UNEP

Harnessing opportunity

Wastewater as a managed resource

GPA Global Programme of Action for the Protection of the Marine Environment from Land-based Activities

GWI GLOBAL WASTEWATER INITIATIVE

Acknowledgements

The UN Environment coordination team provided essential support, in particular: Mette Wilkie (Director, Ecosystems Division), Birguy Lamizana-Diallo (Programme Officer, GPA), Oona Tully (Managing Publisher, UNEP), Petter Malvik (Associate Expert, GPA), Marjorie Nyabuti (Associate Project Officer, GPA), Janet Opati (Team Assistant, GPA) William Ingram (Intern, GPA) and Elizabeth MacAfee (Intern, GPA).

Cover photo: Ultra-pure water resulting from an intensive three-step purification process; Orange County Water District, California.

Photo credits: Pages iv/1, 3, 4/5, 6, 9, 12/13, 31, 32 — IWRM AIO SIDS via Flickr; page 15 — UN; page 17 — Luiz Gustavo Wagner; page 18 — Simone Bittencourt; pages 20/21, 23 — Donna Sue Spencer; page 25 — Belize Project Management Unit, GEF CReW; pages 27, 28 — Orange County Water District, California

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Foreword

Wastewater is a global concern. It has a direct impact on the biological diversity of aquatic ecosystems, with potentially disruptive influences on every aspect of life, from health, education and urban development to food production and industrial output. The issues associated with improper handling of wastewater disproportionately affect the poor, women and children. Addressing these issues is important to the achievement of several Sustainable Development Goals, including Goal 6, with its specific target to ensure availability and sustainable management of water and sanitation for all.

The Global Wastewater Initiative (GW^2I), under the auspices of UN Environment and its Global Programme of Action for the Protection of Marine Environment from Land-based Activities, is working to promote better management of wastewater. As a platform to exchange information and best practices for wastewater management and to encourage new investments in wastewater, the GW^2I brings together UN agencies, international organizations, government agencies, scientists, the private sector and other stakeholders, creating a basis for new partnerships and programmes to address the challenges and potential of wastewater.

The work has a dual purpose: to avert the societal and environmental costs associated with not taking action and to demonstrate the benefits of using wastewater as a valuable resource. In fact, the term wastewater is misleading, because—if treated properly—wastewater can in fact be a resource with the potential to solve a web of interconnected health, development and environmental problems.

As a source of water and nutrients, wastewater can be used for crop production, reducing the need for scarce freshwater and expensive fertilizers. As sludge, it can be used as a raw material in construction materials and to generate biogas and biofuel, providing opportunities for green jobs, sustainable development and social well-being.

This publication showcases some of the innovative approaches being used and provides guidance on how communities can put their wastewater to purposeful reuse — as reclaimed water — for the benefit of all.

The case for wastewater reuse

The issue of what to do with the wastewater generated by humans, agriculture, livestock and industry has long challenged development experts, companies, environmentalists, policymakers and urban planners alike.

Despite improvements in recent years, the untreated wastewater that seeps into the global water supply continues to devastate families and entire communities. According to the World Health Organization, nearly one million people die each year from illness caused by unsafe water supply, poor sanitation and improper hygiene, including almost 400,000 children under the age of five (WHO, 2015). These illnesses strain local resources and create an economic burden, leading to lost wages, lower productivity and decreased competitiveness.

Poor wastewater management and improper sanitation represent a significant factor in the spread of infectious disease. Untreated wastewater pollutes streets, fields, rivers, lakes, and the coastal and marine environment. It destroys economically valuable fisheries, elevates the health risks after natural disasters and threatens increasingly scarce freshwater resources. The negative impacts overwhelmingly hit the poor and vulnerable, including women who must spend a large part of their day fetching clean water for their families' needs. It is also an issue for girls in poor countries. These girls are at risk for dropping out of the educational system at puberty because schools lack the sanitation facilities that would allow them to tend to their personal hygiene with dignity during their menstrual cycles. This reinforces and deepens inequality and poses an obstacle to reducing poverty and achieving the Sustainable Development Goals (Anderson et al., 2016).

Clearly, there are significant health and environmental costs associated with not taking action on this issue. There is also a strong business case to be made about the potential benefits associated with treatment and reuse of wastewater for agricultural purposes, energy production and sludge generation — in addition to potable uses, such as replenishing dwindling water supplies.

10 guidelines to maximize wastewater's resource potential

1. Create an integrated and comprehensive approach to water resources management that includes wastewater management and reuse
2. Incorporate planning for wastewater management and reuse in community development and urban expansion
3. Shift focus from waste disposal to resource recovery
4. Find the balance between most effective technology and financial, resource and community capacity
5. Develop a coordinated policy framework and establish clear lines of authority by involving policymakers, public and private sector investors and managers, government agencies, and community organizations
6. Enact realistic, enforceable regulations and achievable standards
7. Minimize top-down decision-making by empowering local authorities to set standards and charge fees
8. Increase public awareness through marketing campaigns and by engaging with male and female community leaders and heads of households
9. Apply market-based methodologies, such as the "polluter pays" principle for commercial and industrial wastewater management, to finance operations
10. Promote international cooperation on sustainable wastewater management by building global partnerships and sharing knowledge and best practices

Source: CReW, 2010.

