Strengthening public health response to air pollution in India: evaluation of an acute respiratory illness sentinel surveillance system, 2022

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In 2019, 1.67 million deaths in India were attributed to air pollution. Recognizing the significant risks to public health posed by air pollution, India established a sentinel surveillance programme to monitor trends in hospital attendances for acute respiratory illnesses in cities that regularly failed to meet national air quality standards. By combining data on acute respiratory illness attendance and air quality, the overarching aim of the surveillance programme is to generate information to support action to mitigate the adverse impacts of air pollution. The programme was expanded in 2020, but has not yet been evaluated. Therefore, we selected eight sentinel sites, all secondary/tertiary hospitals in two cities in Haryana state (Gurugram and Faridabad), and assessed their performance against six surveillance system attributes (usefulness, simplicity, data quality, timeliness, acceptability, stability) from January to March 2022. Central and district programme officers, clinicians, data entry operators and nursing staff were interviewed using a semi-structured questionnaire and records were reviewed. Generally, the system was found to perform well, particularly in terms of usefulness, simplicity, timeliness and acceptability. However, several weaknesses were identified, notably a lack of training for hospital staff and feedback; moreover, external factors had affected the stability of the system. Based on our findings, we recommended implementing a comprehensive training plan, creating a formal feedback mechanism, transitioning reporting to the Integrated Health Information Platform, and making greater use of the platform's data analysis and visualization features to streamline air pollution risk communication to local health authorities and the public.

Air pollution poses a significant public health challenge in India. In 2019, 17.8% of all deaths (1.67 million) and 11.5% of all disability-adjusted life-years (DALYs) lost were attributed to air pollution,[1] resulting in an estimated economic loss of US$ 28.8 billion due to premature mortality.[2] The short-term effects of air pollution range from mild to moderate discomfort (for example, irritation of the eyes, nose, skin and throat, wheezing, coughing, chest tightness, breathing difficulties) to more severe acute conditions, such as asthma, pneumonia, bronchitis, and lung and heart problems.[3] The long-term consequences of air pollution are particularly concerning, as evidenced by the significant proportion of DALYs attributed to chronic lung diseases (39.5%) such as chronic obstructive pulmonary disease, lower respiratory tract infection and lung cancer. Other significant contributors to air pollution-related DALYs include ischaemic diseases, stroke, neonatal diseases and diabetes.[1]

Given that acute respiratory problems rank among the most common causes of emergency department visits globally, many countries have established sentinel surveillance systems to monitor the severity of, and trends in, common acute respiratory illnesses (ARI). India started conducting routine ARI sentinel surveillance in 2017, initially in Delhi.[4] Under the direction of the National Programme for Climate Change and Human Health (NPCCHH) and funded by the Ministry of Health and Family Welfare (MoHFW), the ARI surveillance network has since expanded. By February 2022, there were sites in 13 states and 48 cities nationwide. Sentinel sites – either hospitals or other private or public health facilities – are located in "non-attainment cities" (122 cities that have not

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met national air quality standards continuously for the past 5 years and have been singled out for integrated policy action to reduce pollution levels as part of the National Clean Air Programme [NCAP])[5] and must have a 24-hour working emergency department and attract a high footfall of patients in the area they serve.

The ARI surveillance system has not been evaluated since it underwent a major expansion in 2020. We therefore conducted an evaluation of the system by measuring its performance against six attributes: simplicity, usefulness, data quality, stability, timeliness and acceptability.[6] We also evaluated the flow of data and reporting between hospitals, districts, the state and the NPCCHH Secretariat, which is based in the National Centre for Disease Control (NCDC). The aim was to provide evidence-based recommendations to strengthen the surveillance system's capacity to achieve its goals, namely, to generate actionable information in support of the national health authorities' policy and action, and minimize the health impact of air pollution.[7]

METHODS

Study design and setting

The evaluation was conducted from January to March 2022 and employed a cross-sectional study design. From among the three states that had been reporting data on ARI emergency department attendances for at least 1 year before the start of the evaluation period (Delhi, Haryana and Kerala), we selected sentinel sites in Haryana for two reasons. First, Haryana has two NCAP districts (Faridabad and Gurugram). Second, its participating sentinel sites have followed the prescribed flow of reporting from the hospital via district and state levels to the NCDC since 2021. Faridabad has two secondary/tertiary care hospitals and Gurugram has six hospitals that are enrolled as sentinel sites. All eight sentinel sites consented to participate in the evaluation and were included in our study.

