WASTEWATER REUSE

Time to reverse 'unthinkable' waste of municipal water resources

At a time when freshwater supplies are being depleted by cities and industries across the world, massive volumes of municipal wastewater remain untapped and unmined – and the time has come to change this, writes Tony Carnie.

EU Civil Protection and Humanitarian Aid)

Crazed by thirst, the Ancient Mariner pondered the ocean of water that surrounded him and declared: "Water, water everywhere, Nor any drop to drink. . ."

More than two hundred years after Samuel Taylor Coleridge's grey-bearded sailor lamented the irony of scarcity amid abundance, researchers from the United Nations University in Canada have calculated that 380 billion m^3 of municipal wastewater is generated every year – a massive body of largely untapped organics and liquids that could be mined and recycled into freshwater, nutrients and energy.

To put that volume into context, the researchers note that 380 billion m^3 is roughly equivalent to the annual discharge from the Ganges River in India, five times the amount of water passing over Niagara Falls each year – or enough to fill Africa's Lake Victoria in roughly seven years and Lake Geneva in Switzerland in less than three months.

And the volume of this largely wasted resource keeps growing, with a projected rise of roughly 24% by 2030 and 51% by 2050.

Dr Manzoor Qadir, lead author of a study titled ***Global and regional potential of wastewater as a water, nutrient and energy source***, says freshwater supplies are becoming increasingly stressed in several parts of the world and demand keeps growing. In this scenario, ignoring the opportunities for resource recovery from wastewater "is nothing less than unthinkable," he argues.

For example, the volume of water potentially recoverable from wastewater could irrigate up to 31 million hectares – equal to almost 20% of the farmland in the European Union. Recovering valuable nutrients such as phosphorous, nitrogen and potassium from wastewater could provide more than 13% of current agricultural demand for such fertilisers – while simultaneously reducing pollution and eutrophication of dams and river systems.

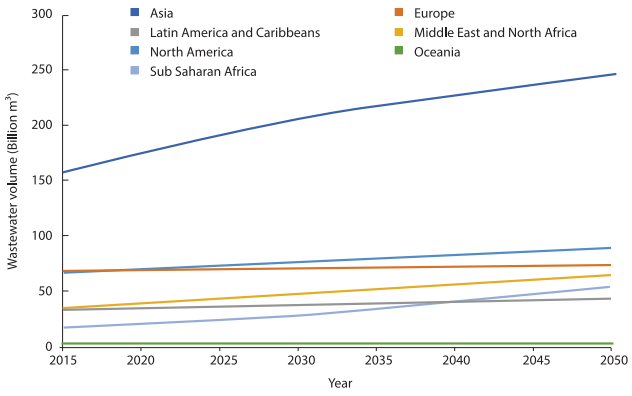
Eutrophication is caused by excessive levels of nutrients in water bodies, which, in turn, leads to the growth of dense mats of algae and other water plants, as well as the death of fish and other aquatic animals due to a lack of oxygen. Hartbeespoort Dam, west of Pretoria, is just one local example of where eutrophication has become a major problem due to excessive municipal sewage and wastewater pollution loads. In KwaZulu-Natal, eutrophication also threatens vital drinking water resources such as the Midmar Dam system.

Qadir, an environmental scientist and assistant director at the United Nations' University's Institute for Water, Environment and Health (UNU-INWEH), also suggests that harvesting the chemical energy embedded in wastewater could provide enough electricity to supply 158 million households – roughly the number of households in the USA and Mexico combined.

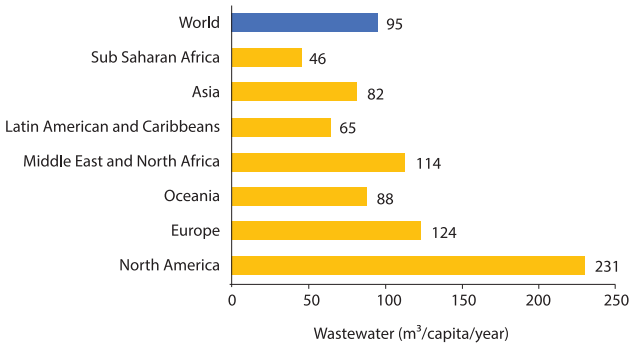
Vladimir Smakhtin, the director of UNU-INWEH, says is it unfortunate that municipal wastewater is often seen as "filth". But the institute believes that attitudes are changing slowly to recognise the potentially enormous economic returns and other environmental benefits that could flow from improved recovery of water, nutrients and energy from wastewater streams.

