

► SPECIAL REPORT



From Reactionary to Anticipatory Integrated Action: Novel Environmental Health Surveillance for Mass Gatherings

Abstract Advances in AI-driven analytics, human-in-the loop techniques, and wastewater monitoring provide the foundation needed to shift from reactive to anticipatory actions for mass gatherings. Traditional surveillance systems focus on clinical and laboratory-based notification pathways, which often result in tardy actions being implemented. Thus, traditional surveillance is becoming outdated. Mass gatherings pose heightened public health risks and hazards, including trauma; injury and substance misuse; deliberate poisoning; and infectious diseases such as food and waterborne illnesses, sexually transmitted infections, and respiratory diseases. There is also a heightened concern due to reduced vaccination coverage. As a result, future international events such as the Olympic Games likely will have an influx of people from regions with active outbreaks, amplifying public health threats. This reality, combined with an increased frequency of terrorism and other mass casualty incidents, highlights the need for anticipatory action. We propose a novel framework that we call the Environmental Health Surveillance and AI for Event Protection (E-SAFE) model. This model leverages and integrates environmental health measures with recent advances in AI, data availability, predictive analytics, and a multilayer defense to anticipate disease outbreaks and other risks earlier and faster. Applying these tools for the 2028 Los Angeles Olympic Games and other mass gatherings could maximize health system readiness and create a scalable and transferable legacy for environmental health surveillance.

Keywords: AI, anticipatory action, disease outbreak, emergency readiness, environmental health, environmental health surveillance, mass gatherings, Olympic Games

Background

The Olympic Games, international sporting competitions, music festivals, and other mass gatherings pose heightened public health risks and hazards. These risks include trauma; injury; substance misuse; extreme weather; chemical, radiological, biological, and nuclear incidents; deliberate poison-

ings; and infectious diseases such as food and waterborne illnesses, sexually transmitted infections, and respiratory diseases (Bongers et al., 2024; Chan et al., 2017). Mass gathering events provide opportunities for rapid disease transmission, increased strain on the local healthcare system, and reputational risks (Chan et al., 2017; Gallien et al., 2024).

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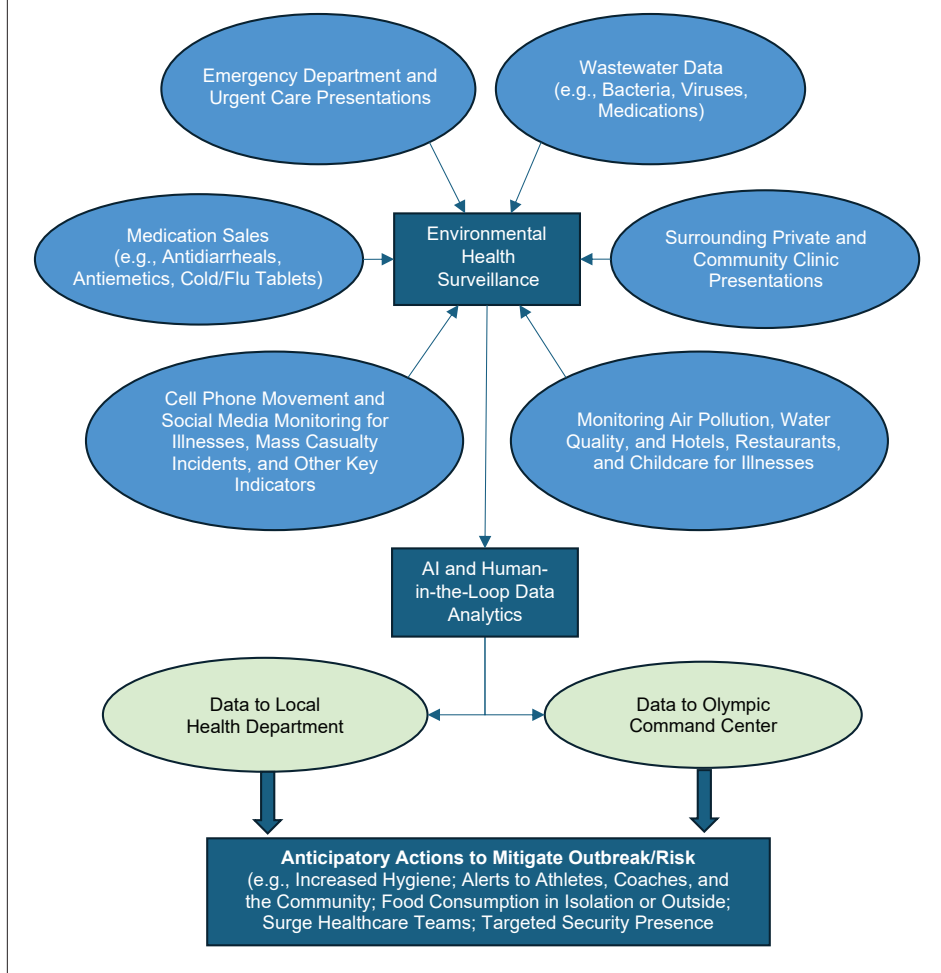
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There are particular concerns with the 2028 Los Angeles Olympic Games and other upcoming mass gatherings in confined settings due to outbreaks of vaccine-preventable diseases such as measles (Centers for Disease Control and Prevention [CDC], 2026a), polio (Namageyo-Funa, 2024), and pertussis (Johns Hopkins Bloomberg School of Public Health, 2024), which are resurging globally. Mass gatherings represent a discrete event to pilot and evaluate integrated enhanced surveillance models.

