,22]

Fig. 7: Iconography used in describing the Waste to Energy project in Nashik, India



Source: GIZ Factsheet http://www.urbansanitation.org/e31169/e58117/

Broader conversations on matter flux, as viewed across system borders, has been put into practice due to the Waste to Energy illustration

Image: GIZ

Vehicle transporting organic solid waste and faecal sludge to the biogas plant that forms a central component of the Nashik Waste to Energy project

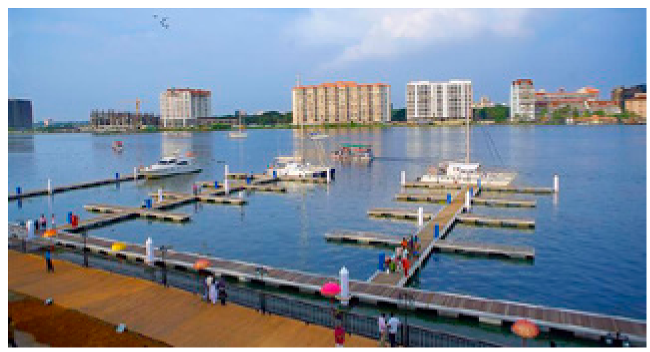
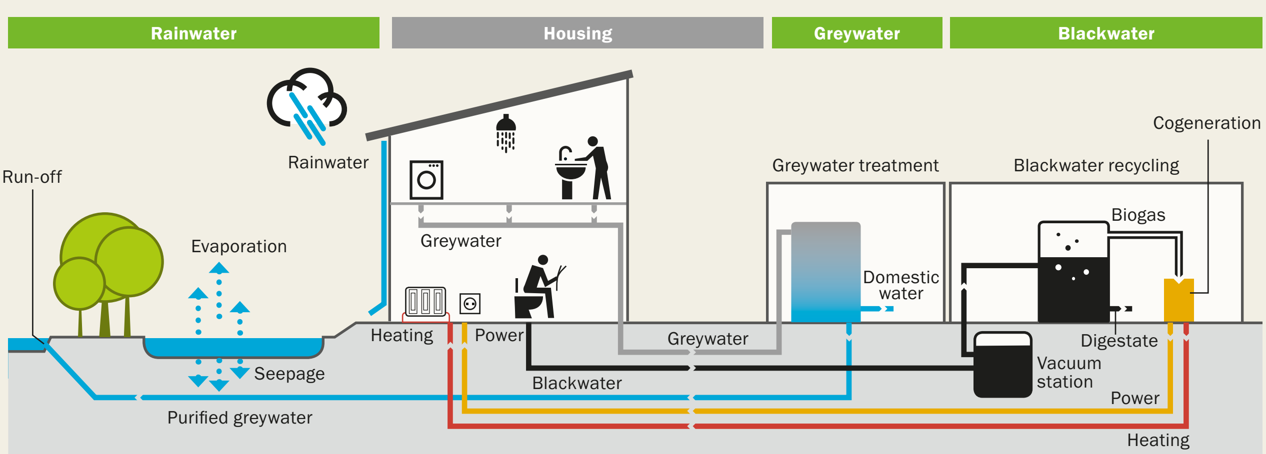


Image: SFD Promotion Initiative

The Hamburg Water Cycle addresses the future needs of a city by being reuse oriented and resource efficient – an inspiration for the development of a sustainable sanitation concept for the city of Cochin, India (Beerman, 2017)[23]

Fig. 8: The Hamburg Water cycle addresses several streams



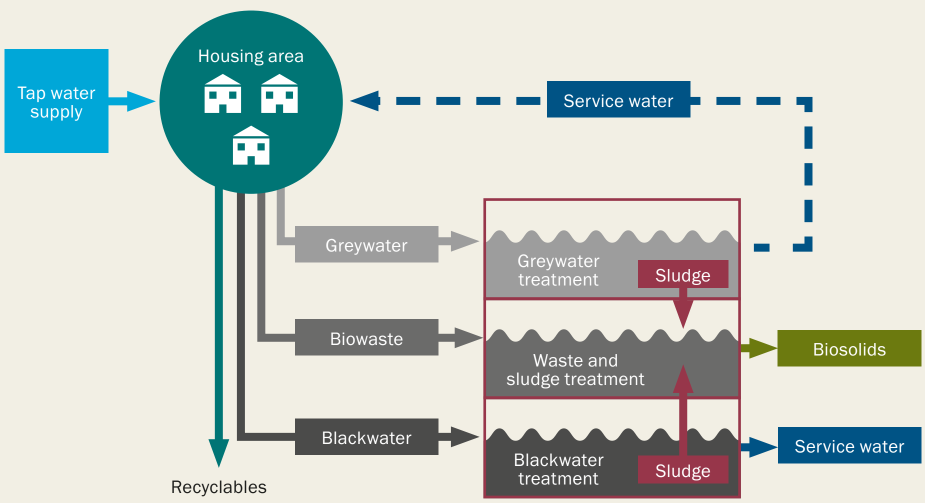
Source: Hamburg Wasser

Water from vacuum toilets is treated together with organic waste, for instance organic oil from restaurants, to produce biogas and fertiliser. Greywater is treated separately and used for urban greening and to improve the quality of recreational areas. A range of urban agencies need to cooperate to make this innovation possible, including the urban utility for wastewater, the city's stakeholder responsible for organic waste, urban planners and the urban department of the environment

Image: Arne Panesar

Members of the Hamburg administration and water utility discussing the Hamburg WaterCycle in front of a model of the newly designed Jenfelder Au quarter

Figure 9: The Semizentral approach addresses water, energy and waste flows



Source: Semizentral Germany, www.semizentral.de

Water from households is treated in a nearby facility, producing service water used for toilet flushing plus additional service water for case-adapted needs such as street cleaning, fire fighting, groundwater recharge, industrial use and others, thereby recycling up to 100%. The resulting sewage sludge is treated anaerobically together with biowaste from households within the same facility, reducing transport needs and producing the energy required for all treatment purposes within the facility. The waste heat produced can be used for heating houses. The remaining digestant can be used as biosolids for urban greening or for agriculture. A range of urban agencies must cooperate to make this innovation possible, including the urban utility for wastewater, the stakeholder responsible for organic waste in the city, urban planners and the urban department for the environment.

Case history 2: The Hamburg Water Cycle

The innovative Hamburg Water Cycle® is an example of closed-loop wastewater management, demonstrating how wastewater can be handled in an economically and environmentally responsible way by unlocking synergies between sustainable sanitation, energy and resource efficiency. The key elements are the separate handling of household water flows and utilising their energy content locally. Europe's largest project showcasing the benefits of closed loop waste water management is the newly designed Jenfelder Au quarter, a residential area in Hamburg which has provided homes for approximately 800 families. In its use of toilets as the starting point for renewable energy, the project is seen by the local government as a forward looking form of sanitation, that addresses the future needs of the city by being reuse oriented and resource efficient.

While still in its implementation phase in Hamburg, the Hamburg Water Cycle[24] has already positively influenced other cities.[23] For example Cochin, India, where a concept is being discussed that would follow the same principles. Here, septic tanks would collect only toilet water which would be transported to specific stations for the management of organic material from different streams, while greywater would be kept separate and treated in decentral facilities with options for local reuse, for instance in improving the urban environment.

The first implementation of the Semizentral approach has been in operation since 2014 in Qingdao, China. The central infrastructure element is the Resource Recovery Center

Case history 3: The Semizentral approach

Semizentral is an alternative infrastructure approach that addresses the challenges of fast-growing urban areas. Key elements of Semizentral are system size, ranging between central and decentral; a district-wise realisation; and high resource efficiency, with the infrastructure of the water, wastewater, biowaste, and energy sectors integrated into one system.[24,25] Treated and disinfected wastewater is used for purposes that do not require drinking water quality, for instance toilet flushing or irrigation. Also, the energy potential of wastewater and solid waste is exploited – biogas from co-digestion of sewage sludge and biowaste is used for heat and electricity production. Semizentral is therefore a far more resource-efficient system compared to conventional, centralised systems (see Fig. 9). The innovative infrastructure approach, developed at Institute IWAR of TU Darmstadt, Germany in cooperation with various research and industry partners from Germany and China such as Tongji University, Shanghai, won the GreenTec Award 2015 given for outstanding achievements towards sustainability in urban infrastructure development. The above picture shows the Resource Recovery Center realised in Qingdao, Shandong, China

Iconography as a valuable tool in achieving the SDGs

As discussed above, many of the SDGs will not be realised without achieving SDG 6 through sustainable sanitation. But sustainable sanitation can be achieved only when addressing SDGs other than SDG 6. Therefore, the German Water Strategy spearheads both approaches, describing needs and guidelines for the sanitation and water sector, and linking the sector to a range of other sectors, and hence other SDGs.

Especially crucial in making holistic sanitation systems commercially viable is the consideration of matter fluxes of organic material, as well as related energy and fertiliser content beyond sanitation-related materials. A sound approach is to first ask which product has the highest market value in a given context, then to plan all sanitation system components such that it becomes easy as well as time-, resource- and cost-efficient to produce that product from organic waste streams including excreta. This calls for a type of urban planning that is rarely seen – an integrated urban masterplan for water, organic waste (including excreta and faecal sludge), energy management (for instance, using biogas produced from waste), and food production.

The German Water Strategy has been developed alongside working papers that clearly address the links between sectors and describe related needs and opportunities.[27] This article stresses the idea that communication between a large range of sectors will be made simpler by using iconography that allows for cross-sectoral communication.

Access to adequate and equitable sanitation and hygiene for all

Dr. Mohammad Akramul Islam, Director, Communicable Diseases, Water, Sanitation and Hygiene (WASH), Disaster Management and Climate Change (DMCC), BRAC

By helping over 41 million people to gain access to hygienic latrines and 2.3 million people gain access to safe water across 250 sub-districts, BRAC's Water, Sanitation and Hygiene (WASH) programme has made an outstanding contribution to continuing efforts to improve sanitation and hygiene in rural Bangladesh for the past decade. BRAC WASH has also helped to bring about a social transformation in the rural areas under its mandate, with significant progress on sanitation particularly for the poorest families. Success has been achieved over a nine year period not only in the provision of hygienic household latrines, but in their use by all members of the family, as well as in good hygiene practices such as handwashing.

To increase access to safe water, BRAC has established water safety plans, installed deep tube wells, tested water quality and provided loans for tube well platform construction which protects water sources from contamination. Arsenic and saline-prone areas are prioritised where alternative water technologies, such as arsenic removal filters, iron removal plants, pond sand filters and piped water supply systems are implemented in schools and communities.

BRAC also provides technical assistance to those who can afford and are willing to construct latrines, ensuring proper design and site selection. Loans are provided to those who cannot afford to pay the full cost of hygienic latrines. Two-pit latrine construction materials, including superstructures and mini water tanks, are offered to ultra poor families free of cost.

BRAC has used its experience from previous large scale programmes to analyse what it understood to be underlying obstacles to progress in the WASH sector. This includes a lack of community participation in decision-making on WASH services; insufficient attention paid to people's behaviours; lack of financial means for the poorest; lack of institutional recognition of the need to address and transform existing gender inequality and power relations; and a lack of active involvement of women in planning, implementing, and managing water and sanitation facilities.

In most BRAC WASH programme areas, critical mass has been achieved and open defecation has become a social taboo. The significant role played by women has changed communities. When the programme began in 2006, it was highly uncommon for men and women in a rural setting to convene and make decisions together. Now, village WASH committees (VWCs) have a balanced gender membership with an active core of women who are accustomed to speaking out and playing a full role in community decisions.

In 2007, BRAC adopted a policy to help realise gender equality in its programmes and organisation. The goals are to serve the needs of women and men and help eliminate all forms of discrimination against women. In the same year, BRAC developed its operational guidelines on addressing gender and equity in WASH.

A gender-inclusive approach to WASH implementation is based on the understanding that, for it to succeed, everyone in a community must play a positive role. Women play a critical role in household decisions on water, sanitation and

Image: BRAC WASH

Image: BRAC WASH

Schoolboys' and girls' latrines constructed with technical assistance and advice on proper design and site selection from the BRAC WASH programme

Double headed tubewell, an innovative transformation of a traditional deep tubewell by BRAC WASH in water-scarce areas of Bangladesh

hygiene but often lose out on wider decision-making, especially relating to finances which are most often controlled by the men of the household. Moreover, men are usually not as concerned about WASH-related issues as women. An approach is therefore needed to convince men that WASH is an issue for them too.

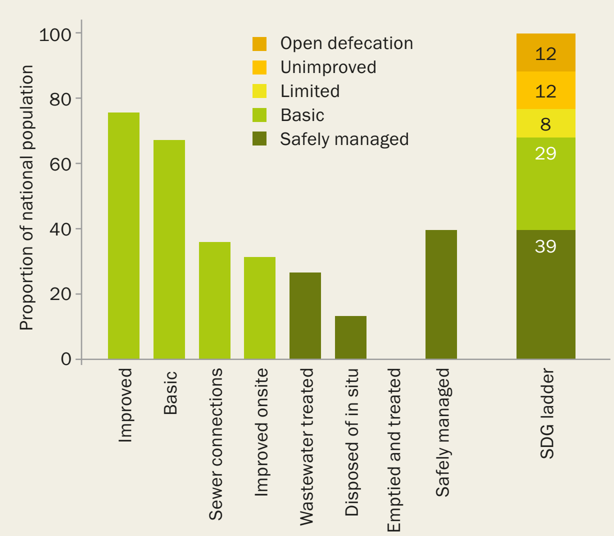
BRAC WASH places the inclusion and participation of women at the centre of its decision-making processes. The community is strongly encouraged to support women's opinions and concerns regarding the locations for latrines and water points and take them into consideration.

Separate hygiene promotion sessions are carried out in the community for men, women, adolescent boys, adolescent girls and children. Moreover, WASH messages are tailored and customised for these groups. Awareness of proper menstrual hygiene management is raised among women and adolescent girls, both in the community and at schools. BRAC's sanitary napkin production centre (one of its social enterprises) has been supplying affordable, biodegradable napkins since 1999, to meet the public health needs of poor women and girls in rural areas. BRAC's health volunteers (shasthya shebikas) sell these sanitary napkins door to door, and also supply them to school teachers so that students can buy them at a minimum cost (approximately BDT5 or US$0.06 per item) while at school.

Among the BRAC WASH-supported schools, 91% of those in areas with eight years of intervention and 100% of those in areas with three years of intervention had separate latrines for girls provided by BRAC WASH (on a cost-sharing basis with the school authority). With regard to the availability of menstrual hygiene management facilities at these schools, even though a good proportion of schools have disposal facilities, progress still needs to be made.

The programme began to recognise that a gender-inclusive approach should not suggest only women's inclusion and empowerment, but that men should be included too. For this reason, action research on an effective method for

WASH world survey



Source: https://washdata.org/monitoring/sanitation

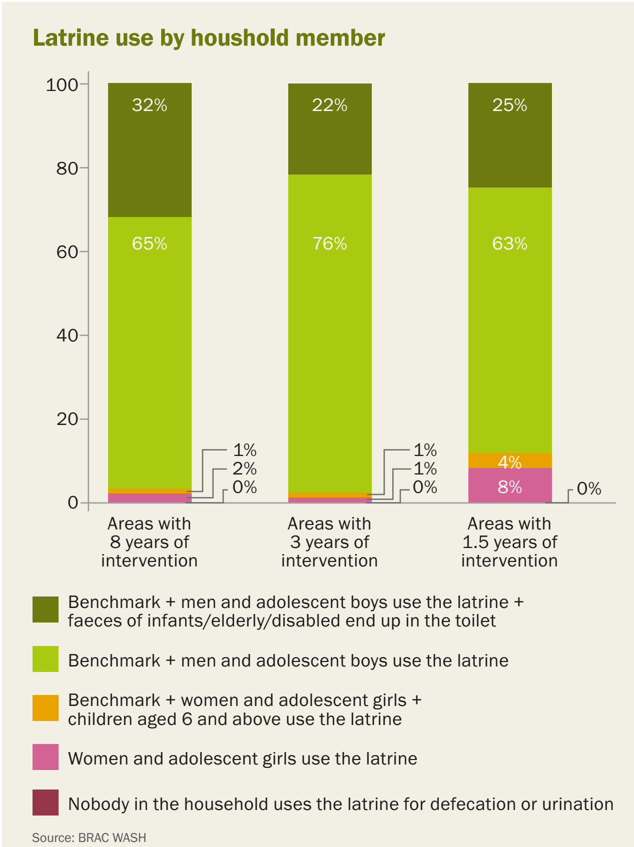


Image: BRAC WASH

Piped water supply system

hygiene promotion for men was conducted, after which 'tea stall meetings' for men were initiated with great success.

To create an enabling environment and ensure sustainability, BRAC WASH helped build capacity with targeted community members, including sanitation entrepreneurs, members of the local government and local elites. Even though women do not constitute a large proportion of these groups, BRAC WASH was as inclusive as possible. Continued empowerment of women is still needed, for example, a more insistent encouragement of female entrepreneurs.

The VWCs, on the other hand, have exemplified the improvement of gender relations and the degree to which women can be empowered. Each committee is made up of eleven members – six women and five men – and has the mandate to assess the water and sanitation conditions of the village and identify issues. One man and one woman from each committee is given leadership training. The VWC is also responsible for identifying poor and ultra poor households that need financial support.

A more detailed look at women's participation shows very encouraging results, with a large proportion of VWCs having female members who speak out and participate in decision-making. The success of the VWC indicates positive social progress in a relatively short time span.

Image: BRAC WASH

Pond sand filter

Image: BRAC WASH

Iron removal plant at a school

Image: BRAC WASH

Hand washing station in school

Image: BRAC WASH

The use of latrines has become routine under the WASH programme

At a time when the Millennium Development Goals were concerned with halving the proportion of people without access to safe water and basic sanitation, and the wider WASH sector mainly prioritising the end to open defecation, BRAC was thinking not just in terms of sustainable service provision, but also taking gender and socio-economic equity, power dynamics, and community participation into consideration. BRAC also made the bold move of investing heavily in hygiene, at a time when that was not a global priority.

Now, during the era of the Sustainable Development Goals (SDGs), all of the above are explicitly stated in the indicators of Goal 6. This provides BRAC with a strong platform to further improve and adapt its approaches to help contribute towards achieving universal access.

In terms of monitoring for SGD 6, the WHO/UNICEF Joint Monitoring Programme is now using service ladders and benchmarks. From its inception, monitoring was considered one of the fundamental elements of the BRAC WASH programme and, as such, played a crucial role in the continuous improvement of the programme. New additions and adaptations were made following the monitoring results.

During the early years, inputs and outputs were measured thorough a Management Information System (MIS). Then an independent quality control unit was established within the programme to ensure accountability and transparency at field level. Beside these, BRAC's monitoring department independently monitored the programme and BRAC's research and evaluation division carried out independent studies including baseline, midline and endline surveys. But there was a need for measuring the quality of services provided by the programme and outcome data, such as changes in the behaviour of the individuals or households; how well and when latrines are used; whether all household members are using it; how well VWCs continue to perform; and to what extent women are integrated in planning and management. Considering that need, the Qualitative Information System (QIS) was introduced to the programme in 2012, developed jointly by BRAC WASH and its long time knowledge partner, IRC.


Image: BRAC WASH

Education session on menstrual hygiene management for adolescent girls

This method quantifies qualitative process and outcome indicators, such as participation and inclusiveness (process) and behavioural changes (outcomes), with the help of progressive scales (ladders). Each step on the ladder has a short description, called a mini-scenario, which describes the situation for a particular score. An example of monitoring with these progressive ladders is shown in the diagram, demonstrating how BRAC had been ahead of its time both in service delivery and outcome monitoring.

From 2016, due to the changing pattern of funding and higher demand for services, BRAC WASH has been scaling up efforts in developing a social enterprise model for providing WASH services to rural (hard to reach) areas as well as to municipalities.

Currently, BRAC is making an effort to address water, sanitation and hygiene as cross-cutting issues across all fields of development. Since January 2017, BRAC has launched a new project where the WASH programme works towards integrating basic water, sanitation and hygiene services into its various other developing programmes including health, education, microfinance, and targeting the ultra poor. This is a step towards the long-term sustainability of services and addressing WASH as an issue for everyone.


Image: BRAC WASH

Good hand washing practice has become a household routine under the WASH programme

Water – a shared responsibility

Ambassador Gil Haskel, Head of MASHAV, Israel's Agency for International Development Cooperation

Much effort has been devoted to identifying a predominant factor for achieving sustainable development. In this context, water is the single most important component of human development. A thirsty child cannot study properly regardless of the quality of his school. A thirsty mother cannot care properly for her children regardless of the quality of the clinics that are built around her. A thirsty cow cannot produce sufficient milk and a thirsty farmer will use his water to quench his children's thirst and not to irrigate his crops. Where there is water, all other development factors follow.

One of the major challenges facing mankind today is undoubtedly water scarcity and water insecurity. Water serves as the critical link between adaptation to climate change, people and the environment, taking into consideration issues such as availability, proximity, quantity and quality, thus becoming a key factor to attaining food security and poverty reduction, and acting as a building block of socio-economic growth and for creating healthy ecosystems for all life on earth.

This multidimensional challenge requires taking into consideration not only access to fresh drinking water and

Image: MASHAV

Improving sustainable livelihoods of communities in arid and semi-arid lands through the introduction of adaptable Israeli water saving and modern irrigation technologies


Image: MASHAV

MASHAV conducts specialized training courses in Israel in water management related fields, combining theoretical knowledge and research with hands-on experience. For this purpose, MASHAV established a demonstration plot at its Agricultural Training Center in Israel, showcasing advanced irrigation methods and technologies originating from leading Israeli experts and institutions, for the benefit of participants from all over the world

basic sanitation services, but also an efficient use of water resources. The promotion and implementation of an integrated water management approach is, therefore, an essential element for facing challenges ranging widely from shortage in water supply for domestic and agricultural uses to dealing with global issues such as soil erosion and desertification.

To meet these intrinsic needs, the 2030 Sustainable Development Agenda sets in Goal 6 new guidelines aimed at attaining food security through sustainable water management by, among others, expanding international cooperation and capacity-building support to developing countries in related fields.

For Israel, water has always represented a chronic problem due to its semi-arid and arid climates and frequent drought years. The very first national projects of the young state, established in 1948, were ones dealing with water distribution. The need to deal with climatic uncertainty and growing water scarcity while continuing to meet the water needs of all sectors, required a new perspective based on the development of innovative water production and treatment technologies and advanced management tools, as well as the development of an inter-disciplinary approach incorporating water policy, national-level water resource development and management, large and small-scale technologies for water-saving and efficient use and appropriate water solutions for the development of the agricultural, urban and industrial sectors.

Moreover, pressure on Israel's water resources has challenged its aquifers, both in their quantity and quality. In order to maintain intensive agricultural production under these harsh conditions there has been a constant drive to increase water use efficiency, to use new resources, and to develop new techniques and methodologies that enable the practice of sustainable agriculture.

Concurrently with promoting research and development of cutting-edge water technologies, the State of Israel is keen to share its unique experience in overcoming obstacles with developing countries worldwide, through MASHAV, Israel's Agency for International Development Cooperation.

As one of the oldest international development cooperation agencies in the world, MASHAV has, since 1958, been conducting training and capacity-building programmes in Israel and abroad, combining the transfer of technology, research and development and hands-on experience with hi-tech technologies originating from leading Israeli experts and institutions.

The knowledge, proven know-how, experience, expertise and technologies accumulated in Israel in dealing with the scarcity of natural resources, particularly water and arable land, are shared by MASHAV for the benefit of peoples all over the developing world with the goal of inspiring fellow nations in their struggle with development challenges. To date, close to 300,000 trainees worldwide, have benefited from MASHAV training in a wide variety of development topics, many of which are related to water and food security.

Israel and Kenya: joining hands to fight water scarcity

The present drought striking Kenya, which is affecting large parts of the country and was recently declared a national disaster, has had a major impact on water resources, including on river flow levels and the availability of water for human and livestock consumption. Most water points in the worst affected areas are in near-dry status, while water supply for irrigated crop production has been reduced as the drought extended over key river basins.

As part of the efforts in dealing with this severe situation affecting millions of people, Israel and Kenya's heads of state signed, in 2016, the Jerusalem Declaration for cooperation in the areas of water and irrigation. Noting that water scarcity poses a challenge to both countries, the declaration acknowledged that Kenya could benefit from Israel's expertise in water resources management, as well as Israeli water and irrigation technologies and proven solutions.

Within this context, in March 2017, both countries announced the official establishment of KIDRAC, The Kenya-Israel Drought Resilient Agriculture Training Center, a joint cooperation venture between MASHAV and Kenya's Ministry of Water and Irrigation.

The Center will be set up at Mwea Irrigation Agricultural Center under Kenya's National Irrigation Board, and will serve as a hub for capacity-building activities and the transfer of know-how addressing all of the issues connected to efficient water management. The overall goal is to train a cadre of professionals from Kenya and the entire east African region to enhance drought resilience and improve sustainable livelihoods of the communities in arid and semi-arid lands.

In its report on "The State of the World's Land and Water Resources for Food and Agriculture," the FAO states that "the challenge of providing sufficient food for an ever-hungrier planet has never been greater, especially in developing countries, where quality land, soil nutrients and water are least abundant." The report recommends "a combination of improved irrigation schemes management, investment in local knowledge and modern technology, knowledge development and training."

This is both our vision and our commitment: To share with others our knowledge and experience and contribute to the prosperity and well-being of all populations facing severe challenges, enhancing the importance of placing people at the heart of development with the hope that, in the words of the Prophet Isaiah, "...the scorched land will become a pool, and the thirsty ground springs of water."

Image: MASHAV

The demonstration plot at MASHAV's Agricultural Training Center in Israel, created for the benefit of participants from all over the world

Accelerating towards universal access to clean water and sanitation – WaterCredit and beyond

Ann Marie Castleman, Heather Arney, Sambhu Rathi and Zehra Shabbir, Water.org

Addressing the world's water and sanitation needs is one of the great human development challenges of our time. While we have known how to deliver safe water and sanitation (WSS) for more than 100 years, today there are still more than 2.3 billion people that lack access to basic sanitation services[1].

It is well understood that safe drinking water and hygienic toilets protect people from disease, enable societies to be productive, and are fundamental to the well-being and safety of a household. WSS advocates argue that progress on the Sustainable Development Goal 6 (SDG 6) – universal and equitable access to safe and affordable drinking water and sanitation for all – is a requirement to achieve other SDG goals, including elimination of poverty and gender equality.

The sums of money needed to achieve SDG 6 are undoubtedly large, and reliance on government and donor financing alone limit the pace at which the required investments can be made. The latest World Bank estimates indicate that achieving universal access to safely managed water and sanitation would cost approximately US$114 billion per year for capital expenditure – an amount that is three times the current investment levels[2].

These realities have inspired Water.org to think of system change, particularly through finance that is as close to the poor as possible. Through its WaterCredit approach (see Figure 1), Water.org works with microfinance providers to create, pilot, and scale affordable WSS financing solutions for the poor. In the case of early adopters, Water.org also provided a grant while the case for WSS lending was being built in the region. This grant helped partners build their technical capacity. These partners then leverage funding from banks and capital markets to disburse loans to their clients, who in turn use the financed amount to build their own WSS improvement.

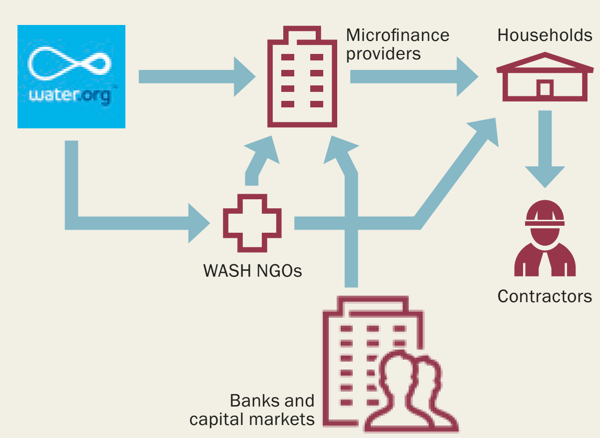
The upfront cost of a toilet or a piped water connection can easily equal a household's entire monthly income, but many are willing to purchase one if they can spread the cost over time. The recycling of affordable WSS capital to the base of the pyramid can help achieve the ambitious goal of SDG 6 by making capital affordable for the poor.

WaterCredit: reach and impact[3]

WaterCredit-led WSS lending has effectively leveraged funding for great impact and has helped to meet ambitious national and global targets, including SDG 6. WaterCredit interventions have disbursed more than 1.6 million loans for WSS improvements, totalling over US$463 million and have positively impacted more than 7.1 million people. The cost per person to deliver water and sanitation solutions has continued to drop with an increase in loan disbursement over time, indicating increasing efficiency of WaterCredit programs (Figure 2).

The success of WaterCredit has demonstrated that the poor are viable customers who are willing to take up loans

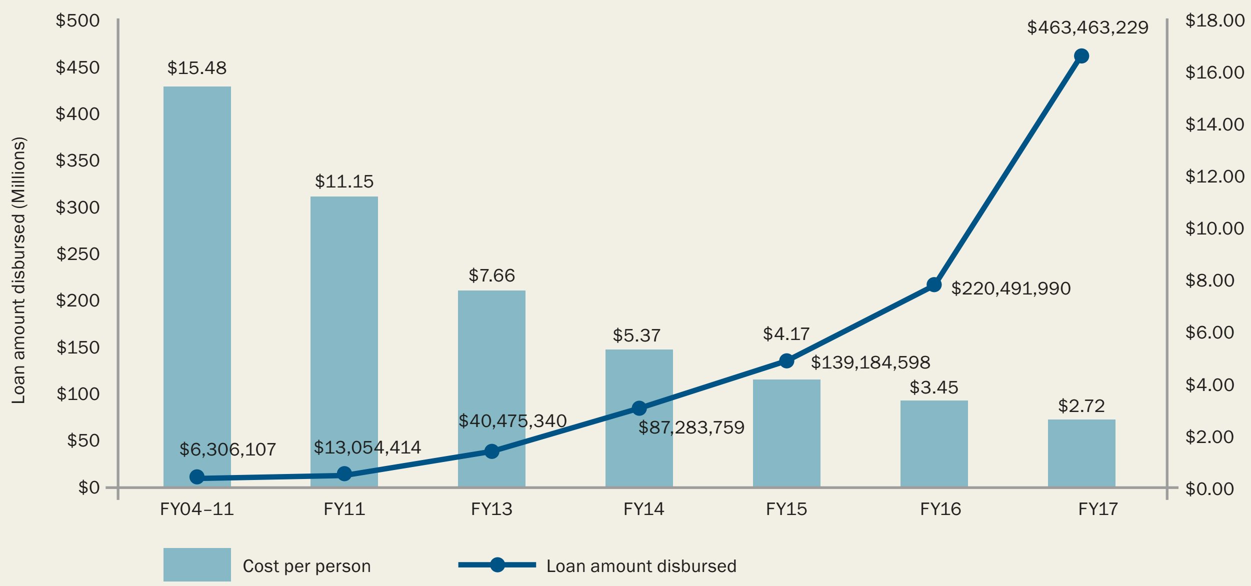
Fig 1: WaterCredit model



Source: Water.org

Image: Water.org

Fig 2: Cumulative cost per person under the WaterCredit program, as of August 2017



Source: Water.org

to improve their water and sanitation infrastructure and are able to repay these loans. A majority of WaterCredit borrowers (55%) are living on under US$1.90 per day. Only less than 1% of very poor water and sanitation loan recipients were delinquent over 30 days. Not only do these clients belong to poor households, a key aspect is that over 90% of these loans are borrowed by women. Table 1 shows the key characteristics of loan portfolios across major countries where loans were disbursed under the WaterCredit program.

