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Assessing Effectiveness of India's Industrial Emission Monitoring Systems

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CLEANER **AIR** &
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PROJECT

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Cover image: Indian regulators observing CEMS installation in a Waste to Energy Plant in Germany. (Image: Sanjeev K Kanchan/CEEW).

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Contact:

Hemant Mallya
Fellow, Industrial Sustainability and Competitiveness
Council on Energy, Environment and Water

Phone +91 11 4073 3300 | email: hemant.mallya@ceew.in

Om Prakash Singh
Chief of Party, Cleaner Air and Better Health Project
Council on Energy, Environment and Water

Phone +91 11 4073 3300 | email: omprakash.singh@ceew.in

Soumitri Das
Project Management Specialist (Environment)
United States Agency for International Development (USAID)
American Embassy, Shantipath, Chanakyapuri New Delhi - 110 021, India

Phone: +91 11 2419 8000 | email: sodas@usaid.gov

Assessing Effectiveness of India's Industrial Emission Monitoring Systems

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Continuous emissions monitoring is essential to ensure compliance with standards.

Image: iStock

Contents

A continuous emission monitoring system installed in an industrial flue gas stack.

Image: Forbes Marshall

Executive summary

Almost every Indian is impacted by polluted air. The Air Quality Life Index (AQLI 2023) reported that India faces the greatest health burden from air pollution due to the large number of people in heavily polluted areas. The average emissions of particulate matter with a diameter of 2.5 microns or less (PM2.5) in India are more than 10 times the permissible limits set by the World Health Organization. Of the various sources that are contributing to India's worsening air pollution crisis, the industrial sector is one of the largest — contributing 23–37 per cent of PM10 and 21–38 per cent of PM2.5 emissions (Ganguly, Khan, and Ganesan 2021).

Urgent measures are needed to improve the monitoring and regulation of industrial emissions, failing which air pollution from this rapidly growing sector will keep increasing. Data transparency in this regard is also essential. There have been several interventions by the national and state governments and regulatory agencies that aim to curb industrial air pollution. Currently, the only legally approved method for monitoring industrial emissions is periodic manual measurements. However, in 2014, the Central Pollution Control Board (CPCB) directed 17 highly polluting industries to install continuous emission monitoring systems (CEMS) at their facilities (CPCB 2014) to measure pollutant and process parameters, while still retaining the manual method as the legally approved method. The guidelines for installing CEMS and monitoring pollutants are provided in the "1st Revised Guidelines for Continuous Emission Monitoring Systems, August 2018," hereinafter referred to as the Guidelines (CPCB 2018).

The Supreme Court, in 2017, directed every state and union territory of the country to display CEMS data on the publicly accessible online CEMS (OCEMS) web portals of the State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) by August 2017. Following the judgment, the CPCB issued closure or show-cause notices to 1,033 industries that either did not install CEMS or did not provide the CEMS data because of a lack of connectivity to the CPCB server (CPCB 2017a). The CPCB and SPCBs have made concerted efforts to instil a culture of self-monitoring and regulation in industries. Providing legal sanctity to CEMS will go a long way in supporting these initiatives by pollution control boards.

Although data from industrial CEMS has been collected since 2014, there has been no detailed independent

> Urgent measures are needed to improve the monitoring and regulation of industrial emissions.

assessment on the data availability and accessibility. This assessment of the data available (as of 31 December 2021) on the OCEMS web portals of all 35 SPCBs/PCCs indicates that there is substantial room for strengthening monitoring and compliance. The objective in this assessment is to evaluate the ease of accessing and interpreting the data made available on the OCEMS web portals. The data availability and pollutant monitoring compliance of the CEMS that are relaying data to the OCEMS portal were also evaluated. Increased transparency is critical to dispel concerns about the reliability of data and non-compliance, identify violators, generate public awareness, and fulfil the overall objectives of CEMS deployment; it would also act as a deterrent because the industry would not like to be seen in a negative light.

The analysis and findings are based on

- scoring and comparative ranking of 35 SPCB-/PCC-specific OCEMS web portals to assess accessibility to the public and transparency;
- estimating data availability and frequency of missing data events using hourly CEMS data across six selected industry types and six states where annual historical data is available for these industry types; and
- analysing pollutants and parameter monitoring compliance for all facilities in six selected industry types from six states with annual historic data.

Note: This study was carried out in 2022 using data collected from online continuous emissions monitoring systems (OCEMS) web portals in 2021. The study covers the accessibility of the web portals as of 31 December 2021, and the quality of OCEMS data relayed by the portals in 2019 and 2020 (for those portals that allowed historical data download). The findings and recommendations of this study have since been presented to three state pollution control boards and a closed door roundtable composed of ex-CPCB officials, SPCB officials, industry stakeholders, OCEMS manufacturers, think tanks and other organisations. While there may have been recent changes to data accessibility and quality, most of the overall findings of the study and the recommendations set forth are still relevant in 2024.

A. Accessibility to the public and transparency

Among the 35 SPCBs/PCCs, 3 have no industry requiring OCEMS connectivity (CPCB 2020b). Of the remaining 32, only 11 have OCEMS web portals that provide 30 days or more of historical data. This makes it impossible to identify solely based on publicly available data those facilities in 20 states and union territories that do not comply with CPCB emission standards.

Additionally, it was found that the OCEMS web portals of the states with more industrial facilities are less accessible than those of less-industrialised states. Tamil Nadu, Gujarat, and Andhra Pradesh have publicly accessible OCEMS web portals, but none of the web portals provides access to historical data or an option to download data (as of 31 December 2021).
There are also significant variations in the amount of data made available on the portals and the ease with which this data can be accessed and interpreted. Figure ES 1 shows the availability and accessibility of OCEMS data.

19 OCEMS web portals were scored and ranked on seven parameters (Odisha's web portal was unavailable as of 31 December 2021); Rajasthan has upgraded its portal in June 2022 and has more information than when this analysis was completed, which is not represented in this report. Chhatisgarh also updated its portal for easier accessibility. The highest score indicates the best portal overall from the perspective of ease-of-use and utility.

Key findings across parameters:

i. **Geotagging:** The Telangana OCEMS portal was the only one among the 19 public OCEMS portals that provides geo-coordinates/geotags of individual facilities, which is essential to understand the influence of industrial pollution on air quality in different geographies.

ii. **Public data access:** At the time of writing, the Chhattisgarh OCEMS portal was the most challenging to access and navigate for two main reasons:

a. Data on each facility resided on a link unique to that facility. There were more than 150 such links.

b. Each facility had chosen a different form of access. The website often sends one-time passwords to the facilities' login ID, effectively restricting the public from accessing the data.

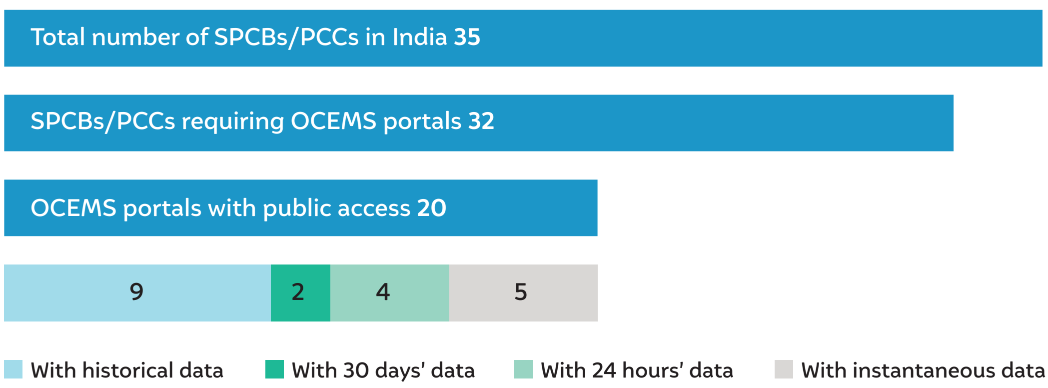
Of the remaining 18, 8 OCEMS portals provided data in the form of charts and tables, thus making the numbers more accessible.

iii. **Ease of access:** Except for Gujarat and Rajasthan, all the OCEMS portals provided a list of facilities that are reporting data. However, only nine provided an 'industry-type' identifier, which is important for understanding the context and while developing mitigation measures for air quality management.

iv. **Data download:** Only 9 of the 19 OCEMS web portals allowed downloading of historical data. Some web portals, such as Jharkhand, only permit downloads of 24 hours' worth of data at a time, which made accessing and analysing the data extremely difficult.

v. **Stack compliance indicator:** This provides the standard that applies to a stack and notes whether its emissions are within the standard. Eight SPCBs/PCCs displayed these standards against the stack data on their OCEMS portals, of which three SPCBs

Figure ES1 Only 20 states have public OCEMS portals, with 9 providing historical data



Source: Authors' analysis

Note: Odisha had an active portal, but it was inaccessible at the time of writing

(Kerala SPCB, Gujarat PCB, and Andhra Pradesh PCB) also displayed the number of times the monitored emission concentration exceeded the CPCB emission standards in the given time interval. Eleven OCEMS portals did not provide comparisons of the stack data against emission standards.

vi. **Data interval:** This refers to the interval between when data points are collected and displayed on the OCEMS web portal. Of the 19 SPCBs/PCCs, 10 provided data at 15-minute intervals, 2 at 30-minute intervals, and 2 at hourly intervals; the remaining 5 provided instantaneous values only.

vii. **Data duration:** Of the 19 OCEMS web portals analysed, 8 provided historical data for at least a year (not including Odisha), 2 provided data for 30 days, 4 provided data for 24 hours, and the remaining 5 provided instantaneous data.

The Madhya Pradesh and Himachal Pradesh OCEMS web portals were the most comprehensive, obtaining full scores in 6 out of 7 parameters, among the 19 portals evaluated. The only feature lacking in these portals is geotagging.

B. CEMS data availability and gaps

The accessible CEMS data was analysed for availability and reporting issues. The subsections below provide the highlights.

Data availability

Only six OCEMS web portals provided downloadable annual data (Assam, Chhattisgarh, Goa, Himachal Pradesh, Madhya Pradesh, and Meghalaya). Six industries were analysed (iron and steel, cement, oil refinery, petrochemicals, aluminium, and pulp and paper) with the highest emission loads in the industrial sector and found that CEMS data availability varies significantly across these six states. Data availability was calculated as a percentage of the hours in a year for which CEMS data is available — that is, the number of hours out of 8,760 hours in a year for which the CEMS relays a zero or positive value.

The CEMS data was analysed for the entire calendar years of 2019 and 2020. In general, the analysis could not account for potential disruptions or shutdown of operations at facilities because each industry type and facility would have had different inoperative periods. The average data availability would increase if those adjustments were possible. Another challenge faced was the disruption caused by the COVID-19 pandemic in 2020. Although shutdown data was not available for inclusion in the analysis, the impact on overall data availability is not expected to be significant. The industries chosen for evaluation likely continued operations through the pandemic because shutting them down would have been operationally challenging. Because there were several COVID-19-related state-wide shutdowns in 2020–21 also, CEMS data from 2019 was also analysed to assess pre-pandemic data availability. On a positive note, data availability increased in 2020 compared to 2019, despite it being a pandemic year.

Key highlights for 2020

- Of the 691 stacks analysed (from 134 facilities with downloadable data), 97 had a data coverage of less than 10 per cent.
- The Assam SPCB had the lowest data availability (10 per cent) among the six SPCBs/PCCs that provided historical data for download, whereas the Meghalaya SPCB had the highest data availability (~67 per cent).
- Among the six selected industry types, refineries had the lowest average data availability (~36 per cent), whereas aluminium plants had the highest (~71 per cent).

Table ES1 Average data availability across select states and industry types (2019 and 2020)

SPCBs/PCCs	Average data availability	
	2020	2019
Assam	10%	0%
Chhattisgarh	57%	65%
Goa	44%	53%
Himachal Pradesh	66%	67%
Madhya Pradesh	58%	30%
Meghalaya	67%	58%

Industry type	Average data availability	
	2020	2019
Iron and steel	50%	55%
Cement	61%	47%
Refinery	36%	9%
Petrochemicals	43%	1%
Aluminium	71%	20%
Pulp and paper	57%	51%

Source: Authors' analysis

Table ES 1 provides the estimated average data availability for the six states and six industry types for 2019 and 2020.