Mass gatherings in an era of rapid global mobility pose risks for amplifying commu-

FIGURE 1

E-SAFE: Environmental Health Surveillance and AI for Event Protection



nica ble diseases. For context, the 2012 London Olympic Games and Paralympic Games hosted an estimated 17,700 athletes from 205 nations, 20,000 accredited media members, a workforce of 200,000 (including paid workers, volunteers, and contractors), and a total influx of 470,000 international visitors (Collier, 2012; Statista Research Department, 2013). Similar figures are expected for the 2028 Los Angeles Olympic Games (Goldstein, 2024).

The scale of these events affects both the individuals attending and the wider local, regional, national, and international communities after the event is complete. In this light, anticipatory action coupled with interventions drawn from multi-indicator surveillance is necessary to safeguard local businesses and the public.

Anticipatory action is acting ahead of predicted hazards to prevent or reduce acute impacts before they fully unfold (Anticipation Hub, 2023; International Federation of Red Cross, 2020). Key aspects of this approach include determining thresholds and decision-making rules based on reliable, timely, and measurable data followed by pre-agreed activities consisting of actions between the trigger moment and the full impact of a shock (United Nations Office for the Coordination of Humanitarian Affairs, n.d.).

Anticipatory action has been used across the globe, primarily for weather-related disasters such as floods and droughts—but also for crises such as conflict-induced displacement and increasingly for disease outbreaks (CDC, 2024; United Nations Office for Disaster Risk Reduction, 2022). Health information systems

are also moving toward routine integration of non-health data to better predict health risks, while a focus on timeliness is driving improvements in rapid responses to outbreaks (DHIS2, 2025; Frieden et al., 2021).

The surveillance approaches used for past Olympic Games have expanded and include: emergency department surveillance for Los Angeles 1984 (Weiss et al., 1988), epidemic intelligence for Sydney 2000 (Jorm et al., 2003), large-scale syndromic surveillance for Athens 2004 (Gallien et al., 2024), and COVID-19 wastewater surveillance for Tokyo 2020 that was expanded to six pathogens for Paris 2024 (Gallien et al., 2024; Kitajima et al., 2022; Toro et al., 2024). Anticipatory surveillance systems at the 2010 Vancouver Olympic Games utilized information from media sources to identify a measles threat from Oceania well before the subsequent outbreak of the same variant in British Columbia (Mekaru et al., 2011).

Despite technological and surveillance advances, mitigation measures commonly are implemented well after an outbreak has commenced, which makes containment difficult. Furthermore, highly infectious diseases (typically respiratory infections) often are made worse by gaps in vaccine coverage (Salmon-Rousseau et al., 2016). For instance, recent measles outbreaks in the U.S. and Europe were detected as cases were clinically identified, compromising effectiveness of the outbreak response (CDC, 2026b; World Health Organization, 2025).

Epidemiologists and environmental public health professionals continue to spend much of their time correcting misinformation or disinformation rather than proactively informing at-risk and affected populations, which potentially compromises both outbreak detection efforts and response during a mass gathering (Gallien et al., 2024). This trend has accelerated with the doubling of social media use since 2015, along with increasing “reassurance” demands in real time by the public, policymakers, the media, and others (Backlinko, 2025; Gallien et al., 2024; McCloskey et al., 2014). Fighting the spread of an infectious disease now goes hand in hand with stemming the spread of inaccurate and false information (Massaro et al., 2021).

