Challenges and Opportunities for Public Health Surveillance

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Passive Case Reporting vs. Dynamic Surveillance

Traditional Case Reporting

▪ **Unidirectional Data Flow:** Health clinics passively report figures up to district levels; information rarely flows back to reporters.

▪ **Static Aggregations:** Relies heavily on historic registries, delayed paper entries, and one-off epidemiological surveys.

▪ **Passive Orientation:** Acts as an archive for national statistics; lacks actionable loops to initiate field control measures.

Core Question: Traditional methods query 'How many cases occurred last month?' rather than 'Where do we act today?'

Dynamic Surveillance Cycle

▪ **Closed-Loop Cycle:** Integrates systematic collection, rapid transmission, processing, active feedback, and decisive policy action.

▪ **Immediate Data Feedback:** Maintains clinician engagement by returning bulletins and trends to primary healthcare centers.

▪ **Action-Based Mandate:** Surveillance data is collected explicitly to justify public health intervention (e.g., dispatching response teams).

✓ **Example:** AFP bulletins return to individual PHCs, sustaining Polio surveillance and proving that feedback keeps systems alive.

A Continuous Four-Step Cycle Transforms Raw Counts Into Public Health Action

1. Collect

Standardized Forms

Uses precise, consistent case definitions to count the same disease occurrences consistently day-to-day.

2. Transmit

Fixed Channels

Moves data along predictable pathways (paper forms, SMS, digital portals like IHIP) on a fixed timeline.

3. Analyze

Trends & Rates

Transforms raw counts into rates per 1,000 or 100,000, analyzing by key variables of Person, Place, and Time.

4. Feed Back

Feedback & Act

Returns bulletins, maps, and dashboards to providers. Uses **signals to trigger investigations*** or adapt policy.

*We will come back to this later

Standardized Case Definitions Ensure We Count Consistently Rather than Exactly

Why Standardize Definitions

▪ Surveillance systems prioritize consistency over absolute diagnostic precision. We seek to track patterns over time rather than establish absolute truth.

▪ Standardization prevents doctors, nurses, and lab workers from reporting clinical events under disparate subjective criteria.

▪ Every robust definition must specify criteria regarding Person, Place, Time, and Specific clinical/laboratory features.

Application: Tiered Cholera Definition

1. Possible Case: An acute, watery diarrheal episode in an endemic setting.

2. Probable Case: Hospitalization for acute dehydration secondary to severe diarrhea.

3. Confirmed Case: Isolation of Vibrio cholerae from stool samples of a probable case.

Case Definitions Balance High Sensitivity with Positive Predictive Value

Epidemiological Trade-Offs

- **Loose (Sensitive) Definitions:** Designed to catch every case (low false negatives). Necessary during initial outbreak detection, but captures many false positives (low PVP).
- **Strict (Specific) Definitions:** Designed to exclude non-cases (high false negatives). Necessary for accurate disease burden estimations and resource allocation.
- Predictive Value Positive dictates that if 80 out of 100 reported Dengue cases are biologically validated, the system's PVP is 80%.

Demarcating the Boundaries

A Case is an Event: It represents a specific clinical occurrence linked tightly to a specific person, place, and date of symptom onset.

A Trigger for Public Health Action: It is designed purely as an epidemiological signal to initiate investigation, quarantine, or policy changes.

Not a Clinical Diagnosis: Surveillance definitions must never be equated with individual clinical diagnostic pathways used for patient therapy.

The Surveillance Pyramid Represents Only the Tip of the Burden

Dimension	Ad-Hoc Survey	Routine Surveillance
Time frame	Snapshot in time (ad-hoc)	Continuous and ongoing
Primary output	Prevalence	Long-term Trends
Funding/Life	Project-based	Systematic (keeps running)
Core value	Deep clinical detail	Actionable outbreak warning

The Under-Reporting Pyramid*

▼ **Loss at Each Tier:** The reported counts reflect only the tip of the iceberg. Cases are lost at every step of the healthcare-seeking journey.

▪ **Step 1 - Care Seeking:** Community infections occur, but only a fraction of patients choose to seek formal medical care.

▪ **Step 2 - Clinical Diagnosis:** Of those seeking care, only a small percentage are correctly suspected and diagnosed with the pathogen.

▪ **Step 3 - Final Reporting:** Of correctly diagnosed cases, a further subset is actually entered into reporting systems

*We will come back to this later

Different Strategies Segment Populations into General, Sentinel, and Risk Cohorts

General Population

Broad National Capture

Tries to capture cases in the entire population. All medical facilities report into a centralized framework.

Denominator: Uses national census statistics to calculate exact population-level rates.

Example: IDSP-IHIP reporting.

Sentinel Surveillance

Selected Sentinel Sites

Captures cases only in highly specific, strategically selected spots (clinics, labs) rather than universal.

Denominator: No broad population denominators available; relies on localized trends.

Example: Sentinel HIV clinics

Special Populations

Vulnerable & Closed Cohorts

Monitors highly specific cohorts where transmission risks are unique, closed, or magnified.

Denominator: Captures special demographics (e.g. total inmates, clinical inpatients, mass festival attendees).

Example: Hospital AMR tracking.

Passive and Active Surveillance Methods During Outbreaks

Passive Surveillance

Patient Initiated

Health clinics and doctors report cases as patients present themselves in hospitals. Surveillance is quietly integrated into everyday routine care.

Pros/Cons: Highly cost-effective and continuous, but suffers from massive under-reporting and poor timeliness.

