ONE HEALTH

Rivers at risk: Rethinking surveillance to prevent waterborne zoonotic outbreaks

A recent Water Research Commission (WRC) funded study suggests that the next zoonotic disease outbreak in the Eastern Cape is likely to be associated with a river that has offered clear indicators of increasing health risks, probably for months in advance. Article by Jorisna Bonthuys.

A study conducted by researchers at Rhodes University's Institute for Water Research identifies rivers as active ecological reservoirs and transmission routes for waterborne zoonoses outbreaks rather than being passive conduits of contamination.

Funded by the WRC, the study, titled 'An integrated approach to timely detection and prevention of waterborne zoonoses outbreaks in selected municipalities of the Eastern Cape, South Africa', was led by Dr Chika Felicitas Nnadozie. She heads up the Centre for Environmental Water Quality at the university.

Dr Nnadozie and her co-authors addressed a central question: Is it possible to detect outbreaks of waterborne zoonoses before clinical cases emerge? Their findings indicate that early detection is indeed feasible, provided that the water sector, health authorities, veterinary services and environmental regulators collaborate and proactively monitor river systems.

The study focused on the Amathole District Municipality and the Nelson Mandela Bay Metropolitan area in the Eastern Cape. The province is highly vulnerable to waterborne zoonoses due to livestock-human-water interactions, climate variability and inadequate service delivery, particularly in water and sanitation.

Against this backdrop, the researchers set out with four aims: identify the rivers and pathways most likely to carry zoonotic disease between animals and humans; determine whether river surfaces – aquatic plants, rocks, even microplastic litter – actively cultivate these pathogens; pinpoint when outbreak risk peaks seasonally; and use this information to design interventions that interrupt transmission rather than document it after the fact.

They employed metagenomic sequencing (a laboratory method used to study all the genetic material recovered from a mixed sample of organisms), spatial risk mapping, community surveys, and stakeholder workshops to identify critical rivers and exposure pathways, integrating environmental and social data to develop a practical framework for early detection and prevention.

The findings reinforce the idea that biofilms on both biotic and abiotic substrates serve as persistent ecological refuges that sustain pathogen populations between outbreaks.

The link between water and infectious diseases

Waterborne zoonoses are infectious diseases caused by zoonotic pathogens, including bacteria, viruses, protozoa, and parasitic helminths (worms), transmitted from animals to humans, and vice versa, through contaminated water.

Globally, most emerging infectious diseases are zoonotic, and many are waterborne. Zoonotic diseases account for nearly 60% of new infectious threats, and affect low- and middle-income countries the most. Damaged ecosystems, shifting land use and closer human-animal contact fuel their spread.

Freshwater pathogens thrive in a remarkable variety of habitats, drifting freely through the water or clustering together on living and non-living surfaces. This ability to attach to surfaces and form biofilms is central to pathogen persistence in aquatic ecosystems, as it enables microorganisms to withstand environmental stressors, exploit localised nutrient sources, and evade hydrological flushing.

Aquatic plants (macrophytes) and rocks have long served as stable, ecologically integrated havens for pathogens, but microplastics now add a new, human-made platform that could intensify these dangers thanks to their durability, movement through water, and strong attraction to resistant and harmful microbes.

Study overview and objectives

South Africa has a long history of waterborne disease outbreaks and of zoonotic disease risks associated with interactions among humans, livestock, wildlife, and the environment.

Recent outbreaks include Rift Valley fever, African swine fever, avian influenza, and foot-and-mouth disease, which underscored systemic vulnerabilities in biosecurity and public health (un) preparedness across the human-animal-environment interface.

Water-related zoonotic pathogens such as *Cryptosporidium* spp., *Giardia* spp., and *Leptospira* spp. have also been documented at human-animal-environment interfaces in South Africa, highlighting the importance of environmental surveillance and integrated One Health approaches to disease prevention and management.

Wastewater effluent, livestock and wildlife faecal contamination and poor sanitation are key factors influencing pathogen persistence and transmission. Waterborne disease risks are exacerbated by fragmented governance arrangements, competing land-use priorities, and insufficient enforcement of water quality standards. Additional pressures include rising animal disease outbreaks and systemic gaps in disease surveillance. Droughts and floods caused by climate change also make it harder to access safe water and often force people and animals to share water sources, increasing the risk of pollution and disease.

Recent studies indicate that waterborne pathogens, including those that can spread from animals to people, are common in South African rivers, home water storage and wastewater systems. This is a major public health concern, especially in rural and nearby urban areas with poor sanitation and reliance on rivers, Nnadozie points out.

For the Eastern Cape, where ageing sanitation infrastructure, free-grazing livestock and seasonal climate extremes converge, that risk has particular urgency. "In many communities, rivers provide domestic water, irrigation, spiritual spaces and livestock watering," Dr Nnadozie says. "These rivers also collect human, livestock, and wildlife waste, wastewater effluent, and runoff, becoming transmission points for pathogens moving from animals to people."

Unpacking the results

The team used geographic information system (GIS) layering of hydrology, precipitation/drought patterns, flood occurrence, proximity to wastewater treatment works, livestock density, agricultural land use and population concentration.