As per the CPCB's clarificatory note on the Guidelines for real-time effluent and emissions data collection, every industry has to ensure 85 per cent data availability every month for all its stations and parameters (CPCB 2017b). It is challenging to evaluate and interpret these compliance criteria at monthly intervals for each stack and pollutant combination. Hence, the 85 per cent criterion was applied to the annual data for the 6 states and 6 industries to determine how many stacks complied.

Figure ES 2 shows the percentage of stacks that were in compliance in 2019 and 2020. The average compliance across all stacks was quite low at 19 and 23 per cent in 2019 and 2020, respectively. Compliance levels vary between years for a given state, but overall, compliance was mostly less than 50 per cent for all states.

Frequency of misses

Apart from the annual data availability, the frequency of missing data events was also evaluated — that is, the number of times there is a data gap in annual reporting. The Guidelines stipulate that a single missing data event should not last for more than 72 hours, and if this happens, the facility may have to stop operations. Approximately 81 and 77 per cent of the stacks had more than 1,000 hours (approximately 42 days) of missing data in 2019 and 2020, respectively. Of the 691 stacks evaluated in 2020, only 37 had zero instances of missing data events that lasted longer than 72 hours. Less than 7 per cent of the missing data events lasted more than 72 hours, but they contributed to more than 92 per cent of the total missing hours. From an enforcement perspective, targeting stacks that contribute majorly to this seven per cent can significantly increase data availability.

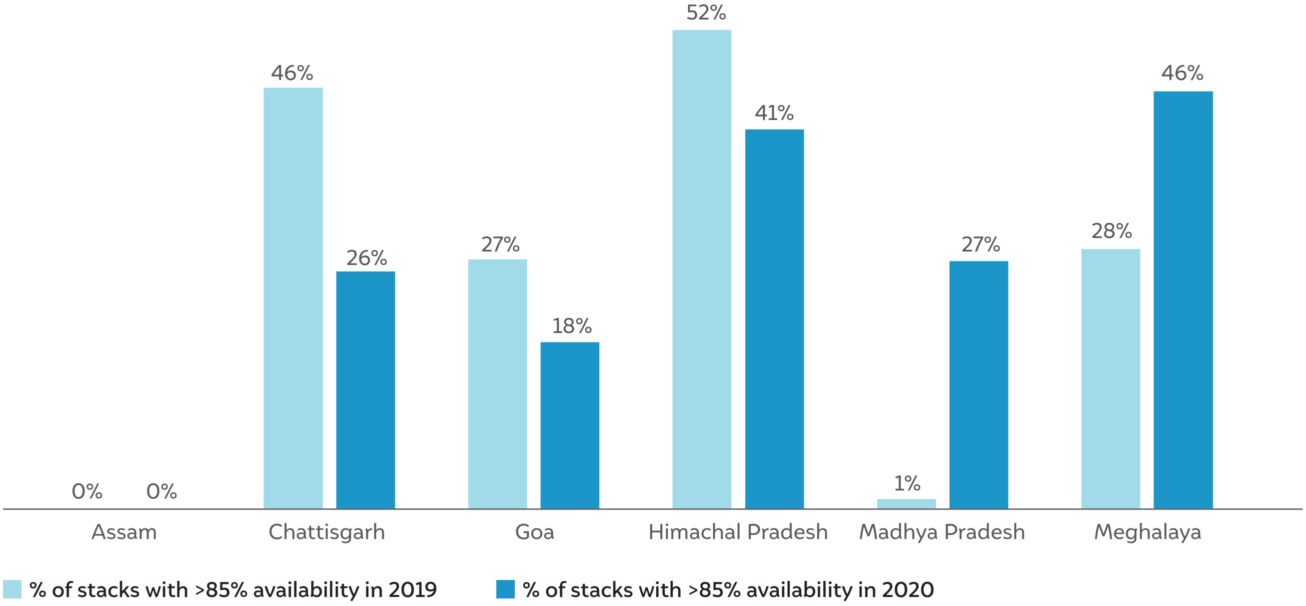
Parameter monitoring compliance

The CPCB mandates the specific parameters (temperature and flow rate) and pollutants that every industry needs to monitor. An analysis of pollutants and parameter monitoring compliance in 6 industry types across 6 states showed that only 65 (47 per cent) of the 134 facilities are fully compliant. Goa had no fully compliant facilities. Chhattisgarh had the greatest number of compliant facilities, but the data of only 56 facilities could be analysed; data for the remaining 43 facilities could not be downloaded. Of the rest, 15 per cent are not compliant, and 38 per cent are only partially compliant.

Ambient air quality monitoring at industrial facilities

The CPCB requires that all large and medium-sized industries located in critically polluted areas, and facilities in the 17 highly polluting industry sectors, install ambient air quality monitors (AAQMs) through a separate directive (Dube 2010).

Figure ES2 On average, only 20% and 27% of the stacks complied with the 85% availability requirement in 2019 and 2020, respectively



Source: Authors' analysis

It was found that 12 states had 527 industrial facilities with continuous ambient air quality monitors (CAAQM) for all the industry types reporting CEMS data. Several facilities also had more than one CAAQM within their premises. Data from these CAAQMs can be used to supplement the air quality data from CAAQMs utilised by the CPCB and SPCBs/PCCs that were established under the *National Air Quality Monitoring Programme* (NAMP) (CPCB 2022).

C. Way forward

Monitoring industrial pollutants through CEMS is an important first step in mitigating emissions. However, to fulfil its purpose, data from CEMS need to be used to inform decisions related to governance and management. This requires both transparency and access to the data it generates. The following measures are recommended to make CEMS an effective tool in managing industrial air pollution.

- **The CPCB should work towards providing legal sanctity to the CEMS data** and approve its use as a primary means of emissions monitoring for facilities that have CEMS installed. The CPCB should develop indigenous certification systems and empanel laboratories for CEMS performance tests.
- **The CPCB should consolidate CEMS requirements** into a single regulation that incorporates various guidelines, directives, and notifications. In addition, this regulation should incorporate the knowledge gained by the verification and enforcement processes of the SPCBs/PCCs during the past years while utilising CEMS data.
- **The CPCB should integrate CEMS data into their OCEMS web portal** — because it already collects the data — and make historical data (at least one year) accessible to the public. This will also reduce the burden on states to maintain their individual OCEMS web portals.
- **The SPCBs/PCCs should develop decision support systems that integrate the CEMS data** such that enforcement-related metrics are distilled and summarised periodically for decision-makers.
- **The CPCB should revise the Guidelines** as follows (or incorporate into the new regulation the following) to enhance its effectiveness:
  a. Include basic requirements for OCEMS portal attributes so that the OCEMS portals are made uniform across states (or incorporate it in its own portal, per recommendation (iii) above).
  b. Provide guidance on applying industry-specific standards to CEMS on common (or combined) stacks.
  c. Provide methods for filling in missing data using historical data or calculative methods that utilise correlations between activity and emissions.
  d. Make information on the vintage and technology of CEMS devices deployed publicly available to enhance understanding of data quality and limitations in monitoring various pollutants.
  e. Collect information on operating hours to evaluate data availability and missing data correctly.
  f. Make a concerted effort to collect temperature and flow data, so that the emissions load of industrial stacks can be estimated, which will inform efficient mitigation and management of air pollution by the industrial sector.
- **The CPCB/SPCBs/PCCs should utilise the data from CAAQMs at industrial facilities** to supplement the data from the limited number of CAAQMs across the country that were established under the NAMP.

1. Introduction

India has been dominating the headlines on air pollution for several years now. The *World Air Quality Report 2021* (IQAir 2022) indicates that 21 of the 30 most polluted cities worldwide are in India. It also places India fifth in the ranking of the world's most polluted countries. Several locations in the country face a public health challenge because of deteriorating air quality. There are four critical, perennial sources of air pollution: industrial, power, residential, and transport sectors. Of these four sources, the industrial sector accounts for a significant share of the PM10 and PM2.5 (primary particulate matter of diameter 10 microns or less and 2.5 microns or less) emissions load in India in terms of the absolute mass of pollutants emitted into the atmosphere. An emission assessment study by CEEW indicates that the industrial sector is the largest contributor to criteria air pollutants. The study attributed 23–37 per cent of PM10 and 21–38 per cent of PM2.5 emissions to the industrial sector (Ganguly, Khan, and Ganesan 2021). Furthermore, India has pegged its economic growth to substantially growing its industrial base, and, therefore, the air pollution from this sector can be expected to increase in the coming years.

To regulate the emissions from the industrial sector, the Government of India introduced a system of sector-specific emissions standards for air and water for more than 100 categories of industries/activities in 1984 (Grobot et al. 2016). Section 25 of the Environment (Protection) Act, 1986 (CPCB 2000), notifies the standards.

1.1 The limited efficacy of the manual monitoring system

Industries are required to undergo manual pollution monitoring to check for compliance. The monitoring is to be carried out by environmental laboratories approved by the National Accreditation Board for Testing and Calibration Laboratories (NABL), the CPCB, SPCBs, or the Ministry of Environment, Forests and Climate Change (MoEFCC). The monitoring is done weekly, twice monthly, or monthly. The labs submit the report and data to the respective state pollution control boards (SPCBs)/pollution control committees (PCCs). The industrial facilities generally submit the compiled monitoring report quarterly.

The current software systems installed by SPCBs/PCCs on their portals allow facilities to upload manual monitoring reports once they are available from the third-party laboratory every month or at shorter intervals. However, the manually monitored data by the third party does not provide a complete year-long profile of emissions. There is no way to ensure compliance with standards using these low-frequency manual monitoring snapshots. In addition, SPCBs/PCCs have limited resources, and there is a lack of public scrutiny. Therefore, even if the CPCB tightens industrial emissions norms with time, industrial emissions will still keep rising because of a lack of compliance, poor monitoring networks, and incomplete or no reporting (Kanchan 2019).

To overcome challenges related to manual monitoring, industries needed to acquire an advanced monitoring system, where the data would be reliable and monitoring efficient. Therefore, to introduce a resilient industrial emissions monitoring system, in 2014, the CPCB (through the SPCBs and PCCs) directed 17 categories of

- highly polluting industries,
- common effluent treatment plants,
- sewage treatment plants,
- common bio-medical waste incinerators, and
- common hazardous waste incinerators nationwide to install online effluent quality monitoring systems and CEMS (Central Pollution Control Board [CPCB] 2013).

1.2 CEMS provides real-time access to emissions data

In November 2013, the CPCB introduced the "Specifications and Guidelines for Continuous Emission Monitoring Systems (CEMS) for PM Measurement with Special Reference to Emission Trading Programs," which provides CEMS selection and guiding principles, specifications and guidelines for the use of CEMS, and calibration techniques (CPCB 2013). In addition, this document also identified public accessibility to CEMS data as being essential for transparency and openness. However, it did not provide specific instructions to industry or SPCBs/PCCs to make such data public. The CPCB incorporated various reviews and recommendations made by several stakeholders into a revised guideline, "1st Revised Guidelines for Continuous Emission Monitoring Systems, August

> Ensuring compliance with emission standards using existing manual monitoring methods is not possible.

2018," henceforth referred to as the Guidelines (CPCB 2018). The Guidelines laid down by the CPCB directed all facilities in the industry categories covered to set up their CEMS and transmit the real-time data to the respective SPCBs/PCCs and the CPCB by 31 June 2015. The parameters and pollutants monitored through CEMS are industry-specific, but monitoring process parameters (temperature and flow) at each stack is mandatory.