Example: Routine SARI reporting in India.

Stimulated Passive

Reinforced Capture

Clinicians still report when patients present, but the surveillance center actively prompts them via weekly reminders, visits, and phone calls.

Pros/Cons: Substantially improves reporting timeliness and sensitivity without duplicating field-level clinical infrastructure.

Example: Acute Flaccid Paralysis (AFP) surveillance.

Active Surveillance

Systemic Outreach

Public health teams actively visit villages, households, and clinics to detect cases. The system does not wait for patients to come to hospital.

Pros/Cons: Near-perfect sensitivity and completeness, but consumes immense funding and human resources; usually temporary.

Example: Active TB case-finding campaigns.

Indicator and Event Surveillance Merge under IHIP to Deliver Immediate Real-Time Alerts

Indicator-Based Surveillance (IBS)

▪ **Structured Formats:** Routine, weekly aggregated diagnostic reports submitted systematically from mapped clinics.
▪ **Scope:** Monitors established, epidemic-prone pathogens (e.g. Cholera, Malaria) against historical seasonal baselines.

Event-Based Surveillance (EBS)

▪ **Unstructured Signals:** Rapid, unstructured intelligence pulled from social media, local news, and community reports.
▪ **Scope:** Designed specifically to spot highly unusual events, clusters of unexplained deaths, or bizarre veterinary spillover.

Integrated Health Information Platform (IHIP) is Shifting India to Real-Time Case-Based Surveillance

✓ **Case-Based tracking:** Moves India away from rigid, aggregate weekly summaries to immediate, single case upload registries.

✓ **Hyper-Timeliness:** The central digital infrastructure guarantees that a district surveillance unit learns today what occurred today.

✓ **Automated Signal Alerts:** Employs programmatic alerting algorithms to identify case clusters and trigger rapid response investigations.

Leveraging Frontline Community Networks to Detect Clusters Early

Communities as Frontline Sensors

▪ **The Grassroots Network:** Surveillance systems must extend beyond hospital walls to capture community indicators before clinical presentation.

▪ **Local Mobilization:** Leverages ASHAs (Accredited Social Health Activists), ANMs, and village volunteers as first-line eyes and ears on the ground.

▪ **Grassroots Integration:** Empowers rural and remote communities to report unusual local signals directly upwards into the IDSP-IHIP platform.

Syndromic Triggers & Applications

▪ **Fever Clusters:** Detection of localized, concurrent fevers across several adjacent households in a single village block.

▪ **Diarrheal Outbreaks:** Rapid tracking of sudden clusters of acute watery diarrhea

▪ **Unexplained Animal Deaths:** Immediate alerting for die-offs in poultry or livestock, serving as a primary indicator of potential zoonotic spillover.

▪ **Digital Crowd-Sourcing:** Employs mobile-based reporting apps that enable direct, participatory crowd-sourced notification of community health metrics.

One Health Alliances Can Address Zoonotic Threats

Bridging Human & Animal Systems*

▪ **The 75% Burden:** Approximately three-quarters of all emerging and re-emerging infectious diseases in humans originate as zoonoses in animal reservoirs.

▪ **Environmental Intersection:** Pathogens jump species at intense physical interfaces (slaughterhouses, bird sanctuaries, wetlands) where humans, animals, and vectors converge.

▪ **Unified Policy:** The National One Health Mission drives structural collaborations between health, veterinary, and environmental departments to coordinate data sharing.

Targeted Surveillance Programs

✓ **KFD (Kyasanur Forest Disease):** Monkey deaths in forest areas act as a sentinel trigger to immediately initiate human fever testing and tick surveillance in a 5 Km radius.

✓ **Rabies & Brucellosis:** Links dog rabies cases and dog-bite registries. Screens sheep, goat, and cattle populations through bovine serology.

✓ **Japanese Encephalitis:** Surveillance of pig sentinel populations and ardeid bird nesting coordinates with vector entomological surveys.

✓ **Avian Influenza:** Continuous concurrent screening programs across domestic poultry units and wild migratory flyways in wetlands.

*We will come back to this later

Environmental Wastewater Screening Captures Pathogens Across Entire Cities

Why Wastewater Surveillance works*

▪ **Unbiased Population Coverage:** Captures biological shedding from the entire population (animal & human) catchment of a sewer network, bypassing healthcare-seeking behaviour completely.

▪ **Asymptomatic Monitoring:** Tracks overall viral loads from both clinical and completely asymptomatic patients, serving as an early indicator.

▪ **Proven Lead Time:** Demonstrated success globally, including detecting Polio variants in London and Omicron spikes days before clinical hospital waves occur.

The Multi-Pathogen Sewage Matrix

✓ **Gastrointestinal viruses:** Rotavirus, Norovirus, Polio, Hepatitis A, and Hepatitis E are easily detected

✓ **Gastrointestinal bacteria:** Tracks shedding of Vibrio cholerae, Salmonella typhi, Campylobacter, and Shigella species

✓ **Respiratory threats:** Enables rapid molecular quantification of SARS-CoV-2, Influenza A and B, RSV, and Adenovirus shedding.

✓ **Beyond pathogens:** Picks up overall AMR (Antimicrobial Resistance) gene prevalence, and chemical/illicit drug markers

*We will come back to this later

Genomics and Open-Source Intelligence Detect Novel Pathogens/Diseases

Genomic Characterization

▪ **Beyond Identification:** Sequencing tracks fine mutations, lineage developments, relative virulence changes, and the emergence of AMR markers.

