

2. Environmental Surveillance – Environment

Environmental surveillance has emerged as a vital tool in modern public health and ecological management, as it allows scientists and policymakers to detect early signs of disease outbreaks, monitor pollution, and safeguard ecosystems.

Environmental Surveillance – Overview and Significance

1. Concept and Definition

Meaning – Environmental surveillance refers to the systematic collection and analysis of environmental samples – such as wastewater, air, soil, and even ambient sound – to detect pathogens, pollutants, and other health-related indicators outside traditional clinical settings.

Objective – It seeks to identify disease-causing organisms (pathogens) and chemical or biological threats in the environment, providing a community-level snapshot of health trends.

Rationale – Many pathogens are shed by infected individuals through biological waste (stool, urine, saliva), even before clinical symptoms appear – allowing for early detection of outbreaks.

2. How Environmental Surveillance Works

a. Sampling and Detection

Sampling Sources – Includes wastewater treatment plants, hospital effluents, open drains, stormwater systems, air filters, and even soil in agricultural or urban areas.

Analytical Techniques – Involves molecular tools like polymerase chain reaction (PCR), metagenomic sequencing, and immunoassays to detect pathogen RNA/DNA or other biomarkers.

Newer Frontiers –

Air Sampling – Detecting airborne pathogens such as influenza or SARS-CoV-2 in ventilation systems or crowded spaces.

Soil Sampling – Tracing parasitic worm eggs or fecal contaminants in soil, especially in rural and peri-urban zones.

Audio Surveillance – Using AI and machine learning to analyze patterns such as coughing or sneezing sounds in public spaces, estimating respiratory illness trends.

b. Wastewater Surveillance in Detail

Sampling Points – Wastewater samples are collected from sewage treatment plants (STPs), hospital waste channels, transport hubs (airports, railways), and community drains.

Pathogen Presence – Wastewater often contains viral fragments, bacterial residues, and parasitic ova shed through feces and urine.

Examples of Pathogens Detected –

Viruses – SARS-CoV-2 (COVID-19), Poliovirus, Measles virus, Hepatitis A, Norovirus.

Bacteria – *Vibrio cholerae* (Cholera), *Salmonella typhi* (Typhoid).

Parasites – *Ascaris lumbricoides* (Roundworm), *Ancylostoma duodenale* (Hookworm).

Detection Timeline – Studies show wastewater can reflect infection trends 5–7 days earlier than clinical testing data – making it a powerful early-warning tool.

Why Environmental Surveillance Matters

a. Early Outbreak Warning – Detects pathogen circulation before symptomatic cases appear, providing critical lead time for public health interventions. Allows local governments and health agencies to mobilize testing, vaccination, and sanitation measures proactively.

b. Overcoming Clinical Limitations

Traditional Testing Gaps – Relies on symptomatic individuals seeking testing. Asymptomatic or mild cases often go unreported. Clinical testing can underrepresent the true disease burden.

Environmental Advantage – Captures infection signals from the entire community, including those not tested in clinics.

c. Non-Invasive and Cost-Effective

Non-intrusive monitoring – No need for direct contact or consent of individuals.

Efficient – Enables broad coverage of large populations through few sample sites, lowering operational

costs.

d. Tracking Emerging and Zoonotic Threats – Helps identify new pathogens in wildlife reservoirs and animal-human interfaces. Particularly relevant for avian influenza, Nipah virus, and zoonotic coronaviruses, where environmental surveillance provides early warnings.

e. Ecosystem and Pollution Monitoring – Detects industrial pollutants, antimicrobial resistance genes (ARGs), and pharmaceutical residues in wastewater and soil. Aids in protecting freshwater and marine ecosystems by identifying land-based contamination sources.

f. Public Health Planning and Policy Support – Provides data for epidemic forecasting, hospital preparedness, and vaccination targeting. Enables evidence-based allocation of health resources, especially in urban areas.

India's Experience and Initiatives

a. Historical Use

Polio Surveillance (2001) – India's first wastewater epidemiology initiative began in Mumbai to track poliovirus circulation, helping India achieve polio-free certification in 2014.

Long-standing Utility – Environmental surveillance has supported tracking of cholera, measles, and enteric diseases for decades.

b. COVID-19 Expansion – During the COVID-19 pandemic (2020–2023), India expanded wastewater-based monitoring to five major cities, including Delhi, Mumbai, Pune, Bengaluru, and Hyderabad. Provided real-time viral load data, which correlated with subsequent spikes in clinical cases. Enabled data-driven public health responses during waves of infection.

c. Current National Plans – The Indian Council of Medical Research (ICMR) announced in 2024–25 an ambitious plan to –

1. Track 10 high-risk viruses across 50 Indian cities, including SARS-CoV-2, measles, avian influenza, and hepatitis viruses.
2. Establish a national wastewater surveillance network integrating laboratories, health departments, and municipalities.

The initiative aims to make environmental surveillance a permanent part of India's disease monitoring architecture.

Challenges and Gaps

a. Institutional and Data Challenges

Fragmented Efforts – Many surveillance projects are isolated or short-term, lacking integration with national health systems.

Data Sharing Gaps – Poor coordination between urban utilities, laboratories, and public health authorities limits data utilization.

Standardization Issues – Absence of uniform sampling and analytical protocols leads to inconsistent results across regions.

b. Technical Constraints

Infrastructure Deficiency – Inadequate sewage treatment coverage (especially in small towns) reduces representativeness.

Analytical Capacity – Limited access to advanced genomic sequencing facilities and trained microbiologists hampers scale-up.

c. Policy and Governance Barriers – Lack of a long-term regulatory and financial framework to sustain environmental surveillance. Need for inter-departmental coordination – linking health, environment, water, and sanitation ministries under a common mandate.

Future Directions and Innovations

a. Integration into Public Health Systems – Environmental surveillance should complement clinical and syndromic surveillance under Integrated Disease Surveillance Programme (IDSP). Regular wastewater monitoring can act as an early sentinel system for urban and peri-urban disease control.

b. Advanced Analytical Approaches – Metagenomics and AI-based analysis can detect emerging or unknown pathogens. Real-time biosensors and automated samplers may provide continuous, high-

resolution environmental data.

c. Multi-Source Surveillance – Combining wastewater, air, soil, and wildlife monitoring into a One Health-based early warning network. Facilitates a holistic understanding of disease ecology at the interface of human, animal, and environmental health.

d. Emerging Tools – Audio Surveillance – Machine learning models analyze coughing or sneezing sounds in crowded spaces (e.g., railway stations, airports) to estimate respiratory disease prevalence. Smart Wastewater Analytics – Linking sewage data with population mobility and weather patterns for predictive disease modelling.

Conclusion

Environmental surveillance represents a paradigm shift in public health intelligence – from reactive diagnosis to proactive detection. In a densely populated country like India, it offers a non-invasive, community-wide, and cost-effective means of tracking infectious diseases and environmental health risks. Strengthening institutional frameworks, data integration, and local capacity will be crucial for scaling it into a national early-warning system aligned with One Health principles and Sustainable Development Goal 3 (Good Health and Well-being).

Source - [https - //www.thehindu.com/sci-tech/science/why-is-environmental-surveillance-important-explained/article70114347.ece](https://www.thehindu.com/sci-tech/science/why-is-environmental-surveillance-important-explained/article70114347.ece)