During 2023 and 2024, they collected 78 environmental samples from the Kat and Swartkops rivers – not just water, but biofilms scraped from rocks, macrophytes and plastic debris in the river. Each sample went through DNA extraction and metagenomic sequencing to generate a detailed genetic snapshot of the bacterial communities living in and on a river.

The researchers analysed microbes on various substrates to assess pathogen distribution and persistence. They evaluated seasonal patterns through repeated sampling and statistical analysis. The researchers also conducted structured household questionnaires (181 respondents), focus groups, and stakeholder workshops across Kat, Swartkops and other catchments to document river-use behaviours, exposure pathways, reporting practices and institutional coordination.

The results demonstrate that macrophytes hosted the most diverse and abundant biofilm communities, often exceeding those found in water samples. Rock biofilms and macrophytes supported *Leptospira* and other genera associated with direct contact and ingestion.

Wastewater effluent, livestock and wildlife faecal contamination and poor sanitation are key factors influencing pathogen persistence and transmission.

Additionally, plastics and other hard surfaces concentrated ***Legionella*** and provided colonisable microhabitats, demonstrating a 'microplastisphere' effect.

The findings reinforce the idea that biofilms on both biotic and abiotic substrates serve as persistent ecological refuges that sustain pathogen populations between outbreaks.

The results show that both natural and artificial substrates serve as reservoirs for zoonotic bacterial pathogens. Furthermore, the pronounced winter increase in genera such as ***Legionella***, ***Mycobacterium***, and ***Leptospira*** suggests that colder conditions may elevate exposure risk, particularly for aerosol- and water-associated transmission pathways.

Novel risk map generated

Each layer of information gained during this study was integrated onto a five-point risk scale and combined into composite catchment risk maps of the province. This mapping exercise enabled them to classify rivers by vulnerability to waterborne zoonotic pollution.

The risk map shows that the Eastern Cape is mostly characterised by low to moderate risk levels. These reclassified layers form the basis for identifying areas of heightened potential for contamination and prioritising rivers within the province.

Approximately 89% of the province's area falls within low- or moderate-risk categories. However, the remaining 11%, concentrated in specific, identifiable zones, accounts for the majority of the risk. According to Dr Nnadozie, the five risk-level zones they identified are characterised by dense human settlement, intensive river use, and inadequate wastewater infrastructure.

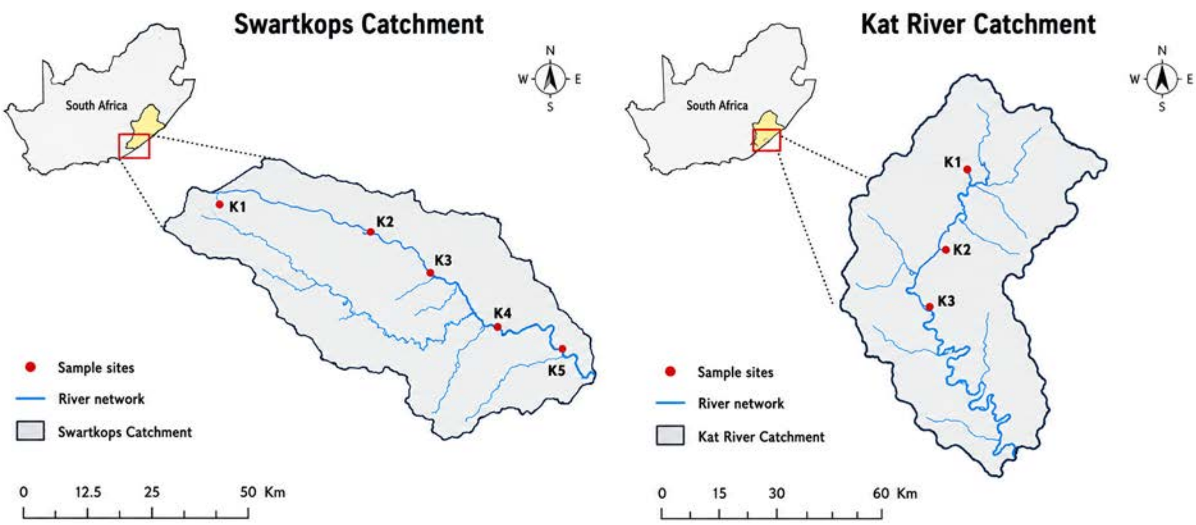
The spatial distribution of risk levels identified reveals geographical variation in vulnerability to waterborne zoonotic diseases across the province.

High-risk areas are clustered near Uitenhage, Hankey, Kirkwood and Humansdorp, the central coastal belt near King William's Town and pockets of the north-eastern interior. Very high-risk zones are most prominent around Gqeberha and KuGompo City (East London), as well as along the north-eastern coastal corridor near Butterworth, Bizana, Lusikisiki, and Port St Johns.

Human behaviour matters – not just proximity to high-risk rivers

The study demonstrates that exposure risk is structured less by people's proximity to rivers than by how people and animals interact with these rivers. While most activities involved low-risk contact, ingestion-related pathways associated with fishing, ritual practices, and domestic water use posed a significantly higher risk of outbreaks.