▪ **Established Networks:** Integrates into global sequencing hubs

▪ **Disease X Preparedness:** Essential for detecting the 'next unknown' respiratory or zoonotic spillover event, aligning directly with the 100 Days Mission.

Open-Source Intelligence

▪ **Media Signal Capture:** Recognizes that early outbreak signals frequently occur first in local news report listings, preceding official bureaucratic channels.

▪ **Active Scrapers:** Leverages automated analytical scrapers such as ProMED-mail, Canada's GPHIN (which flagged SARS early in 2003), HealthMap, and WHO's EIOS portal.

▪ **The Hybrid Model:** Modern surveillance centers must actively blend official indicator reporting with rapid, open-source web signals to confirm spikes.

Utility of AI and Climate Analytics for Predicting Epidemic Spikes Weeks Before They Occur

Artificial Intelligence

Uses machine learning to parse thousands of unstructured hospital records and lab sheets.

Key Functions: Automates anomaly detection, isolates subtle symptom clusters, and forecasts upcoming flu/dengue trends.

Digital Trace Data

Tracks real-time Google search queries, public forum discussions, and social media mentions.

Key Functions: Offers rapid, wide geographical coverage, but is plagued by high data noise and requires constant validation.

Climate Integration

Fuses clinical data with real-time IMD weather indices (rainfall, humidity, temperature).

Key Functions: Predicts seasonal vector-borne spikes (Dengue, Malaria) and environmental spillover (Leptospirosis) weeks in advance.

Regular Evaluation Forces System Readiness and Timeliness

Ethics & Data Governance

- **Core Ethical Pillars:** Surveillance systems handle massive personal clinical registries. Must rigidly enforce necessity, proportionality, confidentiality, and clear accountability.
- **India's Legal Framework:** India's Digital Personal Data Protection (DPDP) Act, 2023, and ICMR's National Ethical Guidelines (2017)
- **Equity & Trust:** Maintains public trust by ensuring strict equity in reporting, guaranteeing that marginalised or remote cohorts are counted, not ignored.

Evaluation of Surveillance

- **Periodic Audits:** Surveillance networks must undergo scheduled evaluations to verify they still address active public health decisions.
- **Data Quality:** Assesses key data attributes including sensitivity, Predictive Value Positive, completeness, and representativeness.
- **System Quality:** Measures structural attributes: simplicity of reporting forms, flexibility to add new viruses, stability of servers, and speed (timeliness).
- **Feedback Integrity:** Checks if actionable bulletins are actually reaching the reporting health facilities on time to sustain reporting loops.

Integrated early warning system for dengue surveillance using epidemiological and entomological surveillance in Coimbatore district

Demonstration of how automated early warning signals incorporating entomological indicators can strengthen the fight against Dengue Fever

Dr M Sivachandran, MPH
District Epidemiologist

Objectives: Building and testing the integrated system

EpiTrack · Integrated dengue early warning, Coimbatore District

To evaluate the timeliness and completeness of dengue signal detection using the integrated early warning system, compared with the existing manual process.

Results: Automated detection - more signals, earlier warning

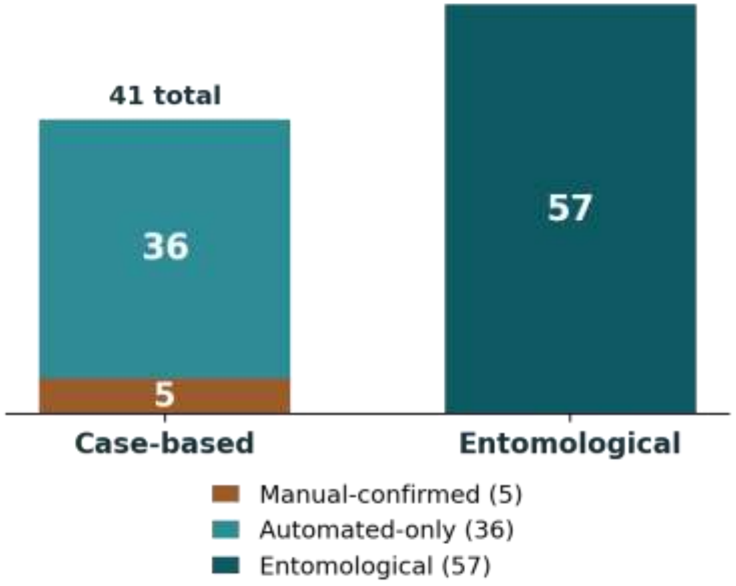
EpiTrack · Integrated dengue early warning, Coimbatore District

Detection lead time of automated versus manual and combined surveillance methods

Comparison	Median lead	IQR
Manual vs automated case-based	2 days	1–3 days
Automated case-based vs combined	2 days	1–4 days

Distribution of early warning signals by detection method and signal type

(manual caught 5 of 41 case-based)



Recommendation

EpiTrack · Integrated dengue early warning, Coimbatore District

- ❑ EpiTrack should be integrated into routine district dengue surveillance due to its demonstrated feasibility and acceptability among frontline health workers.
- ❑ Combined case and vector surveillance should be adopted as the standard approach, as integrating both data streams improves signal detection compared with case-based surveillance alone.