One recent report notes that the 330 km^3 of municipal wastewater produced globally each year is enough to irrigate 40 million hectares — equivalent to 15 per cent of all currently irrigated land — or to power 130 million households through biogas generation (Mateo-Sagasta, Raschid-Sally and Thebo, 2015). Already, some 10 per cent of the world's population consumes food that was grown using wastewater for irrigation and fertilizer. Clearly, the potential is there.

In a time of depleting natural water resources and growing concern about water availability, communities around the world are starting to think differently about their approaches

to wastewater management. In addition to understanding the importance of good wastewater management to improve health and reduce environmental impacts, they are starting to view this treated wastewater as a resource that can yield significant economic, health and environmental benefits.

Harnessing this opportunity requires a massive change in mindset, and a three-pronged focus on establishing enabling policies and regulations, on deploying the appropriate technologies and approaches, and on identifying financing approaches that support long-term operational sustainability.

Building a supportive policy environment

Strong and supportive policies, regulations and laws underpin any and all efforts to deploy wastewater as a resource. Effective policies are needed to promote the importance of proper sanitation, set priorities and mobilize resources. Equally important is political will and commitment on the part of authorities to take action.

At the international level, a framework of support already exists. Sustainable Development Goal 6 specifically references the importance of wastewater treatment as part of the broader effort to end poverty, fight inequality and injustice, and tackle climate change by 2030. Countries from around the world have affirmed their commitments to improve wastewater treatment and support international assistance and cooperation through communal statements such as paragraph 124 of "The Future We Want," adopted at the United Nations Conference on Sustainable Development held in Rio de Janeiro in June 2012.

Multiple covenants, treaties and agreements address the range of issues affected by the wastewater and sanitation challenge, including gender, health, pollution, water quality, environmental protection, maritime life and trans-national waterways. The UN's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) is mandated to address these issues on a global scale, providing support for countries and encouraging coordinated action and investment in wastewater-related initiatives through Regional Seas Programmes and global partnerships such as the GPA's Global Wastewater Initiative (GW^2I).

At the national level, many countries have passed laws stating that access to a healthy environment is a fundamental human right. These laws form the baseline rationale behind initiatives ranging from cleaning up polluted waterways to improving sanitation. Increasingly, such legislation is being used in support of efforts to reuse wastewater for a variety of purposes. Other national-level efforts, such as National Plans of Action to address pollution priorities, are also moving toward a broader-based approach that includes wastewater. At the local level, municipalities are beginning to make use of a variety of legislative tools to support new wastewater recycling initiatives.

Given the unique circumstances of local communities, the vast array of governing structures, and the differences in the interplay of local-, state- and national-level authorities, it is important to note that a prescriptive, one-size-fits-all legislative approach is not the solution. What is required is a customized approach that takes into account the specifics of the situation, works within the particular legislative framework, and builds on best practices from other communities. This section showcases tailored policy interventions undertaken by two nations that have enabled better wastewater management and increased wastewater reuse.

What is in a National Plan of Action?

Finland's National Plan of Action features efforts aimed at reducing eutrophication and "dead zones" in the Baltic Sea, where the many cities that dot the coastline have expelled their treated wastewater. A primary goal is to reduce and recycle nutrients and improve the status of the Archipelago Sea in collaboration with other Baltic states.

In **Argentina,** the National Action Plan is focused on cleaning up the Matanza-Riachuelo river basin, the most polluted in Argentina and one of the 30 most polluted in the world. Since a 2008 high court ruling mandating restoration, change is apparent, with construction of three new water treatment plants that provide clean water to one million people, expansion of 11 sewage treatment plants, closure of 186 garbage dumps and conversion of 177 polluting industrial facilities to cleaner uses.

In the **United States**, the National Action Plan details steps that federal agencies can take to improve the management of freshwater resources in a changing climate.

Sources: UNEP, 2015b; Interagency Climate Change Adaptation Task Force, 2011.

South Africa: Bold policies pave way for improved sanitation and award-winning reclamation efforts

The eThwekini municipality in Durban is home to many poor residents who lack access to basic sanitation services. Aided by a national legal framework that encourages bold action, municipal officials designed policies that allow free provision of services to increase access, while creating a roadmap for using wastewater as a resource, yielding cost savings for industrial firms and preservation of a water supply that was rapidly shrinking due to increased demand.

The context: Global leadership and political will create enabling environment

South Africa is a global leader in wastewater treatment research and development. As one of the first nations to experiment with innovative wastewater processes such as industrial-scale, low-loaded trickling filter plants, the country has long demonstrated interest in putting wastewater to use as a resource. Among its successful innovations are the world's first direct potable reuse application, filed in 1968, and the first use of ozone and granular activated carbon (GAC) in water reclamation, set up in 1978. The eMalahleni Water Reclamation Plant also broke new ground as the world's first facility to treat acid mine drainage water for reuse as drinking water (UNEP, 2015b).

The problem: Lack of universal sanitation; water scarcity

Despite this long-time leadership, more than 20 million South Africans lacked access to adequate sanitation services when the apartheid regime ended in the 1990s. The sanitation issue was most acute in large urban areas like Durban, where more than 500 informal squatter communities housed an estimated 300,000 people, living in flimsy shacks with limited access to running water or electricity (Arde, 2014).

This immediate problem was coupled with the grim reality that South Africa faced a longer-term and far-reaching threat: water scarcity.