Some innovative examples from Africa include the Namibian capital, Windhoek, which has been recovering a significant volume of drinking grade water from municipal wastewater for more than 50 years. The first Windhoek plant started to produce drinking water in 1968 – the first such plant in the world – and in 2002 a new direct potable reuse plant was commissioned. This plant is operated by a consortium made up of Veolia and WABAG.

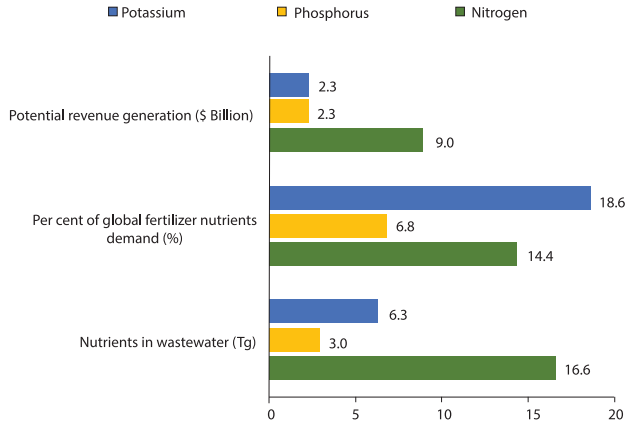
"In Windhoek, every drop of water counts," according to the Windhoek Goreangab Operating Company (WINGOC).



Global wastewater production across regions in 2015 and predicted until 2050. (Source: World Urbanization Prospects, 2018)



Annual volumes of wastewater produced per capita across regions. The world average is based on the total amount of urban wastewater produced and the urban population at the global level in 2015. (Source: UNU-INWEH)



Current levels of nutrients—nitrogen, phosphorus and potassium—embedded in wastewater and the percentage of global fertilizer nutrient supply that can theoretically be supplemented by these nutrients. (Source: UNU-INWEH)

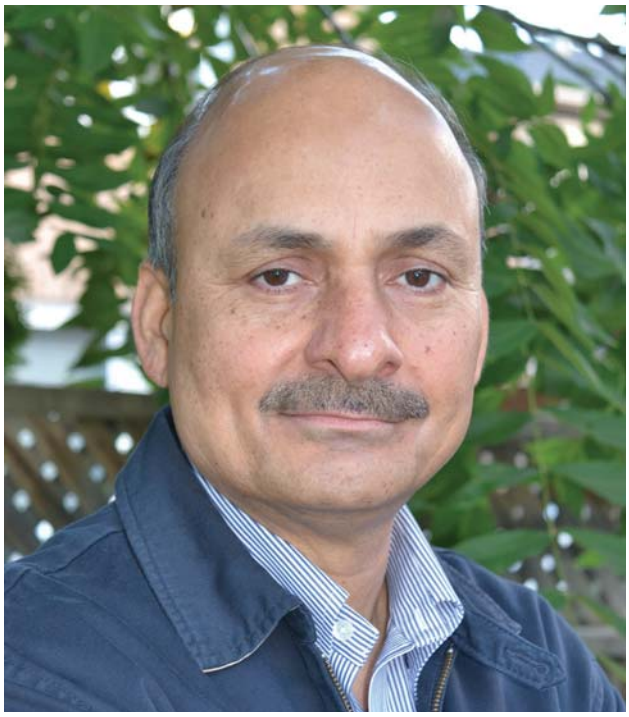
Namibia is one of the most arid countries in Africa. The average rainfall is 250 mm per year, but the heat causes more than 80% to evaporate, allowing only about 1% of rainwater to infiltrate into the ground. Consequently, Windhoek depends mainly on boreholes and three dams, and the growing city had to look for alternative solutions to secure its water supply in a sustainable way.