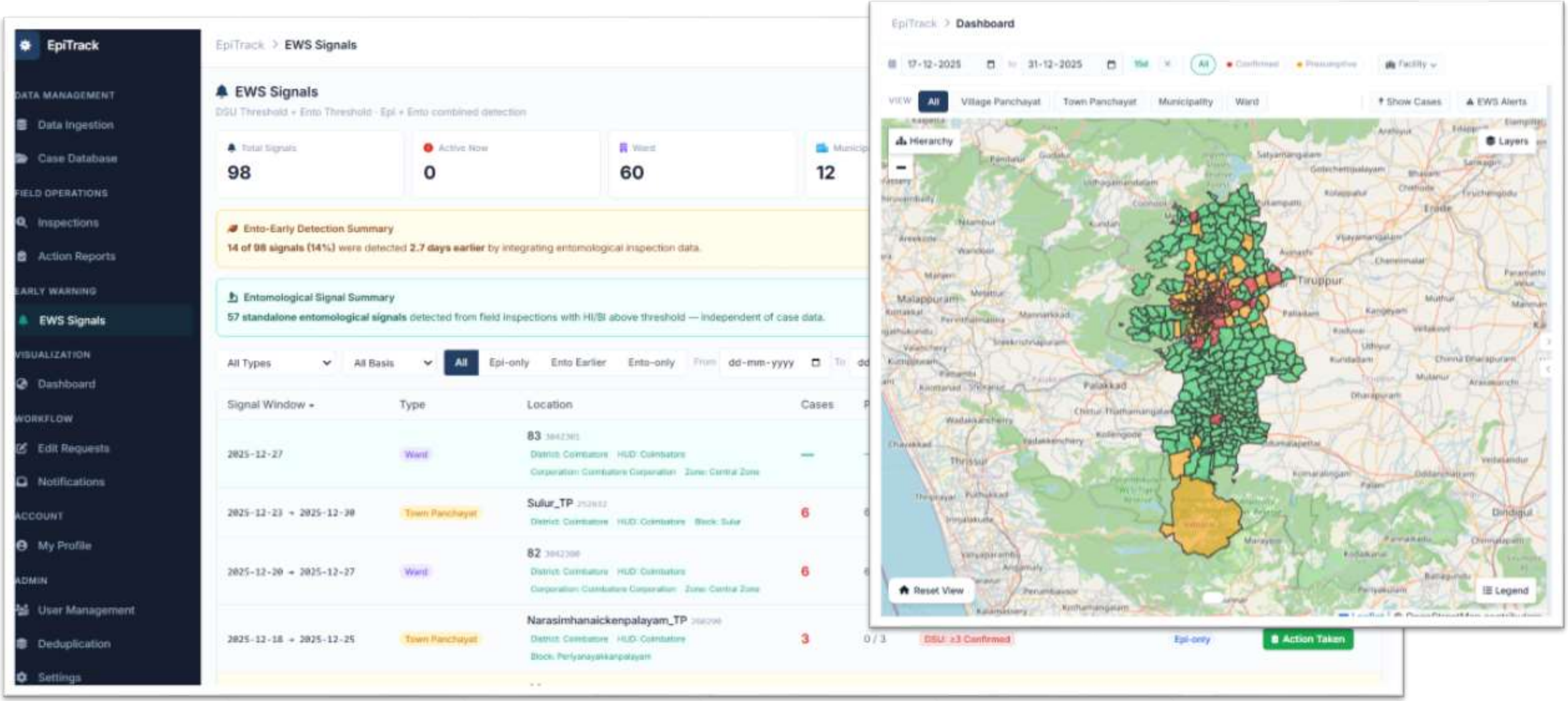
9 Principles of Designing a Digital Tool

EpiTrack · Integrated dengue early warning, Coimbatore District

Principle	Matching feature in the tool
Design with the User	Offline sync; role-tailored screens; first-login password; mobile-friendly
Understand Ecosystem	Official area codes; existing IDSP forms; real roles; entomological data
Be Data Driven	Automatic alerts; case hotspot map; entomological + case combined
Build for Sustainability	Error checks; activity log; 30-day backups; documented
Be Collaborative	Cross-facility alerts; edit approval; action records; multi-level sign-off
Design for Scale	Grows from one office to the whole district
Open Standards / Open Source	Open data formats; free software; code shared on GitHub
Reuse and Improve	Builds on area directory and IDSP forms
Privacy and Security	Encrypted passwords; role-restricted access

Screenshots from EpiTrack

EpiTrack · Integrated dengue early warning, Coimbatore District



Links to EpiTrack

EpiTrack · Integrated dengue early warning, Coimbatore District

- https://epitrack-cbe.web.app/
- https://dphcbe-atr.web.app/
- https://coimbatore-corp-web.web.app/

Capacity Building and Framework Development for SARI Burden Estimation and Forecasting in India

An attempt to estimate the burden of Severe Acute Respiratory Infection and build infectious-disease forecasting capacity.

An Attempt to Measure SARI's True Burden

Severe Acute Respiratory Infection (SARI) drives substantial hospitalization, disability and mortality in India, but its true scale is poorly measured. This project builds hospital-based surveillance across three sentinel sites and a companion forecasting framework, so that burden estimates and outbreak signals reach public health decision-makers in near-real time.

THREE SENTINEL SITES

AIIMS Raipur
Chhattisgarh

Madurai Medical College Hospital
Tamil Nadu

Govt. Medical College, Aurangabad
Maharashtra

Two Objectives: Measure the Burden, Build the Forecast

OBJECTIVE 1

To estimate the disease burden due to SARI hospitalization episodes, disability and mortality in selected sites across India.

OBJECTIVE 2

To develop a framework for infectious disease modelling and forecasting.

THREE SUB-OBJECTIVES

Community burden

Estimate the SARI burden circulating in the community, not just what reaches hospitals.