1.3 CEMS is mandatory but without legal sanctity

CEMS monitoring has been in force since the direction for installing real-time monitoring was issued in February 2014 (CPCB 2014). In February 2017, a judgment by the Supreme Court of India directed every state and union territory of the country to display CEMS and Continuous Effluent Quality Monitoring System (CEQMS) data online on publicly accessible SPCBs/PCCs web portals, by August 2017.[1] Furthermore, the Supreme Court directed the National Green Tribunal (NGT) to monitor compliance with the Court's orders. Following the judgment, the CPCB issued closure/show-cause notices to 1,033 industries that either did not install CEMS or did not provide CEMS data because of a lack of connectivity to the CPCB server (CPCB 2017a). However, to establish non-compliance with the standards prescribed, the board had to depend on the inspections conducted by board officials, as manual monitoring alone has legal sanctity under the EPA, 1986, the Water (Prevention and Control of Pollution) Act, 1974, and the Air (Prevention and Control of Pollution) Act, 1981 (CPCB 2015). The procedure for revocation of closure also depends on the manual monitoring report by a laboratory recognised under the EPA, 1986 (CPCB 2017c).

Additionally, the CEMS-reported data often does not match the actual emissions (Centre for Science and Environment 2019; Guttikunda and Jawahar 2014).

While the CPCB has made commendable efforts to instil in industries the habit of self-monitoring to comply with prescribed standards through the installation of CEMS, the goal of strengthening monitoring and compliance can only be achieved when such systems are given legal sanctity under the governing laws.

What is CEMS?

Continuous Emission Monitoring Systems (CEMS) for air pollution in industrial settings includes an emissions measuring device that is located within a stack, chimney or duct that releases air pollutants into the atmosphere to periodically measure the concentration and release rate of the pollutant. It also includes data capture and processing elements that convert the information from the measuring device into standard units, such as normal milligram per cubic metre (mg/Nm^3).

What is an OCEMS?

An Online CEMS (OCEMS) is a web portal that provides information related to and collected by CEMS devices across multiple stacks or chimneys associated with equipment within a facility and across multiple facilities in a given geography (typically a state). This could include emissions concentration, release rate, temperature, and calibration information.

What is a stack?

A stack is a conduit for evacuating emissions from the combustion chamber or emissions source to the atmosphere. In combustion equipment, a stack is also referred to as a chimney.

1.4 The public has limited to no access to CEMS data

A status report submitted by the CPCB on 4 February 2020 to the NGT with regards to the case mentioned earlier[1] stated that of 33 SPCBs/PCCs required to have a publicly accessible online CEMS (OCEMS), only 14 had complied with the order (CPCB 2020b). However, a later analysis (up to October 2020) showed that 19 SPCBs/PCCs had developed a publicly accessible OCEMS portal (Verma 2020). The remaining 14 SPCBs/PCCs were still not compliant with the Supreme Court's February

1. Paragraph 17 of Judgment dated 22 February 2017 of the Supreme Court in *Paryavaran Suraksha Samiti & Anr vs Union Of India & Ors.*, Writ Petition (C) No. 375/2012 ((2017) 5 SCC 326).

2017 order. Without public accessibility to industrial emissions data through OCEMS portals, information on the compliance of industrial facilities with emissions standards will be limited or unknown. CEMS was introduced to provide a reliable form of monitoring with greater transparency and to achieve a reduction in regulatory and long-term monitoring costs (Pathak 2016) — objectives that remain unfulfilled.

Accessibility to the public is essential for emissions management

Public accessibility to CEMS data will play an integral role in inculcating a self-monitoring environment within industries, as there would be public scrutiny of industrial emissions data. It will further empower SPCBs and research organisations to support an informed and data-driven decision-making approach to address the issue of air pollution. Finally, CEMS data can provide legally valid evidence of facilities' compliance with the Guidelines. For example, the United States' Environmental Protection Agency mandates the use of CEMS to determine compliance with and exceedance of standards as a part of its air emissions regulations. It also makes all CEMS data publicly available; for example, its Clean Air Markets Program Data web portal makes hourly emissions data available for every regulated facility across the country (U.S. EPA 2022).

Public accessibility provides credibility through scrutiny

The CEMS devices are self-financed and deployed by the facilities themselves. However, because of a lack of transparency and legal sanctity, the use of this valuable data is limited to generating automated messages to send to the facilities. This is a loss for both the regulator as well as the industry because they cannot use the data either for enforcement or in legal matters. Besides, industries are perceived as bad actors even if some facilities are fully compliant. Hence, making CEMS data accessible to the public is necessary to dispel concerns regarding reliability and non-compliance and to identify violators.

1.5 About this study

Although data from CEMS in industrial facilities has been collected since 2014, there has been no detailed independent assessment on the data availability and accessibility. This study analyses and evaluates the current level of CEMS deployment in the industrial sector in India with a fourfold objective. First, the ease of public access and transparency of the CEMS data on OCEMS web portals were evaluated. Access to air pollution data is essential in holding polluters responsible and generating awareness among the general public. Pollution data also indicates which states are following the Supreme Court's ruling in letter and spirit. The CPCB can utilise this data to formulate effective policies to tackle air pollution by industrial facilities. Also, transparency can, in some ways, be a deterrent. The negative consequences associated with a company being seen as a violator could motivate at least some in the regulated community to comply with the requirements. Finally, SPCBs/PCCs can follow best practices in terms of access and transparency in making CEMS data public through the OCEMS portals.

> Access to air pollution data is essential in holding polluters responsible and generating awareness among the public.

Second, this study evaluates CEMS data availability on criteria pollutant emissions by six categories of industrial facilities. It summarises findings from an analysis of a year's worth of data (for 2020) for six states (which make historical CEMS data publicly available) to determine the level of compliance with the Guidelines (states other than these six do not make historic CEMS data publicly available). This study does not discuss the veracity or quality of the CEMS data.

However, through this study, the aim is to provide a better understanding of the CEMS data reported by industries, which will assist SPCBs/PCCs and the CPCB in utilising the data more effectively. For example, the CPCB can utilise the findings to improve the Guidelines, and the SPCBs/PCCs can also utilise them to develop automated verification and notification systems, if not already available, to bolster their capabilities because they have a limited workforce. Where such notification systems are already in place, SPCBs/PCCs can develop decision-making systems to ensure robust compliance. Third, the study evaluates the pollution parameters monitored for compliance by the states. The CPCB requires monitoring of PM, NOx, SO_2, fluoride, CO, and effluent parameters. However, the parameters to be monitored vary depending on the industrial category. The study evaluated whether the parameters required to be monitored are actually monitored and, consequently, determined the level of compliance.

Finally, the study identifies and evaluates the availability of ambient air quality monitors (AAQMs) at industrial facilities. The data from these monitors can potentially supplement data on ambient air quality from continuous AAQMs (CAAQMs) across geographies. This will significantly bolster the quality of air quality data and increase data coverage.

Note: Since the completion of this analysis, the Rajasthan SPCB has made its CEMS data available online. Both Rajasthan and Tamil Nadu also have links for accessing historical data. Chhattisgarh has also improved the accessibility of the CEMS data. However, this study does not take into account the access and availability of this new data. This study covers the accessibility of the OCEMS web portals as of 31 December 2021, and the quality of OCEMS data relayed by the portals in 2019 and 2020 (for those portals that allowed historical data download). The resulting findings and recommendations were presented to three SPCBs and a closed door roundtable composed of ex-CPCB officials, SPCB officials, industry stakeholders, OCEMS manufacturers, think tanks and other organisations. While states may keep revising their OCEMS portals and associated data, the recommendations and most of the findings of this study remain relevant in 2024.

2. Public accessibility and transparency

There are 35 SPCBs/PCCs in India. The study analysed the OCEMS web portals of all the SPCBs/PCCs that were operational and accessible online as of 31 December 2021. It first evaluated the public accessibility of the data featured on the OCEMS web portals set up by the individual SPCBs/PCCs. The main objective was to evaluate the ease of accessing the data on the web portals. In addition, it investigated whether one could interpret the available data with the information available about the data, which is essential for transparency.

2.1 Scoring methodology for public accessibility and transparency

The Guidelines provide directions on what air pollutant data must be collected and provided to the CPCB/SPCBs/PCCs. However, there are no instructions on how to make the data available in the public domain accessible and fully transparent.

> The CEMS Guidelines provide no instructions on how to make CEMS data publicly accessible and fully transparent.

Therefore, to study the ease of using the OCEMS web portals of various SPCBs/PCCs, a methodology was devised to score and rank the OCEMS web portals based on seven parameters. The seven parameters and scoring within each parameter to compare and rank the public OCEMS portals are given below. For each parameter, the score is followed by an explanation of the score value.

i. **Public data access:** It represents the way in which the CEMS data has been integrated into the portal and made accessible to the public:

(1) The portal provides third-party links to view CEMS data.

(2) The portal assimilates the CEMS data, but the user can view the data only in a chart format.

(3) The portal assimilates the CEMS data, and the user can view the data in either chart or table format — that is, numerical readings are available.

Unlike parameters discussed later, public data access does not have a 0 score, because only those OCEMS web portals that provide CEMS data in some form were evaluated, which precludes a 0 score.

ii. **Ease of navigation:** It represents whether users can choose a particular facility from a list of facilities to view CEMS data and whether the portal categorises the facilities by industry type:

(0) The portal displays the facilities' data on a rolling basis but has provisions to choose a particular facility.

(1) The portal lists the facilities but does not mention the industry type.

(2) The portal lists the facilities with respective industry-type categorisation.

iii. **Data duration:** This represents the duration of historical CEMS data available through public access:

(0) Instantaneous data

(1) 24 hours of data

(2) 30 days of data

(3) One or more years of historical data

iv. **Data download:** This represents whether users can download the CEMS data through public access:

(0) No provisions to download data.

(1) Data can be downloaded in .csv, .pdf, or .xlsx format.

v. **Geotag:** This represents whether the portal provides geo-coordinates (latitude and longitude) of each facility:

(0) Geotag is not available.

(1) Geotag is available.

vi. **Stack compliance identification:** This represents whether the OCEMS portals indicate the appropriate emissions standard for each stack and identify stacks for which emissions exceed the appropriate standard — that is, whether the stack is compliant or not:

(0) Stack standard and compliance indicators are not available.

(1) Stack standard indicator is available, but compliance indicator (frequency of violations) is not available.

(2) Stack standard and compliance indicators are available.

vii. **Data interval:** This represents the data interval at which the CEMS data is available on the portal:

(0) Instantaneous data

(1) 1–24 hours

(2) 30 minutes

(3) Less than or equal to 15 minutes

2.2 Findings for public accessibility and transparency

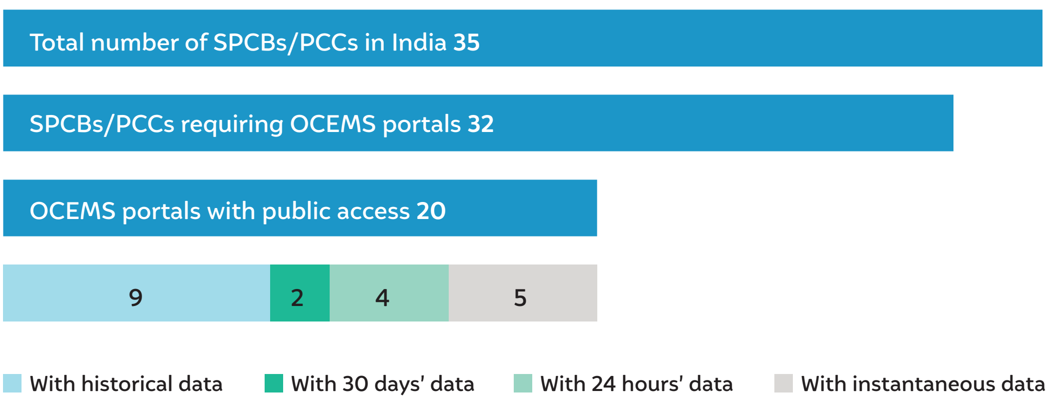
Among the 35 SPCBs/PCCs, 3 (Arunachal Pradesh PCB, Lakshadweep PCC, and Mizoram SPCB) have no industry requiring OCEMS connectivity (CPCB 2020b). Figure 1 summarises the OCEMS web portal access and transparency for the remaining 32 SPCBs and PCCs.