Apart from direct benefits in terms of improved water and sanitation facilities, household investments in access to water and sanitation have shown to produce significant returns, including socio-economic and health impacts. In a recent evaluation in India, around 25% of WaterCredit borrowers reported reduced illness and one in five reported reduced medical expenses. Previous studies have shown that reducing illness improves children's school attendance and lifetime earning potential. Access to improved water and sanitation also reduces the incidence of chronic diarrhoea, which correlates to improved cognitive function and reduced risk of impaired growth. Research suggests that impaired growth decreases the likelihood that children will lead healthy, economically productive lives.

Access to improved on-site water and sanitation brings dignity, safety, and privacy to the family, especially for women, children, and the elderly. External evaluations of WaterCredit interventions show that women with a toilet in the home are safer and have more privacy than those who must find isolated locations far from the home to defecate. Around 39% of sanitation loan recipients reported increased safety, after acquiring a toilet at home[4].

A large percentage of households with improved access to water and sanitation have experienced increased household income. Before taking a loan, only 53% of WaterCredit borrowers in India made at least US$47 per month; after the loan, this proportion nearly doubled to 97%, suggesting that the investment in water and/or sanitation may have contributed to households' abilities to generate income. According to the WaterCredit impact evaluations, nearly 25% of borrowers attributed increased income to extra time for women, regained from minimised water collection times. Similarly, one in five attributed increased income as a result of increase in overall productivity due to fewer negative health impacts from water or sanitation[4].

Lessons and challenges

A joint World Bank and Water.org study found that microfinance is a key tool in breaking down the barriers that prevent those at the bottom of the economic pyramid from accessing improved water and sanitation[5]. In reaching more than 7.1 million people through WaterCredit, Water.org has grasped a better understanding of the factors required for increased sustainability and scalability of WaterCredit operations and has made and proven the case for WSS financing. A recent evaluation of a WaterCredit intervention in India showed that trained MFI staff and self-help groups were valuable change agents in their communities, helping to drive behaviour change and providing necessary product information[5]. The intervention's success in the notoriously challenging state of Odisha also demonstrates that there can be a healthy demand for WSS microfinance, even in areas that are deemed to have less favourable microfinance environments[6].

To address sustainability and scalability, a recent case study[7] outlined the major enablers and constraints identified in WaterCredit partners in India. Among the factors, access to loan capital was identified as a major constraint by half of the India WaterCredit partners in the study, largely due to reluctance among commercial banks to finance WSS portfolios. However, the inclusion of WSS in the Reserve Bank of India's Priority Sector Lending in April 2015 has enabled more capital to be unleashed towards WSS portfolios. By reaching more than half a million households in just four years with a unit cost significantly lower than traditional WSS programs, WaterCredit in India demonstrates that microfinance can significantly amplify the reach and impact of investments in the WSS sector.

On a global level, multilateral stakeholders like the World Bank stress the role of blended finance – the strategic use of development finance and philanthropic funds to mobilise private capital flows to emerging and frontier markets[8] – in achieving SDG 6. It has been touted as an effective tool for stimulating lending interest from the commercial financial sector, helping educate commercial banks about opportunities in the financial sector as well as dispelling the perceived risks related to WSS lending[9]. This messaging aligns directly with Water.org's model and helps propel the importance of finance-driven solutions for the WSS challenge.

Beyond WaterCredit

Evidence from Water.org's programs demonstrate that a viable market can be made for financing water and sanitation improvements. However, WaterCredit alone cannot make up for the gap in financing that is needed to achieve SDG 6. To expand and accelerate impact, Water.org has been developing and testing new innovations on the central theme of financing for water and sanitation. These new approaches include working with utility companies, the supply chain, and impact investing to increase both the amount of financing mobilised

Image: Water.org

Table 1: Key characteristics of loans disbursed under the WaterCredit program as of August 2017

	Bangladesh	India	Cambodia	Indonesia	Philippines
Number of WaterCredit loans	79,386	1,101,725	16,618	34,682	222,505
People reached	423,485	4,570,982	55,373	142,684	962,005
Women borrowers (%)	98	97	85	86	99
Loan amounts disbursed (US$)	20,181,906	220,640,074	7,368,529	8,264,689	47,952,863
Water.org grants to partners (US$)	2,644,573	11,012,189	436,940	1,315,857	673,536
US$ leveraged ratio	7.63	20.04	16.86	6.28	71.2
Cost per person (US$) – partner grant cost only	6.24	2.41	7.89	9.22	0.70
Average loan size (US$)	254	196	443	238	216
Average repayment rate (%)	98	99	-	99	99

	Ethiopia	Ghana	Kenya	Uganda	Peru
Number of WaterCredit loans	322	149	77,326	2,740	109,203
People reached	1,977	17,121	439,010	68,653	423,177
Women borrowers (%)	43	38	55	45	47
Loan amounts disbursed (US$)	194,190	420,448	21,518,516	2,292,573	134,629,441
Water.org grants to partners (US$)	305,802	64,031	1,586,567	637,798	687,535
US$ leveraged ratio	0.64	6.57	13.56	3.59	195.81
Cost per person (US$) – partner grant cost only	154.68	3.74	3.61	9.29	1.62
Average loan size (US$)	603	2,822	278	837	1,233
Average repayment rate (%)	83	-	90	99	99

Source: Water.org

Image: Water.org

for water and sanitation as well as water and sanitation access at the base of the economic pyramid.

In Indonesia and the Philippines, Water.org is partnering with rural and municipal water utilities to enable financing for household water connections. In addition to paying in cash to connect to the utility water system, households can pay cash instalments to the utility company or take out a loan from a microfinance institution. Similarly, Water.org is working with financial partners in Kenya as well as Indonesia to facilitate loans to water utilities for infrastructure extension and service improvements to boost availability and the quality of services.

In addition to working with water utilities, Water.org is engaging the supply chain. In India, Water.org provides technical assistance and grants to scale up and expand operations for two supply chain enterprises – one social business manufactures and distributes toilet kits to rural villages, and the other provides access to clean drinking water, both using local entrepreneurs via a decentralised distribution model, among other methods.

Water.org is also pursuing scale by offering WaterCredit via groups of institutions, with technical assistance designed using the evidence generated to date.

Similarly, in India Water.org is engaging several partners to accelerate an ecosystem for WSS financing in both the public and private sectors. Partnering with UNICEF to integrate finance availability into its demand creation programs among households for water and sanitation, Water.org works closely with both commercial banks and microfinance partners to align lending where UNICEF is activating community

Image: Water.org

The leader of three joint-liabilty women's groups in Palanjogihalli, India. Her sanitation loan bought a toilet for her family and is now in repayment

demand. This includes channelling financing to remote rural areas via the India Post Payments Bank and self-help groups linked to the State Rural Livelihoods Missions, a government-managed program.

Lastly, WaterEquity, a Water.org innovation, unlocks affordable social investment capital to help microfinance institutions and other enterprises to scale their water and sanitation efforts to meet market demand. It provides a variety of financial instruments and technical assistance to microfinance institutions to help them launch loan portfolios. The loans enable the world's poor to pay for a connection to a water source or install a toilet in their homes.

With these innovations, Water.org is highlighting the fact that ending open defecation and ensuring basic access to water and safe sanitation to everyone, everywhere, by 2030 cannot be achieved without WSS financing mechanisms.

United Arab Emirates supporting the Kingdom of Morocco to address water security challenges

H.E. Reem bint Ibrahim Al Hashimy, Minister of State for International Cooperation, UAE

Located within the least water-secure region in the world, the United Arab Emirates is committed to finding solutions for tackling the global challenges in water security and management.

As one of the top ten water-scarce countries globally, water is valued as a precious resource in the UAE.[1] Recognizing the importance of sustainable water management practices, the UAE has adopted long-term strategic measures to ensure development initiatives are in line with its green growth plans. This includes implementing policies that reduce water consumption, encourage innovative water technologies, and promote conservation. As a result of the country's commitment and efforts, the UAE has a well-integrated water resource management system and is on the path towards ensuring a water-secure and sustainable future.

To help countries and local communities achieve similar outcomes, the UAE works with governments, local communities, and other partners to provide access to clean drinking water and sanitation in humanitarian and development contexts. Advocacy for SDG 6 spans the UAE Foreign Assistance Policy and Strategy that is largely supported through the Country Partnerships for Development Programme, Transport and Urban Infrastructure Programme, and Humanitarian Assistance Programme. Implementation of UAE foreign assistance programmes is carried out through a diverse network of UAE donor entities consisting of governmental and semi-governmental institutions and charitable foundations each with their own areas of focus and specialisations. Understanding that needs and development levels vary within any country, the UAE works closely with partner countries to deliver transformative initiatives that are guided by country strategies and contribute to national development priorities.

Image: MoFAIC UAE

The drying beds

Image: MoFAIC UAE

Boujdour station, National Office of Electricity and Drinking Water

Increasing access to potable water

The National Office for Electricity and Potable Water (ONEE) aims to ensure universal access to safe drinking water for all citizens, working within the integrated vision of the National Water Strategy to achieve three key objectives:

- To maintain the progress made in water management through the maintenance and rehabilitation of existing infrastructure
- To mainstream access to water under the banner "Right to Water" and focus on accelerating the supply of potable water, particularly in rural areas
- To improve citizens' health through protecting resources for the purification of potable water.

With the UAE grants administered by ADFD, the projects have supported ONEE in upgrading and building new infrastructure to increase potable water supply in three locations.

Dakhla City is built on a narrow peninsula located along the Atlantic coast in the arid Western Sahara region. US$15.3 million was provided to increase the supply of potable water to the city. The funds will be used to build a new desalination plant, as well as a new treatment plant to purify water from underground sources. New water storage tanks are also being built inside the new station to retain fresh water that has been desalinised. Funds will also be used to upgrade and provide maintenance to the existing water processing plant. The project is expected to benefit an estimated 97,746 people.

Boujdour is another town located on the Atlantic coast in the Western Sahara region. The US$9.5 million grant will support the US$12.2 million project to improve and modernise the town's water supply networks. The funds will be used to build a desalination plant, a reservoir, four pumping stations, a water treatment plant, and a 6km transmission pipeline. The project is expected to benefit an estimated 64,245 people.

Kouribga is located inland in the Béni Mellal-Khénifra region. The US$24.3 million grant will be used to strengthen and expand the potable water supply by increasing access to the city and neighbouring areas through the construction of a pumping station, a water treatment and processing plant, and a 6km transmission pipeline. The project is expected to benefit an estimated 550,000 urban residents and 530,000 rural residents in surrounding areas.

The development arm of the UAE Government with a focus on infrastructure – the Abu Dhabi Fund for Development (ADFD) – is the main supporter of large-scale water infrastructure projects in partner countries. Since the formation of the nation in 1971, ADFD has been helping developing countries to reduce poverty and achieve sustainable socio-economic growth through the provision of financial assistance in the forms of concessional and non-concessional loans, and management of government grants and equities. As of December 2016, ADFD has financed 488 projects in 83 countries. The Fund's investments serve two main objectives: to support countries in achieving social and economic growth in key sectors, and encouraging private sector participation in accelerating economic development.

ADFD's approach to working with other countries is demand-driven and based on cultivating partnerships where the partner countries take the lead in the implementation of their development agenda. The Fund targets public sector projects and works with government institutions within the partner country to support the achievement of their development needs and priorities. Therefore, projects supported by the Fund are part of the partner country's development goals and are linked to key sectors outlined in their development plan.

While respecting the development levels and needs of each partner country, project proposals are evaluated based on the extent to which they are economically, technically, socially, and environmentally sound and will have a long-term sustainable impact. Development results are aligned to partner country-led planning mechanisms that define their approach to development, priorities, and expectations of achievement. Assistance provided by ADFD is untied, providing partner countries the freedom to procure goods and services as they see fit. To support formulating sector policies and allocation of required resources, public sector loans are subject to review and approval by parliaments of partner countries, and ratified by their legal authorities. To ensure accountability, partner countries are required to monitor projects and submit progress reports. Progress is also discussed during field missions as well as when new projects are submitted for review and approval. Evaluations are completed by a third party for selected projects and lessons are drawn and shared with relevant stakeholders.

As part of a five year grant announced in 2013, the UAE is providing US$1.25 billion to support projects proposed by the Government of Morocco in transport, health, education, energy, and water.[2] The grant is managed by ADFD, which has a long-standing relationship with the Kingdom of Morocco dating back to 1974 that is based on a common goal of achieving sustainable development across all economic sectors. Approximately US$202 million – 16% of the total grant – has been allocated to support seven key projects in the water sector across Morocco, including three desalination projects and four dam projects.

As with all countries, water is an important resource and has major implications for the socio-economic development of Morocco. The Kingdom is a water-scarce country with a semi-arid climate and is facing extreme climatic events such as drought and flooding due to climate change. Its dwindling water resources, coupled with rising demand, has led to the overuse of water resources, placing pressure on the country's aquifers. To address these challenges, under the 2010–2030 National Water Strategy, the government has planned several major initiatives to achieve an integrated water management system to secure water and ensure access

Image: MoFAIC UAE

Dakhla station, National Office of Electricity and Drinking Water

Image: MoFAIC UAE

Pumping station

Image: MoFAIC UAE

General view of the wastewater treatment plant

for all citizens. To tackle rising demand, the strategy focuses on generating additional water resources and encouraging responsible consumption. Under this vision, the plan is to build 59 dams, construct desalination plants, and increase the reuse of treated wastewater and the collection of rainwater. The government will also introduce water-saving technologies, particularly in irrigation, improve efficiency in its water networks, revise water tariffs, and encourage water recycling.[3]

Boosting water supply to households and to the agricultural sector

Agriculture production is a major driving force of Morocco's economy, making up 19% of its GDP (agriculture 15%, agro-industry 4%), and employing 4 million or 40% of the labour force.[4] However, the agriculture sector is highly dependent on rainfall with only 15% of its total agricultural land being irrigated, making it extremely vulnerable in times of low rainfall and drought.[5] To reform the agricultural sector and integrate agricultural production into international markets, a national agricultural strategy – the Green Morocco Plan – was adopted in 2008. The Plan is designed to promote the development of a sustainable, modern, and competitive agriculture sector. To reduce risks and volatility in the sector, the Government has focused on investments in irrigation and the improvement of water management.[6] Several initiatives have been introduced under the Plan, which is also integrated into the National Water Strategy, such as the construction of dams, connecting the dams with irrigation schemes to improve water supply, the introduction of water-saving irrigation techniques, and the conservation of groundwater.

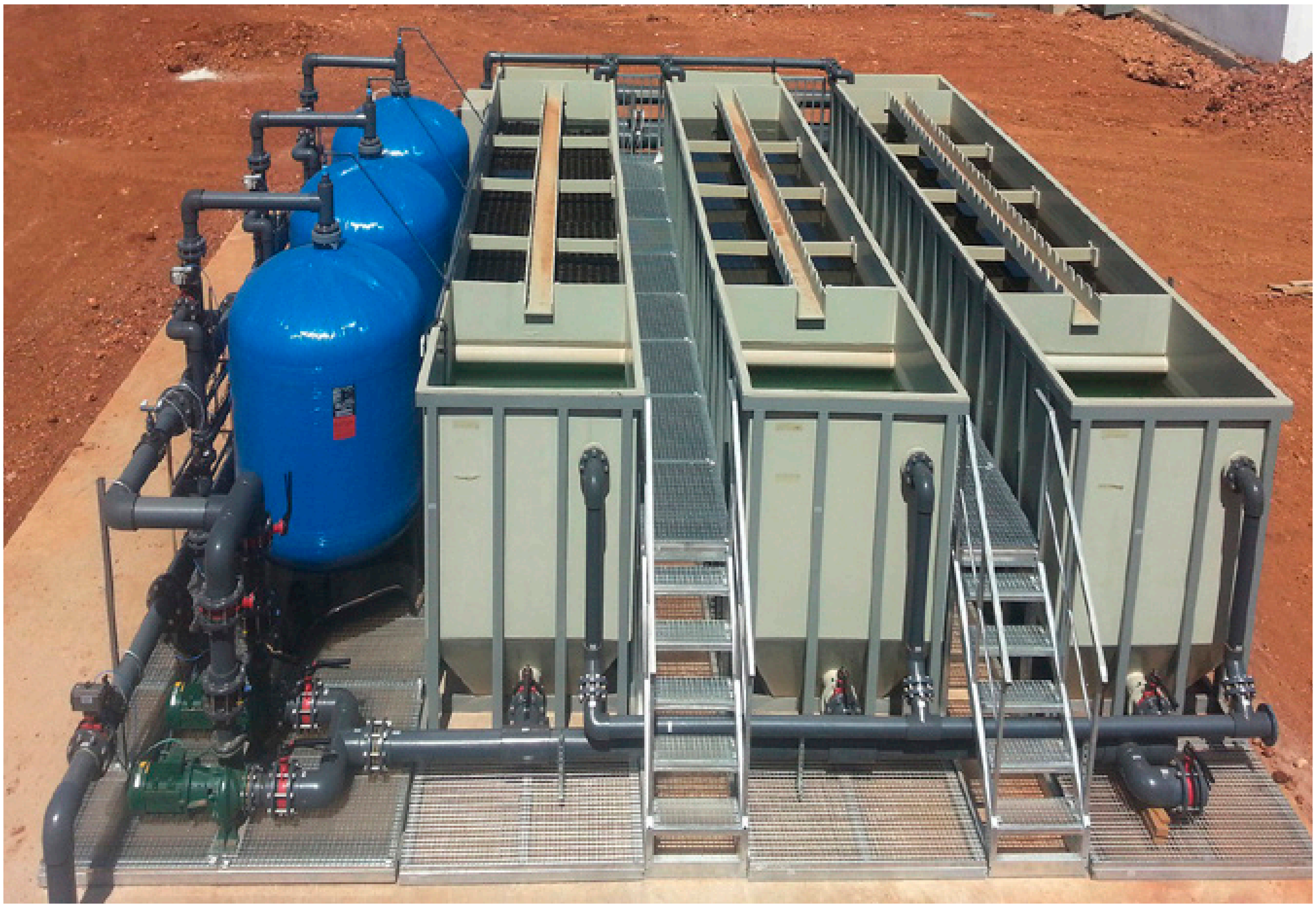


Image: MoFAIC UAE

Monobloc cooling unit

The UAE grants administered by ADFD have supported four major projects in the construction of large and small-scale dams. Dams play a vital role in regional economies across Morocco by providing drinking water, regulating the flow of water, reducing flood risks, providing water for irrigation of farmland, as well as producing electricity. The following two interventions highlight how the UAE is supporting the Moroccan government to implement its Green Morocco Plan and National Water Strategy to increase water supply for drinking and irrigation purposes.

A US$17 million soft loan was provided to build the Tamkit Dam located in the arid Errachidia province of the Meknès-Tafilalet region. With a storage capacity of 14 million m^3, the dam will supply water for drinking and irrigation purposes to the areas of Goulmima, Tinjdad, and surrounding rural communities. The dam will support the local economy by protecting agricultural production through the prevention of floods and recharging aquifers to maintain adequate flow of water, thus strengthening the farmers' capacity to manage agricultural production. The project is expected to benefit an estimated 150,000 people, including 120,000 residing in rural areas.

The Kharroub Dam is considered one of the most important strategic projects under the Green Morocco Plan and National Water Strategy. The US$137 million grant project is located 45km south of Tangier City and 22km east of Assilah town. The dam will increase water supply for drinking, industrial, and irrigation purposes. The dam will have a storage capacity of 185 million m^3 and will regulate an annual volume of 40 million m^3 of water. The dam reservoir will also create opportunities for environmental tourism by increasing access to local communities. The project is expected to benefit more than 1,700,000 people by 2030.

UAE's assistance to the Moroccan government in expanding its network of dams and water connectivity supports the country's long-term strategy in meeting its 16.5 billion m^3 of water needs by 2030.[7] As emphasised in the initiatives under the National Water Strategy and Moroccan Green Plan, the projects funded by the UAE will support the country in becoming resilient to future shocks, ensuring water is accessible, managed, and used sustainably.

Guided by the UAE Foreign Assistance Strategy – which emphasises a cohesive approach to effective development cooperation throughout the UAE foreign assistance sector – implementation of the 2030 Agenda for Sustainable Development will continue to be supported across key sectors, including water and sanitation. Pursuing collaborative partnerships with country partners will continue to drive the UAE's approach to international development and humanitarian relief. The UAE remains committed to working with partner countries to achieve their development priorities, and supporting water and sanitation sector projects that have an essential role in the socio-economic growth of its partner countries.

Water management strategies for the Nile Basin

National Water Research Institute, Planning Sector, Nile Water Sector,
Ministry of Water Resources and Irrigation, Egypt

The water resources available for Egypt's entire gamut of economic and service activities is extremely reliant on the River Nile, with a dependency ratio estimated at 97 per cent[1]. A fixed 55.5 billion m^3/year passes through the High Aswan Dam – Egypt's quota, according to the 1959 treaty between Egypt and Sudan – constituting 92.5 per cent of the country's total renewable water resources; the remaining 7.5 per cent being quantities of renewable, fossil groundwater and desalinated water plus a small number of rainfall showers. The total actual resources currently available for use in Egypt are 59.25 billion m^3/year, while water usage is 80.25 billion m^3/year. The gap between the needs and availability of water is approximately 21 billion m^3/year, and this is managed by reuse from drainage water, shallow groundwater and treated wastewater. The overall efficiency of the Nile system in Egypt exceeds 80 per cent, but the country's total water demand is 114 billion m^3/year to meet a steady population that has been estimated at 96 million capita for the year 2017. Therefore, 34 billion m^3/year of virtual water is being utilised.

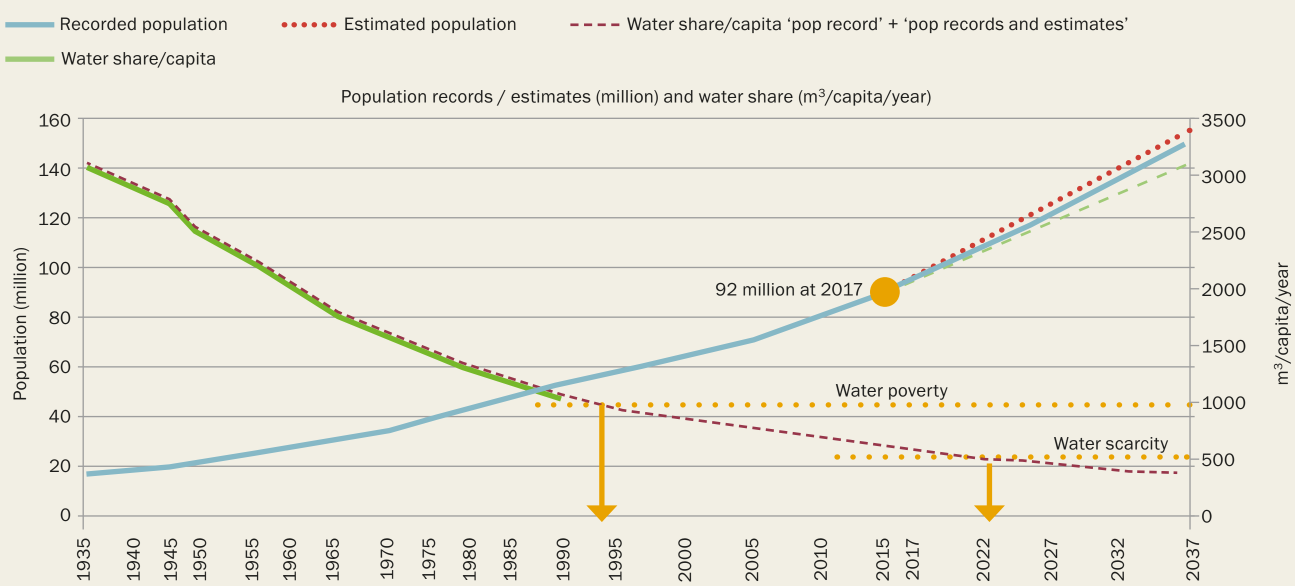
Downstream from the High Aswan Dam, the River Nile is 100 per cent regulated using a number of large barrages and irrigation structures with the result that the water resource system in Egypt is partially closed, and thus has a tendency to retain pollutants.

Water management policy over the last five decades maintained that drainage water should be reused in the Nile delta, a decision that created severe environmental concerns, causing a number of mixing stations to be closed.

Since 1990, Egypt has reached the so-called water poverty line with respect to the per capita share of water of almost 1,000 m^3/year. In 2017, the share decreased to almost 600 m^3/year, and it is expected to fall to less than 500 m^3/capita before the year 2030, when the population is expected to touch the 130 million mark. Meanwhile, an increase in cultivated land in Egypt is vital to produce the necessary quantities of food to feed the growing population and secure social and political stability in the country. This will add more challenges to improve Egypt's utilization of its limited water resources and to develop new resources to cover the needs of the cultivated areas as well as other uses.

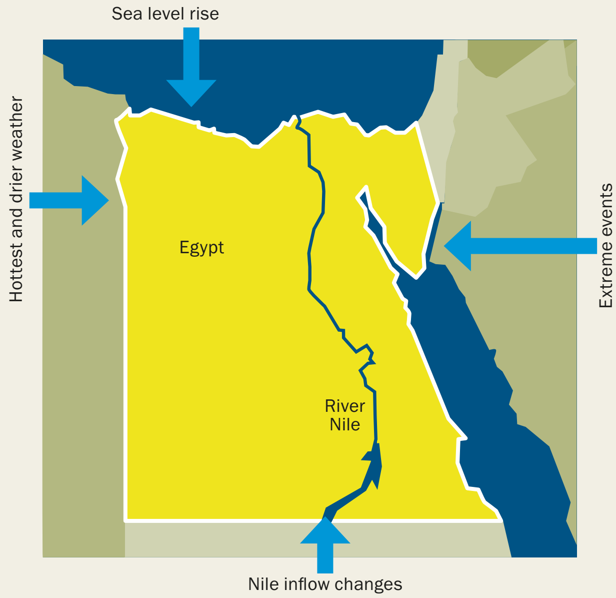
Egypt's vulnerability to climate change touches several sectors and the common cause of this vulnerability is water. The results of studies on climate change impact show that Egypt will face numerous threats to its economy, social and environmental sustainability, agriculture and food security, water resources, energy, human health, coastal zones and physical infrastructure. Climate change studies anticipate that the productivity of two major crops in Egypt, wheat and maize, will be reduced by 15 to 19 per cent but that this

Change per capita water share of Egypt



Source: national water resources plan (2017-2037)

Impact of climate change on Egypt



Source: national water resources plan 2017–2037

Image: MWRI

Extreme events witnessed in Alexandria

percentage could be increased without adaptation. Moreover, 12 to 15 per cent of the most fertile arable land in the Nile Delta is negatively affected by a rise in sea level and salt water intrusion, deteriorating ground water quality. Also, the increase in both seawater temperature and salinity in the coastal lakes is negatively affecting fish species, with a serious impact on low-level lands in the delta and the adjacent highly populated cities such as Alexandria and Port Said.

The impact includes the destruction of weak sections of the sand belt, inundation of valuable agricultural land, damage to the ecosystems and communities of the Northern Lakes, and the endangering of recreational tourism beach facilities. It is believed that up to 6 million people and 4,500 km^2 of land may be affected, resulting in a more significant challenge – the migration of people from the affected areas.

Egypt is the furthest downstream of the countries in the Nile Basin, the most dependent on the basin's resources and the most arid. Studies using global and regional climate models show a high degree of uncertainty regarding the impact of climate change on the Nile Basin's precipitation and runoff. Accordingly, the main objective of Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction is to increase the flexibility of Egyptian communities when dealing with the risks and disasters that might be caused by climate change and its impact on various sectors and activities. The Ministry of Water Resources and Irrigation (MWRI), in coordination with all ministries concerned with the management and use of water, has therefore prepared a National Water Resources Plan (NWRP) which looks as far ahead as 2037, and is based on the principle of integrated water resources management (IWRM).

NWRP 2037 is not the first Egyptian national water resources plan. MWRI had already developed a plan covering the period 2005–2017, following the same methodology, and in full cooperation and coordination with all stakeholders. With the approach of 2017, it was necessary to develop a new strategy, with the lessons learned from the implementation of the first plan used as one of the main inputs. NWRP 2037 will pursue four objectives:

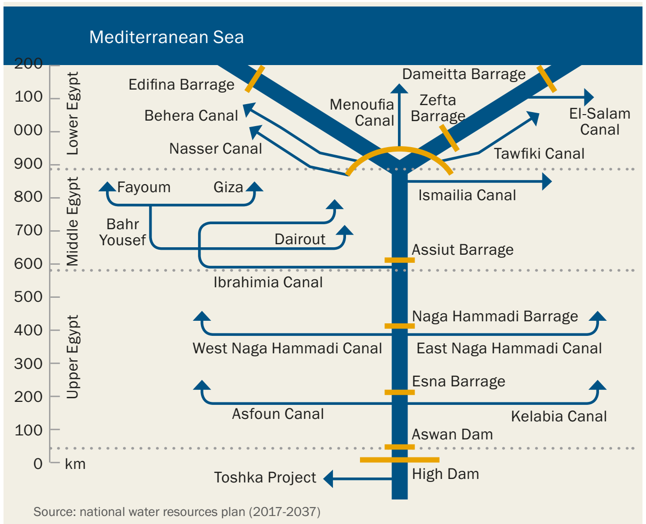
- Improving the enabling environment for IWRM, planning and implementation
- Increasing the availability of freshwater resources
- Improving water quality
- Enhancing the management of water use.

In addition, the new plan takes into consideration the objectives of Egypt's Sustainable Development Strategy 2030, and the latest circumstances surrounding the water sector. As part of the government's overall orientation toward decentralisation, the NWRP supports this trend in the water sector, as well as supporting the required interaction between public policies and determinants at national level and the actual needs and priorities at local level. Governorate water resources plans have been developed in full cooperation and coordination between the stakeholders at governorate level in order to support the required interaction.

In the NWRP, several measures are currently being considered to adapt to a climate change impact on water resources. These efforts include, but are not limited to: Improving irrigation and draining systems; changing cropping patterns and farm irrigation systems; reducing surface water losses

Image: MWRI

Sarabium siphon, 60m below ground, built to transfer agricultural drainage water to the eastern part of the Nile Delta



Schematic of irrigation system in Egypt

Image: MWRI

Egyptian women working within the agriculture sector

by redesigning and lining canals; rain water harvesting; research and development for low cost desalination techniques; treated wastewater recycling; developing new water resources through upper Nile projects; and developing new species of crops to cultivate in high temperatures.

Adaptation options for coastal zones are highly site-dependent. However, changes in land use, integrated coastal zone management, and proactive planning for protecting coastal zones are necessary adaptation policies. In this regard, MWRI has developed a comprehensive master plan for rehabilitation and replacement of the major hydraulic structures on the Nile and the main canals and rayahs, which distribute water to large and medium-sized canals. New Esna and Naga Hammadi barrages have been constructed, and work has been underway in Assiut Barrage which will be fully operational by early 2018, while a tendering process is continuing for the new Dairout group of regulators. Meanwhile, irrigation improvement and IWRM projects have been developed in the Nile Delta, with construction of flood protection works totalling approximately £500 million between 2014 and 2016 and £700 million between 2017 and 2018.