Influenza severity

Assess the severity of seasonal influenza activity across sites and seasons.

WHO estimator tool

Apply the WHO seasonal-influenza burden-of-disease estimator to standardise outputs.

Four Workstreams

Prospective Surveillance

Commenced March 2025 across all three sentinel sites. 3,203 SARI cases enrolled to date.

Healthcare Utilization Survey

Completed in Madurai (Jun–Nov 2025); and in Feb 2026 in Raipur

Hospital Admission Survey (HAS)

Scope revised to aggregated one-year data. Raipur and Madurai have started data collection;

Disease Modelling Workshop

US CDC experts and NIE scientists met (sessions convened August 2026).

One Health Zoonotic Spillover Surveillance

Combined Spillover & Triangulation Analysis Across Two Sentinel Networks

1. Slaughterhouse (Assam, Punjab, Telangana)
2. Bird Sanctuaries & Wetlands (Sikkim, Maharashtra, Tamil Nadu)

One surveillance design, two contact interfaces

Both studies apply the identical One Health design, weekly sentinel sampling of humans, animals and the shared environment, with cross-component co-detection triggering referral for next-generation sequencing. They differ only in the interface being watched.

SLAUGHTERHOUSE INTERFACE

16 slaughterhouses (organised + unorganised)

Occupational, high-intensity contact: butchers, eviscerators, clean-handlers exposed daily to blood, viscera, urine and lairage effluent. 16 priority pathogens under surveillance.

426	3402	31507	1481
workers enrolled	animals screened	tests performed	environmental samples

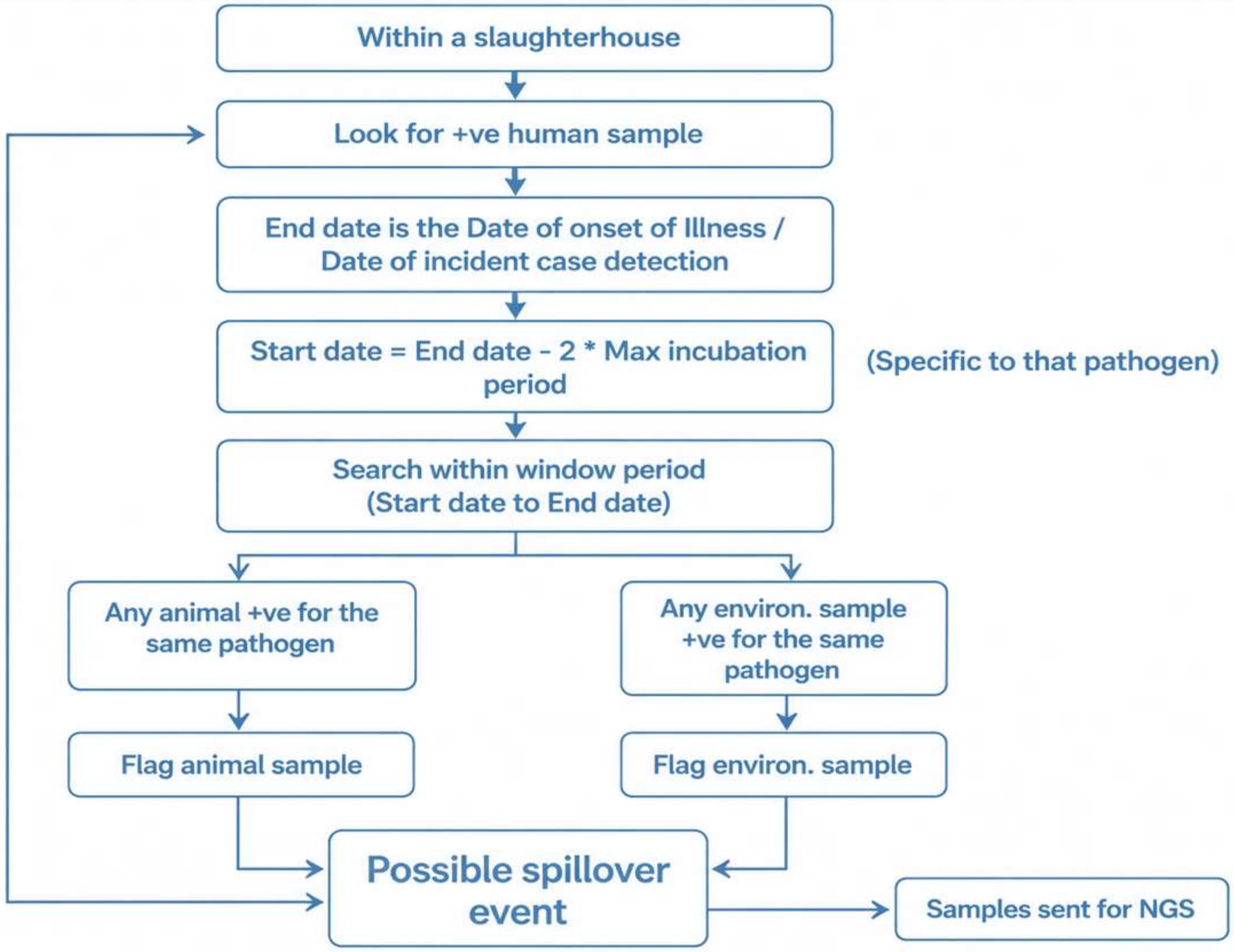
BIRD SANCTUARY & WETLAND INTERFACE

13 sanctuaries and wetlands

Ambient, intermittent contact: sanctuary staff and peri-wetland workers exposed to droppings, ornithogenic soil and surface water rather than to animal tissue or body fluids.

