RESEARCH HIGHLIGHT

Earth and Environmental Sciences

Field-deployable wastewater sensors for public health

Heni Wang, Muhammad Adeel & Zhugen Yang[*]

Faculty of Engineering and Applied Sciences, Cranfield University, Cranfield MK43 0AL, UK

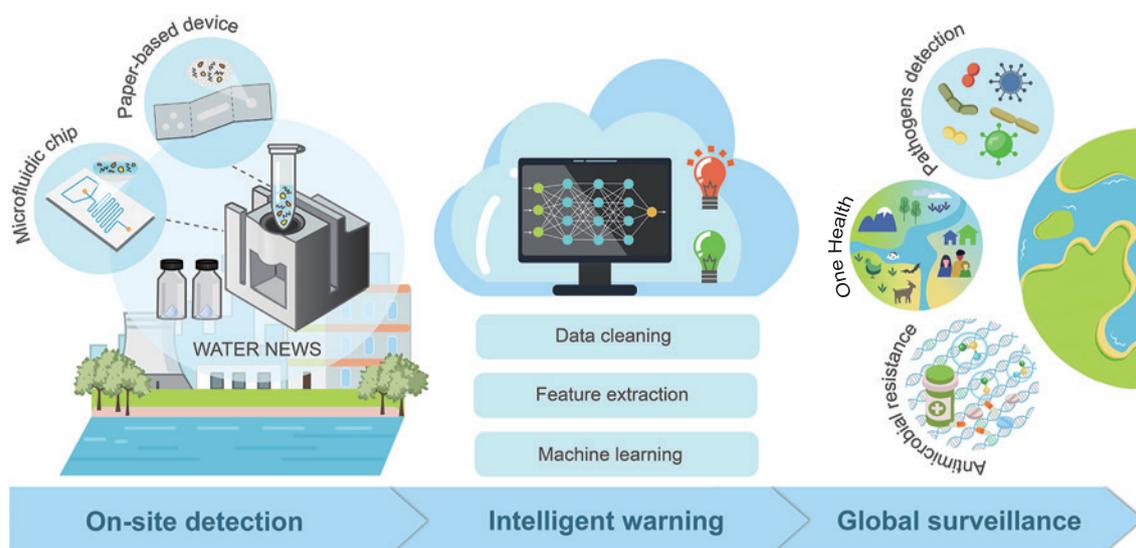*Corresponding author (email: zhugen.yang@cranfield.ac.uk)

A sustainable early warning monitoring system can overcome key limitations of conventional approaches for managing infectious diseases and epidemics. It enables consistent monitoring of pathogens, including SARS-CoV-2, in wastewater treatment plants (WWTPs).

Wastewater-based epidemiology (WBE) analyses biological markers excreted in sewage to monitor community health. It has emerged as a powerful tool because it is cost-effective, non-invasive, and capable of detecting pathogen circulation within the population, even before clinical cases are reported [1]. These features provide WBE a clear advantage over traditional clinical testing, particularly by enabling the early detection of new variants [2].

Although WBE has been widely implemented in developed countries, its progress in low-resource settings is constrained by the lack of infrastructure and limited policy support. Traditional laboratory-based polymerase chain reaction (PCR) remains the primary diagnostic tool; however, it is time-consuming and laboratory-dependent, making it unsuitable for large-scale field deployment. Alternative technological approaches involve the design and engineering of miniaturised devices that employ isothermal amplification methods, such as loop-mediated isothermal amplification (LAMP) or CRISPR-based systems, which require fewer procedural steps. Such approaches enable rapid and simplified detection without the need for thermal cycling and can be readily integrated with advanced engineering platforms, such as microfluidics and other portable devices [3,4]. However, challenges such as extremely low concentrations of biomarkers in wastewater and the need for cold-chain storage continue to hinder broad adoption.

Yu *et al.* [5] report an isothermal CRISPR-RPA platform, WATER NEWS, designed for on-site wastewater detection in the *National Science Review*. This system represents a significant step forward, addressing long-standing barriers to field deployment. By freeze-drying all reagents into a one-pot assay, the system avoids multi-step handling, reduces contamination risks and eliminates cold-chain requirements. Results are delivered within 15–20 minutes, nearly three times faster than other CRISPR-based diagnostics. The lyophilised powder remains stable for almost 50 days at room temperature. A portable, battery-operated device further enables one-step sample collection and detection, achieving over 90% sensitivity and 100% specificity at about half the cost of conventional methods when tested against the SARS-CoV-2 virus.

To achieve the practical implementation of Yu and colleagues' technology for water surveillance and the detection of community-spread pathogens, further improvements are required. For example, (i) rapid sample

Figure 1 The graphical illustration of on-site wastewater detection to intelligent global health surveillance. The field system WATER NEWS, developed by Yu and his colleagues, demonstrates the potential of sustainable wastewater detection in WWTPs. In the future, one can integrate those assays with microfluidic or other engineering approaches to streamline field operations. Data generated from the distributed sampling sites would be transformed into intelligent early warnings by ML, advancing more equitable and globally connected health surveillance and management.

pretreatment is critical for ensuring sensitivity and accuracy in complex wastewater samples and could be streamlined through paper-based or microfluidic devices [6,7]. (ii) Multiplex detection would improve efficiency and provide a more realistic view of community health from the wastewater containing multiple health-threatening pathogens. (iii) By combining distinct crRNAs and reporters within one reaction and the device in a single shot [8]. (iv) User-friendly design of the monitoring systems with less or no training requirements to minimise errors among non-professional users.

In the future, sustainable wastewater surveillance will rely on automatic devices that generate real-time data from WWTPs. Advanced sensing technology and machine learning (ML) can transform these data into actionable insights [9], extending beyond pathogen detection to antimicrobial resistance (AMR) and the broader "One Health" agenda [10]. The increasing demands for global health surveillance, global data-sharing platforms coordinated by the World Health Organisation (WHO), such as Global Antimicrobial Resistance and Use Surveillance System (GLASS) and International Pathogen Surveillance Network (IPSN), must ensure data compatibility and interoperability across devices and laboratories, which will accelerate the shift from "on-site detection" to "intelligent early warning". In this context, systems like WATER NEWS are not just diagnostic tools, but a pioneering approach for the next generation of intelligent global health surveillance, as shown in Figure 1.

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Conflict of interest

The authors declare no conflict of interest.

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