The water reclamation facility features state-of-the-art 'multi-barrier' technology (ozone treatment, biological activated carbon, granular activated carbon, ultra-membrane filtration and residual chlorination amongst others) that eliminates pollutants and contaminants.

Singapore has also become a world leader in this arena through the development of a multiple-barrier water reclamation process known as NEWater. According to the Singapore PUB National Water Agency, the genesis of NEWater dates back to the 1970s, when the government commissioned a study to determine the feasibility of producing reclaimed water. Although the study found it was technically possible, the high costs and unproven reliability at that point posed insurmountable concerns.

But by the 1990s, the cost and performance of membrane technology had improved considerably and in 1998, PUB set up

Image: Supplied



Dr Manzoor Qadir believes that it is "unthinkable" to ignore the growing opportunities for resource recovery from wastewater.

a team to test the latest membrane technology for use in water reclamation for potable purposes. In 2000, it commissioned a full-scale demonstration plant that could produce 10 000 m^3 daily and a battery of tests and audits showed it was a safe and sustainable water source. The three-stage process involves microfiltration and ultrafiltration, followed by a second stage of reverse osmosis and a final tertiary stage of ultraviolent disinfection capable of killing both bacteria and viruses.

An international group of experts in engineering, biomedical sciences, chemistry and water technology also found that NEWater's quality was consistently safe and high, and well within the World Health Organisation requirements for drinking water. They recommended it be used for indirect potable use, by introducing it into raw water reservoirs during dry periods. This blended water then undergoes naturalisation and further treatment in conventional waterworks to create drinking water.

Significant quantities are also used for non-potable uses in industry or for air-con cooling at industrial estates and commercial buildings. The biggest users of NEWater are wafer fabrication plants, which require water quality that is even more stringent than water for drinking.

Closer to home, the city of Durban has been a leader in recovering high quality water from municipal waste streams, and over recent decades it has pioneered several exploratory projects to harvest nutrients from both urine and faeces. In 2001, the city established South Africa's first private water recycling plant in Merebank (adjacent to the Southern wastewater treatment works) to recycle more than 10% of the city's total wastewater flows.

The plant is designed to treat up to 47.5 million litres of domestic and industrial wastewater to a near potable standard for sale to a large paper mill and fuel refinery. By reducing the amount of treated tap water used by local industry, the project indirectly frees up more drinking water for up to 300 000 people. It has also reduced the volume of polluted wastewater pumped into the sea via marine pipelines.

Nevertheless, huge volumes of wastewater still end up in municipal treatment works across the world, largely untapped for their water, nutrient or energy potential. Qadir and his research colleagues acknowledge that challenges remain to

Durban recycles more than 10% of the its total wastewater flows for industrial use.

Veolia

An aerial view of the Windhoek water reclamation plant and Goreangab dam. The Namibian facility, the first plant of its kind in the world, was established in 1968.

convince some consumers about using reclaimed water for direct potable use, yet it can also be used to irrigate new areas or to replace valuable freshwater where crops are already irrigated.

> *"human urine is known to contain highly concentrated nutrients, including nitrogen and phosphorus - much more than faeces."*

"This is already happening as farmers use treated and untreated wastewater directly for irrigation or indirectly when it is discharged into freshwater bodies where it becomes diluted and diverted to the agricultural farms."

They also note that despite growing tap water constraints, several cities still discharge municipal effluents directly into the sea. So, it could decades to achieve full-scale wastewater collection, treatment and alternative use in irrigation and other purposes, even though natural water supply is limited.

At a global level, Asia is the largest wastewater producer, generating an estimated 42% of the world's urban wastewater. In contrast, Sub-Saharan Africa produces the lowest annual amounts of wastewater per capita, almost five times lower than the volume of wastewater produced per capita in North America.

