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STOPPING THE SUPERBUGS: SURVEILLANCE THROUGH WASTEWATER SYSTEMS

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South Africa faces a high burden of communicable and non-communicable diseases (NCDs) due to socio-economic factors, an aging population, and challenges in the healthcare system. The rise of so-called 'superbugs' — pathogens resistant to multiple antibiotics—threatens to undermine modern medicine, making common infections and routine surgeries potentially fatal. Addressing the antimicrobial resistance challenge requires innovative, scalable, and cost-effective solutions that can complement current traditional infectious disease management approaches. Wastewater-based surveillance (WBS) is an innovative public health tool that offers a proactive, scalable approach to infectious disease management, providing a critical layer of intelligence to complement traditional detection, reporting, and treatment systems. By leveraging this tool, public health systems can enhance their capacity to combat AMR threats, protecting both public health and antibiotic efficacy. This approach also holds significant promise for transforming early detection, reporting, and treatment strategies.

Introduction

Antimicrobial resistance (AMR) is a mounting global health crisis, and current estimates suggest that by 2050, AMR would cause up to 10 million deaths per year, positioning it as the most pressing threat to health in the 21st century. Options for new antimicrobials are few and there is a critical need for innovation. AMR has emerged as a bigger killer in Africa than malaria, HIV or tuberculosis (TB). AMR occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial drugs. Consequently, antibiotics and other antimicrobial agents become ineffective, and infections become difficult or impossible to treat, increasing the risk of disease spread, severe illness and death. Drug-resistant infections also impact on the health of animals and plants, threatening our economy and food security. Major drivers of AMR include the overuse and misuse of antimicrobials such as antibiotics in both humans and animals, migration, suboptimal vaccination rates, and environmental contamination from various sources. Drug-resistant-pathogens or superbugs, pose a threat to everyone, everywhere, and the world has responded.

World AMR Awareness week (18-24 November) is global campaign to raise awareness and understanding of AMR while also promoting best practice for responsible use. The 2024 theme is "Educate. Advocate. Act now " is more relevant than ever, considering that AMR is on an increasing trend that requires dramatic and swift action. Global leaders have approved a political declaration at the 79th United Nations General Assembly meeting in September this year committing to a clear set of targets and actions which will be facilitated through the Global Quadripartite collaboration. In the context of One Health, the declaration underscores the need to understand how human, animal and environmental factors contribute to AMR. Furthermore, the declaration advocates for prevention and addressing the discharge of antimicrobials into the environment, while also striving to understand the environmental dimensions of AMR.

According to the World Health Organisation 2023 country report, South Africa faces a high burden of communicable (such as malaria, tuberculosis, HIV/AIDS) and non-communicable diseases, due to socio-economic factors, an aging population, and challenges in the healthcare system. Tuberculosis (TB) remains a significant public health issue in South Africa, with concerning trends in multidrug-resistant TB (MDR-TB). While the country is actively working to enhance early case detection, treatment and reporting, there are still gaps. Investing in integrated and innovative approaches is critical for overcoming these challenges and addressing AMR. By analysing wastewater (wastewater surveillance), it is possible to monitor the presence and spread of diseases, antimicrobial-resistant bacteria and genes within communities, even before clinical cases are reported. This approach enables real-time data collection at a population level, providing critical insights into resistance patterns and hotspots.

Role of wastewater-based surveillance (WBS) in managing superbugs

The Water Research Commission (WRC) and the Durban University of Technology (DUT) are jointly conducting a study to explore the potential of wastewater-based surveillance (WBS) for establishing the presence and levels of a group of closely related bacterial pathogens that cause tuberculosis (TB) in humans and other animals, other pathogens and antibiotic resistance genes at a national scale. This collaborative research aims to assess how WBS can be used provide early insights into the prevalence and spread of superbugs, such as drug-resistant TB strains at the community level. Professor Reddy, who is affiliated with the Faculty of Health Sciences and the Institute of Water and Wastewater Technology (IWWT) at DUT, asserts that wastewater environment is a hotspot for increasing risks of AMR, either through ingestion or acquisition of an AMR pathogen in downstream applications or through the evolution of new AMR in the wastewater treatment process. Successful pathogen tracking using wastewater was utilized during the COVID-19 pandemic to detect and act on infection peaks and new variants within the connected community. Similar reports for the early detection of influenza, polio and monkeypox outbreaks show the potential of wastewater surveillance.