Traditional public health surveillance models have emphasized early detection of pathological disease via clinical and laboratory

patient-centric notification pathways. In contrast, environmental health measures that are designed to be proactive and community-based are often underutilized in large-scale mass gatherings. Emerging tools, such as AI analytics, provide an opportunity to strengthen integration of these capabilities and provide the shift needed toward anticipatory surveillance.

These tools, along with emerging human-in-the-loop techniques, could efficiently combine decision-making with AI data analytics (Mosqueira-Rey et al., 2023). Complementary to this model could be a “Swiss Cheese” risk mitigation model with multiple layers of information (and preparedness) that offset the inherent weaknesses or uncertainties in one layer (Cleveland Clinic, 2021; Ryan et al., 2022; Seshia et al., 2018). The benefits of this type of integrated framework were demonstrated by Baylor University, one of the few universities to sustain in-person operations during the COVID-19 pandemic (Ryan et al., 2022).

The 2028 Los Angeles Olympic Games are perhaps the most visible upcoming and timely opportunity to demonstrate how recent advances could be integrated to anticipate disease outbreaks and other health risks (Chaves-Gonzalez et al., 2022). This integration could include the development of empirical approaches to prioritizing diseases using wastewater monitoring, clinical data, environmental health measures, and clinical metagenomic surveillance.

In particular, the evolution and proven validity of wastewater monitoring as a surveillance tool provide an opportunity to use spatially explicit differentiation techniques to target anticipatory actions and rapidly implement mitigation strategies (Langan et al., 2025). This approach is particularly important with emerging infectious diseases, increased vaccine hesitancy, and the density of the population in and around the Olympic Games.

Our proposed framework, which we call the Environmental Health Surveillance and AI for Event Protection (E-SAFE) model, would leverage AI, data availability, predictive analytics, and human-in-the-loop techniques plus a multilayer defense approach (Figure 1). A key distinguishing point of our proposed model is the use of environmental health measures as the cornerstone for guiding public health actions and targeted responses. Leveraging these capabilities will

allow Los Angeles and the U.S. to maximize readiness for the 2028 Olympic Games. Furthermore, this approach would create a scalable and transferable legacy for a long-lasting environmental public health surveillance system. A blueprint for how E-SAFE could be implemented and sustained is outlined next.

Approach

The proposed E-SAFE model would be developed and implemented over eight sequential phases. Each of these phases is interlinked and focus on promptly detecting, identifying, and responding to diseases and other health risks. E-SAFE would also help contain post-event spread and build a long-lasting surveillance system. The phases for achieving this approach are outlined in the following:

1. Sourcing and integrating data: This phase would include prioritizing and integrating key data sources. Foundational to this step would be identifying data sources that are rapidly and frequently accessible, which could include emergency department, urgent care, and clinic case presentations; purchases of medications (e.g., antidiarrheal, antiemetics, cold/flu tablets) and other retail indicators from dominant suppliers; active environmental health monitoring of air and water quality; and illness at hotels, restaurants, and childcare facilities, particularly in and adjacent to entertainment districts. These datasets would provide a multilayered approach to early detection. Nontraditional clinical surveillance sources such as blood donor deferral rates due to history or examination of presenting “well” blood donors could also be included. There is a precedent of blood donation serosurveillance (Stone et al., 2022); however, syndromic surveillance of “well” blood donors remains underutilized (Williamson et al., 2020).

2. Focusing and instituting wastewater surveillance: Targeted monitoring for polio, influenza A, influenza B, mpox, norovirus, COVID-19, measles, and any drugs and substances of interest would be undertaken using wastewater. To maximize efficiency and health outcomes, the diseases and indicators of interest could be prioritized following engagement with interested entities (Gentry et al., 2023). These targeted approaches could be supplemented by agnostic metagenomic sequencing for bio-

logical agents of concern and nontargeted analytical chemistry techniques for other drugs or chemical compounds of interest.