Surveillance system data flow

India's ARI sentinel surveillance is an event-based daily reporting system that operates throughout the year. The reported events include aggregated daily total numbers of all emergency department attendances, acute respiratory emergencies, nebulized cases, cases admitted and cases requiring ventilatory support. Trained hospital nodal officers are responsible for collating daily data from hospital emergency departments and submitting monthly reports to district nodal officers. District nodal officers transmit these reports once a month to the state nodal officer, together with air quality index (AQI) data collated by the State Pollution Control Board/Central Pollution Control Board (CPCB). The combined report is shared with the NPCCHH programme Secretariat at the NCDC in New Delhi and then with the MoHFW. Feedback is given to all reporting units and stakeholders. A flowchart of data pathways through the surveillance system is shown in **Fig. 1**.

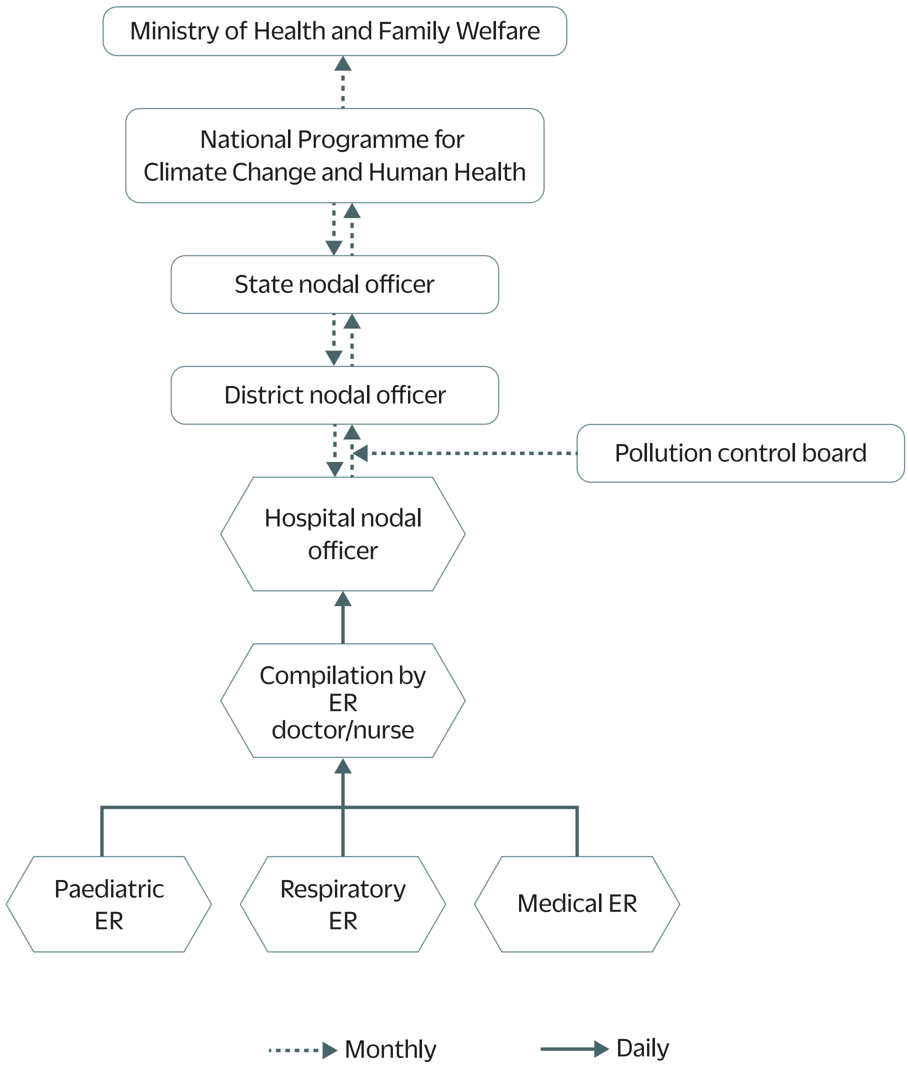
Definition of surveillance system attributes

Six surveillance system attributes were evaluated: simplicity, usefulness, data quality, stability, timeliness and acceptability. Each attribute was assessed through a set of measurable indicators designed to reflect a specific surveillance system objective or performance target (**Table 1**). System attributes and their associated indicators were based on the United States Centers for Disease Control and Prevention guidelines for evaluating public health surveillance systems.[6]