So policy-makers had good reason to explore alternatives that would help improve the sanitation situation and ensure a steady supply of water for years to come.

The approach: National legal framework supports municipal action

South Africa's legal framework for wastewater management began to take shape in the 1990s, following the end of apartheid. Reforms included a series of laws focused on human rights and sustainable development, addressing issues such as housing, wastewater and sanitation. The nation has built on this legal base by adding new laws over the years. The "Free Basic Services Policy" was enacted in 2001, followed by the Free Basic Sanitation Implementation Strategy in 2009. These policies allowed municipalities to provide essential and basic sanitation services free of charge for poor households.

For a city like Durban, this meant that the municipal water department, eThekwini Water and Sanitation, could now deliver services to poor families, even if they could not afford to pay.

The municipality's government set up a waterborne sanitation zone, within which levels of waterborne sanitation services are delivered based on a sliding fee scale. The squatter communities are located outside this zone. They receive free services under the country's national free basic services policy, including temporary use of public toilets and showers until mandated housing upgrades are complete.

National law also forms the basis for the city's proactive and innovative wastewater reuse and reclamation programmes. The country's comprehensive compendium of water laws

and regulations establishes guidelines and governance for municipalities interested in setting up operations to return effluent and other wastewater back to the water supply. This baseline support, combined with the growing concern over future water shortages, has catalyzed the municipality's initiatives to use wastewater as a resource.

How it helped: Award-winning approach transforms lives, yields bottom-line business benefits and protects water quality

Nationwide, sanitation services have expanded significantly in the last two decades, with nearly 80 per cent of South Africans now able to access better sanitation (Brand South Africa, 2015). At the local level, Durban's proactive policies have made a real difference in the lives of 700,000 poor people, who can now take care of their sanitary needs in a healthy way. For its transformative and inclusive approach, eThekwini Water and Sanitation was awarded the Stockholm Industry Water prize in 2014.

As the transformation progressed, the municipality was faced with new challenges. With more residents gaining access to water, demand increased. Meanwhile, with the expansion of the service area came the question of what to do with the additional wastewater collected. To address these new challenges, the municipality began to explore options for wastewater treatment and reuse, initiating policies, programmes and pilots, guided and enabled by the national legal framework.

One strong outcome resulting from these actions is the fully operational industrial-grade plant at eThekwini's Southern Works. The plant treats domestic and industrial wastewater to stringent standards for use in industrial applications. The municipality sells this reclaimed water at a lower price than potable water to industrial customers, helping companies save money while freeing up drinking water for an estimated 300,000 throughout the city (eThekwini Municipality, 2012). Other innovative initiatives underway include feasibility studies to explore reclamation of treated wastewater to supplement the city's shrinking supply of drinking water and use of biomethane for electricity generation.

Jordan: In arid country, enabling policies for wastewater reuse

Combined with a rapidly growing and increasingly urbanized population, the severe limitations in Jordan's renewable water supply pose a continual threat to Jordanian society. The country's policymakers have long understood the importance of sound policies to better manage the country's water, including an integrated strategy that considers wastewater as a key national water resource.

The context: In a rapidly urbanizing nation with desert climate, a policy framework to ensure long-term water availability

About 78 per cent of Jordan's people currently live in urban areas, mostly in the northern and central regions of the country. (The details and data for this case study are drawn from UNEP, 2015b.) The trend has picked up in the last several decades: in 1980, just fewer than 60 per cent of the population lived in cities. By 2030, nearly 90 per cent of Jordanians will be city dwellers, according to estimates from the World Resources Institute. The growth in urban populations creates new demand for housing, offices, factories, grocery stores, roads, bridges, schools, hospitals and other facilities.

The lynchpin of this urban infrastructure is water. Jordan's policymakers have long understood that water would become an increasingly precious resource, given the desert climate and that water availability would always be a concern.

The problem: Rising demand; scarce resources

The Hashemite Kingdom of Jordan is among the 10 countries most affected by water scarcity worldwide. As many natural water resources in Jordan are severely stressed, the country relies on underground aquifers, which are depleting rapidly. Annual renewable water resources have dropped to about 130 cubic meters per person in recent years — the equivalent of about 94 gallons or 356 litres per day — compared to thousands more per person in 1946. At the same time, with successive waves of immigrants from other parts of the region, the country also has one of the highest average population growth rates in the world. A growing population requires more water.

The confluence of rising demand, limited resources and rapid population growth has caused the supply of natural water became seriously stressed. Smaller, outlying communities faced additional water accessibility and sanitation challenges. All of this has put even more pressure on government authorities to solve the water scarcity problem.

What they did: **Legislative building blocks and integrated water strategy**

Jordan's policymakers took the long view, enacting several key pieces of enabling legislation through the years. In 1988, the government enacted Water Authority of Jordan Law Number 18, and its amendments, which created an "autonomous corporate body, with financial and administrative independence" (Arab Countries Water Utilities Association, 2013).

This landmark legislation was followed in 1992 with the Ministry of Water and Irrigation By-Law Number 54. Next came the Jordan Valley Development Law Number 30 of 2001, the Groundwater By-law Number 85 of 2002, and, most recently, the 2006 Environmental Protection Law Number 85.

The strong policy foundation opened the door for innovation. The resulting partnership between the public and private sectors helped build a robust water resources management and service delivery institutional structure. Several types of public-private partnerships are used, including limited liability corporations, build-operate-transfer schemes, management contracts and micro-service contracts.