Among the 32 SPCBs/PCCs required to have a publicly accessible OCEMS web portal, only 20 OCEMS web portals provide public access to industrial emissions data collected through CEMS installed on industrial stacks/chimneys/ducts. All of them collect similar data, but they vary significantly in their ease of access and navigation and the granularity of the data they provide. Of these 20 SPCBs/PCCs, only 9 provide historical data access — that is, access to data for the past year or more. Two SPCBs/PCCs provide 30 days' data, four provide 24-hour data, and five provide instantaneous data.

The Guidelines stipulate that the CEMS cannot be inoperative for more than 72 hours. Of the 32 states with CEMS deployed in industries, only 11 states have an OCEMS portal with 30 days or more of data. Therefore, identifying non-compliance to CPCB emission standards is impossible for 21 states and union territories based on publicly accessible data.

Publicly accessible OCEMS web portals vary significantly in terms of the amount of data and the ease of access. On the one hand, Chhattisgarh SPCB's OCEMS portal provided third-party links for every facility with login IDs and passwords, which is cumbersome to navigate, and on the other hand, Madhya Pradesh PCB's and Jharkhand SPCB's OCEMS portals had CEMS data of all the facilities residing and accessible on the portals themselves. One could view the data conveniently online in either chart or table format. Each of the public OCEMS portals was evaluated for ease-of-use and transparency. Figure 2 provides a ranked listing of the OCEMS web portals, with the highest score indicating the best portal overall from an ease-of-use and utility perspective.

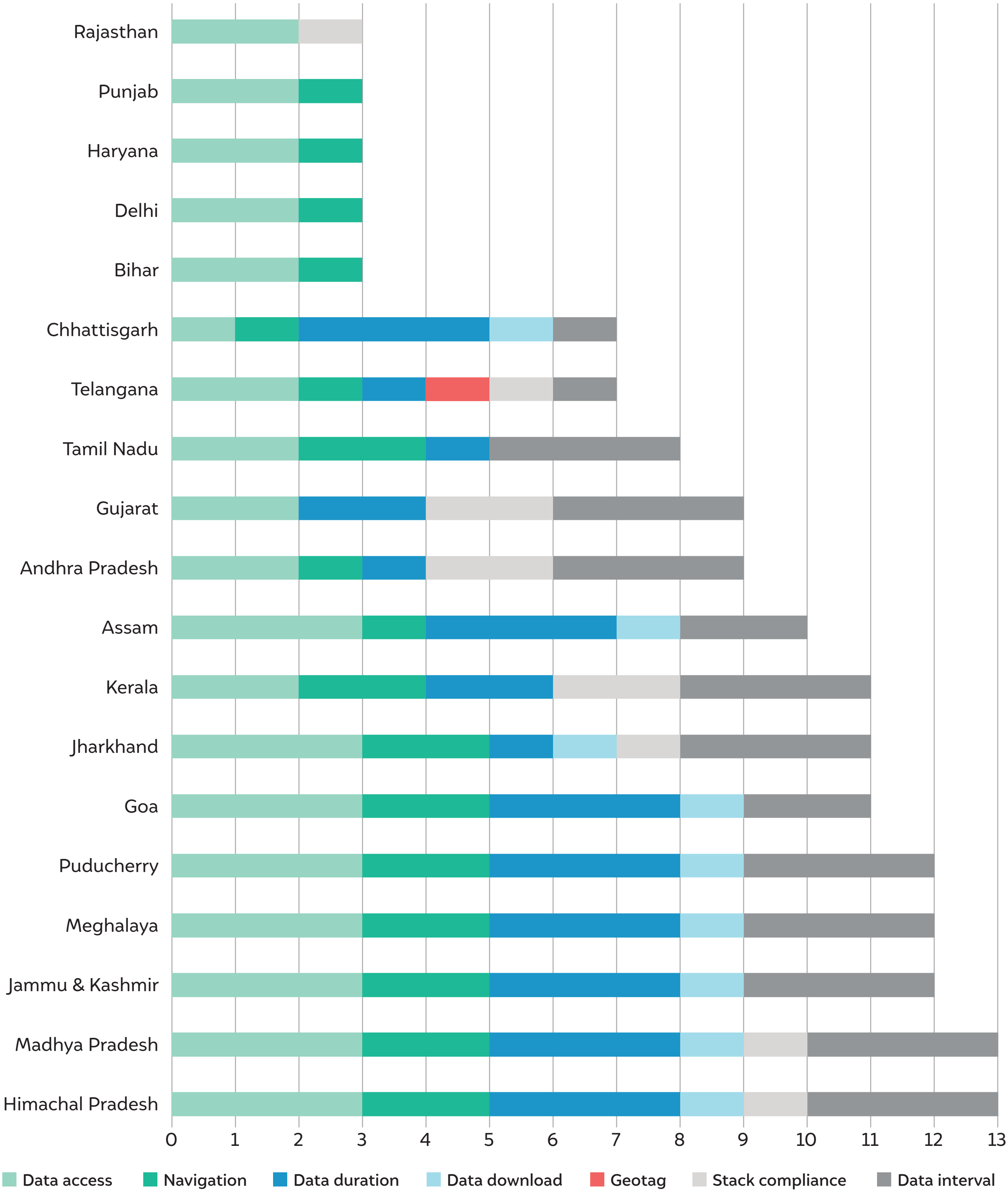
Figure 1 Only 20 states have public OCEMS portals, with 9 providing historical data



Source: Authors' analysis

Note: Odisha had an active portal, but it was inaccessible at the time of writing

Figure 2 The Madhya Pradesh PCB and Himachal Pradesh SPCB have the most accessible and transparent OCEMS web portals



Source: Authors' analysis

The Madhya Pradesh PCB and Himachal Pradesh SPCB OCEMS web portals stood out by obtaining full scores for six parameters. The only drawback was that the geo-coordinates/geotags of the facilities are not available. The Telangana SPCB portal was the only OCEMS portal among the 19 public OCEMS portals that provides the geo-coordinates/geotags of individual facilities. The geo-coordinates of facilities are useful for mapping emissions from all the large industries in a region, which is critical for air quality modelling and management. They are also useful from the perspective of safety because accurate geo-coordinates will assist citizens in identifying facilities near them, empowering them to raise alarms to the respective SPCBs when they see or smell sudden escalations in stack emissions.

The following subsections describe the findings for each parameter shown in Figure 2.

Public data access

The Chhattisgarh OCEMS portal was the most challenging to use as the data for each facility resides on a link unique to that facility. As of December 2021, there were more than a 100 links representing each facility reporting CEMS data in Chhattisgarh. The portal has since been updated to centralise the information.

Air emissions from a prilling tower of a Urea fertilizer plant in India.

Ease of navigation

All the OCEMS portals, except those of Gujarat and Rajasthan,[2] provide a list of facilities reporting data. Of these, only nine provided an industry-type identifier. Although Punjab, Haryana, Delhi, and Bihar provided a list of facilities to choose from, the data from these facilities was only instantaneous, and no historical data was available.

Data duration

Nine states provided complete historical data on CEMS from all its facilities, although the Odisha portal was not accessible at the time of analysis. Telangana, Tamil Nadu, Andhra Pradesh, and Jharkhand provided data for only 24 hours. Gujarat and Kerala provided data for 30 days. Five states only provided instantaneous data, as noted previously.

Data download

Of the 19 public OCEMS portals accessible, only 8 allowed downloading of historical data that can be used for analysis. Jharkhand did allow for data download, but only 24 hours' worth at a time; hence, accessing and analysing historical data was difficult. Without historical data, it is not possible to evaluate the compliance of the individual facilities with the Guidelines or develop a robust mechanism to mitigate emissions from industrial facilities.

Stack compliance identification

The industrial facilities name each stack being monitored by CEMS and transmit the data to SPCBs/PCCs and the CPCB. The data is then uploaded on the individual SPCB/PCC portals. It was observed that a significant number of stack names from the OCEMS portal do not indicate the unit of operation associated with the stack — for example, boiler stack or furnace stack. Rather, they often have generic numbering, such as 'Stack 1', 'Stack 2', and so on. Therefore, it is not always possible to determine what emissions standard applies to a particular stack and whether the stack is compliant or not. Eight SPCBs/PCCs displayed standards against the stack on their OCEMS portals, of which three SPCBs (Kerala SPCB, Gujarat PCB, and Andhra Pradesh PCB) also displayed the number of times the monitored emission concentration has exceeded the CPCB emission standards in the given time interval. Eleven OCEMS portals did not provide standards against the stack data.

> Only 8 OCEMS portals allowed downloading of historical data usable for analysis.

Data interval

Of the 19 SPCBs/PCCs, 10 provided data at 15-minute intervals, which is the most preferred. Assam and Goa provided data at 30-minute intervals. It was difficult to classify the data from the Chhattisgarh SPCB from a data interval perspective because the different facilities directly providing data have varying data intervals. However, most of the facilities report hourly data, and hence the state has a score of one for data interval, which is better than instantaneous data, but there is no information on data missing within the interval.

Overall, the relatively less-industrialised states and union territories (Figure 2) have a better-developed public access OCEMS portal than more-industrialised states. The three states with the most industrial facilities are Tamil Nadu, Gujarat, and Maharashtra (Reserve Bank of India 2020). Among them, Maharashtra did not have a publicly accessible OCEMS portal. Although the other two states had a publicly accessible OCEMS portal, they did not provide access to historical data or an option for data download.

3. CEMS data availability

Among the states with an OCEMS web portal, only six states provided downloadable annual data.[3] These states are Assam, Chhattisgarh, Goa, Himachal Pradesh, Madhya Pradesh, and Meghalaya. Therefore, the assessment of the CEMS data itself was limited to these six states. Evaluating monthly data would not have given a clear picture of the availability of CEMS data because there is always the possibility of an abnormal month in terms of operations or data collection and reporting. Seventeen industry sectors are required to install CEMS at their facilities. However, given the challenges with downloading, cleaning, and analysing the data, the study was limited to the top polluters.

2. Based on the old Rajasthan OCEMS web portal, since this analysis was completed before the newer version of the portal was launched.
3. This does not include the Rajasthan OCEMS web portal that was activated post the completion of the analysis required for this Brief.

Nationwide, six types of industries with high emissions loads were selected based on the industry's contribution to India's current emission load (Gupta et al. 2019). These are (i) aluminium, (ii) cement, (iii) iron and steel, (iv) petrochemicals, (v) pulp and paper, and (vi) refinery industries. No inventory provides a detailed estimate of emissions for each of these industry types, but a recent report suggests that these six industries might contribute to more than 90 per cent of the total PM10 emissions from large industries (Datta 2021). There are significant emissions from small- and medium-sized industrial enterprises, but they do not usually fall under the purview of CEMS monitoring, given their size.

For the 6 states and 6 industry sectors in the states analysed in this study, 256 facilities were estimated to require CEMS installation as of December 2021. However, the OCEMS web portals of these states list 177 facilities, but data was available only for 134 facilities. The most significant observed difference between listed facilities and facility data access was for Chhattisgarh, where data for 42 facilities is not accessible. This is because the Chhattisgarh SPCB makes data available for each facility as a separate link (as shown in Figure 3).

There was a large difference between the number of facilities that were estimated would require CEMS (256) and the actual number with CEMS installed (177) as per the SPCBs, which is difficult to comprehend. This discrepancy could be related to the size of the facilities because the data could include smaller units that do not require CEMS installation. It could also be that certain facilities are unaware of this requirement, the SPCBs exempted certain facilities, or some facilities ceased operations. State-wise information on data accessibility is given in Table 1.

3.1 Methodology for CEMS data availability assessment

To analyse CEMS data relayed to SPCBs/PCCs and the CPCB by the industries, the state OCEMS web portals that provide public access to historical data were identified. Hourly CEMS data for 2020 (1 January to 31 December) was downloaded from the OCEMS web portals of Assam, Chhattisgarh, Goa, Himachal Pradesh, Madhya Pradesh, and Meghalaya.

To assess the availability of CEMS data and the level of compliance of individual stacks and facilities, two parameters were estimated: data availability and frequency of misses.