The WRC study follows on from a preliminary study by the DUT research team, in collaboration with the Bill and Melinda Gates Foundation and the South African MRC, which underscored the utility of using wastewater as an additional tool to track antimicrobial resistance using ***Mycobacterium tuberculosis*** complex and its resistome as a model system. Findings from this study showed the presence of ***Mycobacterium*** spp. in wastewaters across several sub-Saharan African countries, including Ghana, Nigeria, Kenya, Uganda, Cameroun and South Africa. Wastewater from South Africa showed the highest concentration of antibiotic resistance genes linked with resistance to TB treatment. This study has drawn international interest from researchers in the US, Canada and India who are also eager to apply this concept for TB control in their own contexts. This points to the growing concern of multidrug resistant TB not only in South Africa, but globally. Results from this study have shown that wastewater analysis provides an indication of the community burden of AMR, as well as what could be discharged to the environment. Current research supported by the WRC seeks to enhance surveillance of other drug-resistant pathogens in wastewater from different cities in South Africa using Next Generation Sequencing (NGS) which is an emerging molecular method that can broadly survey diverse ARGs simultaneously.

Preliminary findings from the WRC-funded research have revealed the presence of antibiotic resistance genes for most antibiotics commonly used, indicating the true extent of the problem. Diverse AMR genes in raw and treated wastewater suggests possible dispersal of AMR elements to

surface waters and other downstream users. The detection of antibiotic resistance in the treated effluent indicates that current wastewater treatment plants (WWTPs) are ineffective in removing them during the treatment process. Wastewater based surveillance for detection, monitoring and early warning of AMR threats may bridge the gap in countries with poor diagnostic capacity, limited healthcare access, low health seeking behaviors and poor reporting. It is far less costly than clinical testing and could be effectively used in low-income settings. While WBS holds significant promise in streamlining disease and AMR management, further research is still needed to standardise sampling and data analysis. This gap will be addressed by the ongoing study supported by the WRC. Apart from further research, the funding and infrastructure requirements for scaling WBS into a national programme still need to be determined. Policy and legal aspects for the scale up of WBS, such as data privacy, sectoral collaboration, and regulatory frameworks still need to be clarified.

Conclusion

AMR remains a critical global health threat, responsible for nearly 5 million deaths annually. The overuse and misuse of antimicrobials in humans and animals are the primary drivers of AMR. The WHO and other organizations have called on governments and industry to invest in AMR research, promote infection control measures and improve sanitation and hygiene. Wastewater treatment plants have been identified as key for both for the control and dissemination of AMR. They are ideal nodes for AMR surveillance in a community and mitigation prior to release into the environment. However, while wastewater surveillance may be an important tool for AMR detection, it is restricted to areas with sewage networks, leaving a major gap in resource-limited areas without waterborne sanitation systems.

During the COVID-19 pandemic a decline in the AMR burden was observed, and this was facilitated by increased awareness in water, sanitation and hygiene (WASH), as well as heightened understanding of disease transmission. This demonstrated that addressing AMR is possible through sustained efforts. In this regard, continuing to engage on research aimed at enhancing AMR surveillance, capacity building, and stakeholder engagement is key. In the long term, integrating traditional and innovative surveillance mechanisms is critical for building a knowledge and information portal for supporting decision making on AMR. Key performance indicators and accountability mechanisms for the different sectors; health, agriculture, and the environment are also critical for effectively addressing AMR. We cannot wait on policy change; we need to act now. For example, doctors need to practice good stewardship with appropriate antimicrobial prescribing informed by proper diagnostics. Patients need to use antibiotics responsibly by completing their course. Monitoring and continued surveillance needs to be concomitantly implemented, with the development of alternate methods for infections control. Superbugs can only be controlled by collective superhero efforts.

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