At the same time, the groundwork was laid for more integrated management of wastewater as part of an overarching approach to water resources. The 1998 enactment of an exhaustive wastewater management policy codified this approach, with detailed guidance on treatment standards and business operations. The 2009 adoption of the National Water Strategy built on the framework to ensure water availability into the future. The strategy addresses ways to maximize re-use of wastewater, particularly for agricultural irrigation purposes. It also spells out targets such as achieving internationally accepted operational standards at all wastewater treatment facilities.

How it helped: **Efficient and effective water reclamation**

This concentrated long-term effort has led to notable health and sanitation improvements. Today, almost all Jordanians — 98 per cent — have access to basic sanitation, among the highest rates in the entire region.

The country currently generates 115 million cubic meters of wastewater every year. With 28 major wastewater treatment plants in operation, 65 per cent of Jordan's homes are now connected to wastewater treatment networks. Of the collected wastewater, 98 per cent gets treated, with about 90 per cent of this secondary high quality reclaimed water reused in agriculture.

Today, Jordan faces additional challenges, as new arrivals from Syria — estimated at about 620,000 as of June 2015, according to the UN Refugee Agency — are absorbed into urban areas, creating ever greater demand for water. The situation highlights the continuing importance of putting wastewater to work as a resource, and the key role played by a strong policy framework and a collaborative approach.

Tailoring technologies for the right approach

As with policy prescriptions, there is no single solution that can turn the vast untapped potential of wastewater into a viable agricultural or energy resource. The key is to tailor the solution to local conditions, to the public mindset and to the availability of supporting infrastructure.

Technological advances in wastewater treatment mean that wide-scale use of reclaimed water is a realistic and achievable goal. However, with so many technologies available, it can be challenging to identify the optimal approach. Guidance such as the Wastewater Technology Matrix, developed by UN Environment: GPA and the International Water Association, can help. The matrix is a tool for selecting appropriate wastewater management technologies. Taking into account physical, environmental, social and financial considerations, it provides a range of technology options and helps decision-makers identify the approach that works best for their situation.

Today, many countries facing water and sanitation challenges are in the process of testing both high tech and low tech solutions that show potential. Pilots such as Egypt's reuse of treated sewage to produce biomass for energy generation are showing promise as a way to maximize economic investment returns and environmental benefits. In the high desert Moroccan city of Ouarzazate, an integrated approach is combatting land degradation, loss of biodiversity and desertification by using solar energy to pump treated wastewater to irrigate newly planted trees surrounding the city in a green belt. Sludge-to-energy systems are gaining traction in China, where plans are under way for such systems in Beijing, Changsha, Chengdu and Hefeifour to help reduce high pollution levels (Zhong, et al., 2016).

The next few pages highlight the diverse technologies that can unleash wastewater's potential as a resource on a broad scale.

Singapore: Innovative technology underpins water reclamation

Singapore's strong economic development trajectory includes a high tech, water-intensive manufacturing base. With a small land mass and a densely concentrated population, the city-state's ability to harness natural water resources was limited. As demand for water outstripped supply, Singapore deployed its research and technology capabilities along with thoughtful strategy and enabling policies to address the issues.

The context: In an economically and educationally advanced city-state, focus on technological solutions to water problems

Located at the southern tip of the Malaysian peninsula, Singapore gained independence from the United Kingdom in 1963 and from Malaysia in 1965. Since then, this city-state has experienced rapid economic growth. Today's Singapore is a hub for financial services, trade, transportation and logistics, as well as a centre for electronics and semiconductor fabrication.

The problem: Small land mass, limited room for storage

Despite its tropical climate, Singapore is a small city-state with a limited area to store rainfall and no natural underground aquifers or lakes. With the second highest population density worldwide (7,987.52 per square kilometre, according to the 2014 *CIA World Factbook*) and a growing population, this water-scarce state had to figure out a way to overcome water shortages that were only projected to get worse.

What they did: Blending conventional and innovative technologies

Over the course of the last 50 years, Singapore has developed a national strategy to overcome shortages. Large-scale wastewater reuse in potable water production is key to this four-pronged strategy, which also includes importing water, storing rainfall and desalinating seawater. In the implementation of the strategy, the state committed significant financial and scientific resources to research, develop and refine technologies that could turn wastewater into potable water on a large scale.

Launched in the year 2000, Singapore's NEWater initiative focused on technologically advanced reuse of wastewater in the production of "new" potable water. A 10,000 m^3/day demonstration plant was commissioned, incorporating conventional water treatment

processes, along with innovative techniques such as dual membrane microfiltration, reverse osmosis and ultraviolet disinfection.

Following a 30-month pilot that featured extensive monitoring of health impacts on animal subjects, the government approved a broader roll-out. By 2002, two full-scale facilities were operational, representing one of the first large deployments of wastewater reuse systems for potable water production in the world.

To reduce pollution in waterways and safeguard the quality of the water harnessed from the catchment, the system was designed with separate networks for wastewater and rainwater collection. It includes a deep tunnel sewer system running beneath the water purification plants, which helps ensure that all wastewaters are collected, treated and purified. It also enables the safe discharge of treated wastewaters into the sea or further purification for use as reclaimed water.