Quite apart from recovering water, municipal waste streams also contain a virtually untapped source of commercially-viable nutrients such as nitrogen, phosphorus and potassium. Using World Bank commodity data for fertilizers, the study notes that urea has a commercial value of around US$ 249/t, triple superphosphate (US$ 347/t) and potassium chloride (US$ 216/t). Collectively, 25.9 Tg of these three nutrients are embedded in annual wastewater flows, comparable to 78 times the mass of the Empire State Building.

Assuming the recovered nutrients have the same quality and market acceptance as industrial fertilizer, the recovery of these nutrients from wastewater could result in revenue generation of $13.6 billion globally with $9.0 billion from the recovery of nitrogen, $2.3 billion from phosphorus and $2.3 billion from potassium.

Though it is highly diluted by the time it reaches the municipal treatment works, human urine is known to contain highly concentrated nutrients, including nitrogen and phosphorus - much more than faeces.

"It is thus no surprise that human urine is also responsible for 80% of the nitrogen loading and 50% of phosphorus loading to municipal wastewater treatment plants."

If such nutrients could be recovered at source (directly from the toilet using urine-separation technology) this would not only benefit aquatic environments by reducing eutrophication but it would also reduce the cost of municipal wastewater treatment.

The chemical energy in wastewater could provide a third potential revenue stream, or a significant saving in treatment costs, through the recovery of methane-rich biogas. Wastewater is also a source of thermal energy, but this must be reused as close to the source as possible.

Assuming full energy recovery from wastewater, they calculate a current global energy value of around 53.2 billion m^3 methane

Veolia

Above and top: Windhoek has been reclaiming potable water from municipal wastewater for over 50 years. The newest plant features multi-barrier technology (ozone treatment, ultra-membrane filtration and residual chlorination) to eliminate pollutants and contaminants.

Veolia

Singapore has been reclaiming high quality water from municipal wastewater for nearly two decades. The biggest users are semiconductor wafer fabrication plants, which require water quality even more stringent than potable water.

with a calorific value of 1,908 billion MJ – enough to provide electricity to around 158 million households.

The researchers conclude that the torrent of "waste" water will continue to grow from rapid urbanisation, population increase and economic development and there is an urgent need to exploit this unmined resource.

"The good news is that a shift in research and practice supporting collection, treatment and fit-for-purpose and productive use of treated municipal wastewater is underway. It is important to note that many innovations are available and are being refined to bridge the gap between current resource recovery levels and resource recovery potential."

"For countries to progress, there is a need to invest in a supportive regulatory and financial environment towards a green economy, and to leverage private capital for resource recovery related business models that are financially feasible and increase cost recovery from municipal wastewater," concludes co-author, Pay Drechsel of the International Water Management Institute in Sri Lanka.

Wastewater – fast facts

- The energy value in 380 billion m^3 of wastewater is estimated to be 53.2 billion m^3 of methane – enough to provide electricity for up to 158 million households (or between 474 million to 632 million people, assuming an average of three to four people per household).
- In agriculture, the volume of water potentially recoverable from wastewater could irrigate up to 31 million hectares – equal to almost 20% of the farmland in the European Union. This reclaimed water can be used to irrigate new areas or to replace valuable freshwater where crops are already irrigated.
- World wastewater production is expected to reach 470 billion m^3 by 2030 – a 24% increase from today. And by 2050, it will reach 574 billion m^3, a 51% increase.
- Asia is the largest wastewater producer, with an estimated 159 billion cubic meters, representing 42% of urban wastewater generated globally.
- Other regions producing large volumes of wastewater: North America (67 billion m^3) and Europe (68 billion m^3)
- Full recovery from wastewater could, theoretically, offset 14.4% of global demand for nitrogen as a fertilizer nutrient; phosphorus 6.8% and potassium 18.6%.
- The nutrients in wastewater could theoretically generate revenue of US$13.6 billion globally: US$9.0 billion from the recovery of nitrogen, US$2.3 billion from phosphorus, and US$2.3 billion from potassium.
- Human urine is responsible for 80% of the nitrogen and 50% of phosphorus entering municipal wastewater treatment plants.

Source: PUB Singapore National Water Agency