893	1981	4933	3336
workers enrolled	wild birds trapped	tests tested	environmental samples

Spillover Detection Algorithm



Spillover is detectable - where the design lets you see it

What the data establish

- The slaughterhouse interface has produced a genomically proven livestock-to-human spillover cluster in this programme
- Both interfaces carry a substantial reservoir and environmental pathogen load

Where the system is failing

- Twelve of eighteen candidate events failed at genome retrieval
- The bird sanctuary design cannot link a trapped wild bird to a specific human exposure, leaving triangulation effectively unidentifiable.

Recommended actions

- Prioritise deep sequencing for samples from co-detection events over routine 5% negative-sample screening.
- Introduce paired, same-day human-animal-environment sampling at bird sanctuaries triggered by any incident case, rather than fixed-schedule trapping.
- Report genome retrieval and coverage alongside every declared event as a standing evidence-grading field.

Multi-Pathogen Wastewater Surveillance in India

Nationwide multi-pathogen wastewater-based epidemiology, linking molecular sewage signals to public-health action via IHIP.

A Nationwide Early-Warning Network

Wastewater-based epidemiology (WBE) is a low-cost, passive surveillance tool that tracks pathogen circulation across whole communities by testing sewage, without depending on individuals seeking clinical care. India's multi-pathogen WWS network links molecular signals from sewage directly to public-health action.

Community-Level Tracking

Multi-pathogen WBE monitors population-level disease circulation as a passive, low-cost tool.

Targeted Early Warning

Flags temporal and geographic trends in priority pathogens before clinical spikes emerge.

Equitable Coverage

Captures shedding from sewerage and drains

Integrated Action

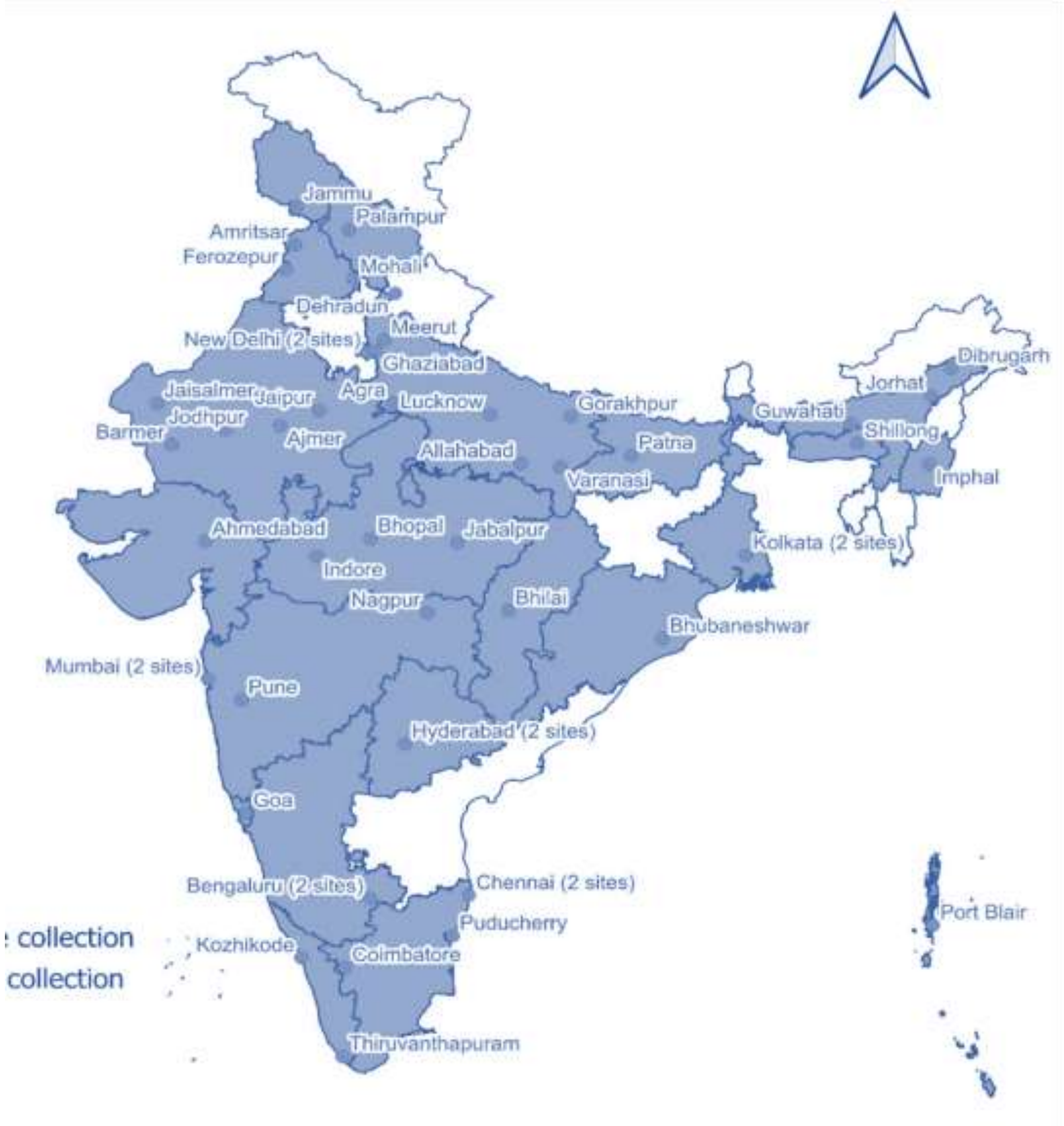
Bridges molecular wastewater data with clinical reports on IHIP to guide rapid intervention.