Coastal flood protection works have been completed in Rosetta, Baltim, Ras El Bar and Alexandria in addition to the implementation of an integrated management plan for the protection of Northern Lakes from sea level rise and salt water intrusion. Moreover, public awareness is being raised on the need for rationalising water use, enhancing precipitation measurement networks and encouraging data exchange among Nile Basin countries as well as developing regional circulation models to predict the impact of climate change on national and regional water resources.

Laws and rules governing the irrigation sector

The MWRI is the official authority in charge of development, allocation and distribution of all conventional and non-conventional water resources in the country. It is the central institution for water quality management and for formulating the national water policy for resolving the problems of water scarcity and water quality deterioration. Under Law 12 (1984), MWRI retains overall responsibility for the management of all water resources, including the available surface water of the Nile system, irrigation water, drainage water and groundwater. And for the empowerment of water users, Irrigation Law 213 (1994) and Ministerial Decree 1490 (1995) were issued to supplement Law 12.

Law 9 (1962) was the first legislation to control the disposal of wastewater in sewerage systems and water bodies. It was followed by Law 48 (1982) created to control discharge of wastewater into the Nile River and other water courses and bodies. As the Egyptian government had become increasingly aware of the importance of environmental protection to sustain economic development, health and quality of life, Law 4 (1994), which places an emphasis on the protection of the coastal waters and the marine environment, was passed to enable environmental conservation in a comprehensive manner with the aim of achieving sustainable development.

In 1993, an environmental information system was set up as an integral part of the Egyptian Environmental Affairs Agency, with the capability to monitor water quality for the purpose of pollution abatement and mitigation. A national permit system for wastewater discharge and point of source pollution from other sectors (municipal, energy, heavy industry) has been put in place where authorised discharge is monitored and controlled. In addition, norms have been established for the usage of fertilisers, manure and pesticides.

Transboundary aspect

Egypt believes in the inevitability of cooperation between the Nile Basin states in the utilisation of the basin's water resources. Egypt has participated in the establishment of the existing institutional framework that governs the relations between the riparian states. It also played a leading role in establishing several cooperation initiatives, including the Nile Basin Initiative (NBI) in 1999. In 2010, Egypt suspended its participation in NBI activities in response to the non-consensual decision taken by some upstream states to leave the draft Cooperative Framework Agreement (CFA) open for signature. Egypt considers this unilateral decision to be a breach of the NBI rules of procedure and of those of the negotiating committee. Since then, the NBI has continued to function as a non-inclusive and non-consensual framework. Nevertheless, driven by its belief in the inclusiveness of the initiative, Egypt has engaged in a consultative process to further address its concerns and exchange views with other NBI member states in order to seek ways for Egypt to resume its participation in NBI activities on a permanent basis. Despite the challenges and difficulties facing this process, Egypt is determined to continue its efforts to restore inclusiveness to the NBI in order to manage the transboundary waters of the Nile Basin in accordance with the principles of international law, paving the way to enhancing cooperation on the basin level. To this end, Egypt believes that genuine cooperation among the Nile Basin states should be based on the following pillars:

- All states should respect and uphold existing obligations under international law, including the existing bilateral, plurilateral and multilateral agreements
- The consensual decision-making process should form the basis of the management of transboundary waters
- Riparian states should abstain from unilateral actions that could harm other riparian states. The principle of no-harm and timely prior-notification should be respected where the construction of projects has cross-border effects. In the case of the Grand Ethiopian Renaissance Dam (GERD), where Ethiopia failed to abide by the relevant necessary legal process, Egypt entered into talks with Ethiopia and Sudan, with the countries agreeing to form a tripartite international panel of experts in 2013, and a declaration of principles being signed in Khartoum in 2015. The three leaders met in Addis Ababa in January 2018 to address all differences related to the GERD and it is hoped that a resolution is imminent.
- Riparian states should exert their utmost efforts to reach an agreed definition of the equitable and reasonable utilisation that avoids causing harm to any of those states.

Finally, development partners and private sector actors should promote the establishment of consensual institutional arrangements to facilitate the management of transboundary water resources. The United Nations should play a more active role in facilitating and enhancing cooperation among riparian states to enable them to achieve the agreed SDGs.

Image: MWRI

El-Salam mega pump station

Image: MWRI

Subsurface drainage network used to control the groundwater level and soil salinity

Improvement of water use efficiency through Smart Water Management

Seong Han Kim, Vice President and Chief Research Officer, K-water; Nam Soo Lee, General Manager, Water Policy Research Center, K-water; Ah Leum Lee, Researcher, Water Policy Research Center, K-water

Annual precipitation in the Republic of Korea is approximately 1,300mm, 1.6 times the world's average of 813mm. The country's annual total water resources amount to 132.3bn m³ but, due to a high population density, the average annual water resource amount per capita is 2,546m³ – one sixth of the world's average of 15,044m³. Since 65% of Korea's topography comprises steep-sided valleys, river gradients are also steep. Therefore, during the rainy season from June to September in which 68% of annual precipitation occurs, flash floods and increased water flow make water management difficult. Droughts are also increasing in frequency and intensity since precipitation is scarce for most of the year. Water management policy has therefore focused on securing and storing flood waters in dams and reservoirs during the rainy season.

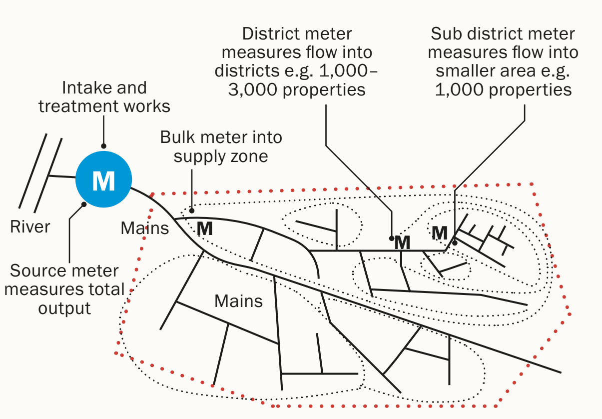
The water supply penetration rate in Korea is more than 98%, with most people using water services. However, significant challenges are created by water loss[1] caused by the deterioration of water pipes and the gap between metropolitan and provincial pipeline networks. Korea is no exception to global climate and weather changes, and some recent years have seen unprecedented droughts, with various regions facing serious water problems.

Korea's waterworks business operates both with a multi-regional water supply, delivered on a wholesale basis by K-water from national rivers and dams, and a local supply which is operated on a retail basis by local governments, either using their own water source or a multi-regional water supply system.

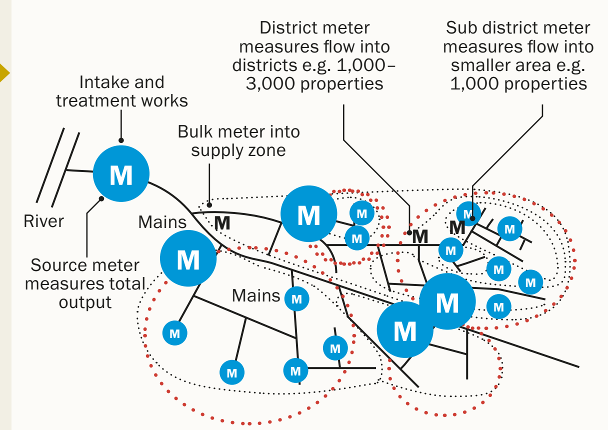
One of the most important tasks for Korean water supply services is now to minimize the amount of leakage and to supply consistently safe water to users. Smart Water Management (SWM) technology is therefore essential as it allows operators to use real time information to cope with such challenges. SWM combines various technologies such as information and communication (ICT) systems,

Improvements through smart meter technology

- Flow rate and pressure management by 1 DMA (1 Flow™ plus general meter for customer)
- 500–1500 customers/DMA
- Monitoring only 1 MNF
- NRW management monthly



- 1 DMA + 3–5 SDMA (1 Flow™ +3–5 SM + SM for every customer)
- About 300 customers/SDMA
- Hourly base monitoring by SDMA
- Daily base NRW management



Source : K-water Internal Data

Supervisory Control And Data Acquisition[3] (SCADA) systems, smart meters and other devices to ensure stability and efficiency throughout the network. SWM specifies technologies and creates standards for the overall water circulation system. Examples of application include Smart Water Grid (SWG)[4], Smart Water City (SWC)[5], Integrated Water Quality Forecasting System (SUIRAN)[6], and Integrated Water Management System (K-HIT)[7].

A smart meter enables the transmission of information concerning consumer tap water usage measured by time. The use of digital meters and IoT technology as an alternative to traditional analog meters allows operators to read meters remotely as well as manage the water usage rate in real time. The smart meter monitoring program analyses usage, abnormal flow, and indoor leakage from the metering information and provides usage and tariff information to customers through the Internet and a mobile app. Previously, flow and water pressure were managed in one District Metered Area (DMA), but with the application of smart meters, the DMA is divided into three to five SDMAs (Sub-District Metered Area). The management of the daily water flow rate enables quicker responses than before.

Smart metering makes it possible to quickly identify leakage locations – immediate detection can reduce leakage from burst pipes and reduce non-revenue water (NRW) – to quickly correct inaccurate or damaged meters, to reduce supply costs, to improve asset management efficiency, and ultimately to enhance customer satisfaction.

Seosan, Chung Cheong Nam Do

Case study – Seosan

In Seosan City, Korea, the Boryeong Dam is supplied by 80,700m^3 of water per day, sufficient for a population of 157,000. The water penetration rate is 91% and the NRW is 16.6%. One area of the city, Cha-ri, was operated by two DMAs and it was difficult to identify and cope with water loss due to the relatively wide supply area. Efforts to reduce loss were nevertheless essential because of drought.

In general, Seosan City has a relatively low NRW, whereas that of Cha-ri was, in 2015, the city's highest at 32%. Improvements were made by installing smart metering, and nine SDMA systems were built within the existing two DMAs. In addition, NRW analysis, which had been conducted on a monthly basis, was converted to a daily analysis system. Finally, water flow monitoring was expanded from three branches to twelve.

After installing smart metering, intensive leak detection was carried out on vulnerable sections, reducing flow meter errors. As a result of comparing the DMA flow rate and the total flow rate of the water supply area in Cha-ri, a difference of 430m^3 per day was found, inflow meter failures were detected and flow meters were substituted.

After analysing the patterns of both seasonal and hourly customer usage through smart metering, water pressure management is now conducted hourly. Automatic control of the decompression valve through SCADA facilitates adjustment according to usage, depending on seasons and holidays.

Non-revenue water (NRW)[2] by region

Region	NRW (%)	Region	NRW (%)
National average	15.7%	Chung Cheong Nam Do	20.1%
Seoul	4.9%	Jeolla Nam Do	31.5%
Busan	8.3%	Jeolla Buk Do	31.5%
Daegu	8.8%	Gyeong Sang Buk Do	31.0%

Source : Water Supply Statistics 2015, Ministry of Environment(2016)

NRW comparison, 2015 and 2016, Cha-ri water supply area, Seosan

NRW (%)	March	April	May	June	July	August	September
2015	40.8%	36.5%	37.8%	28.8%	34.4%	26.2%	28.5%
2016	37.5%	26.6%	30.6%	26.8%	29.6%	11.6%	9.8%
Variation Rate	↓3.3%	↓9.9%	↓7.2%	↓1.9%	↓4.8%	↓14.6%	↓18.7%

Source : K-water Internal Data

There is now greater flexibility in managing the response times required to address complaints of failure. As a result of installing the first smart metering system in June, 2016, an NRW of 10% was achieved.

As indoor leak detection has been improved, the NRW has also improved, as has customer satisfaction. The control system allows for the analysis of customers' usage patterns according to the time of day. It also provides a "leak suspicion" alarm enabling inspectors to quickly visit a site and take recovery action if a leak is detected. This has resulted in a reduction of approximately 55% of customers' water usage and a consequent reduction in cost to the customer of 70%.

Based on the results of the operation monitored over two months, the net financial benefit[8] is expected to be about 610m KRW over the next eight years (B/C = 2.1) with a 20% improvement in the NRW and a 190,000m^3 per year leak reduction[9].

Case study – Paju

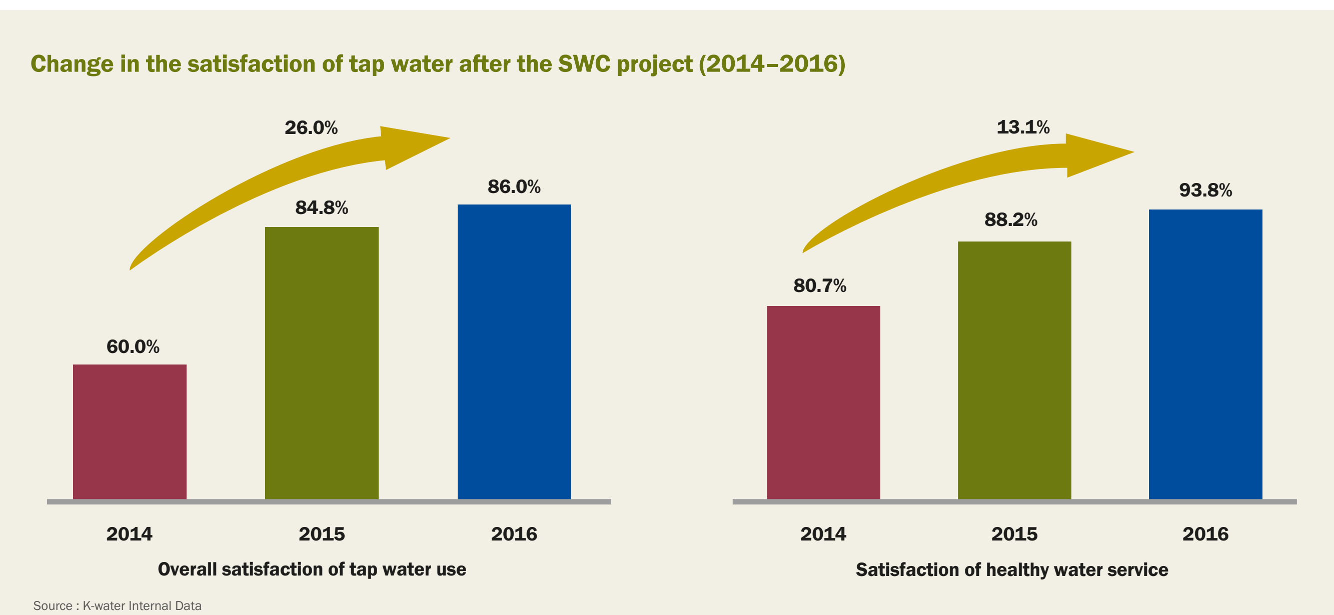
Another Smart Water City (SWC) project was conducted in Paju City – a municipality where 390,000 out of a total population of 410,000 are connected to the water supply. Here, K-water has built a smart water management system that supplies safe water from the source to the customer by improving the stability and efficiency of the supply based on scientific management, using ICT.

The project has enabled the citizens of Paju to check the water quality in their neighbourhood and homes in real time using a water quality signboard and a smartphone app. The provision includes a water coordinator service that checks water quality from the tap, and a water doctor service that checks the condition of indoor water pipes and cleans them. As a result, civil complaints have decreased from 4.5 to 1.3 cases per month and the average tap water drinking rate has increased from 1% (before the SWC project commenced) to 41.5% after implementation. Consumer dissatisfaction of tap water quality was allayed and the overall satisfaction of water services was greatly improved.

At a time when it is necessary to respond to water crises caused by both rapid economic development and climate change, the Republic of Korea is responding by integrating ICT into water management. SWM creates a new paradigm of innovative water management such that it can improve water security and welfare by addressing global water issues and the imperative of sustainable water usage. With those goals in mind, and in partnership with Asian Development Bank, K-water is giving technical assistance in the application of SWM to countries such as Bangladesh, India and Sri Lanka.

Image: K-water

The headquarters of the Korea Water Resources Corporation (K-water)



A comprehensive approach to building a water partnership for sustainable development

Yoonjin Kim, Director, Korea Water Forum

The lobbying by multiple stakeholders to recognise the scale of global water challenges has succeeded in making water partnership one of the top priorities in the achievement of sustainable development. Good governance plays an important role in the development process, but its management is impossible without a bond of empathy concerning the issues at stake.

From follow-up to creation

The Korea Water Forum (KWF), a member of the international water community since 2005, has made huge efforts to unite multiple levels of stakeholder for the purpose of building a sustainable water partnership.

Since global efforts contributed to the creation of the 7th World Water Forum in 2015, various follow-up actions have been mooted to realise the forum's core value – implementation. Many activities have now been planned to bring best practice and relevant technologies to bear in response to resolutions on imminent water challenges, and the Korean government has upheld the forum's core value by implementing change, using the diverse ideas collected there.

The forum emphasised that change had to come from practice rather than discourse; the application of technologies rather than the needs of new technologies; developed policies to deal with regional cases rather than a lack of well developed policies. To realise this change, advice and ideas from multiple stakeholders with their abundant experience were essential.

In preparation for full scale follow-up action, the Korean Ministry of Land, Infrastructure and Transport (MoLIT) formed a committee along with the Ministry of Environment (ME), Daegu City, Gyeongsangbuk-do Province, and KWF to organise the Korea International Water Week (KIWW) in 2016. 14 international advisory committee members were selected to assist, and leading Ministries including MoLIT and ME, pooled their experience and knowledge to create what turned out to be a valuable event.

The KIWW invited diverse stakeholders from various fields and with multiple levels of expertise including high-level decision-makers as well as young, non-professionals and contributors from outside of the water industries. The forum focused on solution provision through various programmes, each of which was designed to emphasise participatory processes and preparation procedures to ensure that each would maintain a case history of solution implementation.

The KIWW was launched in 2016 with the theme of 'Water Partnership for Sustainable Development'. Four pillars of

Image: KWF

Heads of state joining at the 7th World Water Forum

Image: KWF

Water leaders' Round Table discussion between ministerial staff and heads of private and public organisations, NGOs, and academia

focus were given as: seeking global leadership for SDGs; implementation of solutions; creation of economic and social values; and knowledge sharing and capacity building.

Seeking global leadership for sustainable development

Making water issues the primary political agenda requires raising awareness of the interface between science and policy development. It is essential for decision makers to consider technical solutions as the template for policy development so that technologies are applied in the right place and at the right time. To that end, the Water Leaders' Round Table (WLRT) has been convened, comprising ministerial staff, heads of private and public organisations, NGOs, and academia. More than 30 government heads and delegates, together with various organizations and citizens were offered the opportunity to discuss the agenda which had been shared in advance.

In 2017, the Round Table dealt with one of four focus areas selected from the last year's leaders' declaration. The areas are: promoting the application of science and technology to water management; the improvement of sanitation and water reuse; the implementation of Integrated Water Resources Management for sustainable economic development; and the formation of sound partnerships for water management.

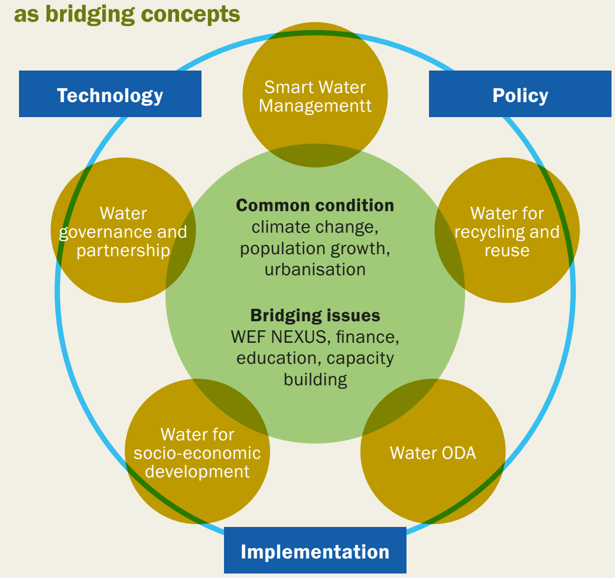
With its heads of various countries and organisations, the WLRT publicises its results every year, contributing to raising awareness on imminent water issues and disseminating leaders' willingness to resolve water problems. At the next KIWW, high-level delegates will convene to decide on the next actions based on these four focus areas.

Implementation of solutions

The sharing of experiences and understanding of new technologies and policies encourages the implementation of sustainable solutions. Two representative programmes were designed for the purpose of providing a forum for sharing solutions with both the problem owners and the solution providers.

The World Water Challenge (WWCH) became one of three primary programmes generated by the 7th World Water Forum in 2015. By defining the world's water challenges, problem owners were invited to submit cases that are emblematic of those challenges requiring urgent action. The WWC encourages solution providers to share knowledge and best practice in tackling the challenges, and the best solution provider was given the honour of presenting its case history and solution at the 7th World Water Forum. The second and third WWCs were held in 2016 and 2017 in which, amongst 36 solution candidates from 17 countries, the Sorain Bucket[1] was selected as the best solution for fresh water supply. The WWC becomes more competitive every year and is valuable for the exchange of best-fit technologies and policies applicable to identified water problems.

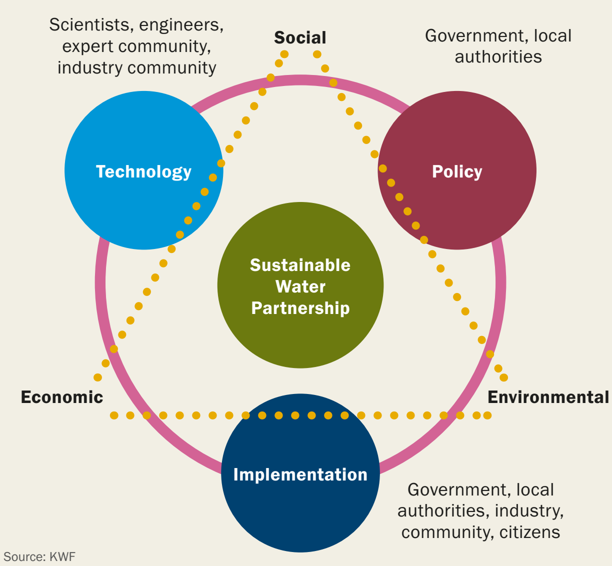
Technology, Implementation and Policy as bridging concepts



Source: KWF

Another programme representing KIWW's values of sharing solutions is the Technology, Implementation, Policy (TIP) platform, which attracts more than 40 applicant organizations. 15 session proposals were selected for KIWW 2017 under five focus areas. In future, to allow participants more space to give and receive real time information, KIWW will extend the TIP platform's remit in further driving participants to implement solutions.

Technolgoy, Implementation, Policy Platform



Source: KWF

Economic and social value creation

In order to provide all-encompassing perspectives and opportunities, KIWW also promotes the connection between private and public entities. For instance, in seeking solutions to water challenges, the Water Business Forum (WBF) provides opportunities to both government and corporations as well as a place to build partnerships between public, private, and multinational development banks or international cooperation agencies. Based on the partnership model, progress is being made in developing countries for water supply management, sanitation, waste water treatment and the revitalising of ecosystems. WBF participants share information and technologies as well as discussing current and planned projects and finding the right partners work with.

KIWW also organizes its 'Business Matchmaker', run by KWF, that enables participants to create meeting schedules. In addition to its participation in the KIWW, the WBF is held three times a year in different regions along with other international water weeks or forums, for instance, the Arab Water Week 2017 and the IWRA Congress, Cancun. The WBF has been the KWF's own project since 2015 and has, with the Korean MoLIT, become one of the model programmes for building a practical partnership through the KIWW.

Knowledge sharing and capacity building

Various activities have been initiated to promote solutions applicable to global water challenges, the first of which was to develop education for capacity building. The Korean MoLIT and ME have, with KWF, worked for water education and capacity building through various programmes. The

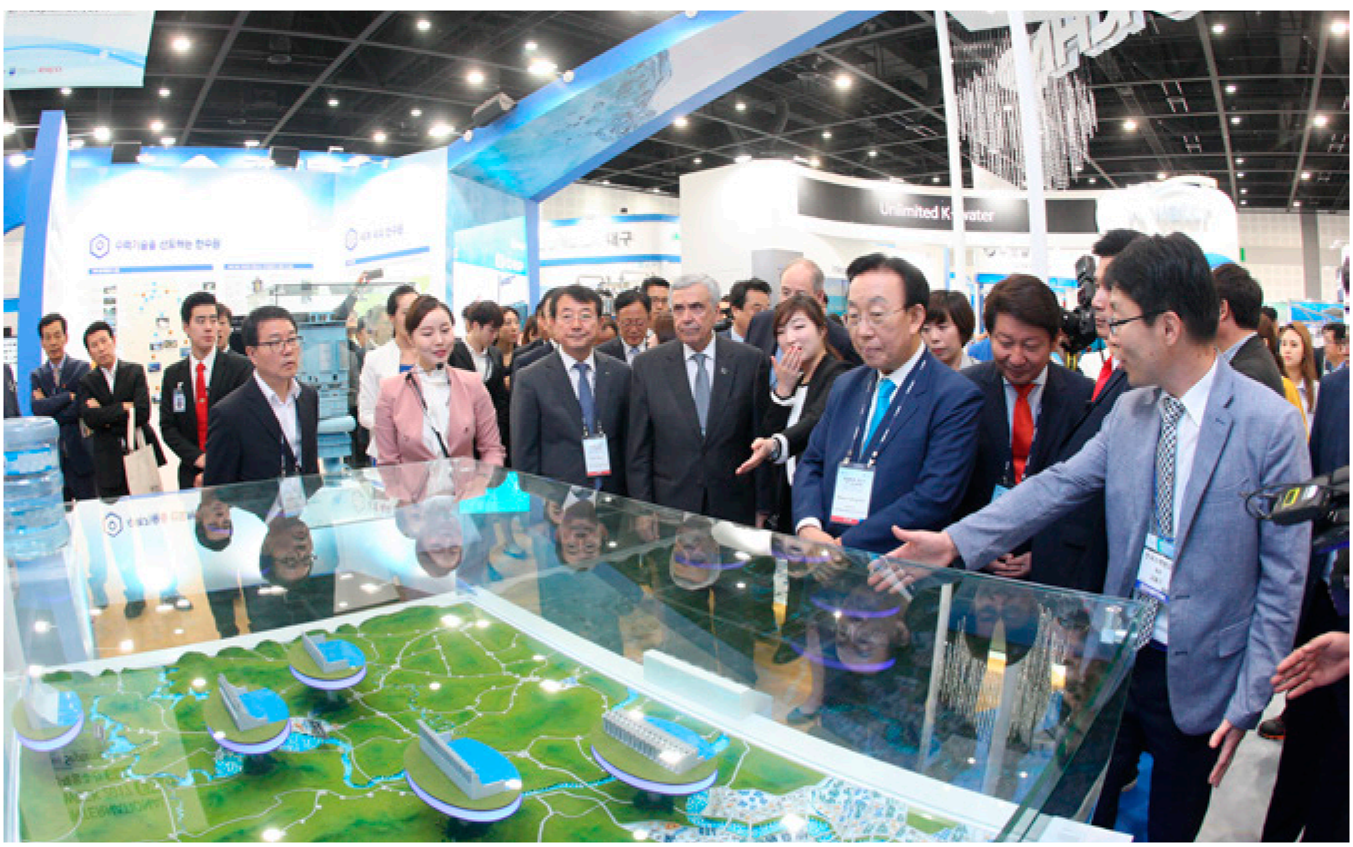


Image: KWF

Case study tour of technologies

Image: KWF

Water education at the Citizens' Forum

Image: KWF

Raising citizens' awareness of global water issues

Image: KWF

A session of the Biz Matchmaker initiative

Asia Pacific Youth Parliament for Water (APYPW) is one of the vanguards of water education, attracting more than 500 youths globally in 2017, among which 60 were chosen as representatives. Selection is always very competitive and the efforts made throughout the programme motivate participants to rigorously engage in the programme over four days in Korea, where they experience the parliamentary decision making process. The programme's chair and vice chair are elected to adopt a declaration pledging practical and political actions by all participants for resolving Asia-Pacific regional water challenges. Importantly, youth from more than 25 countries bring together different values and perspectives in understanding the primary water issues of diverse regions and peoples.

Since after the KIWW was launched in 2016, the KWF as the programme's host, along with the ME, has created a bridge between the youth delegations' contribution and their active engagement in the KIWW. In 2017, previous participants of the APYPW were involved in the KIWW preparation process, bringing different perspectives in the understanding of water. This was highly valued due to its depth of analysis and the strength of future-oriented innovative ideas.

In addition, more than five water education sessions were organised for children, youth and citizens during the KIWW 2017. Every session was held in a different format with creative participatory ideas such as demonstrating innovative technologies in real time, sharing information through a competitive quiz, and Q&A sessions with well known experts. These sessions were supported not only by the ministries but by the private sector implementing their corporate social responsibilities.

Dissemination of the results and procedures is included in the KIWW process. As an organizer, the KWF plays a role as a science and technology topic coordinator under the theme of 'Capacity' while also acting as the sub-regional coordinator of the regional process. The KWF also coordinates the national participation of NGOs and citizens in the citizen's forum.

Throughout the entire processes, the KWF exchanges dialogue and information via the KIWW and the World Water Forum (WWF). The outcomes of the KIWW are collected to contribute to the next WWF and the best examples are reflected in the follow-up action called the implementation roadmap. The KIWW holds annual review meetings where the implementation roadmap annual report is created by the coordinators of the WWF thematic process. Through the 8th World Water Forum committee, every theme dealt with in the 7th World Water Forum is linked to the those of the 8th World Water Forum.

Building a sustainable partnership based on the empathy of multiple stakeholders

With its objective to build a bridge between fields of expertise, levels of influence, race, gender and age, the KWF has pledged to communicate with those both in and outside of the water industries and coordinate its efforts among governments, international organisations, corporations, academia, and citizens. The building of partnerships, leadership of decision makers, performance of practitioners and experts, combination of private and public forces, and the perspectives of civil society, need to be well managed and coordinated.

Among the diverse activities carried out by the Korean government and the KWF along with global partners, the planning and organizing of the KIWW is paramount in creating a comprehensive channel of communication among the right partners and offering a timely arena for the exchange and sharing of practical information and technologies that will eventually lead to the raising of the social, economic, and environmental status of the global water community. Through the entire processes of development and planning, ideas from diverse stakeholders are welcomed as the essential basis for a collective voice and a call to action based on well-balanced and comprehensive perspectives.

China's campaign of improving rural drinking water security

Wang Jianhua, Director and Professor of Engineering, China Institute of Water Resources and Hydropower Research (IWHR); Liu Changshun, Professor of Engineering, IWHR; Li Xiaoqin, Engineer, IWHR

The supply of sufficient, clean and affordable drinking water to the rural population has formed a large part of China's efforts to improve livelihoods, and provides the impetus for the country to realise the UN Millennium Development Goals (MDGs). At the dawn of the 21st century, over 60% of China's rural residents had no access to water supply facilities, and over 320 million people, accounting for one third of the rural population, were unable to enjoy a secure supply of drinking water. China's efforts to rectify this situation included the investment of over 280bn RMB during the eleventh and twelfth Five-Year Plans of rural drinking water security (2005–2015). In 2016, the Chinese government staged a campaign for further improvements, with an eye on ensuring universal and fair access to safe drinking water for every rural resident, so that they could enjoy the same entitlements to drinking water as their urban counterparts.