Data sources and analysis

We used a combination of records review (at hospital, district and programme levels) and stakeholder interviews to collect the necessary data for the evaluation. All personnel involved in surveillance reporting were interviewed in-person using a semi-structured questionnaire. They included the district nodal officers, hospital nodal officers, medical officers-in-charge, data-entry operators, emergency department staff and staff at the level of the national programme. In addition, we reviewed standard operating procedure documents (available from the NPCCHH programme division at the NCDC) and hospital emergency department registers (where cases were recorded) and observed the work of the national staff and district nodal officers. Interview responses were entered into Microsoft Excel and summarized to provide frequencies and proportions for each indicator (**Table 1**). Each indicator within an attribute was weighted equally. Results are presented individually for each indicator, with interpretation based on the attribute's aggregate score. System strengthening recommendations are provided according to indicator scores.

Fig. 1. **India's acute respiratory illnesses surveillance data flow system**



ER: emergency room.

RESULTS

Of the eight hospitals that met our study's inclusion criteria, the six located in the district of Gurugram (75%) reported daily data on emergency department attendances to the district level; monthly data for Gurugram were reported to the state, and then to the national programme level, in accordance with prescribed reporting flows (**Fig. 1**). In contrast, the two hospitals in Faridabad reported directly to the national programme level. One Faridabad hospital stopped reporting during the COVID-19 pandemic and never resumed.

We interviewed a total of 27 stakeholders comprising 23 hospital staff (8 hospital nodal officers, 8 nursing/medical records department personnel and 7 medical officers) and 4 at the district level (2 district nodal officers and 2 data-entry operators), who were responsible for both collating air pollution data and recording the proportion and trends of ARI.

The surveillance system scored highly in terms of the two usefulness indicators (100%) and, thus, met the objective of providing usable information for policy-makers about trends in ARI cases (**Fig. 2**). The available daily district-aggregated data were deemed sufficient to establish trends and patterns in ARI hospital attendance for previous years. A review of the records revealed that ARI trend data were used to help districts and hospitals prepare for the subsequent air pollution season in Delhi

Table 1. **Attributes and associated indicators used to evaluate India's acute respiratory illness surveillance system, 2022**

Attribute	Indicator	Definition	Data sources
Usefulness: Ability of the system to generate reports for action and meet the objectives of establishing trends	Information generation	Proportion of reports generated from the state to the policy-makers during the past 6 months (1 per month)	Review of records at programme division
	Trend establishment	Proportion of districts using data to examine trends in the past month	Review of records at programme division
Simplicity: Ability of stakeholders to understand the workings of the system and the ease of data flow	Knowledge about surveillance	Proportion of staff who can name all the variables given in the form	Interview of district and hospital nodal officers, nursing staff, data entry operator
		Proportion of staff with knowledge of the reporting frequency at their level (district/state)	
	Ease of understanding the surveillance forms	Proportion of staff at hospitals who rate the ease of defining the variables in the surveillance forms as "very easy"	
	Ease of reporting data	Proportion of staff at the hospitals who rate the ease of identifying cases from their hospital register to be reported in the surveillance as "very easy"	
	Time spent	Proportion of staff at hospitals who take less than 15 minutes to fill in the forms daily	
Data quality: Quality of data captured in the system	Reliability	Proportion of staff with formal training on surveillance from a health department	Interview of district and hospital nodal officers, nursing staff, data entry operator
	Reliability – AQI	Proportion of staff at districts with knowledge on air quality data availability	Interview of district nodal officers, data entry operator
	Validity – hospital	Proportion of forms with misidentified cases at the hospital on the day of visit	Review of records at hospital/district level
	Validity – district	Proportion of district officers with knowledge on how to analyse the data before sending to the state level	Observation of district staff
	Data completeness	Proportion of reporting hospitals with no missing data for at least 7 consecutive days in the past 1 month	Review of records at hospital/district level
Timeliness: Capacity to receive reports and feedback on time	Report submission	Proportion of hospitals/districts that sent monthly reports to the next level in the previous month	Review of records at hospital/district level
	Feedback received	Proportion of states/districts/hospitals that sent monthly feedback to the next level in the previous month	Review of records at hospital/district level
Acceptability: Willingness of districts/hospitals to participate in the system	Nodal officers assigned	Proportion of hospitals/districts that have appointed one nodal officer for surveillance	Review of records at hospital/district level
	Willingness to complete the forms	Proportion of forms received at the next level with all six columns complete on the day before the field visit	Review of records at hospital/district level
Stability: Disruptions to the system due to staffing/ equipment issues	Logistics availability	Proportion of hospitals/districts that received uninterrupted funds, internet and computers for the past year	Interview of district and hospital nodal officers, nursing staff, data entry operator
	Human resource availability	Proportion of hospitals/districts without interruptions in reporting due to absence of the nodal officer in the past 3 months	Review of records at hospital/district level
	Disruption of surveillance during unforeseen events	Number of hospitals/districts with disruptions in reporting due to the COVID-19 pandemic in 2021	Review of records at hospital/district level

AQI: air quality index.