Exposure depends on how communities actually interact with contaminated water – and here the team turned to social science, surveying people living near the Kat and Swartkops rivers about their daily use of these waterways.



The two main study areas, showing the sampling sites.

Respondents reported 18 distinct river-related activities. The most common, by far, were low-risk: walking along the banks, observing nature, simply enjoying the landscape. Fishing and ritual water use – including baptism and traditional cleansing practices – were reported less frequently, but these activities involve direct ingestion or intensive contact, thereby carrying a much higher risk of transmission.

Recommendations and next steps

Overall, the findings suggest that waterborne zoonoses outbreaks in the Eastern Cape are not just microbiological issues but also reflect failures in how surveillance, governance and community engagement work together. Dr Nnadozie says the results demonstrate that "waterborne zoonoses outbreaks are predictable outcomes of ecological, behavioural, infrastructural and governance failures, rather than random events".

"Rivers do more than carry waterborne pathogens; they also influence how these pathogens spread and affect their environment," she says. "We know zoonotic pathogens have environmental, hydrological and human drivers. The findings show there is a high likelihood that many waterways may be silently contributing to a high infection rate in the general human population through multiple routes of exposure."

The findings about risk zones have important implications for surveillance budget planning, Dr Nnadozie believes. Province-wide blanket monitoring is unnecessary; instead, targeted interventions are feasible.

Institutionally, the study found that fragmented surveillance and weak reporting systems exclude communities from early warning processes, eroding trust and undermining prevention.

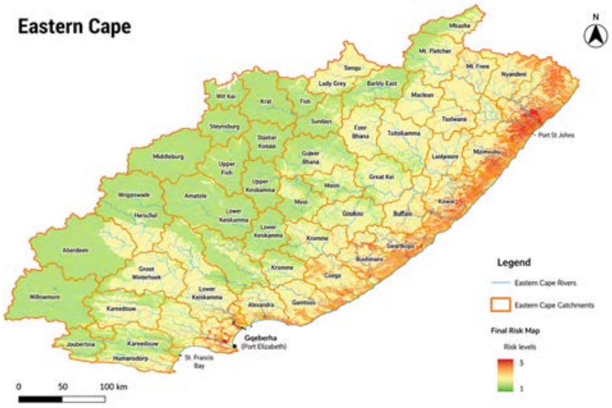
The research positions environmental surveillance indicators, particularly pathogen genetic signals in water, as early warning tools that support timely and targeted public health interventions.

The study identifies clear priorities for follow-up, including longitudinal monitoring to validate seasonal predictors and refine lead times for early warning.

The researchers set out eight key recommendations. They urge that surveillance for waterborne zoonoses be guided by risk, zeroing in on the catchments flagged as high or very high risk, while keeping a lighter watch elsewhere. Environmental monitoring should reach beyond the river's surface to probe the hidden world of biofilm-laden plants, rocks, and plastics where pathogens linger.

Early warning systems must be tuned to the seasonal spike in waterborne diseases each winter. Prevention should home in on places where people are most likely to ingest contaminated water, such as fishing spots, ritual water-use areas, and domestic collection points, rather than relying on broad river-health campaigns. Wastewater treatment upgrades should be seen not just as infrastructure projects but as vital public health measures.

Formal One Health governance should also unite the water, health, veterinary, and environmental sectors under shared goals and budgets, moving beyond reliance on informal cooperation.



Zoonotic contamination potential zones for river systems in the Eastern Cape. The map illustrates spatial variations in zoonotic contamination risk affecting river systems across inland, coastal and north-eastern regions of province, categorised into five risk levels (1 = very low risk to 5 = very high risk.)

In addition, community voices need to be woven into the system through real reporting channels and visible feedback, helping to restore the trust that focus groups found lacking. Finally, future research should sharpen the thresholds that prompt action, test the framework, and identify ways to adapt it in other provinces facing the same tangled risks.

The researchers recommend establishing an operational pilot of integrated One Health surveillance and response in selected high-risk catchments to test governance arrangements, data systems and trigger mechanisms.

Dr Nnadozie believes South Africa could benefit from a surveillance system that "routinely monitors these priority rivers, moving away from being purely reactive to outbreaks".

"An early warning system will provide us with an opportunity to anticipate that these diseases will come into the population and try to prevent it even before it appears," she says. "In terms of what should then be prioritised in terms of surveillance, I would say we should actually not only look at the water column, but look at those substrates as well. In high-risk areas, we need to fix the wastewater treatment points, improve that infrastructure, and maybe incorporate community-based surveillance.

"Wastewater failures and livestock waste inputs continue to be treated as infrastructure or environmental issues rather than as precursors of public health emergencies, allowing preventable risks to escalate into crises."

Both prevention and preparedness are essential, and effective surveillance can facilitate timely responses.

"Outbreaks are not merely microbial, microbiological events, but socioecological failures," Dr Nnadozie concludes. "Rivers are functioning as active transmission interfaces, not passive environments. This means that we have to actively manage the reservoir environments if we want to manage zoonotic diseases."