Finding a way to control odour and minimize foul air was another critical consideration, given the proximity of the proposed facilities to the densely populated city centre. Innovations include a comprehensive odour control and treatment system, featuring odour containment covers over treatment units, extensive odourous air extraction systems and odour treatment plants. The process begins with extraction of foul air, which receives a chemical scrubbing followed by activated carbon adsorption before safe discharge into the atmosphere.

Accompanying the technology investments was a strategic marketing and communication campaign. In advertisements, signage and public service announcements, wastewater was re-dubbed "used water," while wastewater treatment plants became "water reclamation plants."

When low-tech works best

Sometimes, the best solution is the one that does not involve a high level of technological complexity.

In **Georgia**, small farmers have reported increases in agricultural yields after participating in a pilot project implemented by UN Environment: GPA and Women in Europe for a Common Future and the Rural Communities Development Association to demonstrate easy use of the ecological sanitation — eco-san — approach. This involves installation of toilets that require almost no water to operate and that separate urine and feces at the source. After a simple sanitization process, the human waste products are used as organic fertilizer.

In the **Armenian village of Parakar** untreated wastewater was contaminating agricultural lands, jeopardizing food safety, and posing severe health risks. Here, a demonstration project to improve the quality of the wastewater for crop irrigation showed encouraging results by engaging with the local community to introduce small changes.

Source: Global Wastewater Initiative, http://unep.org/gpa/gwi/gwi.asp

How it helped: Reclaimed "new" water meets 30 per cent of freshwater needs

Today, Singapore has its own brand of recycled water: NEWater, produced at four plants that currently produce 547,200 m^3/day of reclaimed water. Currently, the reclaimed water is used primarily for water intensive manufacturing purposes such as semiconductor fabrication, as well as for other industrial uses—electronics, power generation and commercial heating and cooling systems—freeing up potable water for domestic consumption.

In addition, a small percentage of NEWater is used indirectly for potable reuse, a practice in place since 2003 (UNEP, 2015b). Re-injected into reservoirs, it is treated to a standard that surpasses World Health Organization requirements for tap water.

In total, this "new water" meets 30 per cent of the country's freshwater needs. Meanwhile, the effective odour control system reduces the size of the buffer zone needed around reclamation plants, so more of Singapore's limited land can be used for higher value development.

Singapore is not stopping here. With a goal to achieve complete water independence from neighboring Malaysia, the state wants to produce enough reclaimed water to meet 55 per cent of Singapore's freshwater needs by 2060. Plans to accomplish this ambitious goal include building larger water recycling plants and increasing seawater desalination capacity. The government has made a significant financial commitment as well, with continuing investment in research and development to discover the next generation of technological innovation.

Brazil: Chemically treated sludge is secret ingredient in farm productivity

In Brazil's Paraná state, the regional wastewater utility uses an anaerobic process to resolve the issue of how to dispose of final waste by-products on a large scale and in an environmentally appropriate way while creating a safe and cost-effective product to enhance agricultural productivity.

The context: Increased access to sanitation gives rise to new issues

Sewage sludge is what gets left behind when wastewater treatment facilities finish draining liquid from the collected waste and treat it. As global focus on sanitation and wastewater treatment has increased — along with investment in treatment facilities — the issue of how to handle the growing volume of sewage sludge has taken on more importance (Andreoli et al., 2007).

One solution has been around for centuries. Generations of farmers have long understood the benefits of using waste to irrigate and fertilize agricultural crops. However, with a large body of global evidence pointing to the health and environmental risks associated with use of untreated waste for agriculture, the challenge became how to reconcile the two. How could communities take advantage of a practical approach that enhances farm productivity and disposes of waste while reducing the negative/adverse health and environmental impacts?

Science and technology have provided the answers. Today, several technologies are in use to properly treat and process sewage sludge, yielding safe, nutrient-rich organic materials that can improve and maintain productive soils and stimulate plant growth.

The problem: What to do with the leftovers from wastewater treatment

As Brazil's sixth largest population centre, Paraná state has experienced rapid growth in recent years, particularly in its cities (IDB, 2014). Sanepar, the Sanitation Company of Paraná, operates 234 wastewater treatment plants throughout the state. Serving over seven million people, these plants generate ever larger amounts of sludge.

What they did: Reuse of sludge as agricultural fertilizer

In 2002, Sanepar began to address the issue of final disposal of waste by-products in a focused way. The utility introduced programmes in the Curitiba metropolitan area and the Foz do Iguaçu region to process sewage sludge and recycle it for agricultural use. Since then, the utility has scaled up the approach, which now extends throughout the state.

The semi-solid sludge is treated in an anaerobic process at Sanepar's wastewater treatment plants, which are outfitted with anaerobic reactors. Some facilities have secondary, higher-level treatment units, using dissolved air flotation, stabilization ponds, and anaerobic, aerated and percolating filters.

The process starts with dewatering, followed by disinfection through prolonged alkaline stabilization. Along the way, lime is injected into the sludge, to comprise 30-50 per cent of the total solid. The lime elevates the sludge's alkaline level while reducing pathogens. After a 30-day curing period, the sludge is transformed into a value-added product that reduces soil acidity and enhances plant growth (Anderson et al., 2016).

Sanepar transports the treated sludge by truck to farmers in the region who sign a contract to participate in the voluntary and free programme. They use the sludge as a fertilizer for a variety of crops, including mulberries, rye, coffee, sugarcane, barley, citrus, beans, corn, soybeans and grass, as well as for eucalyptus and pine plantations. Amounts are determined by the specifics of the soil and the nutritional needs of the crops. The farms are monitored frequently by an agricultural engineer who provides technical advice and guidance to farmers on proper handling of the material.