China's campaign to improve rural drinking water security

The master plan

Consistent with a portfolio of policies to build a better countryside – poverty alleviation, new urbanisation development, and rural livability improvement – the campaign to improve rural drinking water security has been launched in a bid to increase the centralised water supply and availability of tap water, and to enhance water supply security and water quality compliance, following the principle of urban-rural coordination. Specific objectives include: as of 2020, the centralised water supply to reach at least 85%, and tap water 80%; small-scale water supply facilities to be guaranteed at least 90% of the time, and other facilities to maintain a water supply no less than 95% of the time; tap water pipelines from cities to reach one third of rural administrative villages; the operation, management and maintenance of rural drinking water supply to be enhanced to gradually achieve sustainability.

Universal and fair access to safe and affordable drinking water is envisaged for 2030. To this end, the following key measures have been put in place:

Key measure 1: Reinforcing existing projects

Agencies responsible for the management and supervision of rural drinking water supply projects have been put in place to strengthen the service and guidance for such work. The property rights of projects as well as their management bodies and respective responsibilities have been clarified to form a complete management and operation system. To cover the costs of project operation and management, the water pricing mechanism has been improved in terms of water taxation and fiscal subsidies. Favourable policies have been formulated to encourage private investment. A nationwide information management system or rural drinking water supply has been built to enhance the monitoring and management of the projects.

Key measure 2: Construction and innovation

Previously, rural water supply projects had low standards, were run on a small scale and were poorly guaranteed. The projects have now been properly identified and distributed, coordinating them with measures such as project retrofit, upgrade and connection with the urban pipe network, to improve the standard, size and viability of the rural water supply. Realising a basic water supply in poor regions has been prioritised.

Key measure 3: Enhancing water resource protection and water quality insurance

It is now agreed that project construction, source water protection and water quality monitoring must proceed simultaneously. Improved source water protection, better purification facilities and disinfection equipment are being installed to improve water quality compliance. Water quality watchdogs need to be established with adequate staffing and funding so that both inspection and monitoring can be ensured.

Key measure 4: Ensuring planning implementation

The roles of central and local governments have been aligned, with local governments mainly responsible for implementation and taking overall responsibility for rural drinking water security in its jurisdictions; and central government providing appropriate subsidies for the poor regions as well as supervising, reviewing and providing guidance to local governments.

Recent achievements

In 2016, focusing on the registered poor population, 24bn RMB of investment (3bn RMB subsidised by central government and 21bn funded by local governments) was channelled into 59,000 projects, benefiting a total population of 39m, among which registered the poor population reached 4.26m. 93% of counties in China have established their own regula-

Image: IWHR

Pupils enjoying good quality tap water in a rural school

tory agencies in charge of rural drinking water supply projects; 87% of water supply projects with a capacity of providing more than 1,000 tons of water per day or for over 10,000 people have marked their protected source water areas; and 55% of counties have secured their funding for project maintenance, which cumulatively reaches 1.05bn RMB. In 2017, with continued project construction and management, China is aiming to realise 83% of centralised rural water supply and 77% of tap water availability nationwide.

Contributions from IWHR to rural drinking water security

The China Institute of Water Resources and Hydropower Research (IWHR) serves as the main technological support body to the Chinese Ministry of Water Resources with regard to rural drinking water security, having long been involved in research on water treatment, drinking water disinfection and water quality inspection technologies, application of information technology and standardisation of water supply, as well as project sustainability. IWHR has poured considerable resources into project planning, feasibility studies, and design and technology dissemination, and has played a prominent role in advancing technological development, formulating industry technical standards and promoting the application of related patents.

IWHR has completed two state key sci-tech projects during the eleventh and twelfth Five-Year Plan periods, namely the Research and Demonstration of Integrated Technologies for Rural Water Supply Security and Major Sci-Tech Projects that Guarantee Drinking Water Security in Towns and Villages. IWHR is also responsible for a research project under a state key water programme for research and demonstration of Rural Drinking Water Supervision, Water Resource Allocation, and Standard Technology for Water Purification through Slow Filtering.

IWHR has also developed and promoted a myriad of technologies and equipment that covers the entire water supply process in rural China, including precision prospecting for groundwater in water-scarce regions; high-fluorine water

Image: IWHR

A rural, centralised water supply project

treatment; purification of slightly polluted water; disinfection of supplied water; water quality inspection; project design standardisation and information technology application.

IWHR has led and participated in the compilation of a number of national plans related to rural drinking water supply, including the tenth Five-Year Plan for basic resolution of rural drinking water supply difficulty; the eleventh and twelfth Five-Year Plans of rural drinking water security projects; and the thirteenth Five-Year Plan for reinforcement and improvement of rural drinking water security projects.

IWHR has led and participated in the compilation of many industry technical standards, codes and guidelines, including the Acceptance Code for Construction Quality of Rural Water Supply Engineering (SL688-2013); the Design Code for Rural Water Supply Engineering (SL687-2014); and other technical guidelines concerning water treatment, disinfection, project operation and maintenance. In addition, IWHR has authored such publications as *Rural Water Supply Projects – Technologies and Modes*; *Research on Secure Rural Water Supply Technologies*; and *Selection and Application of Technologies and Equipment for Water Disinfection in Rural Areas*.

IWHR has been heavily involved in the construction of demonstration projects to aid the implementation of rural drinking water supply schemes. 130 projects have been established in six pioneering counties to demonstrate disinfection technologies in six provinces – Shaanxi, Hubei, Jiangxi, Hebei, Liaoning and Sichuan, benefitting 800,000 residents. Multiple sets of automated monitoring systems and construction modes for rural drinking water supply have been established and promoted in many provinces and municipalities – Shaanxi, Jiangxi, Sichuan, Anhui, Beijing and Chongqing – integrating such technologies into autonomous Web configurations, map engines and smart mobile terminals. Four county-wide and 12 water-plant automated monitoring systems have been installed, covering supply to millions of people. For instance, a water supply system with quality certification has been implemented in the Xiaohongmen district of Beijing. With a treatment capacity of $12m^3/h$, the system uses reverse osmosis as its key technology. It is very flexible, with different combinations of ultrafiltration and reverse osmosis modules to manage differences in water quality, and it can supply drinking water compliant with Standards for Drinking Water Quality (GB5749). The system has been installed on existent facilities including a water well, water pump, pump station and water supply pipelines, successfully providing for 30,000 residents. This water supply system operates successfully, significantly contributing to the local drinking water safety and security.

Benefits brought to the rural community
China's campaign has raised farmers' living conditions and improved their health. Now, with access to clean, convenient tap water, half of the farmers benefiting from the campaign have purchased washing machines, water heaters and other household appliances and installed flushing toilets. These changes have created new standards for rural households which benefit from tidy kitchens, clean rooms, hygienic toilets and green courtyards. As a result, the risk of water-borne disease epidemics has been eliminated, with a large saving on medical expenses. It is estimated that, since the implementation of the campaign, the medical expenditure of each household in the Ningxia Hui Autonomous Region of north-west China and cities such as Yiwu, Wenling and Pingyang in Zhejiang Province, south east China, has been cut by 100–250 RMB per year.

The campaign has also liberalised the rural labour force and increased farmers' income. Many people in rural locations have been freed from the hard work of finding, carting or carrying water, leaving them free for more productive work that generates income. According to a survey conducted by the Water Resources Bureau of Chongqing Municipality, south-west China, since implementation of the campaign every rural household has been able to devote 53 more days to productive work – time previously dedicated to water carrying. Counted at 40 RMB per day, the annual income per household has increased by more than 2,100 RMB. Jobs have also been created in rural areas with the development of agricultural product processing and livestock farming, and farmers are now able to work in cities where they can earn more.

Finally, the campaign has helped to create and maintain the harmony and stability of the countryside as water related conflicts have been minimised. Water users are entitled to learn about, participate in and supervise the campaign's projects by sending delegates to take part in the entire process of project construction and management, which has greatly enhanced their sense of democracy and responsibility. In some communities, the farmers have built water use associations, assuming responsibility for project construction and management. Special care is given to vulnerable groups including elderly people without family, those with disabilities and families with financial difficulties, all of whom enjoy a preferential water tariff without having to share project costs. The campaign prioritises people of ethnic minorities and those living in poverty, encouraging ethnic solidarity and helping to more quickly ease water-caused privation.

Image: IWHR

Tibetan villagers with access to tap water

The hidden implications of SDG 6

Dawn McGregor and Debra Tan, China Water Risk

We use water in the home every day, usually with little thought. The water used to grow crops, package food and drinks, generate power, mine resources and produce goods that shape our life, from fashion to electronics, is less obviously recognised.

Greater emphasis on access to safe drinking water and sanitation is an obvious view of SDG 6. Yet, municipal water represents only 12% of global withdrawals in 2016, the smallest sector share, according to the Food and Agriculture Organization of the United Nations (FAO). The largest users and biggest polluters of water globally, industry and agriculture, remain hidden from popular view but play key roles in achieving sustainable water resources for all.

The actions adopted for development will have to go beyond improving access, and making quality and efficiency gains. With many parts of the world now facing extreme water stress and pollution, a new way of managing water is needed as much as changing business behaviours. There will be transitional risks of achieving SDG 6, but are we ready for their hidden implications?

The less obvious – dirty, thirsty fashion

Agriculture is the largest user of water globally, accounting for 69% of water withdrawals in 2016. It is also a major water polluter with its excessive use of nutrients, pesticides, fertiliser and other pollutants. World Wide Fund for Nature (WWF) says that the amount of pesticide sprayed on fields has increased 26-fold over the past 50 years. One of the crops that absorb a significant amount of global insecticides and pesticides is cotton.

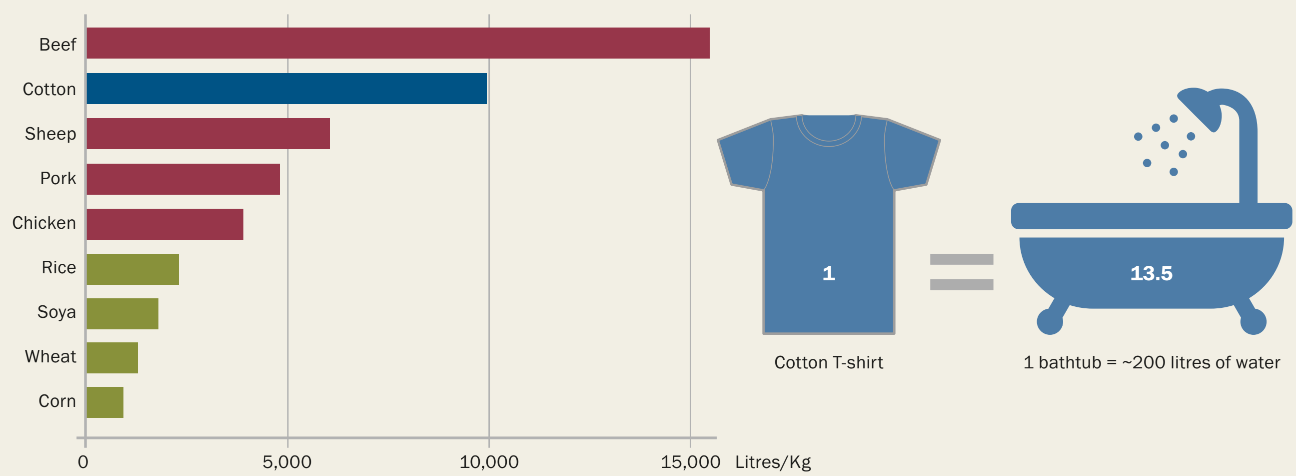
One of the largest water using and polluting industries is textiles. The World Bank estimates that almost 20% of global industrial water pollution comes from the treatment and dyeing of textiles. Cotton production consumes 16% of global insecticides and 7% of herbicides, according to the *Pulse of The Fashion Industry* report, 2017.[1]

A single cotton t-shirt has a virtual water footprint of 2,700 litres, or around 13 bathtubs. Cotton has a higher virtual water footprint per kilogram than some proteins and grains. The number of garments produced annually has doubled since 2000, according to McKinsey & Company. In 2014 the number of garments produced globally exceeded 100 billion for the first time, which equates to nearly 14 items of clothing for every person on earth.

In 2016, China was the leading exporter of textiles and clothing with a 37.2% and 36.4% share respectively, according to the World Trade Organization (WTO). Other key countries fuelling the fashion industry include India and Bangladesh, which account for 5.7% and 3.2% of textile exports and are the global third and seventh ranking exporting countries, respectively.

In China, it is estimated that the textile industry discharges 1.5 times the amount of wastewater than the nation's entire coal industry (and China produces around half of the world's coal). The industry ranks second for use of chemicals, record-

Virtual water footprint: cotton vs food



Source: China Water Risk, the Water Footprint Network

Image: Feng Hu

The Bund in Shanghai, a key municipality of the Yangtze River Delta

ing 8,585 different chemicals, according to the Ministry of Environmental Protection. Some of these chemicals are highly toxic and, according to Greenpeace, hormone disruptors have even contaminated drinking water sources. Chinese environmentalists have lamented the colour of the rivers and waterways, observing that they match the most fashionable colour of that season. In India, it has been reported that dogs were turning blue from sitting in industrial water run-off.

Water-nomics – the sustainable reset

Rapid industrialisation across Asia together with lax environmental regulations has brought about rampant pollution. In China, 60% of groundwater falls into the "bad" or "very bad" category whereas the proportion of monitoring stations with water classified as "unfit for human contact" is 28.8% for rivers and 34% for key lakes and reservoirs, according to the Ministry of Environmental Protection's 2016 State of Environment Report.

Unfortunately, pollution exacerbates water scarcity. Already, 11 provinces in China fall beneath the World Bank's water poverty mark of 1,000 m^3 per capita per annum. This has clear implications for national food security as they include some of China's top farming provinces. This means that 44% of China's GDP is generated from provinces as dry as the Middle East. The question is: will limited water resources constrain economic growth?

We know that the economy runs on water, yet water resource management and the economy are seldom planned and managed holistically. This is about to change. The China Water Risk organization believes that the practice of water-nomics – viewing water as the prime engine of the economy – is particularly pertinent for countries with limited water resources but with a need to develop. Balancing trade-offs between economic development and the availability and quality of water resources is key.

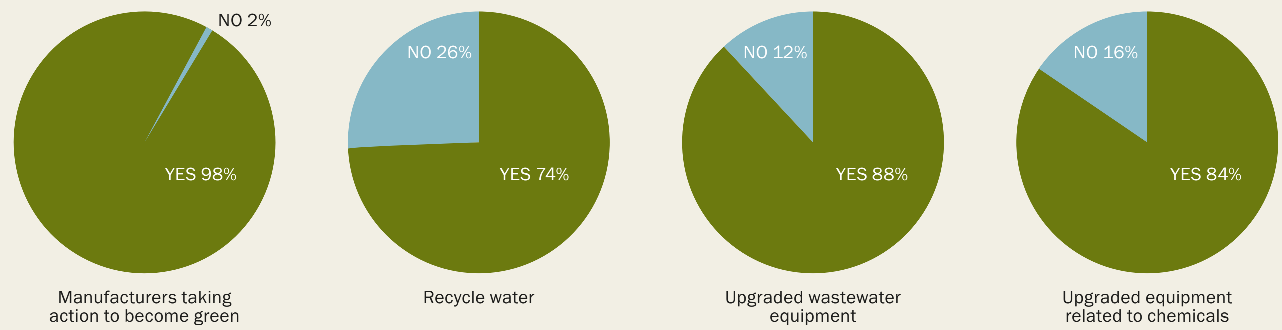
Recognising that sustainable economic growth requires a sustainable environment, China declared its war on pollution in 2014. Since then China has been taking aggressive steps to clean up, including updating environmental law, implementing new and more stringent regulations, and increasing enforcement. As part of the country's Three Red Lines policy on water, targets have been set to increase water efficiency for agricultural and industrial water use and to curb pollution. The policy also sets national water use caps for 2015, 2020 and 2030 which could, according to HSBC, limit GDP growth to 5.7% between 2020 and 2030. Ultimately, the vision is to achieve a beautiful china where economic growth is no longer at the expense of the environment.

Trade-offs and disruptions – blindsided by transitional risks

Managing the economy through the lens of water requires trade-offs – the idea of more crop-per-drop with less pollution is in potential conflict with the growth of industries or goods that provide a larger contribution to GDP and that use significant volumes of water. Selecting which crops to grow and which industries to keep has implications for food security and the economy.

Trade-offs between agricultural and industrial water can also bring about disruption. For example, China produces a significant amount of both cotton and coal in the parched North China Plain. While coal is a part of the nation's plan to ensure energy security, cotton is dirty, thirsty and does not

Survey of 85 Chinese textile manufacturers



Source: China Water Risk report, *Insights from China's Textile Manufacturers*, August 2017

contribute to food security. Research carried out for HSBC by China Water Risk reveals that shifting cotton production from the North China Plain could free up 1.5 million ha of sown land area, which could be used to plant edible crops. Alternatively, it could free up around 9.5 billion m^3 of virtual water for other uses. To put this into perspective, the completed Phase I Eastern Route of the mega South-to-North Water Diversion Project carries only 8.8 billion m^3 of water.

Another way of freeing up more water is through trade, by importing more and exporting less water-intensive goods. This could essentially change China's export-led economic growth model. Transitional risks abound as decisions that are good for China may disrupt global trade and turn out to be risks for others.

Global fashion could be one of those industries since China is a major producer of key fashion raw materials – around a quarter of global cotton and two-thirds of global synthetic fibres. Sourcing problems aren't as easily solved by moving to other countries. India and Pakistan, ranked first and fourth respectively as global cotton producers[2], are also water stressed.

Closing the loop and going circular

Closing the loop also has potential as a solution. We need circular economies that will reduce the use of virgin resource, reduce waste, and increase recycling. To that effect, China has mapped out plans of change for ten industries, some of them are the most polluting in the country, textiles among them.

From a recent survey of 85 Chinese textile manufacturers, it is evident that the transition has already started. 72% see a business benefit in making the transition to a circular economy, in addition to those manufacturers working to be compliant with regulations. 98% of those surveyed said that they are taking actions to be green (clean and compliant). Moreover, 74% recycle water, 88% have upgraded wastewater equipment and 84% have upgraded equipment related to chemicals.

China's national directives for the textile sector present a unique period for the global fashion industry as the goals of Chinese textile manufacturers and leading fashion brands are converging. Both need to clean up and need/want to go circular. The impetus for Chinese manufacturers is domestic regulations, whereas the brands are facing greater scrutiny over their environmental impact than ever before and uncertainty about future supply of resources. As the majority of key fashion raw materials are still produced in China, there is an opportunity to set the foundations for a clean and circular business model. Actions on making this transition have already begun.

Other industries, while not at the same tipping point as textiles, face similar opportunities and risks as China cleans up. Electronics is one such with its heavy reliance on the country for key raw materials. It is estimated that 85–90% of global rare earths, crucial for various electronic products from smartphones to electric cars, are produced in China. A recent report from CLSA[3] warns that smartphone brands' current no-sense strategies, such as low recycling rates, built-in obsolescence and poor repairability, serve only to compound these risks. China is preparing to be future-ready by securing critical raw material supplies, building a circular economy and cleaning up pollution.

There is no circular model to copy and apply to textiles, electronics, or to other industries, for China or for the world. To go circular and ultimately ensure sustainable water for all – municipal, agriculture and industry – we need new ways of doing old things and a holistic approach. Simply put, we need business unusual.

Our water future – climate change uncertainties

Water is both local and global. As the upper riparian, China's move to balance its economic development and environment is a good start. In Asia, there are ten large rivers that flow from the Hindu Kush Himalayan region. Known as the Third Pole, the region is already being impacted by climate change, bringing uncertainties in river flows that feed 16 Asian countries. With the water for over 1.3 billion Asians at stake, a comprehensive water management approach by the entire region is needed if SDG 6 is to be achieved, especially as many of these countries are still developing. Urbanisation rates, power use and resource demand are all on the rise.

It is therefore imperative at this water-energy-climate nexus, that we choose the right type of power as well as make sound business and policy decisions today for our water tomorrow. Water is not simply encapsulated by SDG 6, it influences 11 other SDGs from poverty alleviation, zero hunger, good health, clean energy, climate action, to responsible consumption and production. The stakes are too high not to achieve SDG 6.

Ntabelanga and Lalini ecological infrastructure project

Mike Powell, Harry Biggs, Michael Braack and the Ntabelanga and Lalini Ecological Infrastructure Project team

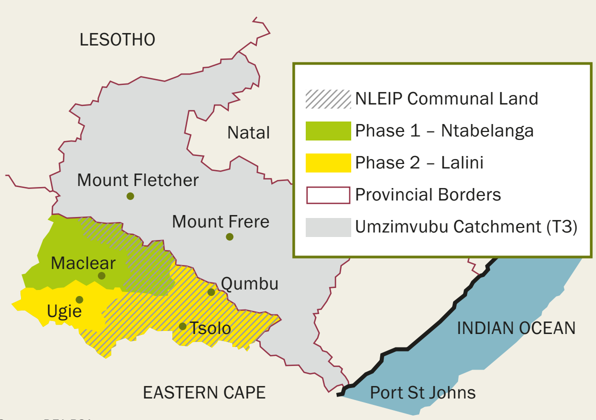
The Mzimvubu catchment in South Africa (SA), in the province of the Eastern Cape is currently undergoing a series of infrastructure developments. Ntabelanga Dam (Phase 1) and Lalini Dam (Phase 2) are both part of the ongoing Mzimvubu Water Project led by the SA governments Department of Water and Sanitation (DWS), and on completion are intended to supply potable water to 730,000 people by 2050 and irrigate about 2,900 ha of land. There is also a hydropower plant planned at the Lalini Dam site. In order for these dams to be filled with good quality water and to reduce sedimentation and other problems which dramatically reduce the lifespan of the dams, it is essential to maintain healthy upstream ecosystems as well as optimise all of the ecosystem services they perform.

In a range of natural resource management and restoration programmes, the SA government's Department of Environmental Affairs (DEA) Natural Resource Management (NRM) Programmes is investing in the catchments around the proposed Ntabelanga and Lalini Dams. The project is underpinned through investing in a research programme that will address the understanding of the management and restoration, and importantly, the social context of the work, whilst trying to understand the drivers of the land degradation within the catchments. This is an area of rural poverty and land degradation; one in which local people could be given the opportunity to build a more sustainable future, based on improving natural resources and building the resilience of ecosystems they depend on. This makes particular sense given that the Ntabelanga and Lalini Dams will silt up prematurely if land degradation in the catchments around them continues. Independent sediment yield calculations for the Ntabelanga Dam predict that it can silt up in 30 to 40 years if no sediment management is applied.[1]

Restoration efforts in these catchments will extend the lifespan of the proposed dams. The exact improved life expectancy due to restoration efforts is unknown, but could be as high as 30%, and depends on the restoration effort invested and co-operation of the land users and stakeholders in the catchment. What is certain is that restoration efforts will reduce the loss of valuable soil, improve water quality, reduce water treatment costs, and prolong and ensure the livelihoods of upstream and downstream land and water users. The programmes aims for the intergenerational equity of the future local residents, who for the first time may inherit a landscape in better condition than their forebears did.

The land degradation in the catchments of the dams has attracted initial research investment. Subsequently, a research investment strategy has been developed by the DEA NRM to ensure that the key drivers and objectives of the project are properly researched and that the results are used to drive the restoration and land management changes that are required for the system to become more resilient.

Eastern Cape of South Africa showing the two phases of the NLEIP



Source: DEA RSA

Image: DEA RSA

The impact of unsustainable fire and grazing regimes in the Upper Umzimvubu catchment

Image: DEA RSA

Women collecting fuel wood during autumn in Upper Umzimvubu

With summer rainfall of ~600–1,000 mm pa, the catchments are marked by steep topography, with the pronounced Drakensberg Escarpment forming the headwaters of the catchment, followed by a second smaller escarpment in the lower catchment. Habitat units include rocky outcrops, montane grassland, pockets of Afro-montane forest, Acacia savannah and wetlands and riparian zones with pockets of highly erodible soils, especially on abandoned cultivated lands. Soils become more erodible towards the lower parts of the catchment, as is demonstrated by the extensive gully features there. Siltation prevention measures could substantially increase the life-span of the dam with major direct economic benefits: every 5% increase in the life-span of the dam could save approximately R1 billion in 2015 currency.

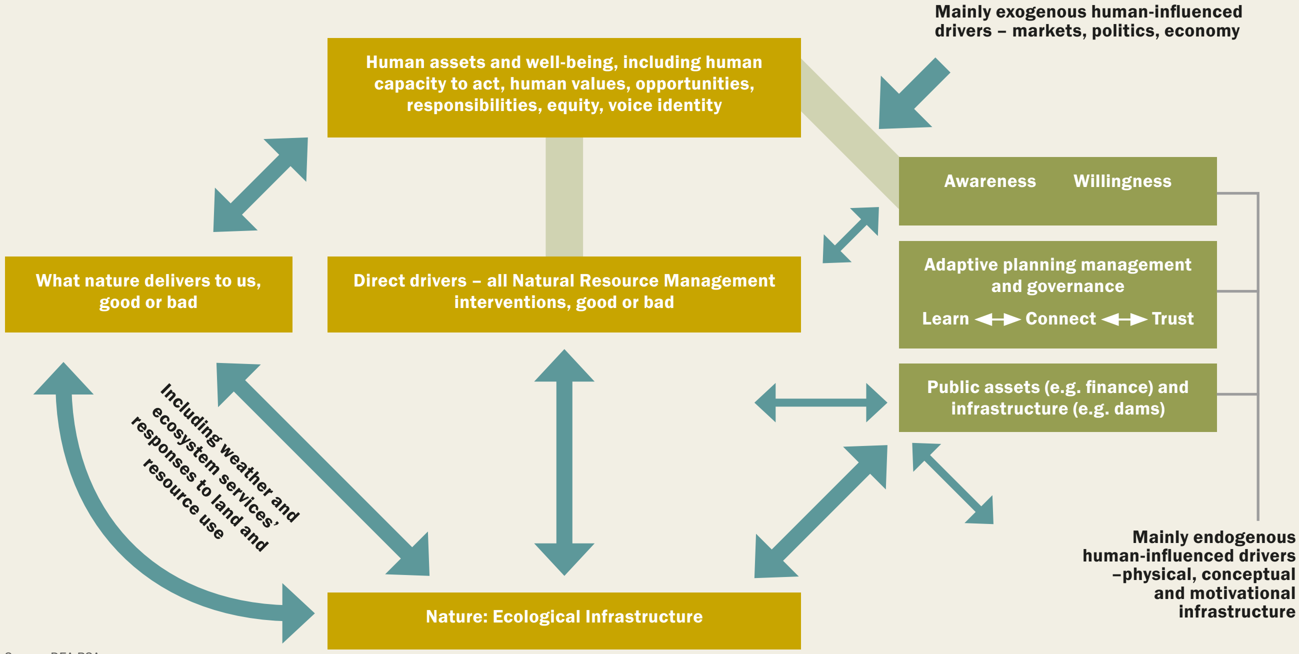
Various socio-economic factors contribute to land degradation. The key historical elements that have impacted on the dam catchments are: the political and administrative separation of the former Transkei homeland from SA; laws that restricted ownership of land; the loss of able bodied men who were enrolled to work in the mines thus reducing available labour in the rural areas; pass controls which prevented women from living in urban areas with their husbands; and limited investment in education, especially at school level. Social grants in the form of pensions have also affected people's reliance on the land, often abandoning agricultural land and practices. Current levels of degradation make any new agricultural activity unlikely to remain successful without continued support and investment.

Poverty prevails within the catchment areas. Investment priorities are therefore focused on the alleviation of poverty and the creation of sustainable jobs that allow the catchment ecosystems to perform their proper functions. The Ntabelanga and Lalini Ecological Infrastructure Project (NLEIP) aims at erosion prevention, the avoidance of habitat degradation and general rehabilitation efforts in the Tsitsa catchment (T35), particularly those that reduce the amount of likely sediment deposits in proposed dams and associated infrastructure.

The vision for the programme is "to support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services." The investments in restoring and maintain ecosystems and their functioning in an optimal condition will sustain benefits that will accrue from the health of the water infrastructure – crops and pastures from irrigation, power supply from the hydroelectric plan and, most importantly, potable water for those communities that have previously been most disadvantaged. This will be linked to the activities of the fledgling Catchment Management Fora (CMFs) in the area.

It is intended that these joint actions and events will be carried out in a manner that engages and involves local communities, both sensitively and with a view to their own benefits. Ecosystems and their functionality are the greatest natural asset to the social-ecological system. It not only protects the direct benefits from ecosystems, such as fertile

A social-ecological systems framework for integrated natural resource management, understanding and action in the Tsitsa catchment



Source: DEA RSA

Image: DEA RSA

Clearing silver wattle in the Upper Umzimvubu to improve streamflow, biodiversity and grazing potential in a land user incentives programme with Conservation South Africa

soil for agriculture, but also safeguards people and ecosystems against natural disasters such as floods, fires, wind and droughts. Ecosystem functions provide three main advantages to human well-being – provisioning services, e.g. water, productive grazing, cultivated crops, firewood, building materials and medicinal plants; cultural services – identity and place attachment; and regulating services such as sediment retention, water absorption, flood regulation and drought resilience.

In the case of the Ntabelanga and Lalini dams, the most valuable ecological infrastructure is robust, fertile soils that can resist erosion and provide a basis for improved agricultural production. The further degradation of ecological infrastructure in these catchments is the greatest threat to the adaptive capacity of people and ecosystems. The robustness of ecosystems and their functionality can be enhanced by increasing natural vegetation cover, improving the organic

Early on, NLEIP scientists and managers drew up a central guiding social-ecological framework (see diagram above) to help conceptually guide and direct actions, processes and interlinkages. As one example of its use, participants can locate their particular initiatives somewhere on the diagram, and are also then able to better see their interlinkages to other elements; and overall, NLEIP administrators and funders are able to see which elements have which levels of attention.

PLUS
Two key overraching issues to remember throughout

1. **Multiple interconnected scales**
   (local – regional – global) and across multiple corresponding levels of governance
2. **A constantly changing milieu**
   with thresholds and tipping points, involving history, power changes, baselines, trends and scenarios

At the centre of the hub are natural resource management interventions which impact on ecological infrastructure (bottom block), in turn influencing ecosystem services (left block; the reason for the curved return arrow is to remind us that sometimes certain exogenous natural happenings like floods or droughts can impact ecological infrastructure without necessarily any human involvement). The ecosystem services in the left block go on to interact with human assets and well-being in the top block. The three closely-positioned blocks on the right refer to endogenous human infrastructures/capitals which play a key role in influencing NRM, whilst the strong arrow coming from the top right-hand corner depicts exogenous human drivers usually out of our control as local residents or actors. The bridges (non-arrowed connections) designate overlaps where it may be difficult to place an attribute in one or the other block category, or the two blocks and their links may need more unpacking than shown here, in order to be clear. Two overall messages (1 and 2) apply throughout.


Image: DEA RSA

Programme participants at an invasive alien plant clearing site as part of the Firewise land user incentives project, Upper Umzimvubu


Image: DEA RSA

The sheer scale of degradation in Ntabelanga catchment


Image: DEA RSA

A community information session, Upper Umzimvubu

content of soils, restoring wetlands, and protecting the banks of rivers and riparian zones. In this way, ecological goods and services will be improved, supporting the success of alternative livelihoods and the well-being of land users.