National Capital Region (September–December) by providing advice to local authorities on when ARI cases would be likely to start rising in their districts.

Analysis of responses from hospital staff to questions relating to system simplicity revealed that the system was perceived as "easy," with 23/23 (100%) staff finding the surveillance forms very easy to understand and complete. Moreover, all interviewed staff reported that it took less than 15 minutes per day to send data to the level above (**Fig. 2**). Acceptability indicators, which measured how willing sites were to participate in surveillance, also received high scores: 10/10 (100%) of the nodal officer positions (at hospital and district levels) were assigned, and 7/7 (100%) hospitals (those that continued reporting post-COVID-19 pandemic) completed the forms.

In contrast, only one of the five data quality indicators achieved a score of 100%. The records review revealed no discrepancies between hospital registers and the submitted surveillance forms in all six of the sentinel hospitals in Gurugram. However, only 5/27 (18%) staff at the hospital and district levels had received training in data reporting. Among the four district officials, only one (25%) was knowledgeable about the data analysis process and one (25%) was knowledgeable about air quality data (**Fig. 2**). Measures of timeliness were also mixed. Six of the eight sentinel hospitals (75%) submitted timely reports to the next level, that is, the district level. One district failed to submit reports to the state level, but national programme-level reporting was maintained through direct reporting from hospitals. However, the provision of feedback from higher levels to the reporting units (hospitals) was virtually non-existent.

Overall system stability was good. Among the eight hospitals and one district we were able to evaluate, eight did not suffer disruptions due to nodal staff absences. Of the five hospitals that were reporting in 2021 before the start of the COVID-19 Delta wave, two did not maintain reporting during the surge. One resumed reporting in October, while the other did not.

DISCUSSION

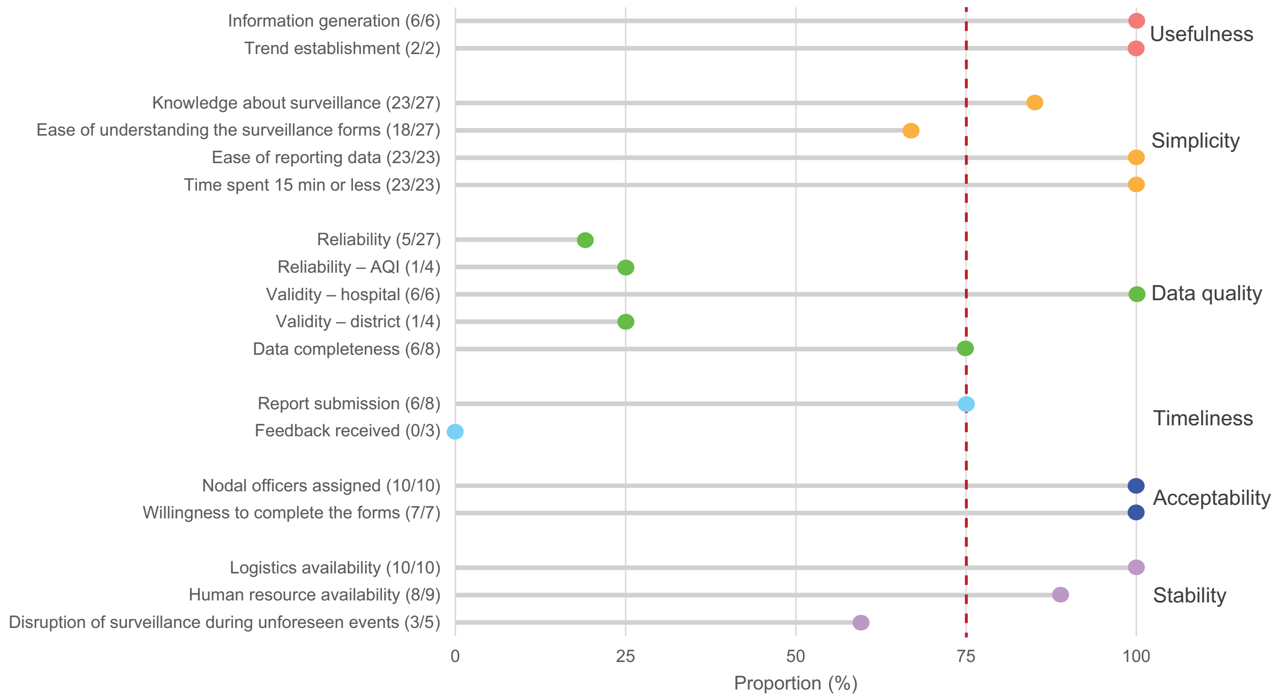
This study found that the ARI sentinel surveillance system generally performed well, scoring highly (above 75%) in all usefulness and acceptability indicators and in most of the simplicity indicators. However, the system performed less well in terms of its timeliness (especially when providing feedback), stability and data quality. The system also suffered disruptions during unforeseen events, notably, the COVID-19 pandemic.