Data availability

The annual data availability was estimated as a percentage for every facility:

$$\text{Data availability (\%)} = \frac{\text{Number of hours of data available}}{8760} \times 100$$

Data availability refers to the number of hours in a year for which the CEMS-reported data (publicly available data on the OCEMS web portals). The availability percentage does not account for failures of the CEMS in collecting the data or any glitches during data transmission to the OCEMS web portal.

When the same CEMS on a stack/chimney/duct is used to monitor more than one pollutant, then the average percentage data availability is estimated.

Table 1 The OCEMS portal lists less than 70% of facilities

SPCBs	Number of facilities on OCEMS portals	Number of facilities with accessible data	Total number of facilities in the state
Assam	18	17	34
Chhattisgarh	98	56	98
Goa	5	5	15
Himachal Pradesh	13	13	41
Madhya Pradesh	31	31	56
Meghalaya	12	12	12
Total	**177**	**134**	**256**

Source: Authors' analysis

As per CPCB's clarificatory note on the Guidelines for real-time effluent and emissions data collection, every industry has to ensure 85 per cent data availability every month for all its stations and parameters to be monitored (CPCB 2017b). Therefore, data availability was evaluated against this 85 per cent threshold, but on an annual basis. Evaluating compliance every month for each pollutant is not only cumbersome, but it is also difficult to depict and interpret. It must be noted that the monthly requirement is not a part of the Guidelines itself.

Frequency of misses

The CEMS data relayed by the industries generally have some data gaps, which can be attributed to regular maintenance and repair of the monitoring device, device failure, internet outages, and power disruptions. The Guidelines stipulate that a single data gap should not be longer than 72 hours, and the facility may have to stop operations if this happens. Therefore the number of times in a year a facility's CEMS data reporting has gaps was determined to better evaluate data availability. The frequency of misses for every facility and stack was also estimated. Frequency here only refers to the number of times data was missing and does not take into account the duration of each data gap.

3.2 Findings for CEMS data availability

CEMS data availability varies significantly across the six states evaluated, as seen in Figure 3. For the six SPCBs/PCCs that provided data downloads for the 6 industry types analysed, the availability for the year 2020 was only approximately 55 per cent on average. Of the 691 stacks analysed, 97 have data coverage of less than 10 per cent. The Assam SPCB had the lowest data availability (~10 per cent) among the six SPCBs/PCCs, whereas the Meghalaya SPCB had the highest data availability (~67 per cent).

The average data availability for all facilities (including all six industries) in each evaluated state was as follows:

- Assam — 10 per cent
- Chhattisgarh — 57 per cent
- Goa — 44 per cent
- Himachal Pradesh — 66 per cent
- Madhya Pradesh — 58 per cent
- Meghalaya — 67 per cent

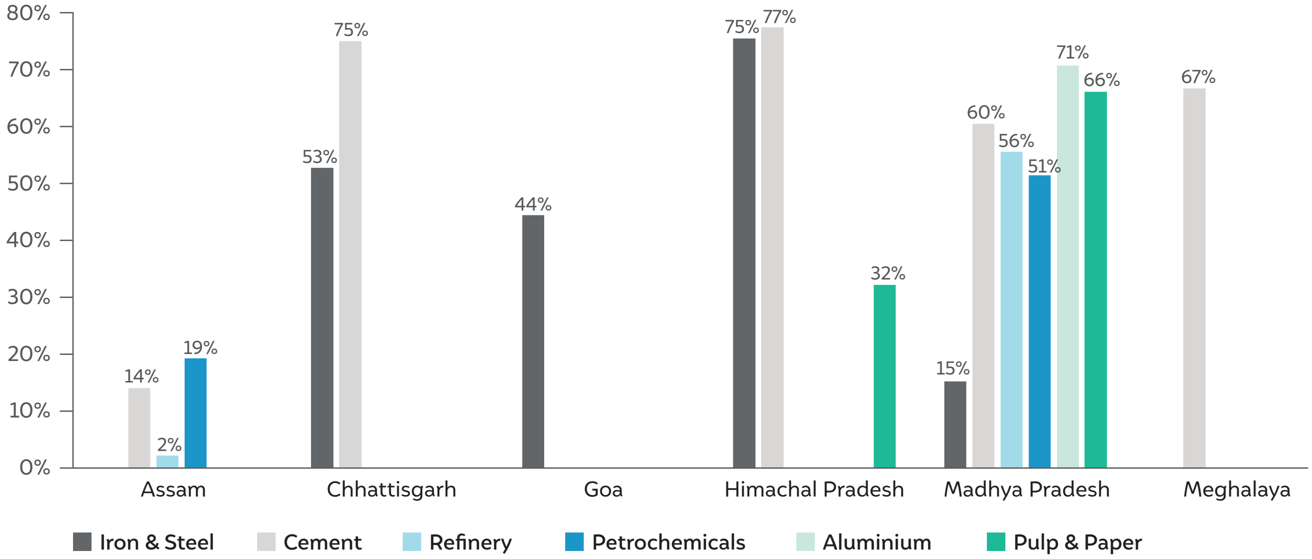
> For the states and industry types analysed, CEMS data availability was only 55% in 2020.

Among the six selected industry types, refineries had the lowest (~36 per cent), whereas aluminium plants had the highest (~71 per cent) average data availability. In Figure 3, missing bars for a specific industry type within a particular state indicate that the industry type does not exist in the state. The weighted average data availability for the different sectors is given below. Note that the overall average values may not match the numerical average state-wise values shown in Figure 3 because of the difference in the number of reporting stacks in each state. For example, the refinery in Madhya Pradesh had an average availability of 56 per cent for the 52 stacks and associated parameters measured. However, the 21 stacks and parameters measured in Assam had an availability of only 2 per cent. Therefore, the weighted average of these stacks and parameters for the refinery sector is 36 per cent.

- Iron and steel — 50 per cent
- Cement — 61 per cent
- Refinery — 36 per cent
- Petrochemicals — 43 per cent
- Aluminium — 71 per cent
- Pulp and paper — 57 per cent

Image: Alamy

Figure 3 Average data availability is 55% for the six industries in the six states in 2020



Source: Authors' analysis

Notes:
1. Parameter values of zero were treated as reported data; only null values signify missing data
2. Missing bars indicate that the industry does not exist in that particular state

Impact of the pandemic

The COVID-19 pandemic had a significant impact on industrial operations. India had a strict lockdown policy in place for several months at both national and state levels, and many industrial facilities had to shut down. This has inevitably reduced the availability of CEMS data. Also, exact shutdown durations cannot be determined because they were different for different facilities and states. The year 2021 saw the second wave of the pandemic in India, so analysis data for this year would still not reflect a business-as-usual scenario. Therefore, to assess whether the low data availability was a result of the pandemic, the data for the year 2019 was evaluated.

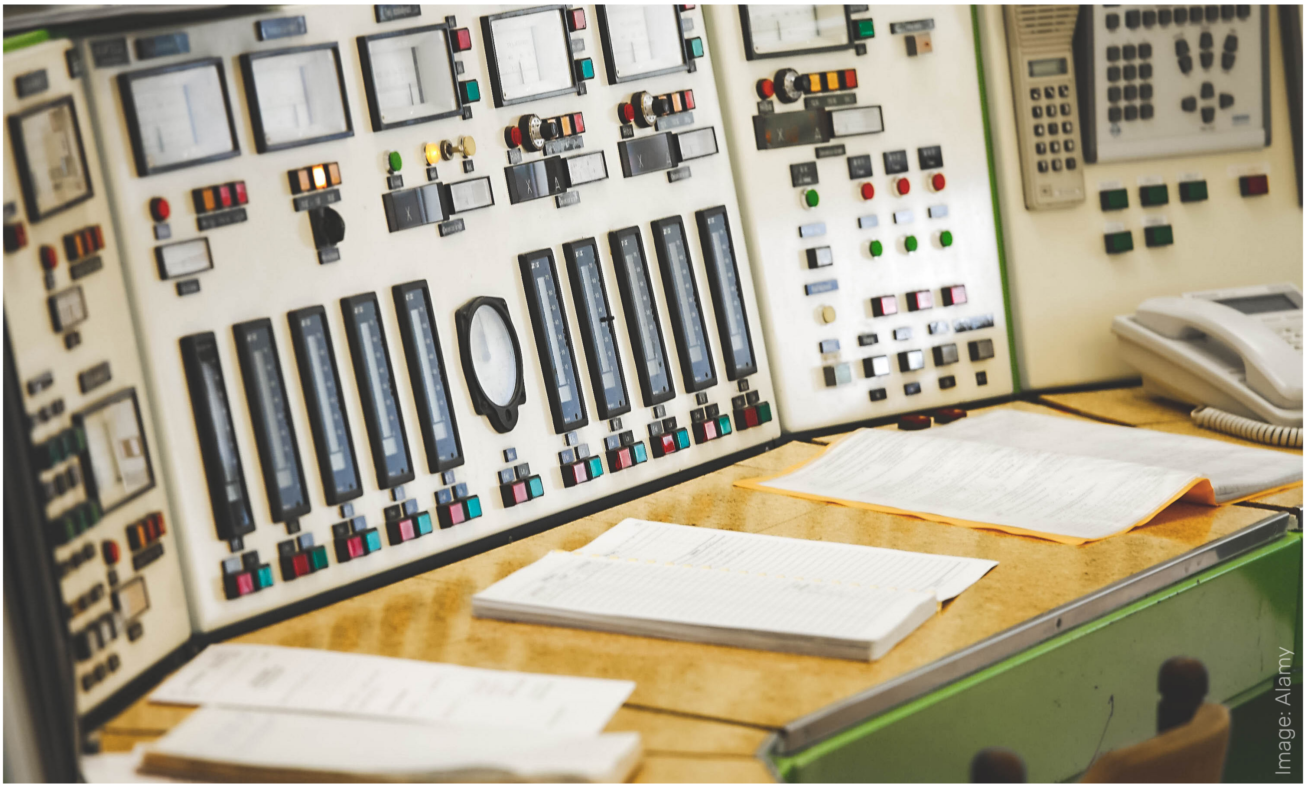


Image: Alamy

Figure 4 shows the data availability for the six industrial sectors and states analysed using 2019 data. The average data availability is significantly lower than in 2020, at 43 per cent, with only 662 stacks in 2019 reporting data as against 691 in 2020. The approximate average data availability for all facilities for the evaluated states is as follows:

- Assam — 0 per cent
- Chhattisgarh — 65 per cent
- Goa — 53 per cent
- Himachal Pradesh — 67 per cent
- Madhya Pradesh — 30 per cent
- Meghalaya — 58 per cent

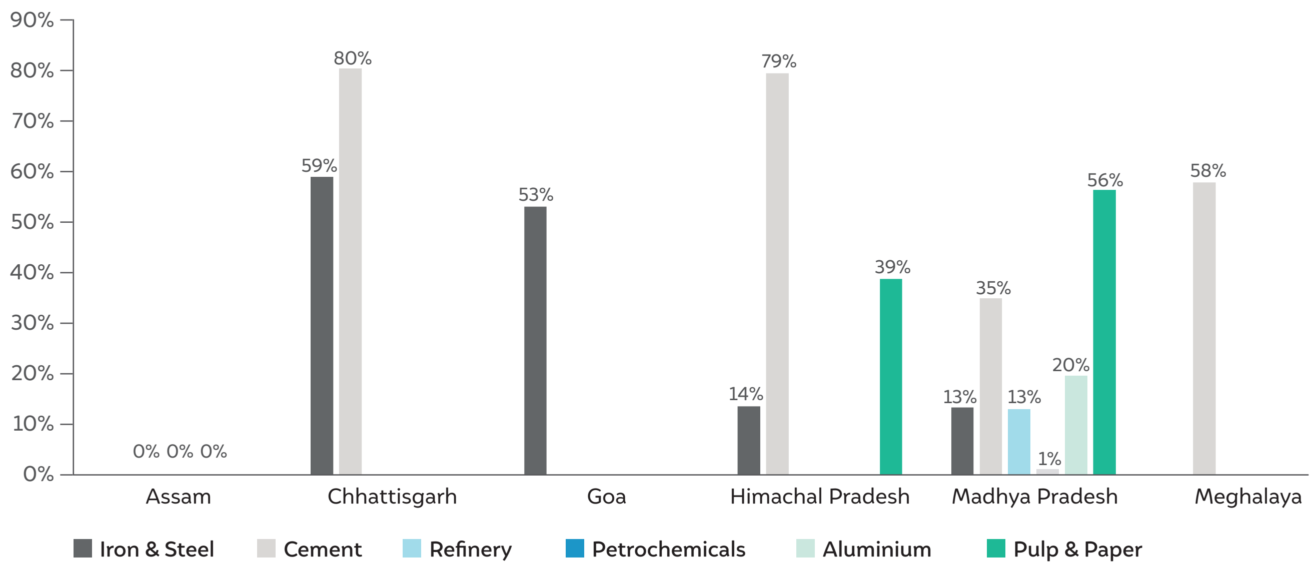
The average data availability for the six industrial sectors is as follows. Note that the overall average values may not match the numerical average state-wise values shown in Figure 4 because of the difference in the number of reporting stacks and individual parameters monitored by each stack in that state. For example, the refineries in Madhya Pradesh had an average availability of 13 per cent for 52 stacks and parameters measured. However, the 21 stacks and parameters in the refineries in Assam did not report any data. Therefore, the weighted average of these stacks and parameters for the refinery sector is nine per cent.