Nationwide Rollout Across 65 Cities

PHASE I

47 cities leveraging existing institutional capacity.

Sentinel network: tier-1 hub cities link outward to tier-2 city clusters, standardised on a weekly ‘fixed day, fixed time, fixed site’ grab sampling protocol.



One Panel, Many Pathogens

Enteric Viruses

Adenovirus · Hepatitis A · Hepatitis E · Enteroviruses · Noroviruses · Rotavirus

Vaccine-Preventable & Respiratory

Measles · Rubella · Respiratory Syncytial Virus · Seasonal Influenza A/B

High-Threat Emerging Pathogens

Mpox · SARS-CoV-2 (E, RdRp & ORF genes)

Bacterial Target

Salmonella Typhi

Detection method: Real-time multiplex RT-PCR assays with centralized reporting to ICMR-NIE, Chennai.

From Grab Sample to Ct Value in 5 days

1. **Grab Collection**
   1–1.5 L samples collected 8:00–11:00 AM

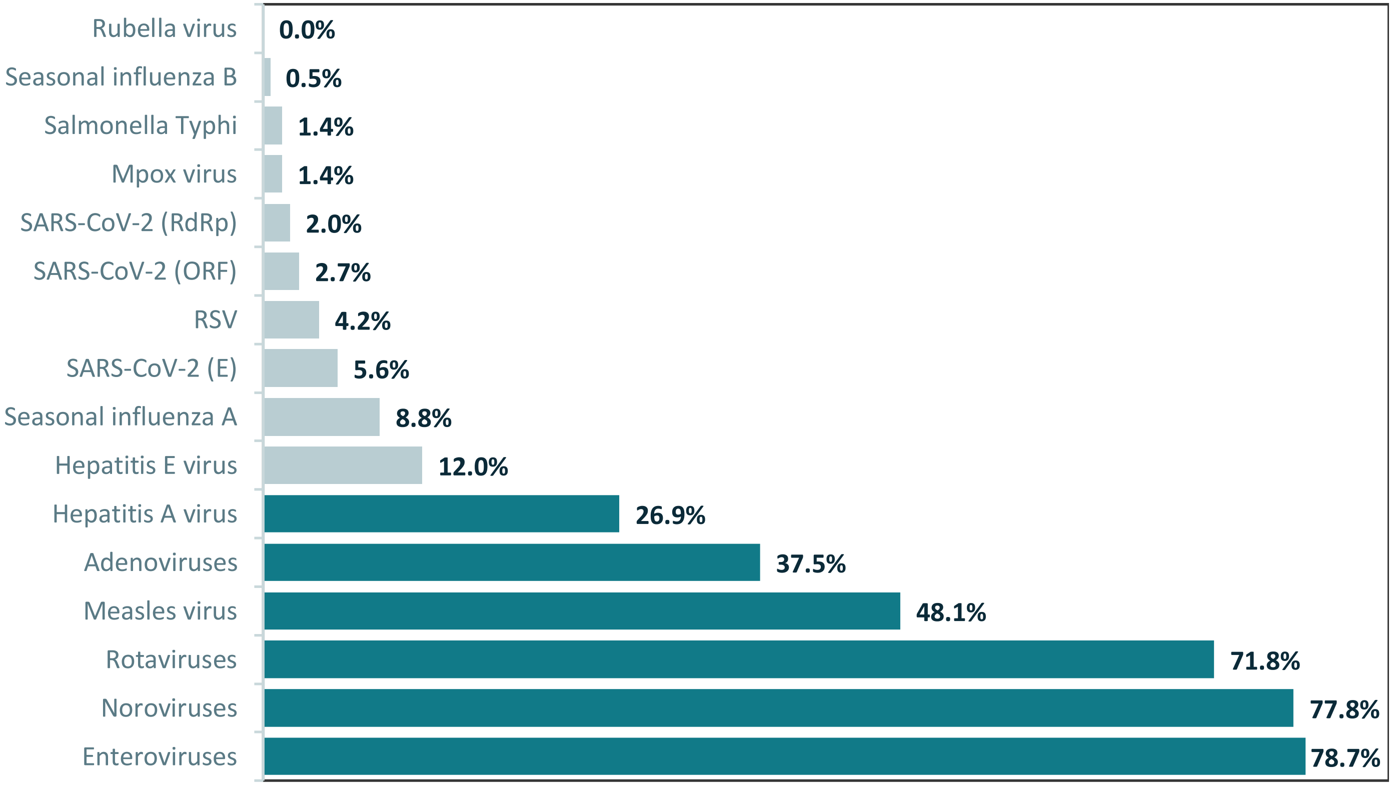
2. **Cold-Chain Transport**
   Transported at 2–8°C to the laboratory