The provisional set of research programmes and interacting management actions are designed to build more resilient societies which can adapt and hopefully flourish in a changing future. In the long-term the NLEIP will strive towards sustainable land use management across the catchments.

NLEIP is a collaborative venture into polycentric governance and the project framing is social-biophysical (or social-ecological as it was termed in the formative initiatives) and systemic (holistic) in nature, and centres around local livelihoods especially in the ex-homeland areas of the catchment. Although the NLEIP began in a top-down manner, efforts are now being made to secure a meaningful, even where possible central, participatory position for local resource users. The restoration plans being developed by the science and management teams don't have corrective actions definitively identified, only some provisional ones.

The actual restoration planning is, at the time of writing, actively being done with the communities living in the catchments. The process began as a biophysically-centred sedimentation and rehabilitation plan but evolved into focusing on social-biophysical linkages and understanding the requirements of the people living in the landscape. In addition a commitment to pragmatic interfacing with the many realities on the ground, such as local power structures and governmental schedules has been investigated and built into the framework adopted by the project.

It is the NLEIP's view that, without these social and other contextual considerations properly incorporated, any biophysical design or restoration action will very likely be unsustainable.

A thorough stakeholder assessment of the sub-catchments related to the proposed Ntabelanga Dam – the first proposed dam of the two – was conducted in 2016.[2] The results from the assessment and the ongoing research clearly showed the complexity of the governance and land use within the catchments. These complexities are a challenge, but with a larger investment in communication, and dedicated staff within the catchment dealing with community engagement, these complexities are better understood and planned for. Despite the presence of various government departments in the catchment, natural resource-related decision making is mainly controlled by individual farmers – with advice and support from their agricultural suppliers – and traditional authorities – chiefs, headmen and sub-headmen.

Planned restoration work will be done through the government's poverty alleviation mechanism, the Expanded Public Works Programme and implemented by DEA NRM. These restoration operations will potentially create 558 real jobs in the green economy per year. This should equate to R450 million injected into the local economies of the catchments. The restoration work in conjunction with the sustainable land use management implicit in the Ntabelanga Lalini Ecological Infrastructure Project goals can be seen as an insurance policy for all the South African governments' investment in infrastructure in the catchment.

The standard approaches to ecological restoration deals directly with the problem and not the cause of the problem. Gully head erosion in wetlands is stopped with engineering interventions in most instances, but the driver of the degradation is generally not dealt with. NLEIP aims to identify the drivers and implement the required change to reduce the land degradation whilst dealing with the identified problems within the priority ecosystems.

A typical large erosion feature that has reached bedrock and is now steadily progressing laterally and removing valuable topsoil

The management of invasive alien plants is being done differently in these catchments. The standard approach works from the top of the catchment down to the bottom. The NLEIP has investigated which species are being used by local communities and which sites the communities would like to have remain intact. The invasive species are primarily used for firewood and building materials. A comprehensive plan is being developed to allow invasive woodlots while clearing the remainder of the invasive plants.

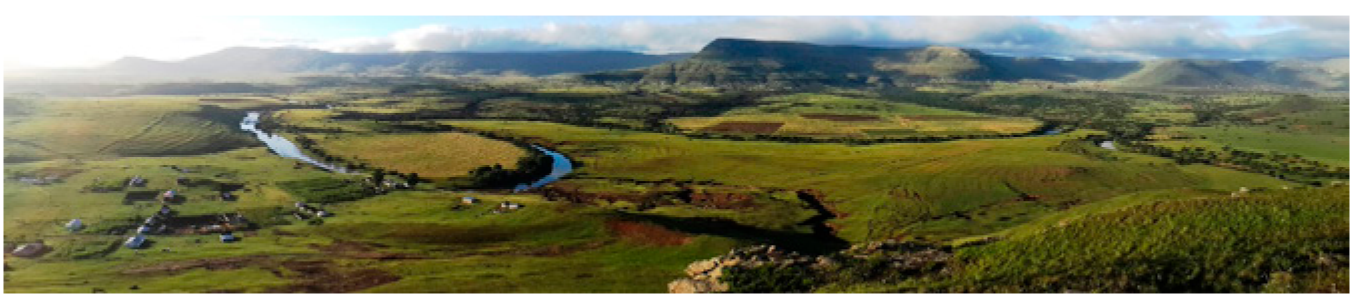
The injudicious use of fire in the catchment needs to be addressed thorough fire management plans that are developed with the land users and the communities living within the catchment.

The restoration of wetlands, grasslands and forests is carried out in a manner that supports local business development. The restoration material, plants, grasses and tree seeds are harvested within the catchment and grown by the local communities. The plants and trees are then bought from them for the restoration work, which they in turn plant and take responsibility for, thus creating a chain of ownership and responsibility. Baseline monitoring of restoration efforts in the catchment is done by trained community members instead of using universities and specialists.

The socio-ecological model for these catchments is centred on people and their livelihoods. This project aims to build intervention measures for improved ecosystems functionality that will, in turn, allow greater access to water and for a longer period of time.

This initiative has thus tried in a bold and ambitious way, to view its challenge through a social-ecological lens – one which considers both social and biophysical domains jointly, not with physical on one side and social on the other. Apart from the participatory emphasis being promoted across the many appropriate levels of resource use and governance, the culture that the project is striving to engender is also explicitly reflexive, using feedback and learning principles from strategic adaptive management and developmental evaluation[3].

Given the task at hand, and the particular history of the catchment, the situation described in this article has taken several years to start realising in this aspirational form. With this longer start-up investment as a basis, the Natural Resource Management Programmes organisation hopes to trial in practice what has long been envisioned – navigating through the complex reality in a manner which takes cognisance of that complexity. This realisation is in its early stages and there are no illusions about the multiple challenges, but it is hoped that it will create a more appropriate approach towards sustainability.



Sunrise over Shukunxa Village in the NLEIP catchment

Clean water and sanitation in rural communities through people-centric watershed management

Suhas P. Wani, Mukund D. Patil and Aviraj Datta, International Crops Research Institute for Semi Arid Tropics (ICRISAT)

Good sanitation and access to clean water, though prerequisites for healthy living, remain elusive for resource-poor rural communities living in the semi-arid tropics. Sustainable wastewater management, using constructed wetlands and implemented on a community scale, not only brings the possibility of healthy and hygienic living but also increases the efficiency of water usage and the beneficial effects of feeding nutrients back into the soil. Better management of rainwater, proper drainage of wastewater and the reuse of treated wastewater can significantly reduce the vulnerability of these communities to climate change. The available technology is both effective and intrinsically eco-friendly, and can involve local villagers at each step of implementation in generating awareness, site selection, construction, commissioning, maintenance and the reuse of treated water in agriculture.

Today, about 80% of global wastewater is released into the environment without adequate treatment.[1] Thus, we need to reconsider the fact that the 500 million people living in water-stressed arid and semi-arid areas, where the drinking water demand exceeds the renewable water resources,[2] can no longer afford to 'waste' the wastewater. Farmer-centric scientific interventions have often focussed on increasing productivity, working on the common misconception that water and fertilizer availability will improve rural livelihoods, despite the reality that one in nine people in the world today does not have access to safe and clean drinking water.[3]

Over the past five years, the World Economic Forum has highlighted water crisis as one of the major global risks.[4] Despite growing awareness, and the efforts made towards improved sanitation[5] and wastewater treatment efficiency[6], there is a mismatch between sewage generation and treatment capacity in resource-poor regions.[7] In a country like India, two-thirds of the population resides in villages where formal wastewater treatment systems do not exist. It is estimated that India's rural population generates liquid waste (greywater) in the order of 15 to 18 billion litres every day.

Inadequate focus on waste management makes a substantial impact on the livelihoods of resource-poor villagers in terms of health, economy, quality of life and the environment. The link between wastewater management and health is well documented[8] – in developing countries as much as 80% of illnesses are linked to poor quality water and poor wastewater management.[9] In 2012, an estimated 842,000 deaths in middle- and low-income countries were caused by contaminated drinking water, as well as inadequate hand washing facilities and sanitation services.[10] During the same year, 361,000 deaths among children under five years old could have been prevented through reducing the risks posed by inadequate hand hygiene, sanitation and unclean water.[11] Sustainable decentralized wastewater treatment, enabling the reuse of water and residual nutrients that are beneficial for farming and seed production, as well as the growing of energy crops, flowers and teak wood, can contribute towards achieving some of the Sustainable Development Goals (SDGs), such as SDG 1 – No Poverty; SDG 2 – Zero Hunger; SDG 3 – Good Health and Well-Being; and SDG 6 – Clean Water and Sanitation. As forecast by studies made by utilities that manage both water and wastewater infrastructure, the annual capital expenditure required to achieve the SDGs is US$100bn and US$104bn, respectively.[12] Thus, there is great need to explore economical and sustainable wastewater management schemes.

An integrated water resource management approach

Decentralized wastewater treatment alone cannot greatly impact the livelihoods of rural communities who might be illiterate or lack adequate information and resources.[13] Moreover, these communities, that have been exposed to poor sanitary conditions for most of their lives, do not often consider the routes to healthier and hygienic living. In the context of these living conditions the lack of availability of improved wastewater management might be only one of many sanitary challenges.

Natural watersheds comprise various types of land use from where rainwater is drained through a common outlet, for instance a lake or river, and can therefore vary in capacity from a few to a million hectares. Watersheds are also socio-political-ecological entities that play a crucial role in determining, social, economic and food security and provide life support services to rural populations. The holistic management of natural resources can give stability to crop incomes during drought, therefore a number of watershed projects have been undertaken in villages to compare crop yields. For example, while the share of income from crops in an average household declined from 44% to 12% in the non-watershed project villages, crop income remained largely unchanged from 36% to 37% in the watershed village.[14]

An integrated watershed management approach has proved to be a suitable strategy for water resource conservation as

One in a series of small check dams constructed in the drainage line provide groundwater recharge zones at regular intervals in the watershed

well as for efficient and sustainable water use. The current model of watershed management adopted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners includes environmentally-friendly options and the use of new technology which, along with a consortium approach to management, enables the empowerment of communities through capacity building and the convergence of every project activity within the watershed.

The long-term success of any decentralized scheme depends on building awareness, competence and a sense of ownership in the local community. Thus, social engineering is critically important. A community keeps its own undocumented knowledge about the locality, including land and water ecosystems. Often, villagers are aware of the limiting factors but lack complete information about constraints to productivity and cannot provide optimum solutions to these problems. For example, in one of the projects, farmers understood that the yield of groundwater wells or bore/tubes was decreasing, but they tried to resolve it by digging another well or extending the depth of the existing bore. Another typical example concerns fertilizer usage, where farmers understand the importance of fertilizers for crop growth, but do not understand that fertilizers are designed to supplement the available nutrients in soil. Inappropriate information, offered to bridge the gaps in knowledge, might achieve short-term success but might not provide sustainable solutions.

The adoption of resource management through rain water harvesting; ground water recharge; wastewater management; pollution abatement of drinking water sources; utilization of biomass for biogas or organic manure production; recommendations based on soil testing; and scientific pest management offer more sustainable approaches.[15] Such interventions create an atmosphere of ownership and trust among the rural communities towards scientific interventions, often critical to their sustainability.[16] The traditional approach of centralized planning and implementation has to be replaced with co-planning and participation, involving the local community.

Rainwater harvesting and groundwater recharge

Groundwater levels are depleting as pressure on water resources is increasing to satisfy the needs of a growing population. Climate change is also disturbing the hydrological cycle as extreme rainfall events have reduced the time over which groundwater recharges. This global issue of water scarcity may be addressed locally by groundwater augmentation through rainwater harvesting at micro-watershed level; efficient use of green and blue water; and the safe reuse of greywater. For example, in a semi-arid region with annual rainfall of 800mm, a 1,000ha micro-watershed has potential to harvest 240,000m^3 of rainwater, which might be equivalent to the irrigation requirement of 40–50ha of agricultural land or the domestic water supply to 1000 households for 600 days. The comprehensive assessment of watershed development in India observed that current technologies are well suited to medium rainfall ecoregions – 700 to 1,100mm annually – and were better in terms of benefit-cost ratio and other parameters[17], whereas regions with rainfall of less than 700mm and those of higher than 1,100mm failed to generate equal benefits because of the scarcity of water on one hand and excessive water availability on the other[18]. As one size does not fit all, different soil and water conservation practices should be defined taking into account the varying rainfall and soil types of the agro-ecoregion, with budgetary allocations for different interventions as needed rather than imposing a system of fixed allocations across the country. There is also need to consider climatic variability including frequency of extreme events while designing a water harvesting protocol. Earlier studies have demonstrated the benefits of low-cost water harvesting structures throughout the toposequence, which benefited a greater number of farmers than the construction of masonry check dams would have done.[19]

The risks of raw wastewater irrigation

A global municipal wastewater discharge of about 330 million m^3 per year can potentially irrigate 40 million hectares[20], or 15% of all irrigated lands. Globally, about 5 to 20 million hectares of land is being irrigated with raw wastewater[21] which is about 2 to 7% of the total irrigated area. However, inappropriate reuse of untreated wastewater is unsafe for farmers' as well as consumers' health.[22] Farmers, oblivious to the potential harm of raw wastewater on human and soil health, utilize it for irrigation during the dry summer months.

Table 1: Details of the constructed wetlands implemented at field scale

Location	Units	Capacity (m^3 day-1)	Collaboration partner/s
ICRISAT, Telangana	1	28	ICRISAT
SAB Miller, Telangana	1	50	ICRISAT, SAB Miller
Kothapally, Telangana	2	35	ICRISAT
Bhanur, Telangana	1	56	ICRISAT, NGO, Asian Paints
Nagolpally, Telangana	1	30	ICRISAT, NGO, Govt. of India
Sangareddy, Telangana	1	10	ICRISAT, NGO
Mahboobnagar, Telangana	1	10	ICRISAT, RECL, NGO
Jhanshi, Uttar Pradesh	1	2	ICRISAT, CAFRI, NGO, Govt. of India
Kurnool, Andhra Pradesh	1	51	ICRISAT, NGO, Power Grid Corp
Kolar, Karnataka	1	10	ICRISAT, NGO, Coca-cola
Chikkaballapur, Karnataka	3	80	ICRISAT, Govt. of Karnataka
Chikkmangalur, Karnataka	6	180	ICRISAT, Govt. of Karnataka
Bijapur, Karnataka	2	90	ICRISAT, GoK, Power Grid Corp
Bellary, Karnataka	2	64	ICRISAT, NGO, JSW Foundation
Tumkur, Karnataka	8	160	ICRISAT, Govt. of Karnataka

CAFRI: Central Agroforestry Research Institute; RECL: Rural Electrification Corporation Limited

Table 2: Wastewater treatment efficiency of the constructed wetland at SAB Miller, Sangareddy

Sl No.	Parameter	Unit	Inlet	Outlet	Removal Efficiency (%)
1	Calcium	mg/L	95.69	88.45	7.6
2	Chemical oxygen demand	mg/L	96	21.1	78
3	Chloride	mg/L	174	166	4.6
4	Electrical conductivity	ms/cm	2.39	2.12	–
5	Potassium	mg/L	58.89	58.72	0.3
6	Magnesium	mg/L	35.23	32.82	6.8
7	Sodium	mg/L	239	197	17.6
8	Inorganic nitrogen	mg/L	18	3.96	85
9	pH at 25°C	–	7.98	8.78	–
10	Phosphate	mg/L	1.88	1.17	37.8
11	Sulphate	mg/L	2.83	0.48	83
12	Total dissolved solids	mg/L	2019.50	1432	29.1
13	Total alkalinity	(mg/L as CaCO3)	406	315	22
14	Total hardness	(mg/L as CaCO3)	410	340	17
15	Sodium absorption ratio	–	5.3	4.5	–

Source: ICRISAT

Constructed wetlands are the one of the most cost-effective solutions for treating wastewater at community level

Indeed, raw wastewater irrigation is a centuries-old practice, particularly in the dry summer months. Now, however, market demand, soil health, rainfall patterns, and the characteristics of the wastewater itself, have changed, making it necessary to question this ancient practice.

Apart from nutrients such as nitrogen, sulphate and phosphate, raw wastewater often contains pathogens, salt, suspended solids, xenobiotics and heavy metals, although wastewater generated by resource-poor semi-arid tropical villages rarely shows heavy metal contamination comparable to urban or peri-urban wastewater. The salt and suspended solid deposits can significantly deteriorate the physical property and fertility of the soil exposed to prolonged raw wastewater irrigation, particularly in the semi-arid tropics where rainfall is often too little to wash the contaminants from the top soil through run-off.

The pathogens present in wastewater pose a risk to the farmer, consumer and other stakeholders in the value chain, particularly when salad crops and vegetables are grown using raw wastewater. Many farmers accept the health risks of parasitic worms, protozoa, viruses, and bacteria as occupational hazards as they cannot afford treatment for some of the health problems caused by exposure. Farmers irrigating with wastewater tend to have higher rates of helminth infection than those using freshwater.[23] Infection to skin and nails may also occur among these farmers.[24] In the absence of proper labelling, consumers and retailers often remain unaware of the health risks of such pathogen-infected farm produce, for instance helminth infections.

The potential of constructed wetland to enable better rural wastewater management

It is estimated that, unlike developed nations which treat about 70% of their wastewater, the treatment capacity of countries located in the semi-arid tropics is between 8 and 28%.[25] Conventional sewage technologies, which are difficult to maintain and operate to full capacity even in urban environments, seem unlikely to be the solution to wastewater pollution in resource-scarce villages.[26] Constructed wetlands (CW) are considered to be a technical, economical, and environmentally sustainable solution for wastewater treatment in small communities since they are efficient in removing diverse pollutants.[27] The various types of CWs used over the last four decades can be grouped into two broad categories: Free Water Surface (FWS) wetlands, which involve the use of a pond, and Subsurface Flow (SSF) wetlands, which make use of dry surfaces. One major advantage of SSF-CWs, though slightly more expensive than FWS-CWs due to the cost of the filtering medium, is better control of mosquitos.

Despite their apparent simplicity, CWs are complex ecosystems created and influenced by many physical, chemical and biological processes. The CWs involve basic biogeochemical processes such as filtration, sedimentation, plant uptake or phytoremediation and microbial degradation in removing contaminants from wastewater. Such systems, devoid of chemicals and moving mechanical parts, have a low operating and maintenance cost. As common gardening skills are sufficient to maintain the system, CWs are a feasible wastewater management solution for small, rural communities with a limited power supply and resources.

The performance of CWs is being evaluated in the field as part of an ongoing Indo-European Union project, Water4Crops, funded by the Department of Biotechnology, Government of India (€3 million) and the European Union's Seventh Framework program (FP7) (€6 million). The project has involved 22 European and 12 Indian partners. The experimental facility at ICRISAT provided scope to compare the phytoremediation potential of several macrophytes in different combinations over a period of three years for the greywater generated by a nearby urban household. A total of twelve constructed wetlands sown with different plant species: *Typha latifolia*, *Cana indica*, *Cymbopogon sp.*, *Pennisetum purpureum*, *Pennisetum purpureum* X *Pennisetum americanum*, *Brachiaria mutica*, and floating macrophytes such as *Eichornea crassipes* and *Pistia stratiotes* were evaluated. Studies with SSF[28] as well as FWS-CWs[29] have clearly shown potential. SSF-CWs sown with *Typha latifolia* and/or *Cana indica* were found to be the most efficient and flexible and were subsequently scaled-up.

Demonstration of constructed wetland in villages

The scaling up of CWs in different villages has been carried out as part of various developmental projects supported by the Indian government and Corporate Social Responsibility projects (Table 1) to reveal possible bottlenecks at a technical, social or policy level. The existing trust base in different watersheds towards scientific development has now given the confidence for CWs to be used for the treatment of wastewater in these villages. The scaling up process involves several stages including an awareness campaign, site selection, construction, commissioning and the reuse of treated wastewater for safe irrigation practices. In the watershed villages, construction and commissioning was carried out involving local NGOs, partners and villagers. The activity was selected as part of an ongoing project, named *Bhoo-Samrudhi*, and was funded by the Government of Karnataka. The site-selection and design of suitable locations in various districts covered under the project were provided to the district authorities by the Panchayat Raj Engineering Department, Karnataka.

Images: ICRISAT

Constructed wetland sown with *Cana indica* at SAB Miller, Sangareddy, Telangana, India. Top: November 2015; bottom: January 2016

Constructed wetland for the treatment of industrial effluent
A small CW was commissioned at the Sangareddy campus of SAB Miller, a large brewery, to investigate the bioremediation potential of industrial wastewater. The CW comprised two chambers; a 20m x 20m x 1m sub-surface cell and a holding tank of the same capacity for the treated wastewater. The sub-surface cell featured a 250mm-deep layer of 40mm-diameter gravel at the bottom, covered with two successive layers of medium (20mm) and small (10mm) gravel, each to a depth of 250mm. A 150mm layer of 1.5mm coarse sand constituted the top layer. The CW was sown with *Cana indica* during November 2015 and the plants were established by January 2016. The hydraulic loading rate was 60m^3/day and the CW operated with a hydraulic retention time of approximately three days. The average wastewater treatment efficiency of the wetland is given in Table 2. The pH value of the wastewater remained in the alkaline range throughout the trial, both at the inlet and the outlet of the CW. The chemical oxygen demand (COD) as well as the inorganic nitrogen removal efficiency (RE) were 78% and 85% respectively. The treated wastewater COD of 21mg/L was much less than the limit of 250mg/L prescribed by the Central Pollution Control Board of India (CPCB, India) for irrigation suitability. The phosphate removal efficiency was 37.8 %.

The high salt concentration was reflected in the electrical conductivity reading of above 2ms/cm for both the inlet and outlet (the 2010 CPCB irrigation standard is set below 4 ms/cm). The overall sodium absorption ratio (SAR) indicated little change between inlet and outlet but fell well short of the 2009 CPCB standards which sets the SAR limit at 26. The treated wastewater had 166mg/L chloride which is less than the The Food and Agriculture Organization of the United Nations standard of 354mg/L. However, alkalinity – the measure of dissolved carbonates, bicarbonates, and hydroxides concentration – in the wastewater was much greater than the desirable 100mg/L limit for agriculture. The combination of high alkalinity and high pH therefore reduced the potential of use for irrigation of the treated wastewater. The treated wastewater was subsequently used for sugar cane cultivation in the adjacent black soil fields with a yield of 43t per acre.

Images: ICRISAT

Phases of sugarcane cultivation at SAB Miller, Sangareddy, Telengana, India, showing: planting; cane sprouting; 38 days after planting; 90 days after planting

Domestic water supply and sanitation in Libya

Omar Salem, General Water Authority, Libya

Libya is an arid country in north-central Africa with a surface area in excess of 1.75 million km² and a Mediterranean coastline of around 1,800km. More than 90% of the country forms part of the Sahara desert, with only the eastern and western coastal strips receiving measurable precipitation, ranging from an average of 150 to over 500mm annually. The country is among the most water-scarce in the world, with renewable water resources of less than 600 million m³/year and a per capita share of 100m³ that will be reduced to less than 75m³ by the year 2030.

Controlled surface water resources are in the order of 60 million m³ and contribute only a small fraction of the total water use, currently estimated at 5.6 billion m³/year, while groundwater accounts for 97% and the remaining 1.5% comes from desalination and wastewater treatment.

During the last six decades, the population has increased from 1.09m in 1954 to 5.66m in 2006, an average annual growth rate of 3.2 % for the period. The present population is estimated at 6.4m and could exceed 8m by the year 2030. The average population density is around 3.6 inhabitants/km² and over 400 inhabitants/km² in the coastal strip.

Economic conditions in Libya have improved steadily since the discovery of oil and gas reserves in the late 1950s, which led to the rapid expansion of irrigated agriculture, urbanization and industrial activities. Signs of water shortage began to emerge in the early 1970s with a decline in water level and a deterioration in the quality of water in the shallow fresh-water aquifers due to seawater intrusion around major urban agglomerations and areas of intensive irrigation.

The volume of water potentially available for use is in the order of 3,820 million m³, of which 170 million m³ is surface water, 650 million m³ is annual recharge to groundwater aquifers and 3,000 million m³ is an acceptable depletion rate of the non-renewable aquifers. Accordingly, the estimated deficit in the water balance has grown from 65 million m³ in 1995 to 1,308 million m³ in 2005, mostly in the Gefara plain. Hydrogeological studies and surveys have confirmed that Libya is increasingly depleting its precious groundwater resources, most of which are presently non-renewable. In 2006, only 13% of the groundwater used was renewable and the front of seawater intrusion was advancing hundreds of meters every year, threatening the traditional supply sources of potable water. Elsewhere, water quality deterioration and signs of pollution were emerging concurrently with aquifer overexploitation, jeopardizing the continuity of the water supply and entailing heavy financial burdens.

In Libya, 80% of the population lives in urban centres varying in size from 5,000 to over 1m inhabitants, relying mostly on the municipal water supply. In rural areas, people depend on private wells, rainwater collection, springs or truck-mounted water. Domestic water accounts for 12% of the total water in use and despite severe scarcity, the average per capita consumption is among the highest in the region at 450 l/c/d.

In 2010, desalination accounted for 13% of the total domestic use, dropping to 12.4% in 2012. In 2015, the total municipal water supply reached 601 million m³ with only 7.85% from desalination. Projected demand will be close to 1 billion m³/year by 2030, compared to only 420 million m³ in 1990, reflecting an annual growth rate of 2.2% which is slightly higher than the projected population growth rate.

The urban population increased from 27.3% in 1960 to 60.7 in 1980 and 79.9 % in 2017 and may exceed 82% by 2030, which is much higher than the average proportion in Africa

Phases of the Great Manmade River project

Phase	I	II	III	IV	V
Source location	Sarir – Tazerbu	Hasawnah (Murzuk Basin)	South Kufra	Ghadames	Sirte
Status	Completed	Completed	Planned	Under construction	Completed
Destination	Benghazi – Sirte	NW-coast, Misurata – Tripoli – Jebel Nafusa	Tazerbu, to enhance Phase I	Zwara and W-coast to Zawia	Sedada
No. of wells	234	586	285	144	To connect Phase I with Phase II
Daily production (million m³)	2	2.5	1.68	0.246	
Length (km)	1600	1676	383	621	190

Source: GWA

Image: GWA

The 40,000 m^3/day Butraba desalination plant, constructed in 2007 for domestic water supply to Al Marj city and surrounding urban areas in north-east Libya

overall. Population growth and rapid urbanization have placed tremendous pressure on the scarce water resources and the fragile ecosystem.

More than 40% of the total area of Libya, particularly the northern parts, is underlain by high salinity aquifers of up to, or exceeding, 5g/l. This is further complicated by seawater intrusion in the most populated areas along the Mediterranean coast.

Previously, most domestic water supplies were produced from local wellfields or individual municipal wells, in addition to scattered irrigation wells in rural areas, with total dissolved solids (TDS) ranging from less than 500mg/l to over 2,000mg/l.

Intensive groundwater extraction near the two largest cities of Tripoli and Benghazi has rendered the water unsuitable for direct use. In 1988, the TDS value of the Benina wellfield south of Benghazi reached 3,000mg/l, and that of the Swani wellfield south of Tripoli, 10,000mg/l by 1993. As a provisional solution, these two major wellfields and several others were shut down to be replaced by new wellfields in relatively more suitable locations.

As the demand for water used in agriculture, accounting for nearly 78% of the total use, continued to rise, it became difficult to maintain an uninterrupted municipal supply of acceptable quality. This was more pronounced in the Gefara plain along the north-west coast of Libya, which includes the capital, Tripoli, and incorporates over 100,000ha of intensive irrigation and nearly 47% of the Libyan population.

A master plan for the management of water resources in this area was launched in 1978 in cooperation with the Food and Agriculture Organization (FAO) and resulted in a number of recommendations to alleviate the problem including inter-basin water transfer from the Murzuk basin in the south of the country.

It then became widely accepted that planned groundwater mining could provide the opportunity for water supply sustainability within a foreseeable timeframe, and that it could also be progressively modified as water technology advances.

In 1983, based on the promising results of detailed hydrogeological studies as well as the continuous monitoring of the groundwater aquifers in the major sedimentary basins of Kufra, Sarir, Tazerbu and Murzuk, the world's largest groundwater conveyance scheme known as the Great Manmade River (GMR) was approved. The project taps freshwater aquifers, via hundreds of wells ranging in depth from 400 to 800m, and conveys the water through 4m-diameter prestressed concrete pipelines for over 4,000 kilometers to the major urban and agricultural areas along the Mediterranean coast. Two pipe manufacturing plants, capable of producing 200 of the 75t pipes every day, were constructed for the purpose. A number of reservoirs of up to 24 million m^3 in size and a total storage capacity of 55 million m^3 are annexed to the water conveyance system. The project comprises several phases and has the potential of transporting over 6.4 million m^3/day.

The proportion of GMR water allocated for domestic use was initially set at less than 20% but modified later to 37.5% to cope with the steady increase in demand since the first arrival of the conveyed water to Benghazi in 1991 and to Tripoli in 1996.

By 2010, 73 sewage treatment plants with a total capacity of 220 million m^3/year have been built and 48% of households were connected to sewage collection networks, but with a significant difference between municipalities in the rate of connection ranging from 9.5% to 91%. Operation and maintenance was, however, inefficient and in 2010, only nine of the 73 plants were still operating and the treated wastewater dropped to 22 million m^3. Moreover, only four of these nine plants continued to operate after 2010. Five new plants were added later to reach an output of 37 million m^3 in 2015.

Similarly, desalination has evolved significantly in the past few decades, but still faces inherent operational difficulties that have become more pronounced in recent years.

The arrival of the GMR water has markedly reduced the dependence on local groundwater as a main source of domestic water supply. Accordingly, the contribution of the local wellfields declined from 42% in 2005 to only 30% in 2015, while that of the GMR has risen from 47% to 62% for the same period. This ratio is expected to grow even further in favour of the GMR.

In 2012, it was reported that 64.5% of the population is served through public water supply networks, while 17.4% depends on private wells for water needs and 16% relies on rainwater collection. The remaining small proportion relies on other sources such as springs or purchasing truck-mounted water.

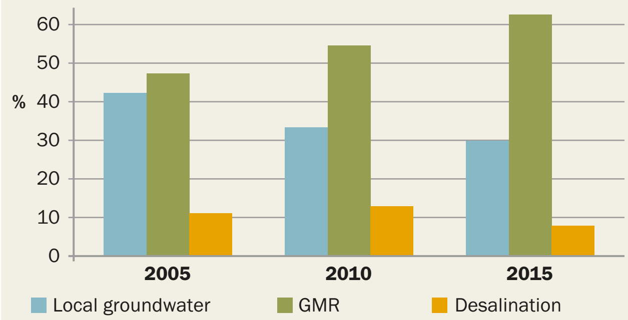
According to the 2014 Africa Water and Sanitation Sector Report, Libya is among the very few countries in Africa that met the millennium development goals (MDGs) as the proportion of its population with access to improved water supply and improved sanitation has reached 92% and 99% respectively in the year 2013, compared to 71% and 84% in 1990.

The MDGs expired at the end of 2015 and are replaced by the Sustainable Development Goals (SDGs) and, in particular, Goal 6 to "ensure availability and sustainable management of water and sanitation for all by 2030". SDG 6 is in line with national water strategies and its implementation will therefore be of utmost importance in response to Libya's international and continental commitments.