- 3. Monitoring social media and cell phone usage:** A range of platforms could be monitored for increases in illness, trauma, distress, and other key indicators. This action could be achieved by monitoring social media posts, keyword trends, geo-tagging, and other features to promptly detect, identify, and respond to diseases and other risks, ultimately streamlining coordination efforts. Similarly, aggregated cell phone usage or movement patterns could be examined, as illustrated during the COVID-19 outbreak (Lu et al., 2021).
- 4. Applying AI-driven analysis:** Advanced machine learning models developed to process aggregated data and identify patterns, anomalies, and potential outbreaks would be needed. This step could occur before the Olympic Games and be aligned with mass gatherings (e.g., National Football League [NFL] and National Collegiate Athletic Association [NCAA] football games, the 2026 International Federation of Association Football [FIFA] World Cup tournament in the U.S., Canada, and Mexico) to effectively establish a series of data indicator baselines. By the time the Olympic Games commence, the AI system could generate real-time risk assessments and recommend early intervention measures based on agreed-on thresholds and triggers.
- 5. Linking human experts and AI tools:** A team of environmental public health experts would review AI-generated insights, cross-referencing findings with clinical and environmental health data. This innovative approach could directly inform or be integrated within an Incident Command Center-type structure. This feedback loop would also improve accuracy in the model and predictions/actions via additional human data, potentially preventing false alarms and enhancing decision-making agility.
- 6. Developing and evaluating the novel environmental health surveillance system:** The design of the E-SAFE model would undergo robust developmental, formative, and summative testing for innovation and learning before finalization (Fagen et al., 2011).
- 7. Defining an actionable response framework and system testing:** Surveillance

methods and tools must be deployed as information for action. Based on AI and expert analysis, response protocols would be developed—including triggers and thresholds, targeted health advisories, intervention strategies, and resource allocation—to rapidly contain potential outbreaks. This step would include exercises and events to continue testing the system, serving as stress tests to identify weakness and opportunities for improvements in advance of the Olympic Games.

- 8. Integrating scalability and sustainability:** The E-SAFE model (Figure 1) is scalable and transferable, ensuring long-term applicability beyond the 2028 Los Angeles Olympic Games. Collaborations with the private sector, local health agencies, and nongovernment organizations would facilitate integration into broader environmental public health infrastructure, enhancing preparedness for mass gatherings in Los Angeles and beyond. This multifaceted approach has the potential to provide a robust, predictive, and proactive disease surveillance system, safeguarding public health while ensuring the smooth execution of the Olympic Games and other mass gatherings.

Implementation

The system would take approximately 2 years to implement, with data stream analyses to be in place 1 year prior to large-scale events such as the Olympic Games. Successful implementation of the E-SAFE model requires not only the studies to show the intervention works in controlled settings but also a continuous organizational learning platform to understand how and what works in practice (Ramawamy & Barach, 2020). Evaluation methods for assessing the effectiveness of E-SAFE need to determine not only if environmental health outcomes have been achieved but also what mechanism(s) they were achieved by, for whom, and in what context. Implementation requires the creation of an internal learning system to document results of the Plan-Do-Study Act (PDSA) cycles to ensure that knowledge about implementation becomes as pervasive as the knowledge about the intervention (Kleinman & Barach, 2018).

Year 1 Implementation

Designing and establishing the multifaceted surveillance system would include identi-

fying partners to provide datasets, indicators, and locations for wastewater sampling. Environmental public health networks with staffing requirements and budgets would be defined and set up. Horizontal learning via a learning collaborative can be a powerful tool for improving pre-event preparation and learning, which is an innovative and comprehensive approach to multidisciplinary action research that brings public health researchers, clinicians, and policymakers together to create a community of practice (Anderson et al., 2015). A community of practice builds trust, shares knowledge, and generates evidence for the use and spread of innovation in quality improvement initiatives.

Year 2 Implementation

In the second year, focus would be on development of the surveillance system and early-stage testing of wastewater systems. Agreements with partners to provide lead indicators would be in place by the middle of year 2. The final few months of year 2 would be further refinement and implementation of the system based on available data and indicators, which would include development and implementation of an actionable response framework for testing at mass gatherings. Following this step, the system would be fully operational with ongoing testing and refinement in preparation for the Olympic Games. A roadmap for the establishment and continuance of the surveillance capabilities would be drafted to enable sustained improvements and expansion to other cities hosting the Olympic Games or other mass gatherings.