- Iron and steel — 55 per cent
- Cement — 47 per cent
- Refinery — 9 per cent
- Petrochemicals — 1 per cent
- Aluminium — 20 per cent
- Pulp and paper — 51 per cent

The CPCB requires that CEMS have data availability of 85 per cent per month. However, it is cumbersome to evaluate monthly compliance and decipher what it means for annual compliance. Also, during the same month, one pollutant could be in compliance, whereas another need not. Problems also arise when a facility is in standby or shutdown mode. When this happens, there are no emissions to report, and it is difficult to take such events into account for the availability criterion. Therefore, the 85 per cent data availability requirement was applied at an annual level for each stack.

Figure 5 shows the percentage of stacks with an availability of more than 85 per cent annually. Less than 50 per cent of all the stacks in the six states and six industries evaluated complied with the 85 per cent data availability requirement in 2020. Assam has no stacks in compliance, and Meghalaya has 46 per cent stack compliance.

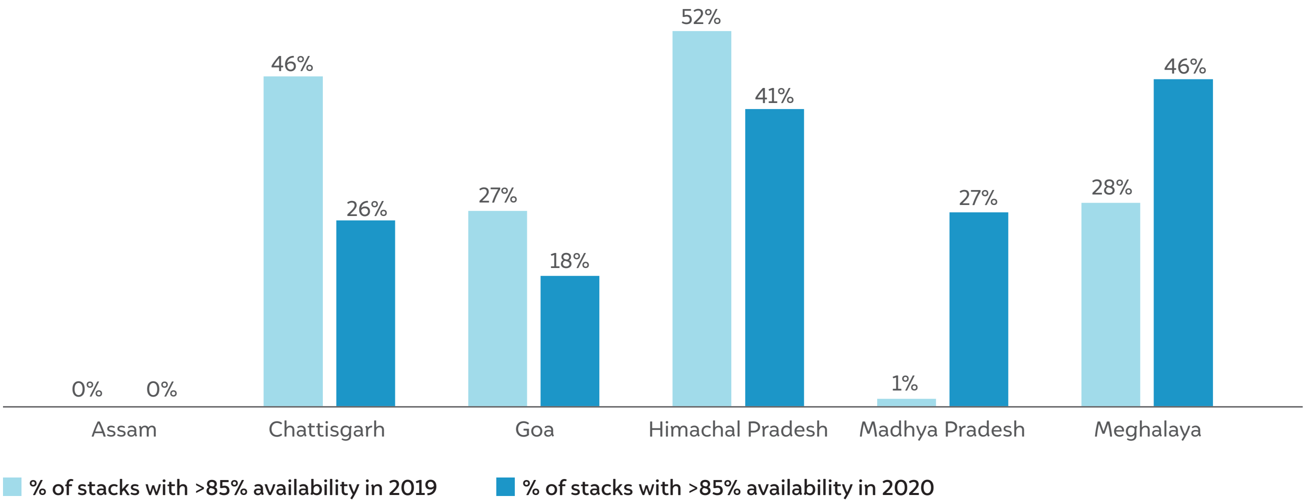
Figure 4 Average data availability is 43% for the six industries in the six states in 2019



Source: Authors' analysis

Notes:
1. Parameter values of zero were treated as reported data; only null values signify missing data
2. Missing bars indicate that the industry does not exist in that particular state, except for Assam, where data is missing for cement, refinery, and petrochemical industries

Figure 5 On average, only 20% and 27% of the stacks complied with the 85% availability requirement in 2019 and 2020, respectively



Source: Authors' analysis

Note: Averaging the values shown in the chart may not match the overall averages given in the chart title because the latter are weighted by the number of stacks and individual parameters that were monitored by each stack

Compared to 2020, in 2019, it can be observed that Chhattisgarh, Goa, and Himachal Pradesh had a slightly better percentage of stacks with greater than 85 per cent annual data availability, at 46, 27, and 52 per cent, respectively. In contrast, Meghalaya had a lower availability at 28 per cent and Madhya Pradesh had an availability of only 1 per cent. Assam had no stacks with greater than 85 per cent annual data availability even in 2019.

Frequency of missing data

According to the current CPCB Guidelines, in case there is a breakdown in the real-time monitoring system, the facility or instrument manufacturer should rectify the problem within 72 hours. If this is not possible, then the facility's operations should be reduced or it should be shut down. However, it is common for facilities to not report data, often for more than 72 consecutive hours or longer; this leads to low data availability on the OCEMS portal.

Figure 6 shows each of the individual stacks (691 in total) from the six states and six industry sectors. The x-axis depicts, for each stack, the frequency of missing data over the calendar year 2020 during which the CEMS did not report data to the OCEMS web portal. The y-axis depicts the total number of hours of all the missing data events for each stack in the entire calendar year 2020.

> Facilities often do not report data longer than the stipulated minimum of 72 consecutive hours or longer.

Missing data refers to null values in the historical data available on the OCEMS web portal, not zero values. The reason for the zero values cannot be determined using the data alone. A zero value could indicate several conditions, including CEMS failure to correctly monitor or transmit data, CEMS being switched off, disruption in the OCEMS portal, or simply the plant being in standby or shutdown mode. However, in a standby or shutdown scenario, one would expect trace amounts of pollutant concentration in the ambient air, especially in industrial facilities, unless the stack is physically shut at the top, which is not the norm. Regardless, it was assumed that a zero value is a reported value and not a missing data event.

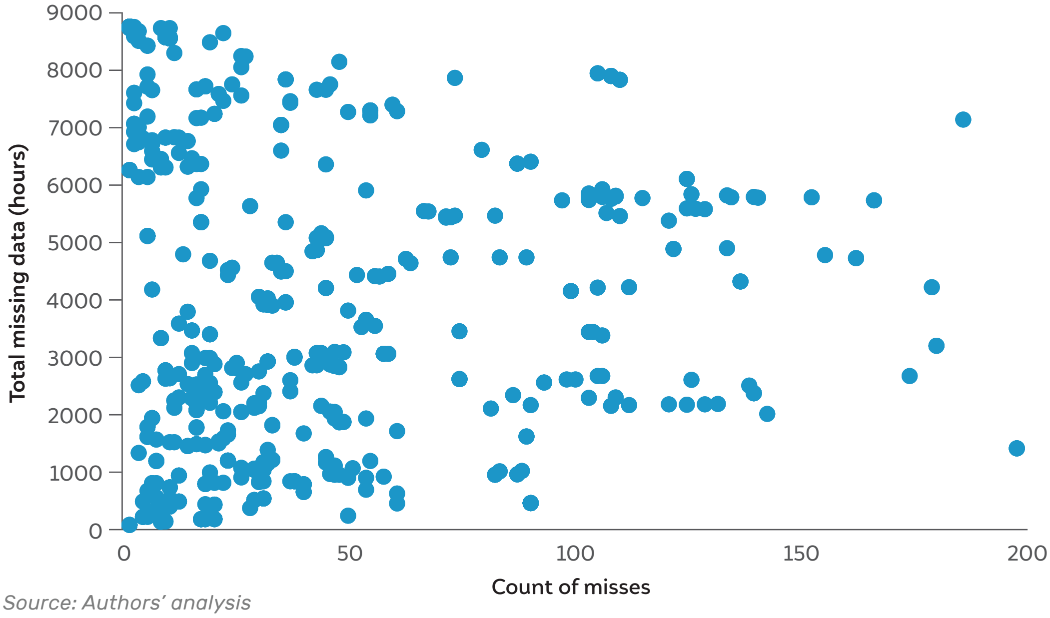
Multiple stacks within a facility were often found with exactly the same frequency of misses and total annual hours of missing data. This is not unexpected because multiple CEMS within the same facility can be expected to follow a similar pattern, either because of the facility's operational reasons or because all the CEMS on individual stacks are typically connected to a single network within the facility. Consequently, in Figure 6, multiple stacks are represented as overlapping points on the plot — that is, a single point could represent multiple stacks, mostly from the same facility.

Figure 6 shows a significant spread in the frequency of missing data events and total annual missing hours. This is likely to be a result of the pandemic where multiple shutdowns could have resulted in CEMS not relaying any data.

About 48 per cent of them have fewer than 20 missing data events, and hence there is data crowding along the y-axis. However, the low count of events can be misleading because the duration of the missing data events is an essential factor. It can be seen that most of the stacks (77 per cent) have more than 1,000 hours of missing data (approximately 42 days) in the calendar year.

A similar plot of the frequency of missing data events for 2019 (Figure 7) indicates a lesser spread across the x-axis — that is, a relatively fewer number of missing data events, but a significant 81 per cent of stacks with more than 1,000 hours of missing data annually.

Figure 6 About 77% of industrial stacks have more than 1,000 hours of missing data in 2020

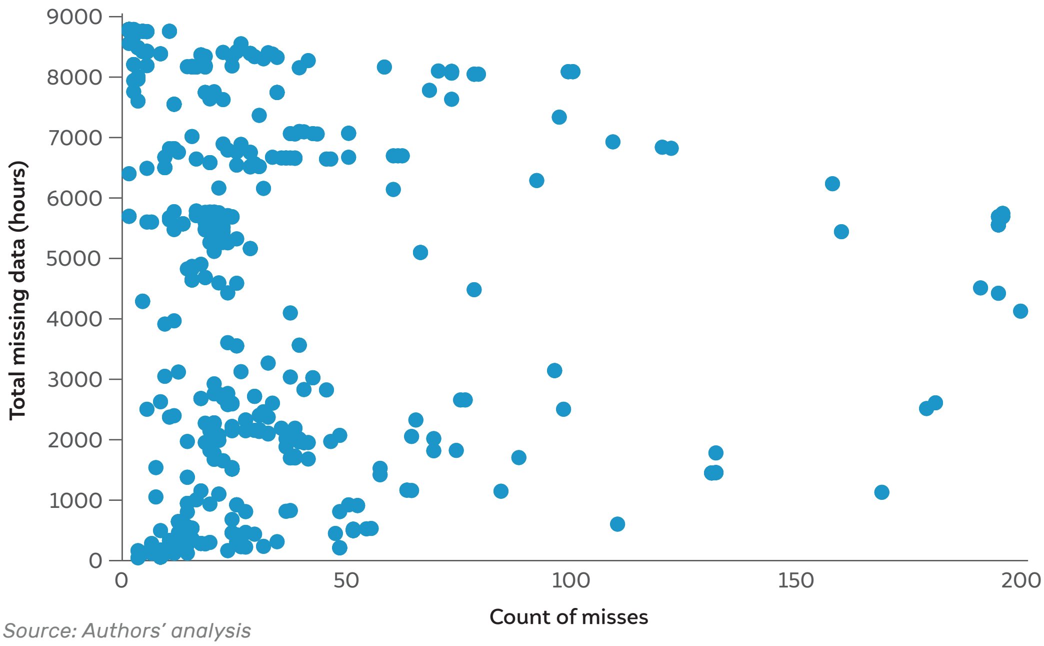


Source: Authors' analysis

Notes:

1. The figure does not show 19 stacks with more than 200 counts of misses, for better visualisation.
2. Of 691 stacks analysed, only 37 had zero instances of missing data events lasting greater than 72 hours.
3. A single point on the plot could, in many instances, represent multiple CEMS with the same frequency of missing data events and total missing data hours in a year.