How it helped: Reduced reliance on natural nutrients; more affordable fertilizer; comparable farm productivity

Sanepar's programme has received a favorable reception in the farming communities where it is available. To date, the use of sludge has replaced 90 per cent of the limestone, 69 per cent of the nitrogen, 83 per cent of the phosphorus pentoxide and 35 per cent of the potassium oxide required in fertilizer production. This has helped reduce reliance on nutrients extracted from mineral sources for manufactured fertilizers and preserve such resources for other uses, with no impact on performance (Marcon, et al., 2015). For poor farmers who could not afford other types of fertilizers the value is even greater.

While Sanepar's initiative has proven successful, it is not without its challenges, particularly as the programme expands. Truck transport may not be the most sustainable mode of transportation on a broader scale. Infrastructure limitations, capacity constraints and lack of laboratory analysis services remain a problem.

In addition, the nature of agricultural cycles, which are concentrated into two peak demand periods of the year, makes it difficult to manage demand and identify appropriate storage mechanisms. Among the recommendations for improvements are regulatory reforms to enable a less bureaucratic management process and new investment in infrastructure.

Financing for long-term sustainability

As with all infrastructure, designing, building, operating and maintaining wastewater treatment facilities is expensive. Annual global investments in modern water and sewer systems currently top $30 billion each year (UNEP, 2015b).

But that is not enough. In the United States alone, an estimated $650 billion in infrastructure investment will be needed over the the next 20 years to meet the nation's water needs (Merrill Lynch Corporation, 2016). In developing countries, the annual cost to build, operate and maintain new water, sanitation and wastewater treatment facilities is estimated at more than $100 billion (UNEP, 2015b).

These are daunting numbers. Still, emerging market nations such as Brazil, China and India are committing considerable resources to developing this infrastructure.

The reason for this commitment is clear. The social, gender equality, health, environmental and economic costs of not taking action are far higher, including financial losses due to loss of productivity and higher healthcare expenditures where sanitation systems are inadequate. One World Bank study estimates that Southeast Asian countries produce about 2 per cent less than they could be every year because of poor sanitation (World Bank, 2008).

The reverse is also true: increasing water investments and improving access to safe water and basic sanitation could have huge economic returns. The prevention of sanitation and water-related diseases could save nearly $7 billion each year in health system costs. The value of deaths averted, based on discounted future earnings, would inject an additional $3.6 billion into the global economy every year (UNEP, 2015b).

Innovative financing approaches and new financing mechanisms that also incorporate fee-for-services methodologies are emerging as countries begin to focus more on ways to make wastewater work as a resource. For example, the United States is exploring a new municipal bond that will help lower the cost of capital and encourage new private investment in water-related infrastructure, part of a broader initiative to improve local

For women and girls, the COST OF DOING NOTHING is unacceptably HIGH.

Women and girls in some countries often spend up to **6 hours every day** fetching water.

In many countries, girls are forced to **drop out of school at puberty** due to a lack of sanitation facilities.

An inclusive approach to WATER AND WASTEWATER INVESTMENTS yields profound societal BENEFITS.

Reducing the distance to a water source from 30 to 15 minutes **increased girls' school attendance by 12 per cent** in Tanzania.

With the same access to clean water and other resources as men, women could boost their farm yields by 20–30 per cent and **lift 150 million people out of hunger**.

Involving women can **increase the effectiveness of water projects** 6 to 7 times.

Source: UN-Water, 2013.

wastewater, drinking water and stormwater systems through innovative financing (White House, 2015).

In developing countries, the work also includes building demand for basic sanitation services, even as more investment in wastewater treatment infrastructure will be needed to keep up with the demand once it is developed. This will require external sources of financing — including donor-funded support — and innovative financing schemes, given the budget constraints and multiple challenges such nations face.

Meantime, new publications, such as the UNEP's "Economic Valuation of Wastewater: The Cost of Action and the Cost of No Action" (UNEP, 2015a) and "The Wealth of Waste: the Economics of Wastewater Use in Agriculture," from the UN's Food and Agriculture Organization (FAO, 2010) yield cost-benefit analyses that demonstrate the viability of such investments.

In this section, examples of innovative financing approaches to wastewater recycling and reuse are highlighted.

Caribbean Region: Sustainable financing for wastewater management

In water-reliant economies, investment in effective wastewater treatment facilities is a health, environmental and economic necessity. Cash-strapped Caribbean countries are leveraging development finance and innovative approaches to fund projects tailored to their unique needs.

The context: For tourism-based island economies, clean water is a must

Water is a lifeline for most Caribbean island nations, where tourism is the primary industry. Many have invested in upgraded seaport infrastructure to accommodate massive cruise ships filled with tourists who spend money on the islands, supporting additional job creation in the retail, hospitality and service industries.

The problem: Limited budgets for sanitation networks

These tourism-reliant economies are in danger. Aside from their susceptibility to natural disasters such as hurricanes, recent studies have shown that Caribbean countries face a major threat from untreated sewage, which can impact public health and the region's rich biodiversity.