Few strategies were adopted in recent years to manage the water supply and sanitation sector. The National Strategy for Water Resources (2000–2025) is a comprehensive plan aiming at reducing the water budget deficit and preventing further water quality deterioration. It calls for redefining the priorities of water use; enhancing the contribution of non-conventional water resources; defining future supply options, in particular inter-basin water transfer and seawater desalination; improving water use efficiency; reviewing agricultural policies and practices; investing in capacity building and institutional reforms; improving legislation and water pricing; and controlling population growth.

The National Programme for Water and Sanitation was launched in 2005 for a intermediary period of three years before finalising water and wastewater plans for all municipalities. The programme was centrally managed by the Ministry of Planning and was later transferred to the newly formed Housing and Utilities Board in 2006 to be replaced by the Integrated Utilities Program for the 400 cities and urban areas of Libya.

Sources of domestic water supply



Source: GWA

In 2007, a Ministry for Electricity, Water and Gas was established and immediately embarked on a long-term strategy for the urban water sector covering the period 2007–2025 along with a five year plan for the period 2007–2012. Parallel to that, a strategy for urban and rural wastewater was prepared while an organization analysis was also conducted for the water and wastewater sectors.

All of these strategies have been preceded by diagnostic analyses of the national water and wastewater position, forming the basis for action plans that aim, among other goals, to reduce per capita consumption; increase supply coverage and reliability; reduce leakage and increase wastewater treatment capacity. Other measures include phasing out of coastal wells to stop seawater intrusion; maximizing the GMR supply for regions near the main lines; introducing desalination for coastal areas when the GMR option becomes too expensive; and ensuring adequate back-up through keeping wells in reserve and increasing storage capacity. Detailed plans for institutional reforms to strengthen the role of government institutions and public utility companies have also been presented.

However, the instability of institutional structures and the lack of qualified human resources have impeded the implementation of most action plans and programmes. Moreover, the political and economic conditions that prevailed during and after the embargoes and sanctions imposed on Libya in the 1980s and 1990s, and the fall in oil prices during the same period, have led to serious budget cuts.

Starting in 2011, the country has undergone a period of political and economic instability that has led to the suspension of most development projects. This phase and its implications may extend for several years to come.

Libya has invested heavily in achieving a robust and efficient water supply and sanitation system, but has been unable to sustain the gradual growth of this sector due to the low technical capacity and the political and economic instability over the past four decades. Nevertheless, Libya is potentially capable of meeting SDG 6, provided that it soon regains stability, and to achieve this, there will be an urgent need to quickly mobilize large investments to implement new water and sanitation projects and renovate existing ones.

In the years to come, development priorities will certainly change, and the country may therefore lag behind, especially with respect to wastewater treatment and reuse.

Strategies for transforming the Malaysian water sector

Shahrizaila Abdullah, Fateh Chand, Salmah Zakaria and P Loganathan, Academy of Sciences Malaysia

Malaysia is a constitutional monarchy and a federation of 14 states, including one federal territory, with each state granted autonomy in the management of its natural resources. Since the early 1990s, Malaysia has embarked on its *Vision 2020* to attain Developed Nation status by the year 2020.

Renewed efforts to accelerate the process of achieving this goal were made in 2010 with the launching of the National Transformation Programme (NTP) comprising a Government Transformation Programme (GTP) and an Economic Transformation Programme (ETP). The ETP comprises 12 National Key Economic Areas (NKEAs) representing economic sectors considered significant in contributing to gross national income and job creation. However, the water sector had not been included as an NKEA, despite its importance nationally as a resource for both livelihood and its supporting of all sectors of the economy.

In order to correct this oversight, the Academy of Sciences Malaysia (ASM), the country's leading thought leader in science, technology and innovation, has since 2008, undertaken in-depth thematic studies pertaining to the water sector on a range of topics such as river basin management; lake basin management; groundwater management; water supply and wastewater management; water demand management; water research and development; agriculture water management; water and climate change; and urban water management. These studies were further complemented by desk studies and expert reviews on auxiliary topics such as water and land use; water and health; water and green growth; water and gender; science and technology awareness; advocacy and capacity building; virtual water; and the water-food-energy nexus.

The extensive knowledge base gained through these studies enabled ASM to develop a comprehensive strategy to address the issues and challenges facing the Malaysian water sector. These efforts have resulted in ASM publishing a two-volume report entitled: *Transforming the Water Sector: National Integrated Water Resources Management Plan – Strategies and Road Map* which was formally launched by the Honourable Minister of Science, Technology and Innovation, Malaysia in December 2016.

Image: ASM

The 12 National Key Economic Areas (NKEAs) under the Economic Transformation Programme

Image: ASM

The Hon. Minister of Science, Technology and Innovation, Wilfred Madius Tangau (third from left) launching the report with Academy of Sciences Malaysia President, Ahmad Tajuddin Ali. With them are (from left) Chief Editor, Shahrizaila Abdullah and Secretary General, Ministry of Science, Technology and Innovation, Mohd Azhar Yahaya

Image: ASM

The National Water Resources Council, established in 1998, holding its 12th meeting on 2 August 2017, chaired by the Hon. Deputy Prime Minister of Malaysia, Ahmad Zahid Hamidi

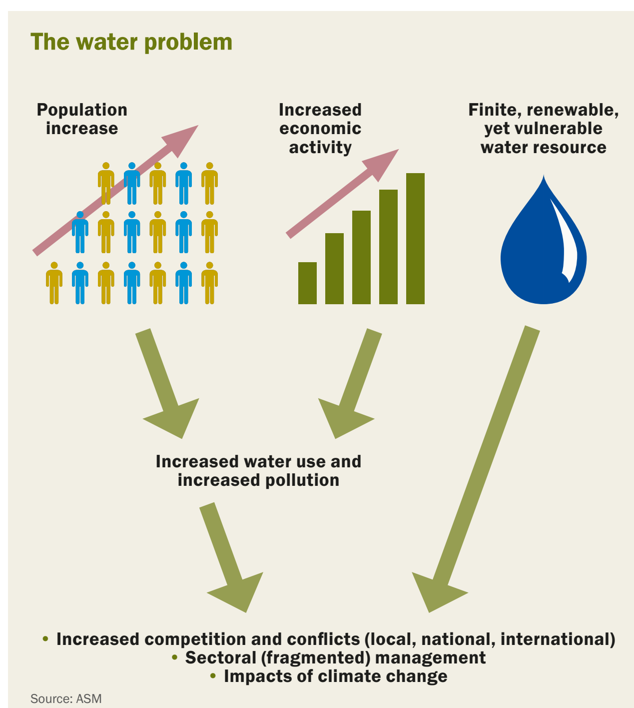
Located in the tropics, Malaysia has abundant rainfall. Studies have shown that the adequate provision of quality water to meet the country's short-, medium- and long-term needs is not dependent on the availability of water resources but on the provision of sound management and good governance at both national and state levels. Some of the water-related issues and challenges that need to be addressed nationwide are outlined as follows: regional water stress affecting some of the water-deficient states; flooding as a result of seasonal torrential rains brought by south-west and north-east monsoons; pollution of water sources in lakes and rivers coupled with environmental degradation as a result of large-scale land development, urbanisation and industrialisation; fragmented management and conflict among sub-sectors; and impending climate change impacts. In short, since gaining independence in 1957, Malaysia has, through investments in water infrastructure over sequential five-year development plans, successfully ensured that water has been adequately and progressively provided for people, food production, agriculture and rural development, economic development, and energy.

Penetration of clean water supply and sanitation currently averages 95% of households nationwide. Disruptions have occurred only during extreme drought conditions, leading to water rationing in some states. On the other hand, the studies also indicate that the country has fallen short in sustainably managing its water resources. Despite a formal declaration and adoption of the Integrated Water Resources Management (IWRM) policy since the turn of the century, its implementation to date has yet to gain adequate traction on a national scale.

Only minimal and sporadic successes have been reported. Notable achievements are: the establishment of the National Water Resources Council in 1998, an apex body chaired by the Honourable Deputy Prime Minister of Malaysia, charged to oversee water resources management at national level; the legislation of a contemporary Waters Enactment[1] in the state of Selangor in the year 2000; the creation of the Federal Ministry for Natural Resources and Environment in 2004, ensuring the separation of powers between water resources management and water utilities provision; the rationalisation of the water services industry through the passing of the Water Services Industry Act and the Water Services Commission Act in 2006; and the launching of a long overdue National Water Resources Policy in 2012.

However, the legacy of fragmented management prevails at national level and the situation in the states is no better, with few exceptions. This can be attributed largely to governance issues stemming from the lack of a robust and uniform policy, and a legislative and institutional framework for the holistic management of the country's water resources both at federal and state administration levels.

Against this, ASM's initiative in undertaking comprehensive studies of the water sector, leading to the formulation and launching of the two-volume report, was indeed timely. Apart from complementing the NTP and ETP, the strategies and roadmap represent critical inputs in meeting Malaysia's commitment to post-2015 SDGs pertaining to SDG 6 and



Total consumptive water demand against total surface water availability for all sectors

State	Land area sq km	Total consumptive water demand (MCM)					Effective rain (MCM/ year)	Excess/deficit (MCM) – unregulated flows				
		2010	2020	2030	2040	2050		2010	2020	2030	2040	2050
Perlis	821	306	299	286	284	281	60	(246)	(239)	(226)	(224)	(221)
Kedah	9,500	2,922	2,976	2,842	2,873	2,876	1,070	(1,852)	(1,906)	(1,772)	(1,803)	(1,806)
Pulau Pinang	1,048	765	829	835	874	894	130	(635)	(699)	(705)	(744)	(764)
Kelantan	15,099	1,632	1,619	1,586	1,600	1,604	2,650	1,018	1,031	1,064	1,050	1,046
Terengganu	13,035	884	975	970	999	1,026	3,310	2,426	2,335	2,340	2,311	2,284
Perak	21,035	1,949	1,923	1,798	1,801	1,811	3,140	1,191	1,217	1,342	1,339	1,329
Selangor	8,396	2,238	2,491	2,570	2,760	2,922	960	(1,278)	(1,531)	(1,670)	(1,800)	(1,962)
Pahang	36,137	726	946	897	911	959	6,460	5,739	5,514	5,563	5,549	5,501
Negeri Sembilan	6,686	340	361	358	366	374	640	300	279	282	274	266
Melaka	1,664	323	366	376	409	439	140	(183)	(226)	(336)	(269)	(299)
Johor	19,210	715	881	1,033	1,164	1,301	3,290	2,575	2,409	2,257	2126	1,989
Pen Malaysia	**132,631**	**12,800**	**13,666**	**13,551**	**14,041**	**14,487**	**21,850**	**9,055**	**8,184**	**8,139**	**7,809**	**7,363**
Sabah	73,631	912	1,356	1,392	1,442	1,469	16,210	15,298	14,854	14,818	14,768	14,741
Sarawak	124,450	1,054	2,162	2,125	2,175	2,247	27,440	26,386	25,278	25,375	25,265	15,193
WP Labuan	91	18	24	26	28	29	30	12	6	4	2	1
East Malaysia	198,172	1,984	3,542	3,543	3,645	3,745	43,680	41,696	40,138	40,197	40,035	29,935
Total Malaysia	**330,803**	**14,784**	**17,208**	**17,094**	**17,686**	**18,232**	**65,530**	**50,751**	**48,322**	**48,336**	**47,844**	**37,298**

Source: National Water Resources Study, 2011

specifically in relation to the target to "implement integrated water resources management at all levels" by 2030.

Preparation of the National Integrated Water Resources Management Plan (NIWRMP) is largely based on the knowledge base developed from thematic studies and expert reviews of some 24 water management related topics, some of which have been reported above. Additional desk studies were also undertaken focusing on the extent to which the states have committed to, and progressed in implementing IWRM, since ownership is vested with respective state governments as directed under the federal constitution.

An important feature of the plan preparation process involving the many thematic studies is the formation of ASM task forces to lead these studies. Each task force comprises an ASM Fellow as the Chair, and co-opted subject matter specialists drawn from the public/private/civil society sector, and academia as members. The approach to each study is multi-disciplinary and consultative through the engagement of all relevant stakeholders from the public, private and civil society sectors.

The NIWRMP is a synthesis of the strategies extracted from the thematic and state level studies, organised in the manner of an IWRM general framework originally developed by the Global Water Partnership (GWP). It comprises four discrete elements: enabling environment; institutional framework; management instruments; and investments in water infrastructure. For each category and strategy, a roadmap is included for implementation over a 15-year timeframe until 2030, the target year set by UN for the realisation of the SDGs. The roadmap is formatted such that each discrete element is split into two halves: Water as a Resource and Water for Livelihood, targeting the achievement of balanced development goals.

A total of 25 recommendations broken down into distinct categories accompanies the NIWRMP. A summary of these recommendations is appended below:

1 **General**: A central recommendation calling for the adoption and implementation of the NIWRMP, thereby providing the stimulus to transform the water sector for a better future. The plan's components will be implemented nationwide and concurrently by the key ministries and respective state administrations.
2 **Enabling environment**: Ten recommendations to address policies, legislation, regulations and finance, among which is the need for an over-arching Integrated Natural Resources Policy; a contemporary National Water Resources Act; and funding arrangements and protocols, especially pertaining to environment rehabilitation works.
3 **Institutional framework**: Five recommendations that focus on the review and strengthening of governance through the institution of oversight and implementation management structures at national, state, river basin and local hierarchical levels, as well as a call for greater intra-ministerial integration.

Images: ASM

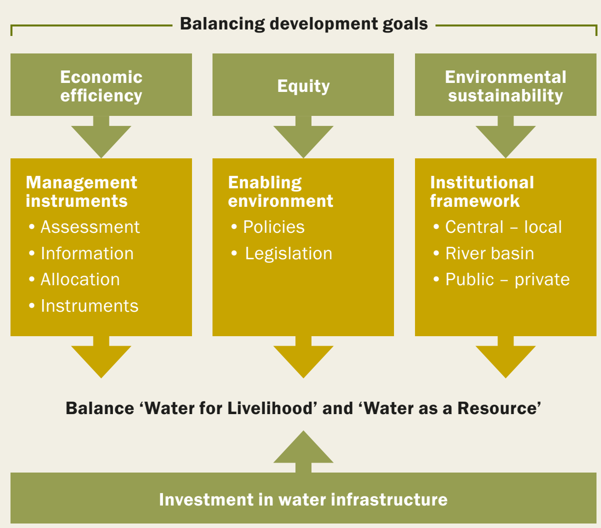
Community-based river care programmes. (Top left) river adoption activity involving urban communities; (Top right) awareness-raising activities targeting school children; (Bottom left) river quality monitoring by local communities; (Bottom right) river quality assessment involving schools

4 **Management instruments**: A further five recommendations to stress the need for the establishment of a central IWRM database built around river basin platforms; the use of economic, financial and technical instruments for greater water use efficiency and accountability and to curb abuse; the implementation of a national agenda for integrated water research; the provision of mechanisms for promoting green growth; and the pooling of resources to establish one-stop capacity building centres to improve skills and raise competence at all levels.

5 **Investment in water infrastructure**: Urgent investment in water infrastructure is recommended to cater for the national water sector needs and to spur the sector's transformation. 15 major programmes with a corresponding 95 Entry Point Projects (EPPs) were identified and broken down into three sub-programmes, namely: five cross-cutting programmes involving 14 EPPs, five programmes related to Water as a Resource involving 48 EPPs, and five programmes related to Water for Livelihood involving a further 33 EPPs.

6 **NIWRMP implementation management structure**: A recommendation for the plan to be managed nationally at the highest political level by the National Water Resources Council, and at state level by the State Water Resources Council, with the support of a National Steering Committee (NSC) to oversee the implementation, and assisted by a National Technical Committee to resolve technical issues. Formation of a dedicated IWRM Implementation Unit is also recommended, reporting to the NSC to ensure the timely and coordinated implementation of the plan.

Integrated water resources management – general framework



Source: ASM

Application of a wastewater treatment system for river restoration with public participation

Dr Rofiq Iqbal, Assistant Professor, Head of Environmental Infrastructure Engineering, Institute of Technology, Bandung, Indonesia

The Citarum River area, West Java, Indonesia has seen rapid urbanization over the last 20 years, causing an increase in polluted water, as well as flooding by untreated household sewage, solid waste and industrial effluents, affecting public health and threatening the livelihood of the low income communities surrounding the river. The Citarum has become one of the most contaminated rivers in the world, although it continues to be used as the main water supply, serving the daily needs of approximately 5 million residents. It is also the main source of flooding due to the impact of climate change.

For this reason, the United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP), together with the Ministry of National Development Planning of Indonesia (BAPPENAS), have created a policy and strategy, using the paradigm of green growth development, to promote an eco-efficient water infrastructure for Indonesia. The strategy has already contributed to increasing awareness and advocacy of eco-efficient approaches in the development of water infrastructure.

BAPPENAS requested that ESCAP continued its support to develop an implementation roadmap as well as pilot demonstration projects on integrated rainwater and wastewater management systems by involving local institutions to enhance the awareness of eco-efficiency at local government and community levels.

The resulting pilot project was designed to support one of the key national initiatives promoted by the Indonesian government to ensure water security in the Citarum River region. The project aims to strengthen the capacities of city government officials and other local stakeholders to manage the effects of climate change through the implementation of capacity building programmes.

The Institute of Technology, Bandung (ITB) was chosen to carry out the pilot project in Kampung Tanggulan, Bandung, West Java. An initial assessment of the river showed a deteriorating stream quality, with biochemical oxygen demand (BOD) up to 5.39 mg/l, and chemical oxygen demand (COD) up to 50 mg/l. The river water in the vicinity of domestic waste influent was more severe, where BOD reached up to 140 mg/l and COD up to 523 mg/l. One of the reasons for deterioration was that domestic wastewater, especially greywater, was flowing directly into the river without treatment.

Another problem was the erosion of the river banks and bed which resulted in shallowing, further rendering the

River water quality

Parameter	Units	River water quality	Water near domestic waste influent
Colour	Pt-Co	30	30
Turbidity	NTU	3.23	59
TSS	mg/	90	64 – 193
Temperature	oC	24.7	22.4
pH	–	7.47	7.34
COD	mg/l	50	111 – 523
DO	mg/l	8.56	8.51
BOD	mg/l	5,5	140
Total Nitrogen	mg/l	25.8	29.5
Total Phosphate	mg/l P	11.05	10.2
Fe	mg/l Fe	0.48	0.72
Mn	mg/l Mn	0.144	0.159

Source: IoT

Image: IoT

Condition of the river before work commenced

Construction of Floating Treatment Wetlands by the local community

river a health hazard to the community. However, despite its quality, the river has still been used as a water source for daily use, with local communities using it for washing clothes. The river is also used as a water source for a public toilet. The objectives for the Kampung Tanggulan project were therefore:

- **River restoration**: by introducing community-based ecohydrology intervention for setting up ecosystem services.
- **Development of innovative models and applying those to a pilot scheme**: by building a demonstration site (with site selection criteria and rationale) for stream restoration, using bio-eco engineering technology with expected outcomes. The key components of the model to be developed were: technology, policy measures, capacity building and stakeholder participation.
- **Ensuring sustainability**: through public participation and a community empowerment programme, to involve the community as much as possible in the project.

Design and implementation

The pilot plan in Kampung Tanggulan included 128 residential units together with public facilities such as a toilet, care unit, and mosque, all sited on approximately 10,000m^2 of land. The domestic wastewater, especially greywater, had been flowing into the river without treatment. The project aimed to restore river water quality by improving the management of wastewater, collecting it into a system of pipelines and feeding it to the treatment plant.

Communal wastewater management is defined as the collection and treatment of wastewater by using a simple and cost-effective technology that is sufficient for protecting the environment. A proper wastewater management programme is designed to protect public health and the environment, with high density and low-economic residences prioritised. Those areas have been mostly served by traditional gravity sewers, force mains, and simple treatment systems.

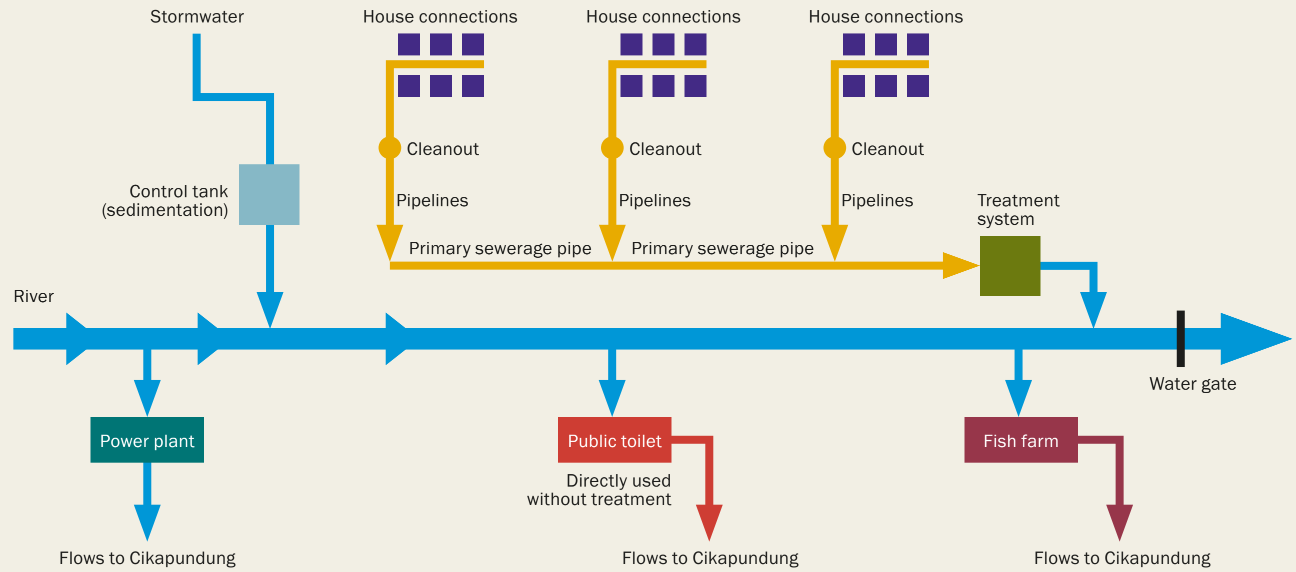
Kampung Tanggulan is a residential area with a high population density of middle- to low-income households. It was decided that wastewater management in this area should comprise a simplified community sewerage treatment system. The community plays an important role, as it is expected that it will manage all operations and maintenance of the system after installation. It was therefore important that the treatment technology was chosen for its ease of operation.

To minimise loads, the system is designed to separate wastewater from storm water and supply it to a treatment plant to be built near the river. The process has three steps:

- **Sedimentation**: the suspended particles are separated in the sedimentation tank which is designed to prevent particles from interfering with treatment processes in the biofilter. An oil and grease trap is also installed.
- **Biological process**: the wastewater flows continuously through the biofilter where it is treated by microorganisms that grow attached to the filter.
- Treated wastewater then flows through the constructed wetland system. This technology provides a good alternative to conventional onsite wastewater disposal systems which usually consist of a biofilter and a soil absorption field.

The type of constructed wetland chosen for the project was a Floating Treatment Wetland (FTW). FTWs employing emer-

Wastewater management system concept design



Source: IoT

gent aquatic plants growing on a buoyant mat are an innovative tool for managing nutrients in ponds, lakes and slow-flowing waters. The system allows plant roots to grow through a floating mat and into the water beneath, providing a large surface area for nutrient assimilation, growth of biofilms and the entrapment of fine suspended particulates. By shading the surface and buffering water turbulence FTWs can also promote the settling of suspended algae and solids beneath the mats.

Because the plants are grown on floating media, this type of wetland is more tolerant to fluctuations in the breadth and depth of water. Plant roots that hang below the mats provide a large surface area for biofilm growth and entrapment of suspended particles. Because the plants are not rooted in the sediment, they are forced to obtain nutrients directly from the water column. In addition to their pollutant removal capability, FTWs are also useful in terms of:

- The availability of resources.
- A high reduction of BOD and solids, but low reduction of pathogens.
- Water biota, such as water hyacinth, grow rapidly and are visually appealing.
- A low to moderate capital cost. Operating costs can be offset by revenue.
- The potential for local job creation and income generation.
- Can be built and maintained with locally available materials.

The project saw the installation of FTWs measuring 1 x 2 metres, each made from 3-inch diameter PVC pipe and coarse netting. The planting medium was cocopeat – a lightweight substance with good water capillarity, made from coconut husk – with a thickness of 5 cm. Kale, spinach and lettuce were planted, each having a growing period of 4–5 weeks. These plants have been widely used in wastewater treatment, have economic value, and are familiar to the community.

The first step in project implementation was the involvement of the Kampung Tanggulan community, facilitated by

Image: IoT

Construction of Floating Treatment Wetlands by the local community

meetings and other social events. Residents were very proactive in providing input at the early stage, with enthusiasm and a willingness to participate very much in evidence. They gave approval for the project, and voiced their expectations for its development.

The sedimentation and shallowing due to the erosion of the river banks and bed has necessitated excavation work which was carried out by a contractor using heavy equipment, along with community involvement.

The installation of pipelines was the most extensive work in the project, with the extent of the digging causing disruption and public complaints. This part of the project required intensive monitoring to avoid threats to the schedule. The use of local workers was advantageous as the community was able to discuss progress with them directly. The sedimentation tank and biofilter were constructed and installed simultaneously with the pipelines.

In order to maximise public participation, construction of the floating wetland was carried out by the community via a competition. ITB provided the funds for this part of the project, including the supply of pipes, planting media, net and plants. The best builder of FTWs received prize money. Post-installation monitoring showed that the plants grew vigorously and were ready for harvesting after one month.

The project was able to deliver many positive effects to the community. During construction, residents were very helpful in finding the path of each of the pipelines through which their domestic wastewater was discharged. After completion of the project, the community began using the river for activities such as fishing and swimming, both quite impossible before the project was launched.

Lessons learned

The ideal of community involvement in these projects is, in practice, challenging and difficult to implement. Some lessons have been learned that may be useful as considerations for similar projects, as follows:

- **Conflict of interest**: in low-economy communities, the common assumption is that a lot of money is involved. There is also a hope within the community that this kind of project might create the opportunity for obtaining money directly.
- **Building trust**: this is a complex challenge, especially where there have been bad experiences from previous projects, leaving the feeling of having been exploited to the benefit of others. The involvement of government officials or a village leader can help to overcome this problem.
- **Culture and attitude change**: there is often the need to change local attitudes in order to gain support for a project. In the case of river restoration, attitudes to dumping waste in the river must change if the project is to be sustainable.
- **Economically attractive**: one approach to garnering full community support is to ensure direct economic benefit. The decision to use FTWs introduced the possibility of harvesting the plants, giving the community products that they can eat or sell. However, in urban communities such as Bandung City, more economically attractive activities might need to be established.
- **Continuity and sustainability**: the main point of community involvement is project sustainability – the ability to maintain systems into the future. The establishment of leadership and organization is necessary to ensure responsibility for operation and maintenance. A simple system – in this case, a simplified sewerage and wastewater treatment system – is more easily achieved as it is more easily understood by the community.

Image: IoT

Daily usage of river water by the community

Image: IoT

The growth of plants on the Floating Treatment Wetlands after one month

Image: IoT

Community involvement in maintaining the Floating Treatment Wetlands

The Mekong River Commission and its transboundary cooperation

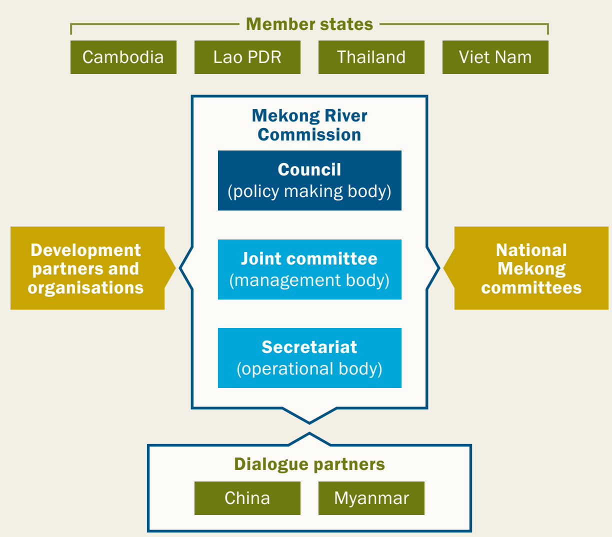
Dr. Anoulak Kittikhoun[1], Mekong River Commission Secretariat

The Mekong is the twelfth longest river in the world. It flows for almost 4,800km from its source in Tibet, through China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam, via a large delta into the sea, draining a basin area of 795,000km^2. The river has a mean annual discharge of approximately 475km^3, the tenth largest in the world.

There is a very large difference in wet and dry season flow, caused by the Southwest Monsoon generating wet and dry seasons of about equal length. Inter-annual variability is also large in terms of river discharge, flooded areas, and the beginning and end of the wet and dry seasons. The seasonal cycling of water levels at Phnom Penh causes a large water flow reversal to and from the Tonle Sap Lake, with the associated flooding and drying creating a rich ecology.

Responsible management of the river has continued without break since 1957, starting with the Mekong Committee. Managing the river since 1995, the Mekong River Commission (MRC) has a comprehensive mandate for water resources management grounded in a political treaty, a basin-wide development strategy, a comprehensive set of procedures for management and a vast knowledge base.

Mekong River Commission governance structure



Source: Mekong River Commission Secretariat

The MRC is an inter-governmental organisation of member states Cambodia, Lao PDR, Thailand and Viet Nam. The mandate, negotiated and established by treaty, the 1995 Mekong Agreement, is: "to promote and coordinate sustainable development and management of water and related resources of the Mekong River Basin". The principles of underlying cooperation are clear: cooperative management of the common river resources, sovereign equality and territorial integrity, and reasonable and equitable development.

The 1995 Mekong Agreement placed the management responsibility of the Commission in the hands of its four Member Countries, outside of the umbrella of the UN. Under the agreement, the four signatory countries agreed to cooperate in developing, managing, using and conserving water resources in areas such as fisheries, food control, irrigation, hydropower, and navigation.

The MRC has three principal organs: the MRC Council, Joint Committee, and the Secretariat. To manage Mekong affairs internally and to facilitate cooperation, each member country has established a National Mekong Committee (NMC), comprising representatives of the relevant major line/implementing agencies in each country and supported by a secretariat (NMCS). With two decades of experience, the MRC's mechanisms of dialogue and negotiation are well established and institutionalised.

Every four years, the MRC member countries convene summits of prime ministers. Every year, environment and water ministers from member states meet to discuss emerging issues related to the Lower Mekong Basin. The MRC Joint Committee, comprising senior officials of the four countries, is then responsible for turning decisions and policies into firm actions. The committee meets twice a year and reports to the Council, functioning as the management body for the MRC. The MRC Secretariat is the operational arm of the organisation and performs technical and administrative functions under the management of a CEO.

This commitment to work together – to meet, talk, listen, and search for solutions – is the quintessential Mekong spirit that has enabled the countries to come together despite their differences at every MRC meeting since 1995. No mechanism in the region has been able to provide a water diplomacy platform as legitimately as MRC at every level, from prime ministers, ministers, and heads of departments to technicians and scientists.

While the responsibility for planning, design and implementation of development projects and water resources

Image: MRC

Construction of the Xayaburi Hydroelectric Power project, Lao PDR

management lies with each member country, the MRC is mandated to promote sustainable development and coordinate management from a basin-wide perspective. Every five years the MRC supports the member countries in identifying common basin-wide needs, opportunities and challenges.