Figure 7 About 81% of industrial stacks have more than 1,000 hours of missing data in 2019

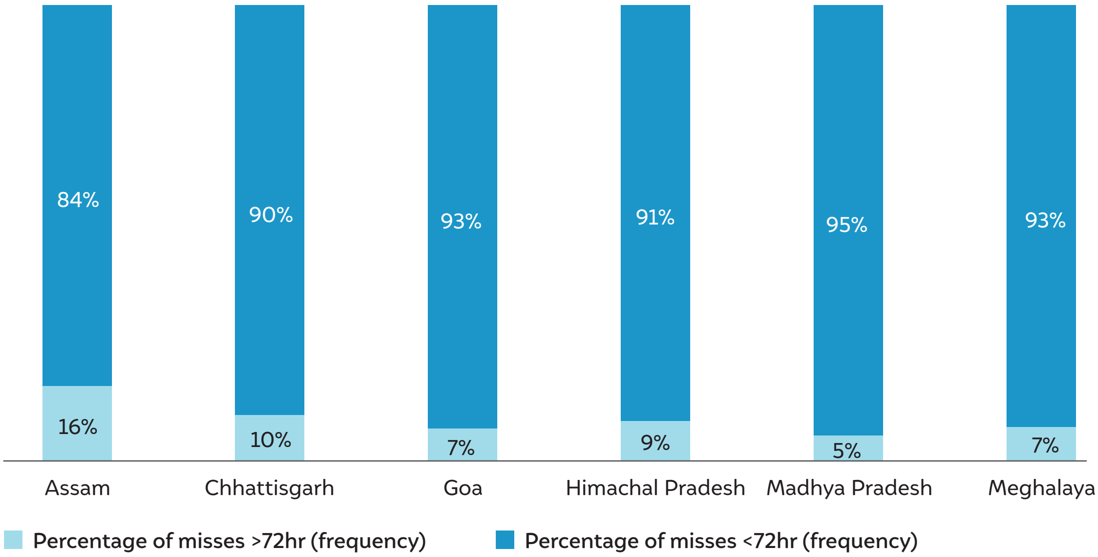


Source: Authors' analysis

Note: The figure does not show 12 stacks with more than 200 counts of misses, for better visualisation

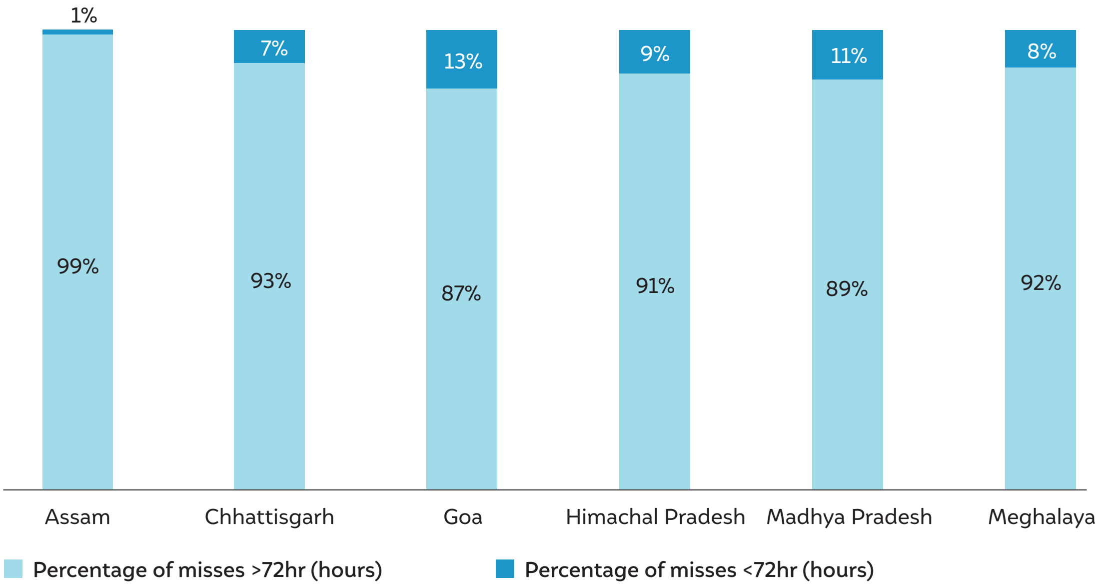
Another way of representing the missing data is by grouping the missing data events according to the duration of the event: either greater than or less than 72 hours. Figure 8 provides a breakdown of the frequency by the duration of the event, and Figure 9 provides the total number of hours of missing data events separated into durations of greater than and less than 72 hours. As shown in Figure 8, the number of missing data events lasting greater than 72 hours for each event is around 10 per cent of the total number of missing data events. However, these events (with a duration greater than 72 hours) account for more than 85 per cent of the total missing data hours, as seen in Figure 9. It can be seen that the missing data events last long, indicating a significant lack of compliance for those stacks.

Figure 8 More than 93% of the missing data events are of less than 72 hours' duration in 2020



Source: Authors' analysis

Figure 9 The missing data events that last longer than 72 hours account for 92% of the total missing data hours in 2020



Source: Authors' analysis

The individual stack and CEMS-level data have been represented temporally in Figure 10. Here, annual data in hours from each of the CEMS is stacked in columns vertically. Each column represents an individual stack and corresponding CEMS data. All hours represented in black indicate a data point (including zero values), and all white spaces indicate missing hours where the CEMS did not report any data to the OCEMS web portal for that particular stack and CEMS device. This representation is shown in separate charts for each of the six states. The column width differences between states are a result of the different number of stacks in each state being fit into the same-sized chart — that is, the width of the column does not have any significance.

It can be observed that Assam has the most amount of white space, indicating that it has the largest amount of missing data. On the other hand, Meghalaya has the least white space, indicating that it has the maximum data availability among the six states.

Several CEMS have not reported data for the entire year. Others have not reported data for significant blocks of hours. However, some facilities have near-complete reporting for the entire year. Therefore, non-compliant actors that are significantly skewing the overall availability of CEMS data at a state level can be identified using such visualisations, apart from the quantitative assessment discussed previously.

Figure 10 Temporal availability of CEMS data at the stack level shows significant data reporting gaps

Source: Authors' analysis

4. Parameter monitoring compliance

The CPCB mandates industry-specific parameters and pollutants that need to be monitored. For example, aluminium plants need to monitor PM and fluoride. Table 2 lists air pollutant parameters required to be monitored by each industry as per the Guidelines. PM is the most common parameter monitored at stacks because almost all facilities across industry types are required to monitor PM.

Apart from industry-specific pollutant monitoring requirements, certain industries are required to install CEMS on their boilers. For example, although pulp and paper plants are exempt from monitoring their processes, the boilers (if any) in their units need to be monitored using CEMS.

4.1 Methodology for parameter monitoring compliance

Pollutant and parameter monitoring compliance was analysed for every facility classified as belonging to one of the six selected industry types for the six states with public access to historical CEMS data for 2020. The Guidelines mandate a specific set of parameters that a particular industry type must monitor. The study estimated the percentage of compliant, partially compliant, and non-compliant facilities monitoring the set of prescribed parameters for all the SPCBs/PCCs having a publicly accessible OCEMS web portal. A compliant facility monitors all the prescribed parameters (at least for one stack within the facility), whereas a partially compliant facility monitors one or more, but not all, of the prescribed parameters.

> ~47% of facilities are fully compliant (i.e. at least for one stack) with the CPCB parameter monitoring mandates.

Facilities that are not compliant do not monitor any of the prescribed parameters (i.e., they report only null values for the entire year).

4.2 Findings for parameter monitoring compliance

Figure 11 shows the level of compliance in each of the six states analysed. Goa had no facility fully complying with the CPCB Guidelines in the year 2020. Although, according to the figure, Chhattisgarh had only one non-compliant facility, data could not be downloaded for 42 of the 98 facilities in the 6 selected industry sectors. The compliance level is therefore shown only for the remaining 56 facilities in that state.

On average, approximately 47 per cent of the facilities are fully compliant, and 38 per cent are partially compliant (i.e., monitoring at least one of the CPCB-prescribed parameters) with the Guidelines. Approximately 15 per cent of the facilities were not compliant with the CPCB Guidelines — that is, they did not monitor any of the prescribed pollutants or parameters.

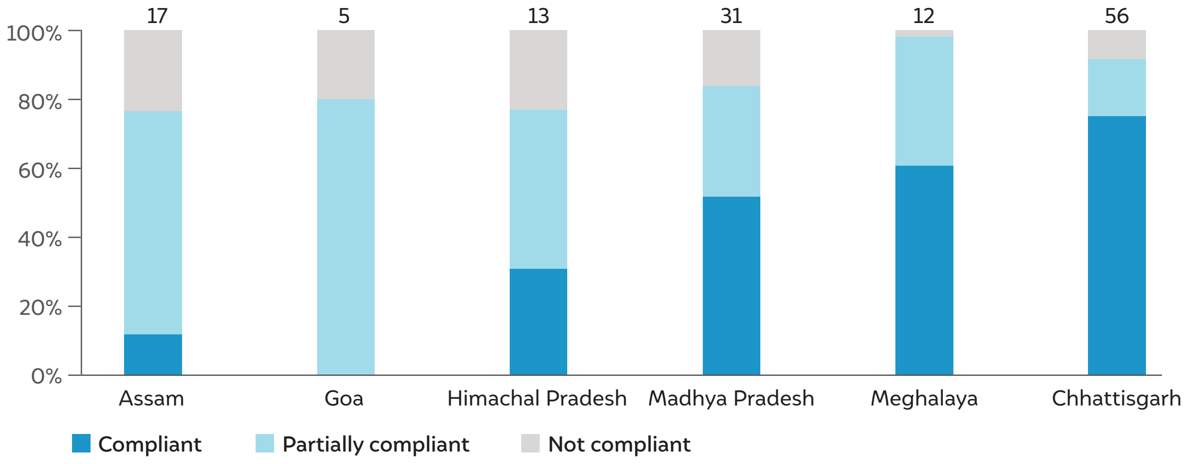
Table 2 Industry-specific parameter monitoring requirements as per the Guidelines

Category	Prescribed parameters				
	PM	NOx	SO_2	Fluoride	CO
Aluminium	✓			✓	
Cement	✓	✓	✓		
Iron and steel	✓	✓	✓		
Petrochemical	✓	✓	✓		✓
Pulp and paper	✓	✓	✓		
Refinery	✓	✓	✓		✓

Source: CPCB 2018

Note: Pulp and paper plants report pollutants only if they have boilers in their facilities

Figure 11 Only 65 of the 134 facilities were fully compliant with pollutant and parameter monitoring



Source: Authors' analysis

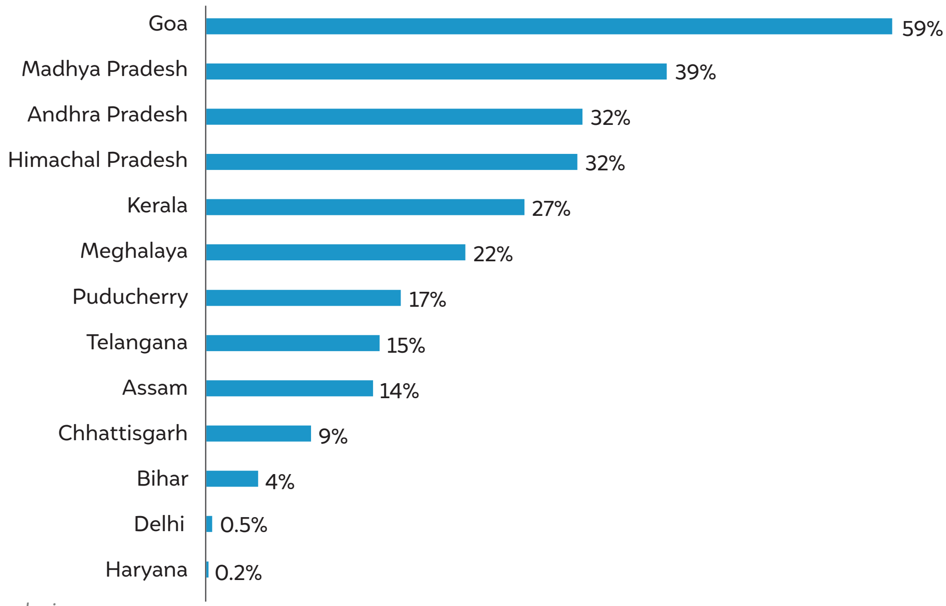
Notes:
1. The number atop each bar indicates the number of facilities in each state
2. For Chhattisgarh, of the 98 facilities in the 6 industry sectors considered, data could be downloaded only for 56 facilities

5. Ambient air quality monitors at industrial facilities

The CPCB requires, through a separate directive, that all large and medium-sized industries located in critically polluted areas and the 17 highly polluting industrial facilities install CAAQMs (Dube 2010). The SPCB/PCC OCEMS web portals display ambient air quality data. This study estimated the percentage of facilities continuously monitoring ambient air quality (AAQ) in every state with an OCEMS web portal for the 6 (of 17) highly polluting industries.