About 85 per cent of wastewater that flows into the Caribbean Sea does not get treated, in part because many homes in the region are not connected to sewer systems and stormwater networks are limited. (The details and data for this case study are drawn from the CReW website, www.gefcrew.org/.) This causes reef degradation, fish kills, algae blooms, red tides and temporary beach closures, in addition to concerns for public health. Such events also tend to deter tourists, with potential economy-wide impacts.

Governments throughout the region have long recognized that the pollution from municipal, industrial and agricultural sectors is a problem, imperiling the region's economic development and the quality of life of its people. However, they all face a major obstacle in solving the problem: the high cost of wastewater treatment facilities and sewer and stormwater connections and networks.

What they did: **Regional collaboration and development finance**

The problem was too big to handle alone, but severe enough to require prioritized attention. Progress toward sustainable solutions came with the establishment of the Caribbean Regional Fund for Wastewater Management. Known as CReW, the fund was set up by the Global Environment Facility in partnership with the Inter-American Development Bank and UNEP.

The goal of the four-year initiative was to pilot revolving financing mechanisms similar to those used in the U.S. and to encourage meaningful and effective wastewater management reforms in the region. The focus was on identifying a variety of optimal approaches and ways to achieve economies of scale in infrastructure investments. While helping to lower infrastructure costs for individual nations, the initiative also has emphasized regional dialogue and knowledge sharing for broader benefits.

CReW investments supported the efforts of several Caribbean nations as they implemented innovative financing approaches:

- In Jamaica, where the national water authority set up a consumer fee-based model to create a dedicated funding source for priority water and wastewater projects, CReW's credit enhancement facility allowed the capitalizing of this revenue stream so the authority could access long-term financing for infrastructure improvements.
- In Belize, the Ministry of Finance is managing a $5 million revolving fund that provides low interest, long-term loans for construction of wastewater treatment infrastructure.
- A revolving fund in Guyana is supported by $3 million in Global Environment Facility (GEF) funding and a $500,000 commitment from the government. This fund finances projects under public-private partnership arrangements since the country's major industrial and commercial wastewater facilities are managed by the private sector.
- The National Wastewater Revolving Fund for Trinidad and Tobago directly supports rehabilitation of aging treatment facilities and extending the network of connections to more homeowners. The fund's first project is a $4.7 million effort to refurbish the Scarborough Wastewater Treatment Plant and connect an additional 215 households to the sanitation system.

How it helped: **Pilot projects identify a way forward**

The CReW fund has catalyzed new investment in wastewater treatment and sanitation in several Caribbean nations. These countries all took different routes, based on their individual priorities and what works best in their own context.

In Jamaica, the $3 million reserve guarantee helped the water authority secure a $12 million, long-term commercial loan to finance the rehabilitation of 13 wastewater treatment facilities. The Belize revolving fund is financing three important projects, including construction of sewer lagoons for Belmopan, expansion of the Belmopan sewer system and establishment of the Placencia Wastewater Management System.

While still in its early stages, Trinidad and Tobago's effort to optimize the Scarborough facility's operational capacity is underway. Goals include reducing risks to public health through improved access to sanitation, reversing the trend of environmental degradation to protect delicate ecosystems and enhance the tourism industry, and increasing revenue for the country's water and sewerage authority. In turn, this will help finance more improvements and additional connectivity to sanitation services.

United States: Political will, public acceptance and budget add up for California's wastewater reuse strategy

In California, where years of drought are depleting the state's groundwater reserves, dedicated funding streams are helping to finance ambitious water infrastructure projects. The result is expanded use of municipal reclaimed water for potable and nonpotable uses.

The context: In drought-prone state, public acceptance of wastewater as a resource

The year 2015 brought another severe drought to the state of California, which was already battered by several drier-than-normal planting seasons. A study by Howitt, et al. (2015), of the University of California–Davis estimated $2.7 billion in economic losses for the state caused by the most recent drought, with $1.8 billion in direct losses for agricultural enterprises and 21,000 lost agriculture-related jobs.

In recent years the state's agricultural industry has looked at different ways to reduce water usage. Altering crops for less water-intensive plants, relocating water-intensive crops to parts of the state with more reliable rainfall, and replacing rainfall with other water sources for irrigation are all strategies that have been explored. The most viable of these options has been to pump water up from underground sources for irrigation. Unfortunately, this has accelerated the depletion of these sources, which were already under stress due to a growing population and increased demand for water, particularly in urban centres (First Tuesday Journal, 2016).

The seriousness of the situation forced state and local lawmakers to take a hard look at their existing approaches and to consider alternatives. California's municipalities and commercial users alike began to look more seriously at wastewater as a potential resource that could meet their water needs. The rapid pace of technological advancement, leading to more efficient and cost effective treatment and purification processes for domestic sewage, has allowed the state to tap into this potential. A focused strategy accompanied by education, communication and outreach has brought about a massive shift in approach.

The problem: High cost of infrastructure

The state was faced with an enormous financial challenge as it looked to expand its reuse of wastewater. Potable reuse systems require an expensive setup and extensive treatment processes. Nonpotable systems require a separate piping system to distribute the water, which can add up to as much as, or more than, potable treatment (Cernansky, 2013).

What they did: Dedicated funding streams to support catalytic projects

Beginning in the early 2000s, California voters approved a series of legislative actions that established dedicated funding streams for wastewater reuse initiatives. These funds are channeled through a programme run by the California Environmental Protection Agency and Water Resources Control Board to support water recycling projects and research.