In response to these issues, under MRC's facilitation, a common strategy to develop the Mekong from a basin-wide perspective has been agreed: the Integrated Water Resources Management (IWRM)-based Basin Development Strategy. Agreed in 2011 and renewed in 2016, the strategy sets out shared understandings about development opportunities, long and medium term risks, and priorities for development and management, including five strategically important joint projects: planning and management of the Delta (Cambodia-Viet Nam); 3 S (Cambodia-Laos-Viet Nam); transboundary flood management (Cambodia-Thailand); navigation (Laos-Thailand); and development of the border area of Cambodia-Laos.

In seeking to fulfil its mandate to foster cooperation and contribute to regional integration in water and related sectors, the MRC and its member countries have sought to build active cooperation with strategically important partners.

The MRC member states plus Myanmar are cooperating and striving for regional integration as members of ASEAN, a cause which is fully consistent with MRC's aim of promoting greater regional inter-dependence. In addition, the Mekong countries are also cooperating through other bilateral and multilateral mechanisms, including the Lancang-Mekong Cooperation Mechanism, Asia-Europe Meeting (ASEM), Asia Pacific Economic Cooperation (APEC), Lower Mekong Initiative (LMI), Mekong-Japan Cooperation, Ayeyawady-Chao Phraya-Mekong Economic Cooperation Strategy (ACMECS), the Triangle Development Cooperation, and others.

All Mekong Basin countries are also making advances in regional economic and physical connection under the Greater Mekong Sub-region (GMS) cooperation supported by The Asian Development Bank (ADB). The MRC and ADB continue to work together, building on their partnership agreement, with a view to greater sharing of knowledge and information and in promoting strategically important development opportunities. Alignment of the development strategies established under GMS and MRC cooperation frameworks will support each to succeed in their respective aims. With the MRC transitioning to core river basin management functions,

Weaving fishing nets on the Mekong Delta, Viet Nam

cooperation from the GMS offers an opportunity for the MRC to rationalise and phase out its programmatic work in water-related sectors.

One year after the signing of the 1995 Mekong Agreement, the MRC began to forge a successful alliance and working relationship with its Dialogue Partners, the upper riparian countries, China and Myanmar. Taking a whole-basin approach through cooperation with the Dialogue Partners is crucial for the sustainable management of the river basin.

China and Myanmar have demonstrated an increasing commitment to cooperation, including sharing more data and information on the status of upstream developments and joint capacity-building activities. In 2002, the MRC's cooperation with China under the Dialogue Partner relationship was strengthened with the signing of a memorandum of understanding on the provision of daily river flow and rainfall data from two monitoring stations in Yunnan Province during the wet season. These data help improve the MRC's regional daily forecast of downstream water levels at key points on the Mekong River during the flood season. In turn, the forecasts can help to save lives and reduce damage to property and crops.

In recent years, the MRC Secretariat has cooperated with Myanmar in a number of areas, such as improving the MRC's hydro-meteorological coverage by exchanging relevant monitoring and water-quality data and sharing technical expertise in flood prevention and management. A number of areas, such as navigation safety, strategic environmental assessment, and continued sharing of hydro-meteorological data with Myanmar, have been explored with potential for future technical cooperation.

Enhanced cooperation with China and Myanmar is crucial for the sustainable management of the Lancang-Mekong Basin where flow conditions and sediment delivery downstream have already been modified by hydropower and climate change. Building on the Dialogue Partner arrangement, future cooperation may include institutionalising a more extensive information sharing system on river flows and reservoir operations as well as joint technical studies, state of basin reporting, and experience exchanges in flood and drought management.

Other stakeholders include development partners that fund the MRC through technical and financial collaborations in addition to contributions from the four member states. Broader stakeholders including academia, media, NGOs and the private sector have also participated in MRC activities.

The long history of river investigation and planning in this area, together with recent basin-wide assessments, has created a regional knowledge hub that supports the member states in planning and decision making. MRC studies and assessments, posted on the website for full transparency, have gone through an extensive process of consultation within and between countries.

In addition to the MRC's dialogue mechanisms, strategy and knowledge base, no other developing basins have such comprehensive rules of procedures for the management of their transboundary rivers. In the Mekong, the MRC countries have established procedures dealing with maintenance of flows, water quality, water use monitoring, data and information sharing, and consultation on infrastructure projects. Individually and collectively these advanced procedures demonstrate the countries' commitment to work together. The procedures take a cooperative, rather than regulatory, approach to management.

In 2010, the member states 'prime ministers met to reaffirm the MRC mandate and institute far reaching reforms to strengthen the organisation's mode of operation, efficiency and effectiveness. These changes have been acknowledged by the independent appraisal commissioned by the development partners of the Strategic Plan 2016–2020, which concluded that the MRC is more relevant than ever. The Strategic Plan has secured approximately 90% of its budget. Member countries also demonstrated continued commitment both with taking up and funding decentralised monitoring activities and increasing the amount of contribution. This is in line with the MRC roadmap for reforms in which countries will fully finance core work by 2030.

Over the last 20 years since its establishment in 1995, the MRC has worked tirelessly to support the member countries to jointly manage the Mekong water resources in an equitable manner. Through cooperation with member countries and development partners, the MRC has generated a large knowledge base, established procedures for sustainably developing and managing the river, acted as a water diplomacy platform for riparian states, achieved verifiable evidence of beneficial changes and has proved indispensable for Mekong transboundary water cooperation and diplomacy.

Image: MRC

Floating market on Mekong River, Mekong Delta, Viet Nam

Image: MRC

Chong Khneas floating village on the Mekong basin

Strengthening citizens' involvement in water and sanitation management

Benjamin Noury, Associate Director, Oxyo Water; Emeline Hassenforder, Researcher, National Research Institute of Science and Technology for Environment and Agriculture, France

In the development of public policies for water resources management, there is a growing recognition among experts on the importance of participation. Participatory management and stakeholder engagement practices are therefore widely implemented. Governance literature and several international institutions, including the Organization for Economic Cooperation and Development, Global Water Partnership, and the Stockholm International Water Institute, recognise participation as a key criterion in defining good water governance principles. The Sustainable Development Goal 6 acknowledges the added value of stakeholder engagement at local level by setting a specific target to "Support and strengthen the participation of local communities in improving water and sanitation management".

These participatory approaches have been strengthened over the years by a more refined legislation at local, national and international level, setting requirements for the dissemination of information, stakeholders' consultation and public participation. According to the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water report[1], 80% of 74 responding countries had clearly defined procedures for engaging service users in water and sanitation management.

However, implementation modalities remain unclear. Policies and procedures for participation of local communities in water and sanitation management are necessary but don't guarantee the level of participation quality. Concrete experiences of public participation that effectively engage citizens and end-users in co-designing water plans or projects through a bottom-up approach are rare. The challenge to improve water and sanitation management towards 2030 is not only to set new stakeholder requirements but also to go beyond traditional approaches with the ambition of a decentralised and participatory management of water resources in polycentric contexts.

There are many economic, environmental and social benefits to be gained from effectively engaging stakeholders in water policies and projects: creating ownership, developing activities that are fit for local needs and contexts, building trust, resolving conflicts among users, strengthening the sustainability of the interventions' impacts, collecting local data, and supporting institutional emergence. However, this ambition raises specific issues. Challenges occur in citizens' mobilisation, in the choice of procedures and impact assessment methods and in the integration of citizen contributions to water policies at different scales.

How do we engage citizens?

A participatory process needs participants. This observation is trivial but its application is a frequent challenge for practitioners and researchers who implement the processes. Citizens are usually easier to engage when confronted with a specific issue – for instance, water pollution, lack of sanitation, construction of a dam – than for preserving a pristine river basin. Citizens' involvement tends to be more spontaneous in crisis contexts. Examples of local struggles against the Sivens dam in France or the Coca-Cola plant in Kerala, India, symbolise the collective ability of a group to organize itself to face a common concern.

It is difficult to engage citizens to preserve natural resources or to discuss less tangible issues such as hygiene or climate change. In these contexts specifically, communication and the raising of awareness are required to stimulate activity. Mass communication campaigns with radio announcements or the distribution of flyers in mailboxes reach a large number of people but with lower engagement rates than the use of real social networks with local structures or of motivated citizens who co-opt other participants. A pilot group or a core group of citizens may facilitate these communication structures in the implementation of participatory schemes.

Another challenge in mobilizing and engaging citizens lies in attracting those who are not yet sensitised to the importance of water and sanitation issues. Innovative tools must be deployed in order to reach the attention of these unconcerned citizens. When it comes to engagement, the attractiveness of the process is often as important as its substance. To that aim, role-playing games or artistic activities such as drawing, forum theatre and movie contests can be useful. Aligning a water-related participation plan with a political, cultural or religious agenda may also trigger the participation of unconcerned citizens, especially workers who are more available in the evening or on weekends.

How can citizens be involved?

Citizens' participation is not a means to strengthen their acceptance to established ideas. Some flexibility must be left within the process in order to allow participants the room to manoeuvre in water-related decision-making. When participation takes place within institutionalised procedures, the instigator of participation, be it an NGO, a donor or a local water management organisation, needs to define this margin of manoeuvre.

Image: Melk

Role-playing session in the AfroMaison project with the Kyempara community in Uganda

Without necessarily going as far as co-decision, the instigator can define the required intensity of participation in the process, including defining parameters for citizens' contributions. These parameters may correspond to a specific stage in the process such as data collection (e.g. citizen science) or action proposal (e.g. participatory planning) or voting (e.g. participatory budget).

In order to enable engagement, participants need to be convinced that they can bring added-value to the issue at stake and that their contribution can produce changes. Thus, it is important to identify their expectations early in the process and to evaluate whether they have been realised at the end. Most expectations can generally only be met if participants are provided with margin for manoeuvre.

Viewing public participation as a means for producing change also requires considering it as a process rather than a succession of events. Even for raising awareness, participation requires behavioural changes. Too often, instigators willing to involve citizens in their project organise a one-shot public meeting or a unique consultation. This method is useful but insufficient for effective citizen participation.

For example, a participatory process was implemented in the Rwenzori region in western Uganda to develop a regional natural resources management plan as follows:

1. **Procedural agreement**: design and validation of the process by facilitators and key stakeholders to match the local context.
2. **Identification of the focal issue**: discussions among participants on a common long-term objective and elicitation of their perspectives, values and preferences.
3. **Proposal of actions**: brainstorming among participants on the potential actions likely to address the focal issue. Actions stemming from expert knowledge are set forth for approval by participants.
4. **Selection and organisation of actions in time, space and at organisational levels using a participatory planning matrix (Cooplan)**: discussions among participants on the feasibility, coherence and efficiency of the resulting water management plan based on available resources and expected impacts.
5. **Test of the plan using a role-playing game developed concomitantly by facilitators and researchers with multiple inputs from participants**: actions from the plan are translated into action cards in the role-playing game allowing participants to explore the social and environmental impacts of these actions and to possibly suggest new ones. The plan and game are interactively readjusted.
6. **Agreement among participants on plan implementation**: who will do what, when, where and with what resources.

This process was adapted from the AquaStress project[2] and implemented in the frame of the Afromaison project[3]. The process lasted for about two years and involved about 70 participants including the government, civil society, the private sector, and religious and cultural representatives. The process was originally meant to be implemented at meso level only (intermediary level between community and national level). However, Ugandan facilitators were enthusiastic about the process, and the role-playing game in particular, and therefore decided to set up a partnership with

Social justice exercise with Tunisian officials in the Programme for Territorial Adaptation to Climate Change

local networks in order to carry out the participatory planning approach at local level in 35 communities throughout the Rwenzori region. About 600 participants were involved. 46% were women, 38% were men and 17% were children. The vast majority were farmers and pastoralists.[4]

How do we integrate citizens' contributions?

Compared to technical reports, the results of participatory processes are often disparaged. Many decision-makers consider that citizens do not have sufficient expertise to make acceptable proposals. For collecting hydrological data, citizens may not be the most relevant stakeholders, but they are the best placed to provide other types of information such as water uses and perceived constraints and incentives for behavioural change.

Citizens do not act according to the scientific overview, but based on their representation of this reality. The coupling of technical and social approaches is therefore critical to understand socio-environmental systems. Too many projects have been diverted from their original objectives by a lack of understanding and integration of local expectations and stakeholder representation.

Conclusion

The SDG target 6.B framework provides a great opportunity to build participation practices for water and sanitation management. The selected indicator for target 6.B rules and procedures is an indispensable requirement for promoting public participation. But the effectiveness of participation will not depend so much on the existence of these rules as on their implementation. In order for citizens to have a positive influence on water management, their contributions must be tangible.

Facilitating the integration of citizens' contribution

The integration of citizens' contribution can be facilitated by:

Raising awareness of administration units
The Programme for Territorial Adaptation to Climate Change (PACT) coordinated by the Ministry of Agriculture, Water resources and Fisheries in Tunisia aims to rally citizens in the rural territories to draw up, implement and evaluate an integrated natural resources management plan on the scale of their territory. Before launching the participatory activities locally, a training campaign was initiated for the agents of the ministry on public participation to highlight its purpose and experiment with a new facilitation method.

Limiting the decision-makers' influence
For the Afromaison project, Ethiopia, the participatory process was implemented in parallel between a group of decision-makers and a group of farmers. This aimed partly at compensating power differences among participants and at fostering regional decision-makers to adopt an open posture favourable to stakeholder engagement.

Bringing expertise
The involvement of experts at specific moments in the participatory process is another way of strengthening its content and legitimacy. These interactions ease citizens' understanding, stimulate the emergence of innovative solutions and confront proposals with a broader complexity.

The fulfilment of this fundamental condition enhances confidence between citizens and decision-makers. It supports a common and peaceful vision for water management. It creates ownership and responsibilities. This condition is a key driver in the success of the sustainable development goal on water and sanitation.

Awarding scientific innovation in pursuit of water and sanitation for all

Abdulmalek A. Al Alshaikh, General Secretary, Prince Sultan Bin Abdulaziz International Prize for Water

The Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) is a leading scientific award, offered every two years, that focuses on innovation. Since its establishment in 2002 by HRH Prince Sultan Bin Abdulaziz (1930–2011), PSIPW had given recognition to scientists, researchers and inventors around the world for pioneering work that addresses the problem of water scarcity in creative and effective ways.

PSIPW offers a suite of five prizes, covering the entire water research landscape. The Creativity Prize, worth US$266,000, is awarded for cutting-edge interdisciplinary work that can be considered a breakthrough in any water-related field. There are also four specialized prizes, each worth US$133,000: the Surface Water Prize, the Groundwater Prize, the Alternative Water Resources Prize, and the Water Management and Protection Prize.

Nominations are evaluated by an international panel of distinguished scientists who serve on various committees for each of the five prizes. Nominations undergo a rigorous three-tiered evaluation process, starting with a preliminary evaluation committee, followed by a referee committee, and ending with a final selection committee.

Winners are awarded for work that is directly relevant to the United Nations Sustainable Development Goal 6 (SDG6), which is to “ensure access to water and sanitation for all”. Their innovative research has made substantial contributions to our understanding of water resources and how to develop, safeguard, and conserve them.

PSIPW’s seventh awards ceremony was held at the United Nations headquarters in New York on 2 November 2016. It was hosted by the UN Friends of Water and presided over by the then UN General Secretary, HE Mr. Ban Ki-moon, and PSIPW Chairman, HRH Prince Khaled Bin Sultan Bin Abdulaziz.

PSIPW has special consultative status with the United Nations Economic and Social Council (ECOSOC) and is an observing member of the UN Committee for the Peaceful Uses of Outer Space (UN COPUOS).

Predicting cholera outbreaks

For the awards given in December 2016, the Creativity Prize was awarded to Dr. Rita Colwell of the University of Maryland, College Park, US and Dr. Shafiqul Islam of Tufts University, US, for developing and successfully testing a model that uses chlorophyll information from satellite data to predict cholera outbreaks up to six months in advance.

Dr. Rita Colwell, an internationally acclaimed oceanographer and microbiologist, has spent the bulk of her career studying the V. cholerae bacterium that causes cholera. She and her colleagues have found V. cholerae in oceans around the world, in isolated lakes and rivers untouched by faecal contamination, and in volcanic springs in Iceland. Colwell and her team were the first to use remote satellite data to develop a predictive model for cholera outbreaks in East Asia, and she is the first scientist to link global warming with a potential rise in cases of infectious disease.

Dr. Shafiqul Islam has applied Colwell’s findings, using satellite data from NASA, to accurately predict cholera outbreaks at least three months – and often up to six months – ahead of time. The model has been tested with chlorophyll information from satellites over the Bay of Bengal region to predict cholera outbreaks in Bangladesh. The team is currently working on testing the model with ground-based observations.

A systems approach to water resources management

Effective water resources management is crucial to meeting SDG6. The Water Management and Protection Prize for the seventh award went to Dr. Daniel P. Loucks of Cornell University for developing and implementing a systems approach to water resources management. He has created and implemented systems tools that provide an effective, dynamic, and successful framework to address practical water resources management problems worldwide. His work examines the interplay between environmental stress, stakeholder participation processes and hydrological systems.

Decision makers in numerous countries, including developing nations, have been trained and influenced by Dr. Loucks’ approach to water resources planning.

Using sunlight to destroy pathogens in water

In 2014, the Alternative Water Resources Prize was won by Dr. Polycarpos Falaras of the National Center for Scientific Research “Demokritos” in Athens, Greece and coordinator of the European Union’s CleanWater project. He has developed a novel water detoxification technology by taking advantage of sunlight and a unique composite membrane to destroy toxins while filtering water.

This is an innovative and efficient process, exploiting solar energy by incorporating nano-engineered titanium photo-

Winners of the seventh award (2016)

The seventh awards ceremony for the Prince Sultan Bin Abdulaziz International Prize for Water was held at the UN headquarters in New York on 2 November 2016. The winners were as follows:

Creativity Prize: Dr. Rita Colwell (University of Maryland, College Park) and Dr. Shafiqul Islam (Tufts University) for using chlorophyll information from satellite data to predict cholera outbreaks at least three to six months in advance.

Creativity Prize: Dr. Peter J. Webster (Georgia Institute of Technology) for a model that forecasts monsoonal floods one to two weeks in advance.

Surface Water Prize: Dr. Gary Parker (University of Illinois Urbana-Champaign) for advances in the scientific understanding of changes in river flows and, consequently, the functionality of river systems as a water source.

Groundwater Prize: Dr. Tissa H. Illangasekare (Colorado School of Mines) for work that contributes significantly to the prediction of the long-term consequences of pollutants in groundwater systems.

Alternative Water Resources Prize: Dr. Rong Wang and Dr. Anthony G. Fane (Nanyang Technological University, Singapore) for developing energy-efficient novel membranes to sustainably sanitize larger volumes of water.

Water Management and Protection Prize: Dr. Daniel P. Loucks (Cornell University) for developing and implementing the systems approach to water resources management.

catalysts into the nanofiltration membranes. Conventional membrane technologies remove pathogenic microorganisms and toxins from drinking water only by physical separation (or sieving), creating a concentrated stream of active pathogenic microorganisms, which poses a serious threat at the discharge site if not further treated.

The new technology, by contrast, uses an advanced oxidation processes to bring about photocatalytic degradation of pathogens during the filtration process, allowing very efficient water purification. Moreover, it does so under normal solar light conditions, a key factor for the reduction of energy requirements in water treatment. Falaras' work also makes use of novel, environmentally friendly materials and represents a cost-effective application of nanotechnology for enhancing water quality.

Algorithms for large-scale water systems

In 2014, Dr. William W-G. Yeh of the University of California, Los Angeles won the Water Management and Protection Prize for his development of optimization models to plan, manage and operate large-scale water resources systems throughout the world. His methodology in utilizing systems analysis techniques – as well as the algorithms he developed for the real-time operation of complex, multiple-purpose, multiple-reservoir systems – have been adopted in the US and throughout the globe, most notably in Brazil, Korea, Taiwan and the People's Republic of China. Dr. Yeh's many achievements include the development of the operation rules and optimization of California's reservoir and water distribution

Image: PSIPW

Winner of the 2016 Creativity Prize, Dr. Rita Colwell, speaking in front of a satellite image showing chlorophyll distribution in the world's oceans systems; the water distribution system model and optimization for water supply for the city of Sao Paulo, Brazil; and the management and operation of large-scale hydropower systems, such as the Brazilian hydropower system and the Three Gorges Project in China. His work represents the practical and novel application of methods to deal with many different and difficult aspects of water management under a wide and diverse range of situations.

Removing arsenic from groundwater

The Bangladesh water crisis is an ongoing problem, with around one in five of all adult deaths being linked to chronic arsenic poisoning. Dr. Ashok Gadgil describes the situation as "the largest case of mass poisoning in world history." He and his team at the University of California, Berkeley won the Creativity Prize in 2012 for developing an innovative, effective and economical method of treating the arsenic contamination of groundwater using electrocoagulation.

The team's work runs from initial research to a functioning technology that is easy to understand, easy to operate, and locally affordable to communities in the world's poorest countries. The required power of 3V to run the machine can be provided by photovoltaic cells. It provides safe groundwater at the equivalent of US$ 0.04 per 10 litres.

Other initiatives of PSIPW

Besides awarding its suite of prizes every two years, PSIPW is active in numerous water-related projects, some of which focus on combating desertification, as well as on community development and sustainable agriculture through the restoration and rehabilitation of degraded land. The organization also has a memorandum of understanding with the United Nations Organization for Outer Space Affairs (UN OOSA). Among their joint initiatives is the soon to be launched Space and Water Portal, an online hub for professionals and organizations working with space technology applications for water-related activities.

Image: PSIPW

Winners of the seventh award. Top row: Rita Colwell, Shafiqul Islam, Peter Webster, and Gary Parker. Bottom row: Tissa Illangasekare, Rong Wang, Anthony Fane, and Daniel Loucks

Image: PSIPW

Dr. Daniel Loucks receiving the Water Management and Protection Prize from HE Mr. Ban Ki-moon at the seventh awards ceremony, New York

Water and sanitation during the flood disaster – a community-driven commitment towards a better world

Kah Yee Lim, Nor Azazi Zakaria and Keng Yuen Foo, Researchers, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM), Malaysia

For several decades, floods have been among the most frequent and destructive natural catastrophes, attracting worldwide attention. In 2004, the worst flood devastated more than a dozen countries throughout the Indian Ocean region, affecting nearly 700,000 people, with 400,000 reported dead or missing, and more than half of the survivors left homeless by the enormous walls of water. The 1931 flood in China was the most disastrous, killing 3,700,000 victims. The deadliest floods in more than 90 countries over the past 60 years have affected nearly 1 billion victims.

One of the most severe problems during a flood is the deterioration of water quality caused by the influence of domestic, agricultural and industrial activities, which contain a variety of heavy metals, chlorides, nitrites, nitrates and sulphate ions. The complete submergence of sewerage systems, septic tanks and sanitary facilities, further pollutes surface water, to become a reservoir for microorganisms such as *Escherichia coli*, *Salmonella typhimurium*, *Shigella flexneri*, *Campylobacter jejuni*, *Enterococci spp.* and protozoa.

In low-lying areas, flood water can flow from the floodplain into local rivers, and then becomes the main source of domestic water. Statistical data is available to suggest that over 80% of water borne diseases – diarrhoea, dysentery, anaemia, cholera, shigellosis, campylobacteriosis, amebiasis, giardiasis, cryptosporidiosis, norovirus, typhoid, paratyphoid fever, leptospirosis, and hepatitis A – are caused mainly by consumption of water from poor supply systems, as well as poor hygiene and sanitation levels.

Malaysia, located in the wet and humid tropics, in lands extending 10 degrees north and south of the equator, with a fair amount of sunshine, a hot climate coupled with an average temperature of 25°C, and a high rainfall rate of 2,000 mm well distributed throughout the year, has undergone the same occurrence for the past 50 years. The worst 2014 flood event, affecting nearly 30,000 km^2 (9% of the country's total land mass) devastated the east coast states of Kelantan, Terengganu, and Pahang, with 200,000 victims, infrastructure damage at RM 9.24 billion, 24 reported deaths, and 8 people still missing. In excess of US$ 28 million was spent on re-stabilising the hill slopes, while US$ 100,000 was allocated for the alleviation of suffering of the flood victims. Approximately US$ 83,000 and 10,000 of blankets were delivered by the International Federation of Red Cross and Red Crescent Societies (IFRC) to 5,000 families for a period of one month, as part of the overall operation. This tragedy imposed multifarious constraints on the socio-economical structure and sustainable development of the local community. The relief and recovery expenditure has had significant repercussions to the national debt, with negative short-and long-term implications for overall economical performance.

Image: USM

The worst 2014 flood event in Kelantan, Malaysia

Image: USM

The destruction of the East-West Highway during the 2014 flood tragedy

Image: USM

The National Flood Management Programme organised by REDAC, Universiti Sains Malaysia in conjunction with the National Cancer Council Malaysia in Kota Bharu, Kelantan, Malaysia

Water sampling analysis of the Pahang River after flood events of 2014

pH	5.02–5.52
Dissolved oxygen (DO)	3.15–4.48 mg/L
Biochemical oxygen demand (BOD_5)	1.00–31.00 mg/L
Chemical oxygen demand (COD)	4.00–125.00 mg/L
Total suspended solids (TSS)	3.50–37.75 mg/L
Ammonical-nitrogen (NH_3-N)	0.91–2.11 mg/L

Source: USM

During this time, the shift in hydrological conditions made dramatic alterations to the physical, social, economic and environmental conditions in the area heavily affected by flood. The Pahang River, the largest in Peninsular Malaysia, has deteriorated significantly in terms of pollution and its influence on geological changes throughout the country. It is the main artery of the Pahang River Basin, with a maximum catchment of 459 km by 236 km, draining an area of 29,300 km^2, from Cameron Highlands upstream to the South China Sea. The area has a hot and humid climate, characterised by a bimodal pattern of south-west and north-east monsoons, with a mean temperature of 25–27 °C, average air humidity of 85%, and a rainfall rate of 1,600 mm/year. According to the Interim National Water Quality Standard (INWQS) proposed by the Department of the Environment, Malaysia, the available water supply was categorized as Class V, designated a level of high pollution.

Meanwhile, heavy metals, including cadmium, chromium, iron, nickel, zinc, copper and lead ions have been detected in the flood water, exceeding the drinking water guidelines permitted by the World Health Organisation and United States Environmental Protection Agency. The flood water had also been found to be contaminated by microbes, with a high level of *Escherichia coli*, *Salmonella typhimurium* and *Shigella flexneri*, ranging from ≤ 50 cfu/100 mL to 96 x 10^3 cfu/100 mL. Analysis indicates that the river water quality has been drastically compromised through flood events, with the water unfit for daily sanitation and consumption, and a high public health risk to the local community.

In addition to the damages to the natural environment, the flood has led to a variety of social changes, notably population displacement, livelihood loss and family disintegration. To better understand the flood risks and create a management plan for preparedness in future flood disasters, a National Flood Management Programme was organised by the River Engineering and Urban Drainage Research Centre (REDAC) and School of Industrial Technology, Universiti Sains Malaysia. This was done in partnership with the state government from the flood-prone areas in Perlis, Kedah, Perak, Pulau Pinang, Selangor, Melacca, Kelantan, Pahang, Terengganu and Johor, Malaysia, with the aim to set up a foundation for long-term comprehensive solutions to flood


Image: USM

Health screening and consultation related to nutrition at a community hall in Kampung Balok, Kuantan, Pahang, Malaysia


Image: USM

The National Flood Management Programme in Segamat, Johor, Malaysia

related problems. The programme has generated specific guidelines and educational initiatives for the local community in the understanding of flood risk management plans.

The programme was led by Dr. Foo Keng Yuen from the River Engineering and Urban Drainage Research Centre and Dr. Lee Lai Kuan from the School of Industrial Technology, along with their research group. Free health screening and consultation related to the nutritional and health status of flood-affected populations were provided by a group of well-trained facilitators. Well-structured questionnaire surveys were conducted in the areas vulnerable to flood to compile data on socio-demographic background, past flood experience, drinking water sources, food aid systems, sanitation and hygiene, as well as the health risks of the affected population during exposure to flood events.

The survey was supported by over 1,500 participants from flood-prone areas in Perlis, Kedah, Perak, Pulau Pinang, Selangor, Melacca, Kelantan, Pahang, Terengganu and Johor. In conjunction with the awareness programme, several technical and non-technical talks related to issues of water safety, hygiene, sanitation levels, and flood borne diseases were delivered by professional health experts for knowledge enhancement, environmental preservation, and upgrading social welfare and quality of life among the flood victims.

Alongside the programme, coping strategies, the application of appropriate sanitation technology in coastal and flood-prone areas, and effective flood risk management approaches were proposed and introduced to safeguard the available water resources. According to the flood-affected populations, the shortage of clean water resources was the most alarming challenge, as the flow of flood water was able to damage the available water supply systems, and conventional tube wells. During this period, the overflowing flood water was mixed with clean fresh water, and the yellowish, smelly polluted water was forced to the only supply for their daily activities. The inefficiency of the water supply and sanitary facilities significantly compromised the hygiene levels of the local community during this disaster, contributing to the spreading of water-borne diseases, specifically among children, women and elderly groups. The survey found that more than 73% of the population had been suffering from fever, dermatological symptoms and diarrhoea. An inconsistent supply of food aid has further affected the nutrition and health of the flood victims.

This collected information was shared with local authorities, water regulatory bodies, health care centres, insurance companies, and government and non-government organisations for future disaster management preparedness, with a view to promote a resilient and sustainable society. The accomplishment of this community-driven project has established a water safety quality assurance strategy and integrated flood risk management plan to generate a reliable database and to review the available flood remedial policies, set up effective emergency response procedures, ensure the reliable management of clean potable water and water treatment infrastructures, provide better health-care facilities, reduce morbidity and mortality rates of vulnerable populations, and minimise the transmission of water-borne diseases.

In conclusion, the programme has highlighted the pressing need to underpin the joint ventures between the stakeholders, not limited to inter-agency collaboration, public engagement and systematic emergency plans, all of which are indispensable for building a sustainable future.


Image: USM

Questionnaire survey in Hulu Terengganu, Malaysia

Wastewater reuse for agriculture irrigation – a sustainable solution for a better tomorrow?

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The pressing need for clean, potable water, due to climate change, demographic growth, economic development, rising living standards and environmental pollution, has become the most critical global agenda. In some parts of the world, water demand has been rising more than twice as fast as population growth. Annual water withdrawal has suffered in excess of a six-fold increase, from less than 600km^3/year at the beginning of the twentieth century to greater than 3,800km^3/year at the beginning of the twenty-first century. Agriculture uses the largest amount of water, accounting for approximately 75% of the available water supply. The dominance of agriculture has been unquestioned up until recently, but the lack of fresh water resources is expected to intensify problems of water scarcity, food security, water sanitation, and health.

These global changes have urgently prompted the possibility of wastewater reuse as the best available option for food crop irrigation practice. Implementation has been widely practiced in developed cities including Berlin, London, Milan and Paris, with approximately 20m ha of agricultural land irrigated with untreated, partially treated or treated wastewater. In developing regions such as Pakistan and Viet Nam, more than 26% and 80%, respectively of national crop production is supported by wastewater from the urban and peri-urban areas. Similarly, in Ghana and Mexico, informal irrigation using diluted wastewater has been performed on plantation areas exceeding 11,500 and 260,000 ha, respectively. In Malaysia, the agricultural sector has been a driver of economic development, accounting for 9.3% of national GDP. With annual rainfall of more than 2,800mm/year, and a total surface water volume of 566bn m^3, this is sufficient to meet domestic, industrial and agricultural demands.

