From wastewater to resource

Petrik, Leslie Felicia; Ngo, Huu Hao; Varjani, Sunita; Xevgenos, Dimitris; Osseweijer, P.; van Loosdrecht, Mark C.M.; Smol, Marzena; Yang, Xuejing; Mateo-Sagasta, Javier

DOI
10.1016/j.oneear.2022.01.011

Publication date
2022

Document Version
Final published version

Published in
One Earth

Voices

From wastewater to resource

Eighty percent of wastewater is left untreated or not reused, exacerbating the water quality challenge, especially in vulnerable communities. This Voices asks: how can we improve wastewater management and convert wastewater into a resource?

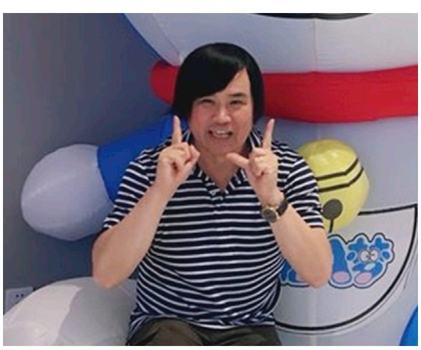
Leslie Felicia Petrik
University of the Western Cape

Carbon escapades

Carbon, although a useful element, is insidious in many of its forms, well known to drive climate change through emissions resulting from combustion of hydrocarbons. Plastics and synthetic organic chemicals are other forms of carbon that are embodied in nearly all consumer goods. Without us understanding that these compounds are designed for long term stability, generally toxic, and persistent, they cause a great deal of mischief. Chemical pollution is invisible, takes long periods to degrade, and is particularly toxic—causing health issues in terms of cancer, endocrine disruption, birth defects, or feminization—yet its impacts are still mostly unrecognized.

Chemicals and plastics do not simply disappear after use; they reappear in unexpected places. When we dispose them through our drains and toilets, they do not break up immediately but travel via sewers, escape through wastewater-treatment plants, pollute water resources, and ultimately end up in the ocean, causing chronic toxicity: a slow death sentence to marine species. They also contaminate our food chains and are transported back to us via food consumption, incrementally damaging our health.

In addition to minimizing our chemical footprints, the reuse of carbon-based wastewater components like plastic is a favorable wastewater-treatment approach and very possible; they can, for instance, be repurposed into construction building blocks or electro-spun fibers. Yet recovering the plethora of carbon-based organic chemicals remains a challenge given the plentitude of various chemical compounds. Adsorption/flotation or degradation with advanced oxidation are possible routes, but better wastewater management is needed to stop carbon escapes from nearly all current treatment systems.



Huu Hao Ngo
Centre for Technology in Water and Wastewater, University of Technology Sydney

Wastewater like gold: A circular bioeconomy view

The enormous amount of wastewater generated each year has become a critical issue globally due to rapid economic development, industrialization, urbanization, and population growth. To realize sustainable development, wastewater treatment that can facilitate a circular bioeconomy is a vital approach. Among various biological conversion wastewater-treatment technologies, bioelectrochemical systems (BESs) are highlighted here given their potential to generate multiple value-added products while purifying water with lower greenhouse gas emissions. For instance, BESs not only produce energy but also use wastewater containing biowaste as feedstock for biomethane generation through microbial electromethanogenesis on biocathode enriched with methanogens. In a cathodic chamber, nitrogen is removed via oxygen reduction reaction, cathodic denitrification reaction, and anammox process, whereas nitrogen and phosphorus recovery are mainly accomplished by chemical precipitation. Heavy metals, as well as precious metals that are key inputs in renewable energy technologies, can be removed/recovered via direct redox reaction and/or biological removal on the cathode. Furthermore, emerging pollutants, e.g., antibiotics, hormones, etc., can also be eliminated by special functional microbes in the presence of electrons on the electrodes. There is, however, room for BESs to improve further to better facilitate a circular bioeconomy. An important aim is to advance research on the modified BES and/or BES hybrid systems for best reuse of wastewater to sustainably produce value-added products throughout the life cycle cost-effectively.