With a goal to maximize the reuse of treated municipal wastewater to augment the state's freshwater supplies, the $625 million programme offers long-term, low-cost loans and grants for planning and construction of large-scale wastewater recycling facilities. Eligible applicants include public agencies and utilities operated by private sector partners. Loans

under the programme extend out 30 years with interest set at half the general obligation bond rate. Individual construction grants are capped at $15 million.

One project funded under this programme is the acclaimed Orange County Groundwater Replenishment System. (The details and data for this project are drawn from the Orange County Water District website, www.ocwd.com/gwrs/, and GWRS, n.d.) Among the world's largest facilities for treatment and recycling of wastewater for potable use, the system takes highly treated wastewater that once would have been discharged into the Pacific Ocean and purifies it in an advanced treatment process. After going through microfiltration, reverse osmosis and ultraviolet light with hydrogen peroxide, the treated water meets or exceeds all state and federal drinking water standards. Once the process is complete, the water is pumped to catchment basins and naturally filtered through sand and gravel to deep groundwater aquifers. It mixes in with the existing water sources in the aquifers, ultimately increasing the local drinking water supply.

To offset the $490 million in construction costs, the Water Recycling Funding Program and its related initiatives provided $92.5 million in grant funding. Additional support came in the form of grants from the California Energy Commission and funding from the Metropolitan Water District of Southern California, which helped subsidize operating costs when the system first opened for business.

How it helped: Increased resilience to cycles of drought; replenishing groundwater supply

Since its opening in 2008, Orange County's Groundwater Replenishment System has supported the potable water supply for more than 600,000 residents. California's funding strategy for such groundbreaking projects has earned the state global recognition as a leader in wastewater reuse.

In 2014, Orange County's water district received the Lee Kuan Yew Water Prize, a prestigious international water award for outstanding contributions towards solving global water problems. In awarding the prize, judges highlighted the effectiveness of the county's communication, education and outreach as critical to the public's acceptance of water recycling for indirect potable reuse.

Today, almost one in five Californians is connected to a utility that uses, or has as part of its water supply portfolio, potable reuse (Cernansky, 2013). Use of treated wastewater for non-potable purposes ranging from agricultural irrigation to geothermal energy production, industrial processing and wetlands restoration continues to expand as well.

The state still struggles with drought cycles and limited water supply. However, the increased availability of purified and recycled wastewater has reduced the strain on its groundwater resources considerably. In addition, as groundwater resources are replenished and storage capacity increases, California's vibrant water trading market continues to expand. This has given the state and its private sector partners another financial tool to invest in long term management of the state's water resources (Public Policy Institute of California, 2012).

Looking ahead: Innovations and issues

With the mainstreaming of wastewater reuse, demand will continue to grow for more efficient, safe and cost-effective tools, approaches and technologies to harness this potential. This expanding market is triggering innovation and catalyzing private sector investment in an emerging wastewater industry, holding strong economic promise. For example, in Texas, the San Antonio Water System partnered with a renewable energy company to build a biogas and digester gas purification plant next to its wastewater treatment facility. The utility makes use of the energy and sells the excess biogas instead of burning it off as waste. This biogas earned the utility about $200,000 in royalties each year, helping to reduce operating costs (Gale, 2014).

The growing private sector interest in wastewater innovation is not limited to alternative energy firms or environmentally-focused companies. Firms in several related industries have seen the future commercial potential and are moving into this niche. Among them is Kohler, an American kitchen and bath fixture producer, which has debuted a low-cost, streamlined residential filtration system that can purify up to 40 litres of water per day. The lightweight system is not reliant on electricity or connections to water infrastructure, making it a viable option for remote villages and poor urban slums that currently lack access to safe drinking water (Kohler, 2015).

Collaborative initiatives such as R3Water, funded by the European Commission, are advancing the wastewater-as-resource agenda as well. The programme, which promotes reuse of water, recovery of valuables and resource efficiency in urban wastewater treatment, brings together technology innovators, academic researchers and business leaders to scale up solutions that will transition treatment plants for urban wastewater to facilities that produce valuable resources.

Emerging issues

Understand the impact of:

Endocrine-disrupting chemicals and other chemical pollutants that can interfere with human and wildlife growth and development

Microplastics that may flow from wastewater treatment facilities and seep into rivers and other waterways

Identify reuse potential for waste such as:

Sargassum, the brown algae that is washing up on beaches in great clumps, decomposing and giving off a foul odour

Along with the increased focus on reuse of wastewater come new issues. Among the challenges which will require attention are:

- Updating policy frameworks and enacting enabling legislation as new uses for recycled wastewater are identified, new financing arrangements become viable and new technologies become available
- Upgrading the world's aging water infrastructure and replacing decaying lead pipes to reduce the risk that the infrastructure itself is contaminating the water supply
- Identifying new financing mechanisms to build needed infrastructure
- Investing in research and development to further advance the technology for increased efficiency, cost-effectiveness and ease-of-use
- Investing in research on how to deal with emerging pollutants such as endocrine disruptors, sargassum, high algal bloom (HAB) and microplastics

Clearly, more research, more innovation and more investment are needed, while the existing successes are contributing to a global knowledge base that will enable progress. Wastewater is a resource that is too valuable to throw away, especially in an increasingly water-scarce world.

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ISBN: 978-92-807-3612-0

Job number: DEP/2053/NA