

# Key innovations shaping wastewater treatment systems

As the world faces mounting water scarcity and increasingly stringent environmental regulations, wastewater treatment systems are undergoing a significant transformation. At the forefront of this change is globally trusted infrastructure firm AECOM.



Left: Terisha Naicker, a water and wastewater process engineer at AECOM. Middle: Nyiko Khosa, an Associate Process Engineer at AECOM. Right: Mohamed Abdelmegeed, AECOM's Technical Director for Water.

**A**ECOM is pioneering cutting-edge solutions to improve efficiency, sustainability and regulatory compliance. "New technologies are helping us treat wastewater more effectively while recovering valuable resources," says Terisha Naicker, a process engineer at AECOM who specialises in water and wastewater treatment.

Key innovations focus on advanced biological treatment methods. These include compact Membrane Bioreactors (MBRs) to produce high-quality effluent and Moving Bed Biofilm Reactors (MBBRs). Energy and resource recovery are also key focuses. Here, anaerobic digestion systems convert sludge into biogas.

Combined Heat and Power (CHP) systems use the biogas to generate both electricity and heat. In addition, nutrient recovery technologies such as struvite precipitation enable the reclamation of phosphorus and ammonia for use as fertiliser. "With deep technical expertise and a future-focused approach, AECOM continues to lead the way in developing sustainable wastewater solutions that meet global challenges head-on," notes Naicker.

Digital and smart technologies are also playing a transformative role. These include real-time monitoring and control through IoT sensors, telemetry and SCADA systems with advanced analytics. Such tools promote water reuse and principles of the circular economy. They enable Direct and Indirect Potable Reuse (DPR and IPR) in water-scarce areas, greywater recycling in buildings for flushing or irrigation, and the integration of Zero Liquid Discharge (ZLD) technologies.

## Pumping systems and efficiency

Pumping can account for 4% to 30% of the energy consumption in municipal wastewater treatment plants, highlights Nyiko Khosa, an Associate Process Engineer with over 19 years' experience. "To address this, the industry initially focused on improving the efficiency of electric motors and reducing energy usage."

Historically, IE2 and IE3 motors were the standard for pumps under IEC 60034-30-1. "Now, there is a shift towards IE4 motors, recently introduced to the market," adds Khosa. These super-premium efficiency motors can be retrofitted to older pumps, enhancing energy performance with minimal disruption.

"Pumping systems are the backbone of modern wastewater management, and their evolution is critical to meeting the increasingly complex characteristics of contemporary wastewater," adds Mohamed Abdelmegeed, AECOM's Technical Director for Water, who has over 27 years' experience in this area. As urbanisation and industrial discharges increase, conventional pumps are being replaced by intelligent, resilient systems engineered to operate under challenging and variable conditions.

One significant advancement is the integration of variable speed drives (VSDs) to run pump motors. These allow pumps to adjust their speed based on real-time demand rather than operating at full capacity continuously. During low-flow periods such as dry weather or off-peak hours, VSDs reduce pump speed. It can result in energy savings of up to 40% while maintaining hydraulic performance.

Evolving wastewater composition, including higher concentrations of solids, rags and non-flushable materials, poses significant clogging risks. In response, manufac-

turers have developed non-clogging impeller designs and self-cleaning mechanisms to enhance reliability and reduce maintenance. Material selection is also key to long-term performance, particularly in corrosive environments caused by hydrogen sulphide, industrial chemicals or saline intrusion.

## Extending equipment life

Modern pump systems increasingly utilise materials such as AISI 316, duplex stainless steel and high-performance polymers for superior chemical and mechanical resistance. In coastal installations, for example, stainless steel is preferred to withstand saltwater intrusion. In industrial zones, ceramic and rubber linings, epoxy coatings, or thermal spray metallising are employed to resist corrosion. These improvements extend equipment life, reduce failure rates and lower lifecycle costs.

Digitalisation is further redefining pump management. IoT-enabled sensors now monitor vibration, temperature, energy use and hydraulic efficiency in real-time. This data feeds into predictive maintenance platforms, enabling early detection of faults and reducing costly downtime.

## Operational challenges

"One of the major operational challenges is a shortage of skilled personnel to operate advanced biological treatment processes," Naicker points out. Other ongoing issues include influent variability, which affects treatment performance; sludge handling and disposal, where volume reduction and dewatering remain problematic; and persistent concerns around odour and vector attraction.

Most existing plants still rely on the conventional activated sludge process, which is energy-intensive, adds Khosa. "The adoption of advanced biological processes could significantly reduce energy consumption," Abdelmegeed concurs, noting that wastewater management is now challenged by a complex web of environmental pressures, ageing infrastructure, regulatory demands and heightened public expectations. These challenges are interconnected and demand integrated, innovative solutions.