In addition to the huge saving and preservation of fresh water, a wastewater reuse strategy would help reduce waste effluents and preserve fresh water ecosystems. Nevertheless, it is possible that the available water resources, which rely primarily on river water, could be severely polluted by a wide range of development projects. According to Datuk Hanapi Mohamad Noor, former director of the Department of Irrigation and Drainage (DID), Malaysia, the major rivers in Malaysia, notably the Klang, Juru, and Pahang rivers, are heavily polluted by domestic and industrial discharges, but have been the primary source for irrigating a variety of food crops.

These sewage and industrial wastewaters that contain a broad range of organic pollutants and heavy metal ions, including zinc, copper, lead, manganese, nickel, cadmium, and chromium ions, have been associated with the long term accumulation of toxic contaminants in the soil structure. These contaminants reach the plants, and subsequently the food chain, creating a large-scale dietary hazard with the accumulation of heavy metal toxicity in the major organs of the human body, specifically the kidneys, bones and liver. Lead, arsenic, mercury, copper, zinc, and aluminium poisoning are related to gastrointestinal diseases such as diarrhoea, stomatitis, tremor, and haemoglobinuria, inducing a rust-red colour to the stool, and causing ataxia, paralysis, vomiting, convulsion, depression and pneumonia. The nature of the contamination could be toxic, neurotoxic, carcinogenic, mutagenic or teratogenic, according to the duration and dose of exposure.

Over the years, the outbreak of heavy metals-induced food toxicity have been widely reported. The incidence of mercury poisoning was recorded in Minamata, Japan as early as the 1950s. It was found that the poison intensifies the degeneration of nerve cells in the brain, and mentally retards the victims' offspring, a condition that could be persistent for more than a generation. In 1964, an endemic illness known as blackfoot disease was discovered in Taiwan, due to the presence of arsenic in the deep well waters. In Japan, over 12,000 infants were poisoned by arsenic-contaminated dry milk, resulting in the death of more than 120 babies. In Malaysia, cases of food poisoning have been rising to a worrying extent. It has been reported by the Ipoh Municipal Council of Malaysia that dried prawns and cuttlefish imported from Thailand were found to contain a high level of arsenic, exceeding the permissible level of 1mg/L. Another incidence of food poisoning was recorded in Negeri Sembilan, where pig farm effluents were discharged into the Sepang, Lukut, and Linggi rivers, to create contamination by copper, zinc, and lead ions.

In Kedah and Perlis, there was found to be a wide variation in the concentration of heavy metals in the paddy fields, such as iron, manganese, zinc, chromium, lead, copper and cadmium. Also, leafy vegetables cultivated in the farmlands of Kuching, Sarawak, were found to contain a higher accumulation of heavy metals compared to other vegetables. Through a series of in-depth investigations it was found

Image: USM

Image: USM

A viable solution to climate change and water scarcity – wastewater irrigation in the plantation areas of Alor Setar, Kedah, and Pekan, Pahang, Malaysia

Image: USM

Soil pollution by toxic metals caused by wastewater irrigation of agricultural land in Sekinchan, Selangor, Malaysia

Image: USM

The present investigation was supported and funded by the Toray Science Foundation Award, Japan

that kale, mustard, long bean, cucumber, okra, and water spinach cultivated in Sarawak and Kuala Lumpur contained the highest level of lead ions, above the maximum permissible levels advised by the Malaysian Food Act 1983, and Food Regulations 1985, and as stipulated in the Codex Alimentarius Commission limits.

The presence of these trace elements, particularly lead, cadmium, mercury, and arsenic found in the agricultural villages, gives cause for concern on issues of food safety, security and toxicity, a fact which has been highly publicised by environmental scientists. In parallel to this development, a national study has been carried out by a research team from the River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, led by Dr. Foo Keng Yuen, and Miss Chow Yuh Nien, with support from the Toray Science Foundation, Japan, local regulatory agencies and authorities, and government and non-governmental organizations, with the specific aims to assess the impact of wastewater irrigation practice on the crops' growth and yield, as well as to examine the uptake and translocation of water pollutants in the water-soil-plant system, and the potential implications on food products, human health, and the ecosystem overall.

A well-structured survey has also been carried out among a group of farmers from the major plantation areas of Perak, Penang, Kedah, Pahang, Selangor and Johor, Malaysia. The investigations took place for both conventional farming and hydroponic cultivation, examining the fastest growing soilless technique under greenhouse conditions. Experiments were conducted to provide temperature control, reduce evaporative water loss, control disease and pest infections, and protect against the changing weather. A number of crop models were used including mung bean, cowpea, water spinach, cabbage, lettuce, and Chinese cabbage.

The results showed that the metal ions, which are also essential micronutrients of these plants, were found to activate plant growth at low concentrations of 0.005 to 0.05 mM. However, they would significantly inhibit the elongation of roots and shoots of the crop models, beyond their specific threshold limits. Further tests have found that the presence of lead, cadmium, chromium, copper, nickel and manganese ions above concentrations of 0.55 mM, 0.025 mM, 0.20 mM, 0.25 mM, 0.40 mM, and 0.05 mM, respectively in the irrigation water may result in profound physical growth inhibition, reduction of photosynthetic pigments, proline accumulation, and alterations of antioxidant enzymes guaiacol peroxidase, ascorbate peroxidase, and catalase activities, due to the metals-induced oxidative stress. Deeper analysis has found that the accumulation of heavy metals was higher in the metals-treated plants models, in the order of roots > shoots > leaves. Toxicity tests using *in vitro* bioassay illustrated that these water pollutants may reduce the viability of the human liver hepatocellular cells, and induce irreversible damages on the deoxyribonucleic acid (DNA) in the cytotoxicity evaluation and comet assay.

These analyses and onsite practical studies have given support to the correlation between the presence of heavy metal ions in irrigation water and their uptake by food crops, causing yield reduction and growth impairment as well as oxidative stress response, cytotoxicity and genotoxicity. These effects could be exacerbated on a wider scale to affect a larger population through the indiscriminate long term application of wastewater in agricultural irrigation practice, especially in the developing industrial zones.

In conjunction with pilot investigations and assessments, a series of awareness programmes and knowledge dissemination sessions have been given to farmers and cultivators in a number of states such as Tumpat, Kelantan; Segamat, Johor; Alor Setar, Kedah; and Pekan, Pahang. The programmes included questionnaire surveys and health risk assessments by professional health experts, attracting the involvement of more than 1,000 farmers throughout the country.

These investigations and surveys provide essential insight into the degree of bioaccumulation of water pollutants, ion speciation and the associated health implications of food crops grown using wastewater irrigation. The programme has contributed significantly to both the local and international communities by proposing quality guidelines for the safe use of wastewater.

The present case study supports the integration of water reuse into the core water governance frameworks, thus reducing the water footprint for food production. It also presents a blueprint for food safety policies for the sustainable protection of human health and natural ecosystems. A large-scale application of the emerging hydroponic technology, which was also a key component of the present investigation, would reduce the incidence of food security and food poisoning, and aid the evolution of vertical farming and the wise management of water resources, preservation of human welfare, and the building of a sustainable future.

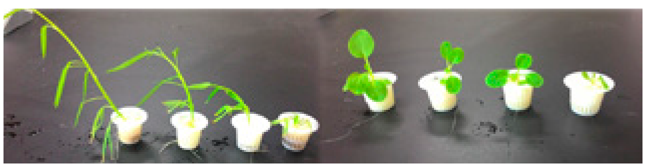


Image: USM

Left: Growth inhibition and distortion effects induced by heavy metals-polluted irrigation water on water spinach and Chinese cabbage seedlings

Image: USM

Image: USM

Cabbage and lettuce cultivated in greenhouses to provide temperature control, reduce evaporative water loss, and control disease and pest infection

Image: USM

Awareness talks and health risk assessments conducted by professional health experts for the benefit of farmers, cultivators, and family members

SDG 6 – New vision for better management of water supply and sanitation in Lebanon

Amin Shaban, Ghaleb Faour, Mouin Hamzé, National Council for Scientific Research, Beirut, Lebanon

Lebanon is a country with available water resources, but with poor water supply and sanitation systems; a problem common to many countries worldwide. This motivated the international agencies and UN entities to highlight the problem and to establish initiatives to find proper and sustainable solutions. Goal 6 of the 17 introduced by the Inter-Agency Expert Group for Sustainable Development Goals (SDGs), aims at ensuring availability and sustainable management of water and sanitation for all. It provides a unique opportunity for Lebanon to join the initiative, enhance existing policies, and help to find new methodologies for water and sanitation monitoring within an integrated national management strategy.

Lebanon has been described as the Water Tower of the Middle East. It is the only area in the Middle East and North Africa region where snow remains for several months on the mountains, occupying approximately 2,500km^2. The snow, together with rainfall of between 700 and 1,400mm, usually results in plentiful water resources including 12 rivers, over 2,000 major springs with a discharge exceeding 10 l/s, and aquiferous rocks[1]. However, the current climate shows a different picture and water shortage is prevalent throughout Lebanon. This is exacerbated by unmanaged and poor sanitation systems, rendering an alarming state of water and sanitation in Lebanon.

The increasing demand has forced local communities to manage the issue on the individual level, and thus it becomes more dependent on alternative sources such as water delivery by truck and storing water. This practice resulted in consumers paying high rates, generally up to 200 to 300% higher than public water fees.[2]

Challenges to water resources include: the country's rugged morphology where mountain chains force the rapid flow of surface water to the sea before it can be used; the occurrence of complex geological structures where significant rock deformations and karstic conduits allow groundwater to seep into undefined strata; the changing climate, notably torrential rainfall and an increase in temperature of 1.8°C; and water shared across administrative regions, where 27.5 per cent of Lebanon's land shares river basins with the riparian regions, and 25 per cent of the territory harbours shared groundwater reservoirs.

There are also challenges to the sanitation sector at both national and institutional levels, including: inadequate maintenance, with an average of 48 per cent of water lost through leakage[3]; inadequate sewage treatment facilities[4] where

An unmanaged water source, a common feature in Lebanon

around 92 per cent of Lebanon's sewage flows untreated into rivers and the sea; significant risk of disease due to severe pollution from solid and liquid wastes; and the arrival, in 2011, of Syrian refugees, accommodated in 1,750 locations, put pressure on an already strained water infrastructure.

There are also challenges on an individual level, including: lack of awareness; open dumping of solid waste and sewage outfall; illegal and unmanaged landfill; unwise use of water; improper and inefficient irrigation; irresponsible behaviour due to cheap, affordable water bills; and lack of motivation for people to work in public sector water management.

The United Nations aims to support countries in monitoring water and sanitation-related issues within the framework of the 2030 Agenda for Sustainable Development in an integrated manner, and to compile country data to report on global progress towards SDG 6. In 2017, UN Water decided that all countries identified as an SDG 6 monitoring focal point would act as both the overall process coordinator and the point of communication within the global initiative.

On the request of custodians, Lebanon, through the National Council for Scientific Research in Lebanon (CNRS-L) and as the International Hydrological Programme (IHP) focal point, has reported baseline data for six SDG indicators: 6.2.3, 6.4.1, 6.4.2, 6.5.1, 6.5.2 and 6.6.1.

There are priorities for Lebanon in elaborating on the SDG 6 indicators, dependent on the degree of the issues relating to each of the indicators and the degree of impact

Baseline data for six SDG 6 indicators, Lebanon

Indicator	Description	Related problem in Lebanon	Negative impact	Capability for solution
6.2.3	Water bodies of water with good ambient water quality	Well pronounced	High	Systematic monitoring control needed
6.4.1	Change in water use efficiency over time	Increased water stress	High	Institutional coordination and awareness needed
6.4.2	Freshwater withdrawal as a proportion of available freshwater resources	High level of freshwater withdraw	High	Legislations and environmental controls must be elaborated
6.5.1	Integrated water resources management implementation	Poorly managed	Moderate	New policies needed
6.5.2	Transboundary basin with an operational arrangement for water cooperation	Few/weak treaties	Moderate	Updated treaties should be followed
6.6.1	Change in the extent of water-related ecosystems over time	Well pronounced	Moderate to high	Institutional coordination and capacity building needed

Source: CNRS-L, 2018

Image: CNRS-L

Unmanaged irrigation due to lack of awareness

Image: CNRS-L

Collection of contaminated (1800c/100ml) drinking water

on water and sanitation. The availability of tools to determine proper solutions pose a significant challenge. The table shows that the six tested baseline indicators for water and sanitation gave unfavourable results. There is clearly a need to take action involving several implementations within an integrated approach to secure water and sanitation systems.

Among the required monitoring actions, an inventory on data and information must be prepared and supplemented by continuous monitoring approaches using various tools and methods. This can be reinforced by adopting successful methods applied in different regions that have proved their effectiveness in the enhancement and consolidation of water and sanitation sectors. The support provided by UN Water is of great importance and has emphasised this as the right time for Lebanon to join the global monitoring system and to be linked to the 2030 Agenda, given the experience and lessons learned during the Millennium Development Goals period.

It is of the utmost importance to establish a mechanism for data monitoring in the context of SDG 6 indicators and this should include collaboration between various interested sectors, mainly based on:

- Identifying the main concepts and elements of application for SDG 6, and benefiting from lessons learned
- Using the baseline surveys done by CNRS-L as guidance for implementing the tested indicators requested by the custodians – UN Water, FAO, UNESCO, and UNECE
- Discussing the subject matter with stakeholders
- Establishing an SDG 6 Consortium for Lebanon representing the key persons working on water and sanitation
- Analysing the applicability of SDG 6 indicators in Lebanon, considering data availability and need for an optimal monitoring system.

According to the report submitted to UN Water by CNRS-L, the proposed mechanism for monitoring the water supply and sanitation in Lebanon can be built through:

- Coordinating with regional and international agencies that have already established or followed successful SDG 6 monitoring mechanisms
- Participation in regional and international assemblies and workshops on water supply and sanitation monitoring
- Identifying a focal person in each of the institutes related to the monitoring of water supply and sanitation
- Coordinating focal persons with a team or consortium that can be proposed as the SDG 6 implementing entity for Lebanon
- Capacity building by various levels of stakeholder for the implementation of SDG 6 objectives
- Establishing a platform for the consortium to be used as a communication tool for discussion and data sharing
- Periodically conducting meetings and surveys between consortium members
- Mainstreaming the results, outcomes and findings to the public as well as to high-level decision makers.

Along with the support introduced by UN Water for Lebanon to make the first steps and progress onto global SDG 6 implementation, CNRS-L took the initiative to carry out a technical report: Developing Institutional Capacity for an Integrated Approach in SDG 6 Monitoring in Lebanon. The report discusses all related issues for SDG 6 implementation, and focuses on the establishment of the SDG 6 Consortium for Lebanon, SDG 6-CL.

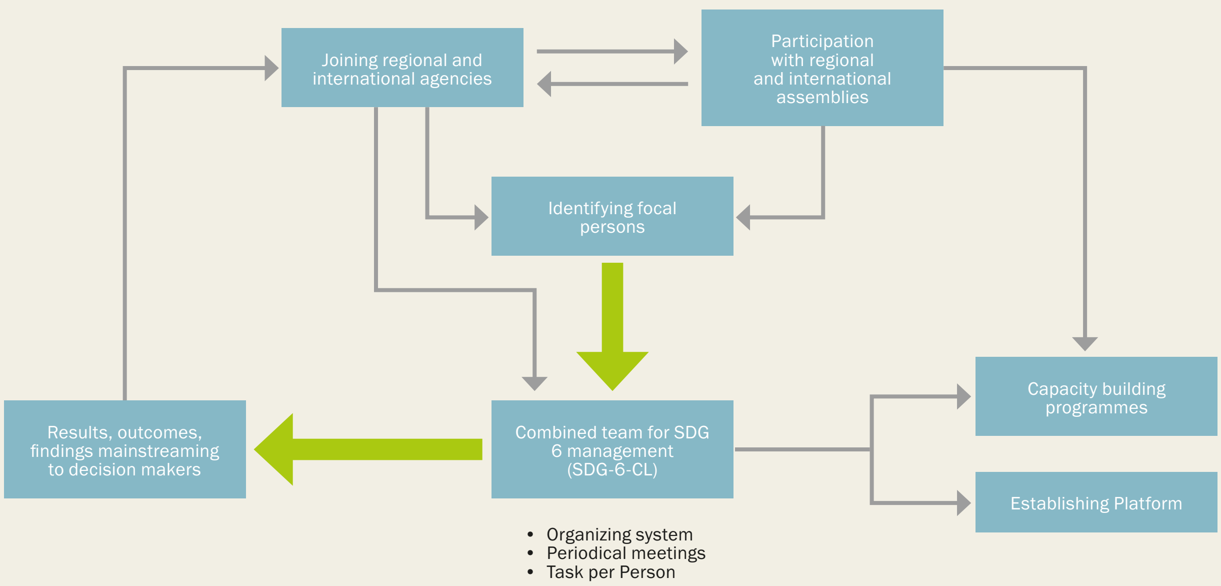
A number of key persons working directly or in relation to water and sanitation monitoring have been assembled to form SDG 6-CL. The members of the consortium represent 14 institutions from various sectors in the country, where all are committed and work towards monitoring and implementation for water and sanitation.

The sustainability of the established SDG 6-CL remains a matter for discussion between the members since the mobilisation of the consortium needs institutional and financial support as well as official recognition. Hence, the consortium's objective to make itself highly visible to high-level decision makers in Lebanon.

The goal of SDG 6-CL is to work in accordance with the requirements of the 2030 Agenda, with the main objectives, illustrated in the report submitted to UN Water, as:

- Compiling a database of water supply and sanitation. This can be shared with the Central Administration of Statistics who can then update it with available data
- Data sorting and preparation (i.e. existing and newly measured data), which is a step toward compiling comprehensive inventory for available data in Lebanon on water, sanitation and related sectors. This will highlight data gaps and encourage appropriate interpolation
- Identifying points of weakness in the monitoring system and proposing the most efficient solutions
- Follow up and involvement with regional and international agencies, e.g. UN Water, UNESCO, FAO, concerning progress, tasks, and activities related to SDG 6 globally

The proposed mechanism for water and sanitation monitoring



Source: CNRS-L, 2018

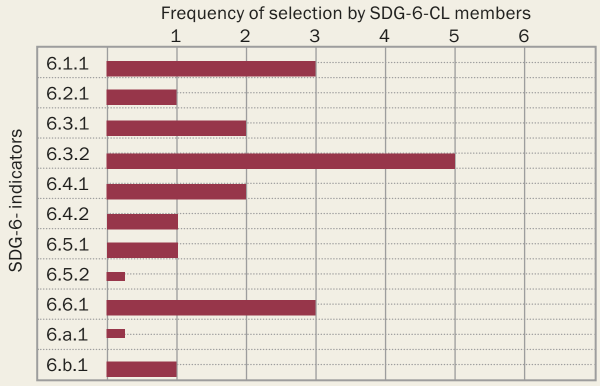
Image: CNRS-L

An old and unmaintained flow-meter

Image: CNRS-L

Uncontrolled and unmaintained boreholes are common in Lebanon

Priority of SDG 6 indicators for Lebanon as evidenced by the SDG 6-CL members



Source: CNRS-L, 2018

Image: CNRS-L

A neglected spring

Image: CNRS-L

Sewage outfall into river water, a common feature in Lebanon

- Facilitating capacity building for stakeholders on crucial issues and problems with water and sanitation monitoring
- Establishing a platform for data sharing and updating news on SDG 6. This can be built as a communication tool linking members of the SDG 6-CL and other interested parties, including decision makers
- Linking ideas, opinions and insights between high- and low-level stakeholders
- Proposing and implementing new monitoring approaches with reference to those applied successfully worldwide
- Adopting SDG 6-CL as the main contact and implementing entity for SDG 6 in Lebanon, which can later assume the responsibilities of an SDG 6 National Committee.

The first step by the SDG 6-CL was to conduct a survey on the priorities of the 11 indicators listed in the SDG 6 goal. This helped to select the most significant indicators to begin dealing with in Lebanon. It became clear to the SDG 6-CL that the priorities are governed by the water sector. Thus, indicators 6.1.1, 6.3.2 and 6.6.1 are the most significant. The priorities were therefore given as follows:

- Indicator 6.3.2: Proportion of bodies of water with good ambient water quality, where 5 priority selections were matched
- Indicator 6.1.1 and 6.6.1: Proportion of the population using safely managed drinking water services; and change in the extent of water-related ecosystems over time, where 3 priority selections were matched for each.

The insights of the stakeholders on water supply and sanitation were summarised as follows:

- Water consumers, farmers and academics are pessimistic about the water and sanitation sectors
- Water and sanitation sector employees stated that solutions should be rapidly taken
- There are many promises of improvement from high-level stakeholders regarding water and sanitation
- It is obvious that capacity building by various stakeholders is crucial.

The following points can be concluded:

- Current water supply and sanitation services are unacceptable
- Mismanagement is the main reason for water problems and sanitation in Lebanon
- Institutional coordination, data exchange and sharing are still unsatisfactory
- Water and sanitation monitoring systems in Lebanon are unacceptable and sometimes bad
- SDG 6-CL has declared that the engagement of Lebanon in SDG 6 is of great benefit, and that collaborative projects run with financial support would be a helpful tool if introduced by UN Water
- Services for water-related ecosystem are poor, and the water is contaminated
- Water efficiency is badly defined and sometimes unsatisfactory, and water systems are obviously stressed
- There is a necessity to adopt all SDG 6 indicators, with some of them modified according to the country's needs.

The contribution of capacity building in achieving SDG 6

Abderrafii Mardi, Training Director; Dr. Mokhtar Jaait, Head of Research and Development, ONEE

The potential of natural water resources in Morocco is estimated at an average of 22 billion m^3 per year; the equivalent of 650 m^3 per inhabitant per year, which is below the commonly accepted threshold of 1,000 m^3, at which shortages and water crises occur. This problem is set to worsen due to a rapid population growth, socio-economic development and climate change.

This situation is common to many countries in the Middle East and North Africa (MENA) region. Even in the countries where water resources are abundant, their quality is unsafe. These facts are worrying for drinking water and sanitation operators at political, social and technical levels. More than 300 million people in Africa are without access to safe drinking water. Sanitation is more worrying as approximately 600 million people do not have access to modern sanitation facilities. These alarming facts have pushed both local authorities and the international bodies that advocate improvement to the living conditions in the region to mobilize huge financial resources for water and sanitation infrastructure projects. However, there are still significant delays and the latest assessments indicate new challenges that test the ability of the actors concerned to target investments, secure and sustain access to water and sanitation services, and optimise the operation of water facilities. One of the main problems is the insufficient number of qualified people with the necessary skills to manage the water sector at technical, managerial and financial levels.

The National Office Of Electricity and Drinking Water (ONEE), Morocco, has long been aware of the importance of human capital in the development of the water and sanitation sector and, in 1978, created the Training Centre for Water and Sanitation (CFTE) dedicated to the training of technicians and specialised workers. Since then, the CFTE has enabled ONEE to meet its needs by training and qualifying staff in charge of planning, implementation and management of projects and infrastructures. This allowed ONEE to carry out its mission as chief body in charge of ensuring safe drinking water and sanitation in Morocco. This has resulted in a drinking water access rate of up 100 per cent in urban areas, a generalization of access to drinking water in rural areas exceeding 96 per cent, and 76 per cent of the urban population being connected to the sewerage system. Morocco is among the few countries in the region that achieved Millennium Development Goal (MDG) 7 by 2015, putting the country in a strong position to reach the targets of the Sustainable Development Goals.

During the last two decades, the rapid evolution and diversification of the demand for drinking water and sanitation services to meet the increasing demands of the populations in the Africa and MENA regions, has led to an intensification of infrastructure projects, increasing the demand for new skills and expertise adapted to local context. In 2008, in response to this challenge, ONEE transformed its training centre into the International Institute for Water and Sanitation (IEA) with the mission of providing capacity development in the water and sanitation sector through training, research and development, technical assistance and knowledge management.

The IEA has now become a centre of reference at national and regional levels due to its educational and research infrastructure, its designation as a World Health Organization (WHO) collaborating centre, the recognition of donors and international cooperation agencies, and the trust of many water operators in the Africa and MENA regions.

The IEA organizes some 20,000 trainee days per year for ONEE staff and water sector stakeholders in Morocco, as well as for water operators in Africa and the Arab region within a bilateral or tripartite cooperation framework. The partners in this North-South cooperation are numerous and diverse, including Japan (JICA), Belgium (Enabel), France (AFD), Germany (GIZ), as well as international or regional institutes such as United Nations Industrial Development Organization, The Islamic Development Bank, and AAE. One of the recent capacity building projects with a focus on training led by the IEA, is the support of the Guinean authorities, over the period 2017–2021, for the sanitation of the capital, Conakry.

The IEA's efforts in research and development are focused on finding effective solutions to help solve the major water problems and meet critical challenges such as supplying drinking water in sufficient and sustainable quantities at a lower cost while respecting sustainable development; guiding the choice of non-conventional resources including artificial recharge, sea water, brackish water and desalination; providing flexible solutions to collect and treat wastewater for reuse; and dealing with natural hazards, mainly floods and droughts, in the context of climate change.

The solutions should be suitable to the specificities of the region by taking into account the local, social and cultural dimensions, and ensuring that the solutions are affordable and technically realistic. The IEA is currently working on an applied research project that aligns with the targets of SDG 6, and which consists of decentralized sanitation using multi-layer system process. The project, carried out as part of a

The International Institute for Water and Sanitation waste water facilities

Supply water management workshop in Cameroon

International Institute for Water and Sanitation expertise in Mauritania

tripartite partnership between the IEA, Cadi Ayad University of Marrakech, Morocco and Chimane University, Japan, aimed to develop a sustainable and low cost sanitation system for small communities. It received the best research prize in the MENA region awarded by the Sustainable Sanitation Alliance (SUSANA) at the 2017 Stockholm World Water Week.

The IEA acts as a resource and expertise centre for project support and technical assistance in the region, sharing Morocco's know-how and experience with other developing countries such as Cameroon, Burkina Faso, Sudan and Guinea. One of the flagship initiatives concerned the IEA's involvement in a project known as *Aftout Essahli* concerning supply of drinking water to the coastal part of Mauritania from the Senegal River to the capital, Nouakchott, with a total cost of US$500 million.

Within the framework of its collaboration and knowledge sharing with WHO, the IEA has been involved in the monitoring of SDG 6 through evaluation projects conducted nationwide. The IEA was designated the focal point of the Global Assessment and Analysis of the Water and Sanitation Sector (GLAAS) project, a UN-Water initiative implemented by WHO. Its objective is to monitor, at global level, the delivery of sanitation and drinking water services, addressing the nature and impact of government policies and institutions, the investments in terms of financial and human resources, the volume and contribution of foreign assistance, and the relative influence of all these factors on sector performance.

The GLAAS report presents data received from 74 developing countries, and from 24 external support agencies, representing approximately 90 per cent of official development assistance for sanitation and drinking water. The report shows that, in many countries, policies and programmes have far too little emphasis on ensuring adequate financial and qualified human resources to both sustain the existing infrastructure and expand access to sanitation, drinking water and hygiene services. Only 7 per cent of aid is directed at maintaining services. The report also shows that inadequate monitoring and limited availability of financial data impede the ability of countries to assess progress and improve performance.

To address this particular challenge, WHO launched the TrackFin initiative. Morocco's significant involvement in GLAAS was an important factor in its selection as one of the pilot countries of the initiative, and the organization of the pilot exercise was entrusted to the IEA in collaboration with the Moroccan Ministry of Health.

The aim of the study is to track WASH expenditure of all stakeholders including government bodies, local authorities, public- and private-sector institutions, NGOs, national and international donors, investors and households, and thereby to provide answers to the following key questions:

- What is the total amount of expenditure in the sector?
- How are funds distributed between the various services and different types of expenditure including investment, maintenance and operating costs?
- Who pays for drinking water and sanitation, and how is the financial burden distributed among the various sources of funding?
- Which entities are the principal channels for financing the sector and in what proportion do they contribute to total expenditure?

The answers to these questions is analysed and presented in the form of tables and standard indicators to facilitate comparison between countries over time.

The IEA plays an important role in building the capacity of the drinking water and sanitation sector at national and regional levels. Its strategy and action plans align with those of stakeholders to sustainably support access to quality water and sanitation services. Its global action is part of a perspective of active listening and openness to its external environment to better meet the needs in terms of the capacity development of its partners, following a sustainable collaboration approach.

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Improvement of water use efficiency through Smart Water Management

1 The difference between system input and authorised consumption. Water loss can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water loss comprises both physical and commercial losses (also known as real and apparent losses).

2 Those components of system input which are not billed and do not produce revenue. Equal to unbilled, authorised consumption plus physical and commercial water losses.

3 Also referred to as a centralized remote monitoring control system or a supervisory control data acquisition system.

4 A high-efficiency water infrastructure management system using advanced information and communication technology to overcome the limitations of existing water resource management systems.

5 A city where water quantity and quality from the source to the customer are managed by using information and communication technology to supply clean tap water.

6 A system that supports rapid decision-making on water quality accidents by providing more accurate water quality prediction data by linking information on meteorology, watersheds, rivers, and reservoirs.

8 K-water's own system embracing techniques for integrated management in watershed areas, considering water quantity and quality, ecology and customers in order to facilitate sustainable water use.

8 Cost-benefit ratio is the ratio of the present value of the benefit to the present value of the cost. This is one of the criteria for comparing business alternatives in a cost benefit analysis.

9 Assuming a 20% improvement in NRW (maintaining NRW of 14% over the next eight years), we applied a selling price of 809 KRW per year. In calculating the incremental benefits, the facility investment cost is 500m KRW, the communication cost is 660 KRW per meter and the repair and maintenance cost is 2.5m KRW per year. The improvement benefit was calculated using 600 KRW per meter of manpower survey cost and 11m KRW per year leak detection cost.

A comprehensive approach to building a water partnership for sustainable development

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Acknowledgement
We gratefully acknowledge the support provided by the Department of Bio-technology, Government of India, for undertaking this development research under the Indo-EU programme of Water4Crops project entitled: Integrating Bio-treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India (India side).

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Strategies for transforming the Malaysian water sector

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Academy of Sciences Malaysia acknowledges the following authors for their contribution to the report: Transforming the Water Sector: National Integrated Water Resources Management Plan (NIWRMP) – Strategies and Road Map, and the article shown in this publication: Shahrizaila Abdullah, ASM Senior Fellow; Fateh Chand, ASM Senior Fellow; Salmah Zakaria, ASM Fellow; P. Loganathan, ASM Senior Analyst

Authors' Note: This paper is a concise version of the two-volume report: Transforming the Water Sector: National Integrated Water Resources Management Plan (NIWRMP) – Strategies and Road Map, published by the Academy of Sciences Malaysia and launched in December 2016. A reader and pdf version of the full report may be accessed or downloaded from the ASM website as follows:
Volume 1: https://issuu.com/asmpub/docs/web_vol1_gf
Volume 2: https://issuu.com/asmpub/docs/web_vol2_gf

The Mekong River Commission and its transboundary cooperation

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Strengthening citizens' involvement in water and sanitation management

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SDG 6 – New vision for better management of water supply and sanitation in Lebanon

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