Sunita Varjani
Gujarat Pollution Control Board

Recovery of resources via electrochemical approach

Water consumption has surged at twice the rate of population growth over the last two decades. Contaminants, particularly those from manufacturing industries such as hydrocarbons, heavy metals, dyes and dyes intermediates, pesticides, and emerging pollutants harm freshwater supplies. Yet a large amount of wastewater is released into the environment without being properly treated, especially in emerging economies that experience rapid industrialization, causing huge economic and health losses as a result of toxicological effects of pollutants on people and the environment. A potential solution to this problem is to recover usable resources from wastewater. However, because the components of wastewater could be complex (suspended solids, nutrients, oil and grease, heavy metals, pesticides, sulfides, phenols and hydrocarbons, etc.), a physical and/or chemical approach alone appears ineffective due to high operation cost, complexity of wastewater, limited efficiency, and potential to cause additional environmental pollution. To improve operational efficiency and quality, procedures such as photolytic processes, advanced oxidation processes, membrane separation technology and electrochemical catalysis, or procedures integrated with biological processes are required. Globally, microbial electrochemical systems have been reported as a potential technology for getting rich resources from wastewater. Effluents can be turned into resource to obtain various value-added products including energy, nutrients, metals, and biopolymers. Despite substantial progress in applying microbial electrochemical systems to extract resources from wastewater, the leap from "promising technology" to "useful technique" remains a challenge. Future research should also focus on improving the quality of recovered resources and establishing a smart and cost-effective wastewater-treatment system especially in emerging economies.

Patricia Osseweijer, Dimitris Xevgenos, and Mark van Loosdrecht
Department of Biotechnology, Delft university of Technology

Water Mining: Recover resources in six European cities

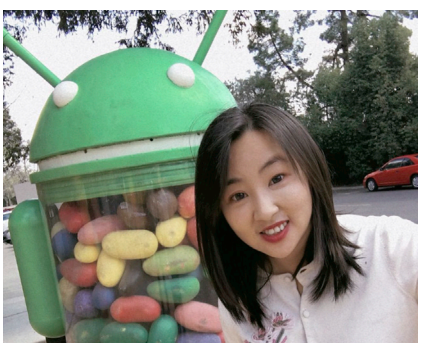
The EU-Horizon-funded project Water Mining, led by Delft University of Technology, aims to co-design implementations of circular wastewater-treatment systems with 38 partners from 12 countries. Via case studies in six different countries, we showcase and validate innovative next-generation water resource solutions at a pre-commercial demonstration scale. Our approach is based on the integration of stakeholder involvement, sustainability, and policy analysis in the design of circular wastewater-treatment systems. We take local issues, needs, and practices into account and pursue the most effective transition pathway that ultimately accelerates societal uptake. Our case studies involve both urban and industrial systems. Targets for industries include a 70% reduction in freshwater use, a 40% decrease in energy use through using waste heat, and a >90% recycling rate for chlorine and sodium streams. In urban cases, we aim to demonstrate cost-effective removal of phosphate and micro-pollutants with ultra low effluents (less than 0,05 mgP/liter) and couple this with 100% water recovery for reuse. Our case studies specially include water provision using seawater, which is crucial for countries and islands around the Mediterranean. In these cases, we focus on diminishing fossil energy use by reducing the overall energy amount and switching to at least 50% renewable energy. We also strive to double water recovery to >80%. To increase citizen engagement and awareness on one's own contribution, we use Living Labs such as Floating Farm and PSA, and we are preparing a groundbreaking exhibition that shows the novel system in detail using virtual reality tools.

Marzena Smol
Mineral and Energy Economy Research, Institute of the Polish Academy of Sciences

Charting a wastewater-phosphorus circular approach

Our world is in the process of transforming toward a circular economy (CE) model, which is based on a sustainable management of raw materials, particularly those that come from secondary (waste) sources. The wastewater sector has a very high potential in fostering the transformation toward CE, because wastes such as sewage, sewage sludge, and sludge ash contain valuable nutrients that can be recovered and reused in the economy. Phosphorus, (P) as an example, is a raw material vital for food production and food security. However, most P we obtain today is from mining phosphate rock, which causes severe socio-environmental problems. Thus, removing P from wastewater could not only help to alleviate eutrophication issues but also foster a more circular P application in food production.