A particularly pressing concern is the increasingly hazardous composition of in-

fluent. Unpredictable industrial discharges, household chemicals, pharmaceutical residues, microplastics and even illicit substances complicate biological treatment and increase the risk of toxic shock events.

In addition, high concentrations of fats, oils, and greases (FOG) and non-biodegradable materials, such as wet wipes and plastics, cause frequent clogging, equipment wear, and costly maintenance. These contaminants also contribute to the formation of 'fatbergs', large solid masses that obstruct pipelines and cause overflows, posing environmental and public health risks.

In many developed countries, wastewater infrastructure is decades old and showing significant signs of deterioration. Ageing pumping stations, cracked pipes and undersized treatment plants are struggling to keep pace with growing populations and rising water usage. The result is frequent leakage, groundwater infiltration and combined sewer overflows (CSOs) during heavy rainfall.

Wastewater treatment is one of the most energy-intensive municipal operations, sometimes accounting for up to 35% of a city's total electricity use. Aeration, sludge digestion and pumping require a substantial energy input, driving operational costs and carbon emissions. Utilities are under pressure to reduce energy consumption while maintaining performance; yet, many still rely on inefficient legacy systems with outdated controls.

Regulations are also tightening in response to concerns around nutrient pollution, water quality and emerging contaminants. New standards, particularly for nitrogen, phosphorus and micropollutants, are compelling utilities to upgrade their treatment processes.

Climate change is exacerbating the situation. Extreme weather events, such as flooding, droughts and heavy rainfall, are becoming more frequent and severe. Flooding can overwhelm systems and lead to sanitary sewer overflows (SSOs), while drought reduces dilution capacity in receiving waters, complicating compliance with discharge standards.

Future-ready infrastructure must now be designed with climate resilience in mind, using adaptive strategies such as green infrastructure, overflow storage and decentralised treatment systems.

## Skills shortages

Despite technological advancements, the wastewater sector continues to face pronounced skills shortages. An ageing workforce and declining interest in technical careers have created a gap that threatens operational continuity and innovation.



Wastewater treatment plants are critical in managing sewage and industrial effluents.

Moreover, digital systems such as SCADA, AI analytics and predictive maintenance require new technical competencies that many utilities are still developing. Without targeted recruitment and training, the effective operation of advanced systems will continue to be a challenge.

Naicker highlights that system monitoring and predictive maintenance are key to optimising plant performance by enabling proactive management, minimising downtime and improving overall efficiency. Real-time monitoring allows operators to track key parameters and receive alerts when values exceed acceptable thresholds. This supports better process control, stability and reduced reliance on manual intervention.

"In today's increasingly complex and regulated environment, monitoring and predictive maintenance are essential for ensuring operational reliability, efficiency and compliance," says Abdelmegeed. These technologies shift maintenance strategies from reactive to proactive and even strategic, supporting long-term sustainability and cost-effectiveness.

Advanced monitoring, typically implemented through SCADA and IoT sensors, provides real-time insights into parameters such as flow rates, pressure, dissolved oxygen levels, chemical dosing and equipment status. This constant visibility enables immediate corrective action, helping to maintain treatment quality within regulatory thresholds.

In large or remote facilities, cloud-based platforms enhance accessibility by enabling remote diagnostics and monitoring. This reduces the need for site visits and allows for centralised oversight of decentralised

systems, a growing necessity for many operators.

Predictive maintenance technologies utilise both historical and real-time data, often powered by machine learning algorithms, to identify patterns that indicate impending equipment issues. They can forecast problems such as bearing failures, leaks, clogging or membrane fouling before they cause operational disruptions.

This proactive approach helps prevent unplanned outages, reduces emergency repair costs and protects process continuity. Industry data suggests utilities can lower operating expenses by up to 30% by transitioning from reactive to predictive maintenance.

One of the key benefits of predictive maintenance is extending the equipment's lifespan. Pumps, blowers, and mixers that are monitored proactively are subject to fewer mechanical stresses and are more likely to operate within their design limits. This results in more stable operations, reduced wear and deferred capital replacements. In addition, intelligent monitoring enhances energy efficiency by identifying underperforming assets and optimising operational efficiency – for example, by detecting oversized pumps that run inefficiently during low-demand periods – thus reducing both operating costs and carbon emissions.

"With regulatory scrutiny increasing, continuous monitoring also ensures better compliance. Automated alerts and reporting support timely corrective action, reduce the risk of violations and improve transparency through streamlined auditing," concludes Naicker.

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