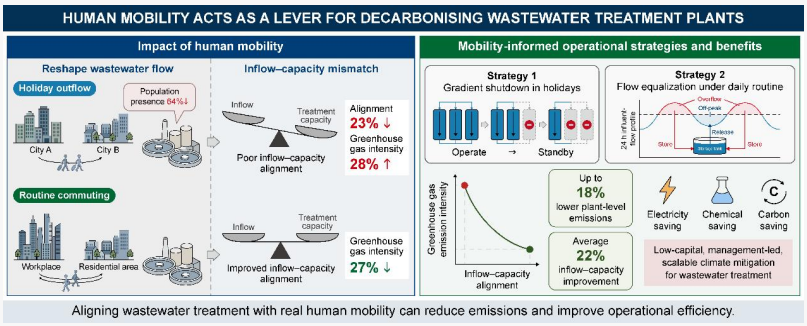
Human mobility emerges as powerful lever for decarbonising wastewater treatment, study finds

GA, UNITED STATES, September 5, 2026 /EINPresswire.com/ -- Wastewater treatment is a growing and substantial source of global greenhouse gas emissions, yet a major decarbonisation opportunity has been hiding in plain sight: human mobility. Researchers have found that the daily ebb and flow of people moving between cities and districts, together with larger population shifts during holidays, profoundly affects how efficiently treatment plants operate, directly influencing their carbon footprint. By tracking population movements using mobile location data, the team demonstrated that aligning treatment operations with real-time population presence could significantly cut emissions without expensive infrastructure upgrades.



Human mobility drives wastewater emissions — and offers a decarbonisation lever.

Conventional approaches to managing wastewater treatment plants rely heavily on static, residence-based census data, which fail to capture the dynamic nature of urban populations. As people commute, travel for holidays, or relocate seasonally, wastewater generation shifts unpredictably, leaving treatment plants operating either underloaded or overloaded — both of which are inefficient and emissions-intensive. This mismatch between fixed treatment capacity and fluctuating influent flows represents a substantial but underexploited opportunity. Based on these challenges, the need for a deeper understanding of how real-time population dynamics can inform operational strategies has become increasingly urgent.

Now, a team of researchers from the Harbin Institute of Technology, the Eastern Institute of Technology, and the Southern University of Science and Technology, along with collaborators in Australia, has quantified this effect for the first time. Publishing (DOI: 10.1016/j.ese.2026.100756) their findings on 23 August 2026 in Environmental Science and Ecotechnology, the study used more than 170 million population heatmap records from Shenzhen — a megacity of over 17 million people — to track how population movements during the Spring Festival and daily commuting reshape wastewater flows and treatment emissions.

The researchers developed a new metric called the Treatment and Inflow Dynamic Equilibrium (TIDE) index to measure how well incoming wastewater matches treatment capacity in real time. They found that conventional load-rate metrics overestimated treatment-inflow alignment by nearly 11% on average in Shenzhen, masking severe inefficiencies. During the Spring Festival, when the city's estimated population presence fell by 64%, the TIDE index dropped by 23%, while greenhouse gas emission intensity surged by 28%. Conversely, intercity commuting — which brings additional people into the city — improved alignment and reduced emission intensity by 27%. By tracking hourly population heat data, the team identified distinct patterns: morning commuters flood employment hubs, while evening commuters return to residential areas, each creating predictable but previously unaccounted-for shifts in wastewater generation. Using long short-term memory (LSTM) machine learning models that incorporated mobility data, the researchers improved influent flow predictions by up to 18% compared with models without these data, enabling two targeted operational strategies.

The authors said: "We were struck by how much leverage human mobility exerts on treatment efficiency — it's a lever that has been right in front of us but largely ignored. The Spring Festival migration is the world's largest annual human movement, and we could see its carbon footprint ripple through the city's treatment plants in near real-time. What excites us is that this isn't about building new infrastructure; it's about operating smarter. The data from mobile devices is already there — we just need to use it to make treatment plants respond to how cities actually breathe."

The proposed strategies — gradient shutdown during holidays and flow equalisation during routine conditions — could reduce plant-level emissions by up to 18%. Applied across more than 350 Chinese cities, the approach offers an average theoretical TIDE improvement of 22%, suggesting widespread potential. The framework is transferable to cities worldwide with pronounced population mobility—from daily commuting to mass travel during holidays such as Christmas in the United States or Diwali in India, though the local electricity mix would need to be considered. This research highlights an accessible, low-capital pathway for the wastewater sector to contribute meaningfully to climate goals, turning population data into a practical tool for operational decarbonisation.

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Lucy Wang
BioDesign Research
email us here

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