Discussion

Mass gatherings serve as a convergence point for diseases, and these type of gatherings pose a threat to the integrity and safety of the event and public health resources of the hosting community, city, or country. For the 2028 Los Angeles Olympic Games, AI-driven analytics integrated with human-in-the-loop techniques and carefully selected surveillance initiatives would anticipate and promptly detect outbreaks, helping to safeguard public health and the Olympics community. A unique element of our proposed SAFE-E model includes specific human-in-the-loop techniques, in which environmental public health subject matter experts and practitioners are directly engaged in diverse

data streams to interpret and act on data science. The Olympic Games and other mass gatherings pose the risk of becoming unprecedented superspreader events if there is not an evolution into anticipatory action. Our E-SAFE model could help mitigate these risks, protect the reputation of high-stakes events, and demonstrate the benefits of environmental health and proactive surveillance for cities that host large events.

AI has emerged as a decision-support tool and can help transform traditional surveillance. Our E-SAFE model requires AI-driven analytics to synthesize diverse and large data streams that span from emergency department visits to wastewater monitoring and cell phone movement patterns to social media signals. The accuracy and predictability of the model can be further enhanced through human-in-the-loop techniques, which would integrate experts to formalize decisions and recommendations. The role of AI in this framework offers scalable solutions to adapt to changing threats and contexts at local levels. Further, establishing baseline data and indicators with refinement from expert feedback will enable dynamic surveillance, which supports anticipatory action by allowing decisionmakers to deploy interventions earlier than if traditional systems were triggering the interventions. Embedding AI and environmental health measures in the model provides the necessary foundation to transform surveillance systems from reactive to proactive approaches.

Our E-SAFE model would enhance existing surveillance systems by expanding the focus beyond disease states to proactive detection. The model includes a multihazard context that aims to enhance understanding of the interplay between different hazards, which if not rapidly addressed could result in cascading, compounding, and complex events (United Nations Office for Disaster Risk Reduction, 2024). The surveillance of disease behaviors—including emergency department, pharmacy, and blood donation center attendance—provides a proxy measure of a reduction in the healthy population. During major events, surveillance is likely to be increased for security reasons, and thus the use of a validated AI-supported model could be helpful in examining the data and mitigating risks. Although it is beyond the scope of this article to include

an ethical analysis of the various environmental surveillance methods proposed, best practices in governance would be part of this integrated framework to offer safeguards for ethical risks.

Leveraging timely data from multiple sources, rather than relying on reactive measures, provides a framework that anticipates outbreaks and other health issues among athletes, visitors, and local residents, thereby enabling action before problems escalate. Furthermore, leveraging existing approaches for prioritizing diseases and drugs of abuse via wastewater surveillance (Bade et al., 2022) could provide a framework for ensuring surveillance efforts are cost-effective, targeted, and actionable for public health professionals (CDC, 2026c). Expansion of a system to include targeted methods with agnostic sequencing (Gauthier et al., 2023) and nontargeted analytical chemistry methods for emerging drugs of concern (Salgueiro-Gonzalez et al., 2024) would add data to protect communities from noninfectious disease threats. Using these integrated data streams within a Swiss Cheese model would enable a lay-

ered defense and alerts to predict and proactively reduce the risk of disease transmission (Popescu, 2021).

For host cities such as Los Angeles, this multilayered system could be adapted and rapidly tailored for future mass gatherings and emergency situations, and the variety of data sources should include other locations such as hotels peripheral to the main gathering. The use of dashboards to show trends and a variety of data sources could be applied to create a disease forecasting model similar to a weather forecasting model (Berdik, 2024). The result could be sustainable improvements in environmental public health surveillance infrastructure that is exportable to other mass gatherings.

Conclusion

Advances in AI-driven analytics, human-in-the-loop techniques, and wastewater monitoring have laid the foundation for predictive and proactive surveillance for mass gatherings. The 2028 Los Angeles Olympic Games present a critical opportunity to advance and showcase anticipatory action in environmental public health and demonstrate global leadership. The

need for this approach is increasing rapidly due to vaccine-preventable disease outbreaks combined with the frequency of terrorism and other mass casualty incidents.

An anticipated influx of participants and spectators from regions with active outbreaks further amplifies this risk. Our proposed E-SAFE model would be scalable, evidence-based, and actionable for decision-making. The result would be enhanced early detection, streamlined response efforts, and protection of healthcare capacity. This model could serve as a blueprint for strengthening local, national, and global preparations for mass gatherings. Applying the suggested tools via a structured process (i.e., E-SAFE) can support readiness for the Olympic Games while creating a scalable and transferable legacy for environmental public health surveillance at other mass gatherings. ✨

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