3. **Virus Concentration**
   PEG/NaCl or two-phase separation, within 24 hrs

4. **RNA / DNA Extraction**
   Purified nucleic acid from concentrate

5. **Multiplex RT-PCR**
   High-precision assay records Ct values

Enteric Pathogens Are Common, As Expected



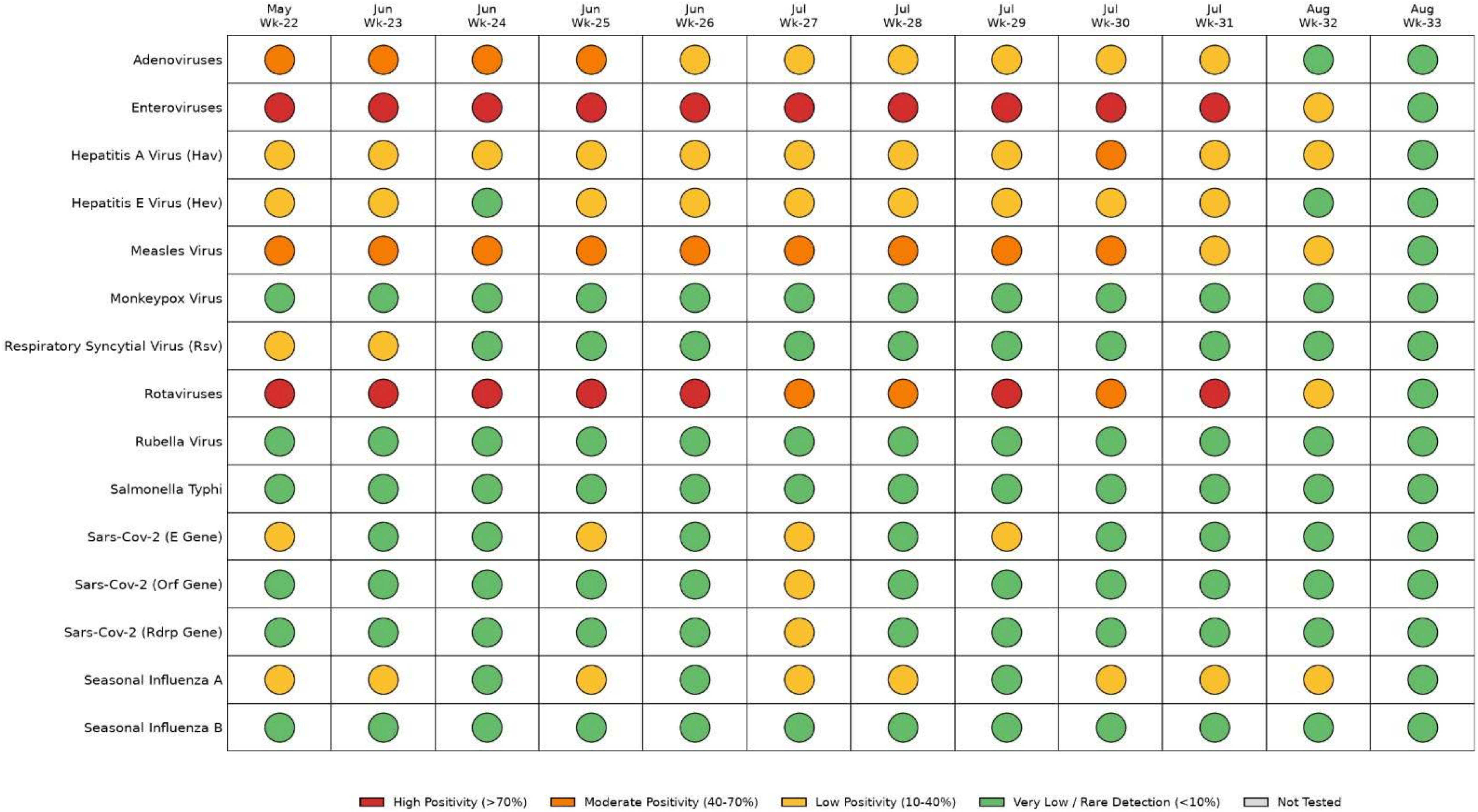
ENTERIC DOMINANCE

Enteroviruses, noroviruses and rotaviruses each exceed 70% of samples tested. Together with measles they account for the overwhelming majority.

PICKING UP RARE-EVENTS

Mpox (3/216), Salmonella Typhi (3/216), influenza B (1/216) and rubella (0/216) sit at or near zero, the low-prevalence signals the network exists to catch early.

Denominators: 216 samples for every target except SARS-CoV-2 RdRp and ORF (147 each, tested by a subset of labs). Weeks 22-31, 2026.


May Wk-22
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Jul Wk-28
Jul Wk-29
Jul Wk-30
Jul Wk-31
Aug Wk-32
Aug Wk-33
Adenoviruses
Enteroviruses
Hepatitis A Virus (Hav)
Hepatitis E Virus (Hev)
Measles Virus
Monkeypox Virus
Respiratory Syncytial Virus (Rsv)
Rotaviruses
Rubella Virus
Salmonella Typhi
Sars-Cov-2 (E Gene)
Sars-Cov-2 (Orf Gene)
Sars-Cov-2 (Rdrp Gene)
Seasonal Influenza A
Seasonal Influenza B
High Positivity (>70%)
Moderate Positivity (40-70%)
Low Positivity (10-40%)
Very Low / Rare Detection (<10%)
Not Tested

Thresholds Likely to Deliver a 1-3 Week Head Start

1

Smoothing

3-week moving average smooths weekly noise & rainfall dilution.

2

Seasonal Baseline

95th-percentile per-site baseline distinguishes endemic shedding from anomalies.

3

Early Warning Signal

Triggered when the moving average crosses the baseline.

4

Alert Dispatch

Routed to IHIP for local field-team action.

WEEK 0 · Wastewater signal rises

1–3 WEEK PREDICTIVE LEAD TIME

WEEK 1-3 · Clinical admissions rise

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QUESTIONS?