Our assessment of data quality found areas of both adequate and poor performance. One component, reliability, was judged as inadequate largely due to evidence of low levels of staff training in surveillance procedures. In contrast, the system performed well in terms of data completeness and aspects of validity. Cross-validation of the entries in primary emergency registers against the final surveillance reports showed that all entries matched with the registers without discrepancies. This demonstrates a high degree of data concordance and confirms that ARI data, once entered, is being reported to policy-makers with minimal error.

Our findings highlight that system attributes are interconnected and influence each other. The high data validity at the hospital level shows that the simplicity and acceptability of the system helped generate quality data, even though less than 20% of interviewed staff reported receiving training on data reporting. This could be further increased by providing timely feedback, which is lacking.

The lack of adequate training among hospital and district staff suggests that the surveillance programme's recommended training protocols are not being implemented effectively. We recommended that this shortcoming be addressed by immediately training all untrained personnel in surveillance methods and data management processes, followed by annual refresher training before the peak air pollution season. While there is limited literature on the evaluation of air pollution-related surveillance in low- and middle-income countries (LMICs), published evaluation studies on dengue and malaria in LMICs suggest that training is one of the key drivers of improvements in data quality.[8,9] In addition, we recommended that district nodal officers receive training to improve their knowledge, understanding and capacity to analyse air quality data; this would have the dual benefit of enhancing data analysis as well as stakeholder awareness. Video conferencing sessions involving district

Fig. 2. **Performance of individual indicators of India's acute respiratory illnesses surveillance system, 2022**



AQI: air quality index.
Values are (*n*/*N*). The dashed line indicates the 75% cutoff for high performance.

nodal officers and representatives from the CPCB and the System of Air Quality and Weather Forecasting and Research would facilitate knowledge-sharing and collaboration on data transmission and AQI sources.

During our evaluation, it became apparent that some hospitals were operating a parallel reporting system, bypassing the district and state levels and submitting data directly to NCDC. We recommended transitioning to reporting through the Integrated Health Information Platform (IHIP) in India, which has been operational since 2021.[8] This centralized platform can streamline data collection and analysis, as it has a built-in data summarization feature that can be visualized and used in near-real time to provide information and feedback.

Limitations

The potential limitations of this study include the reliance on self-reported data to assess qualitative attributes such as simplicity and acceptability. We tried to minimize this by cross-validating with records wherever possible. We did not evaluate representativeness, given this is a sentinel surveillance system and we had no means of cross-verifying whether the recorded events were true by making comparisons with other surveillance or laboratory findings. We acknowledge that our study was limited to one state due to the lack of sufficiently long reporting periods from sites in other states. Nevertheless, we believe our findings and recommendations have helped inform the establishment of new surveillance sites and support the further expansion of the network in more recent years. For example, the recommendation relating to the use of the IHIP to visualize integrated surveillance (health and air pollution) data for real-time monitoring and feedback was incorporated in 2023.

The pressing need for an air pollution surveillance system in India stems from the significant air quality challenges. The sentinel system, encompassing both infective and non-infective emergencies, represents a vital step towards addressing this critical public health issue. In addition to generating valuable reports that have been used to develop public health communications aimed at reducing adverse health effects during peak air pollution months, data from the system have been used to inform other policy actions, including the timing of surveillance staff training, and state action plans on climate change and health.

Conflicts of interest

The authors have no conflicts of interest to declare.

Ethical approval

This evaluation was carried out as a part of an endeavour to strengthen the programme, so appropriate permissions were obtained from the states and districts. Participants provided informed consent prior to interviews. There was no collection of biological samples or any intervention involved in the study.

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