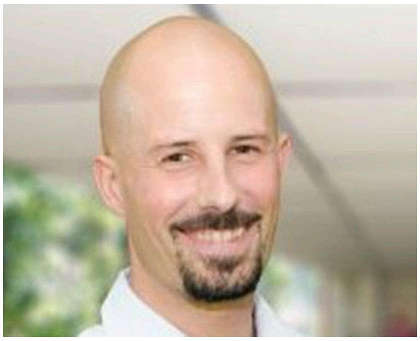
To realize such a wastewater-P underpinned circular approach, we should use highly effective wastewater-treatment methods to retain P in sewage sludge to enable a high rate of P recovery. Such a procedure should also ensure the full reintroduction of P into the economy, e.g., using P in the production of both liquid and solid fertilizers or soil improvers, and should avoid P leakage into surface waters that will lead to eutrophication. In addition, P management should aim to combine P removed from wastewater with P recovered from sewage sludge and sludge ash. Via such a systemic way we would be able to create a sustainable cycle to remove P from polluting water bodies while using such removed P as a valuable raw material in other applications.



Xuejing Yang
National Engineering Laboratory for Industrial Wastewater Treatment, East China University of Science and Technology

The hidden cost of water in a digital world

Because of the pandemic, we are now entering an unprecedent virtual world dominated by instant online communications, where internet and cloud sharing play vital roles in activities like web meetings/conferences, shopping, and entertainment. A “metaverse” also runs into our vision. All of this cannot be achieved in the absence of an ever-developing internet industry, with a booming global production of the 12-inch silicon wafers reaching almost 0.1 billion just in 2020; the figure is soaring with a >20% annual growth rate for top companies. However, the production of each silicon wafer consumes ∼4–5 tons of water, and a large amount of wastewater that contains pollutants including ammonia, fluorine, and copper is also produced simultaneously. Similar scenarios take place in other emerging industries like photovoltaics and batteries. Our thriving through the pandemic and climate change should not be done at the cost of excessive water withdrawals and water pollution. Wastewater treatment that can convert pollutants into resources is therefore a vital approach. However, current wastewater-treatment technologies usually involve acid-base adjustment, coagulation and dilution processes to reduce the ammonia-N, and metal ions to release standards, which often produce chemical sludge that damages the environment. A circular-oriented design is urgently needed to foster synergies between the water-pollution-control systems and resource-reutilization processes. Future efforts should also devote on developing membrane-separation technologies and nature-inspired metal fixation and recycling processes to attain water reuse and inorganic ion recycling with zero liquid discharge.



Javier Mateo-Sagasta
International Water Management Institute (IWMI)

More people, more food, worse water?

As the global population increases and shifts to diets richer in meat and calories, agricultural expansion and intensification are leading to rising levels of water pollution. A recent assessment shows that farming contributes significant amounts of nutrients, pesticides, salts, sediments, organic matter, pathogens, and emerging pollutants to water bodies, with damaging consequences for the environment, human health, and sustainable development. The annual cost of agricultural water pollution likely exceeds billions of dollars globally and will likely rise to trillions. Despite this, the attention this issue receives in global debate is not remotely commensurate with the magnitude of the costs. Business as usual cannot be sustained. The necessary increases in agriculture productivity cannot be achieved at the expense of the environment, as has been the case over the last 50 years.

Water pollution from agriculture is complex and multidimensional; thus, effectively managing agriculture wastewater requires a pack of policy responses beyond end-of-pipe technologies. These responses, such as fostering sustainable dietary shifts, need to act on the key drivers of unsustainable agricultural expansion and intensification. They also need to prevent the export of pollutants beyond farms to protect broader water bodies and help restore affected water ecosystems. Regulations and the use of other instruments to engage various stakeholders are required to influence both farm- and landscape-scale practices. A holistic approach that forms integral water policy frameworks must cover all pollutants and polluters at the national/river-basin scale to create co-benefits, increase food production and farm income, and mitigate and resuse wastewater properly.