For the 6 industries that were analysed, it was found that 13 states had 291 industrial facilities monitoring ambient air quality continuously, as shown in Figure 12. Moreover, several facilities had more than one CAAQM within their premises. Andhra Pradesh had the highest number of industrial facilities with CAAQMs, at 99. It must be noted that some facilities could be reporting ambient air quality through periodic manual monitoring (and not continuously). Hence, a lack of continuous data should not be interpreted as non-compliance with the CPCB requirements.

Figure 12 Several industrial facilities monitor ambient air quality



Source: Authors' analysis

6. Recommendations

6.1 Provide legal sanctity to data obtained from the CEMS

The CPCB first approved the deployment of CEMS more than eight years ago in 2014, but it still lacks legal sanctity. In a 2015 directive, the SPCB clearly retains manual monitoring as the basis for regulatory action. This means that an entity cannot use CEMS data for enforcement or legal action. There are thousands of CEMS deployed across industrial facilities throughout the country collecting air pollution data in real time. But resource-crunched SPCBs/PCCs still have to rely on cumbersome manual methods for regulatory action. Therefore, to efficiently utilise the data from CEMS devices, it is recommended that CEMS be provided legal sanctity through regulatory action. This could also entail making some amendments to the *Air Act*, *Water Act*, and *Environment (Protection) Act*. The credibility of CEMS data is essential for providing it legal sanctity. This will require that the CPCB develop indigenous certification systems and empanel laboratories for CEMS performance tests.

6.2 Consolidate CEMS requirements into a single regulation

Several guidelines, notifications, and directions document the requirements for installing CEMS and monitoring air pollutants from industrial stacks. Furthermore, specific directions have also been provided in individual facilities' Consent to Operate documents. It is recommended that the CPCB consolidate all these requisites into a single regulation that encompasses all the requirements and any lessons learned through the verification and enforcement processes of various SPCBs/PCCs. This will be an enabling step to provide legal sanctity to CEMS data.

6.3 The CPCB should integrate publicly accessible CEMS data into their OCEMS portal for the entire country as it already has the data

Note: Since the completion of this analysis, CPCB has made its CEMS data available on its own portal. However, historical data can be downloaded only for the last 7 days.

The Guidelines require states to report CEMS data to the CPCB. The data is accessible to industrial facilities but not to the public. To access the data, one has to rely on states to make it available on their individual OCEMS portals. This limits public access to critical data, which has a significant impact on the health and well-being of citizens. To address this challenge, the CPCB should make public all the data it receives from all facilities across the states. Alternatively, integrating this data into a portal such as CPCB's CAAQMs (CPCB 2020a) can be efficient from a web portal integration perspective. This will reduce the burden on all 32 SPCBs/PCCs in developing and maintaining their individual OCEMS portal. It will also act as a one-stop portal for CEMS data, enabling ease of access to users.

6.4 Develop decision support systems with automated notification and tracking systems for defaulters

The CEMS data is transmitted directly to the OCEMS portal. The SPCBs/PCCs use this data to notify facilities of non-compliance through an automated notification system. However, compliance enforcement using these automated notification systems is limited and varies across states. The primary reason for this is that the system generates vast quantities of data that must be analysed consistently, apart from the fact that CEMS data does not have formal legal sanctity. Therefore, states need to build decision-making systems that incorporate the data generated from CEMS such that all enforcement-related metrics are distilled and summarised periodically for decision-makers. This can also act as legal evidence if enforcement action is required against any facility.

6.5 Revisions to Guidelines for CEMS

The Guidelines provide directions on how CEMS data should be collected and reported. The CPCB can revise the Guidelines to include some requirements to improve access to data and the quality of data collected.

- **Guidelines for designing the OCEMS portal to make it uniform across states**

  The CPCB can require standardised OCEMS portal attributes across all states with respect to data access and quality. The Madhya Pradesh and Himachal Pradesh portals are model portals, and all states can be made to adopt their structure and features.

In general, the following attributes would make the OCEMS portals robust in terms of access and transparency:

- **Public data access:** Make data available in table and chart formats for easy visual access.
- **Ease of navigation:** A list of facilities can be provided, so that users can quickly identify the facility of interest and peruse the related data.
- **Data duration:** Provide historical data for all the years where data is available.
- **Data download:** All data should be made available for download in easy .csv, .pdf, or .xlsx formats.
- **Geotag:** All facilities must be geotagged with the respective latitude and longitude data.
- **Stack compliance identification:** Each stack must have a standard associated with it, should mention the number of times it has been out of compliance in the month/year, and should have an option to show the compliance level over a selected period.
- **Data interval:** The portal should display data uniformly at fixed 15- or 30-minute average intervals across all facilities.
- **Data availability:** For each stack and facility, the portal should clearly show the percentage of data available per year by parameter and pollutant.

- **Multiple stack provisions**

  In industrial settings, multiple process stacks are often combined into one common stack before emissions are released into the atmosphere. This could be for reasons of convenient routing of exhaust through the facility. Alternatively, it could provide sufficient draft in the stacks/chimneys to effectively evacuate all the exhaust gases. Regardless, common (or combined) stacks are a regular feature in industrial facilities where the Guidelines require CEMS. In such cases, it is not clear what standards are to be applied to the combined stack, and this has been a source of confusion in the industry. One approach is to add all the standards that apply to the individual stacks that are connected to the common pipe. Alternatively, emissions should be allocated to each stack routed to the common stack using calculative methods based on engineering principles. For manual methods, the CPCB has issued directions specifying that each stack should be monitored, not the common pipe. However, it is not clear whether the same applies to CEMS. Therefore, the Guidelines should address this issue and include a dedicated section with guidance regarding the application of standards to common (or combined) stacks.

- **Missing data provisions**

  Data may be missing for various reasons, including legitimate issues with CEMS operation. In such cases, calculative methods should be provided for facilities to fill in the data gap — for example, by correlating fuel type and volume, air-to-fuel ratio, and other process parameters with historical CEMS measurements. Another option is to use rolling averages when data is missing for short durations. Such missing data provisions would ensure that all missing data can be filled. This will help the SPCBs/PCCs get a complete picture of emissions from individual facilities annually.

- **Public information on the type of CEMS technology installed**

  The type of CEMS installed can be indicative of the quality of the transmitted data and the types of parameters that can be monitored. This will also indicate whether the CEMS complies with the Guidelines' requirements. Therefore, the Guidelines should require public reporting of the vintage and technology type of CEMS for each monitored stack.

- **Information on operating hours**

  A CEMS may not be relaying data simply because the facility is in standby or shutdown mode. However, it is not possible to determine this from the data itself. Therefore, the Guidelines should require facilities to report monthly operating hours, so that there is some context to the missing data for evaluating data availability. Alternatively, the CEMS should be required to relay a zero value when the facility/process/equipment is in standby or shutdown mode, so that the operational status is clear at all times. This data should be made public along with the emissions concentration data, so that there are no misinterpretations regarding compliance.

- **Require reporting facilities to monitor prescribed parameters**

  A critical parameter to evaluate the impact of industrial emissions is the emissions load from each facility — that is, the emissions of criteria pollutants on a weight (or mass) basis. The flow rate is essential to estimate the emissions load of a facility or stack. The Guidelines require that facilities monitor temperature and flow along with the concentration of pollutants. However, only two per cent of facilities monitor both parameters, whereas five per cent monitor only one of the process parameters. Therefore, the SPCBs/PCCs should make a concerted effort to identify the facilities not reporting these parameters and specifically verify if the existing CEMS can track flow and temperature. This will allow the SPCBs/PCCs to estimate the emissions load and better manage mitigation measures, especially during periods when air pollution is high.

6.6 Utilise AAQ monitoring data and provide public access on OCEMS portals

The CPCB currently provides continuous ambient air quality data to the public for locations across India using 337 active regulatory CAAQMs managed by several entities such as the CPCB, SPCBs/PCCs, and the Indian Meteorological Department (CPCB 2020a). However, there is a need to scale up India's air quality monitoring network for reliable information on air quality (Upadhyay 2019). One study (Brauer et al. 2019) estimated that 4,000 air quality monitors would be needed for this.

Several industrial facilities required to install CEMS also monitor ambient air quality continuously, with the respective SPCBs/PCCs and the CPCB collecting the data. This data can supplement the air quality data collected by the CPCB regulatory CAAQMs.

The central and state governments are actively working on installing air quality monitors and integrating them into their CAAQM network (Ganguly, Kurinji, and Guttikunda 2020). The monitors installed at industrial facilities should keep track of overall air quality, especially in industrial areas. The data would help determine the contribution of industrial emissions to ambient air pollution. The monitors can further corroborate satellite data and act as calibration nodes for various low-cost air quality monitoring programmes. However, this will also require that the CEMS be regularly calibrated and the calibration information be made available in the public domain (along with the CEMS vintage and technology type information).

The historical continuous ambient air quality data from industrial facilities, if reliably available at OCEMS portals, could significantly bolster the country's coverage and also the quality of such data because the air quality monitoring network in several states is sparse. Table 3 provides a count of CAAQMs at industrial facilities and regulatory CAAQMs for a few states. Integrating these 500+ industrial CAAQMs will significantly add to the states' capability to monitor air quality. Therefore, it is recommended that states actively consider integrating the industrial CAAQMs into their network to generate better air quality data coverage.

Table 3 Ambient air quality monitors at industrial facilities can fill spatial data gaps in air quality

State	Number of CAAQMs in industrial facilities	Number of regulatory CAAQMs stations
Madhya Pradesh	150	16
Andhra Pradesh	187	5
Himachal Pradesh	9	15
Jharkhand	–	1
Meghalaya	4	1
Assam	5	2
Kerala	17	9
Goa	13	0
Gujarat	–	15
Chhattisgarh	35	2
Telangana	88	6
Bihar	8	32
Haryana	5	30
Puducherry	6	1
Tamil Nadu	0	11
Total	**527**	**146**

Source: Authors' compilation as of 31 December 2021

Acronyms

AAQ	ambient air quality
AAQM	ambient air quality monitor
CAAQM	continuous ambient air quality monitor
CEMS	continuous emission monitoring system
CEQMS	continuous effluent quality monitoring system
CPCB	Central Pollution Control Board
MoEFCC	Ministry of Environment, Forests and Climate Change
NABL	National Accreditation Board for Testing and Calibration Laboratories
NAMP	National Air Quality Monitoring Programme
NGT	National Green Tribunal
PCC	Pollution Control Committee
PM	particulate matter
OCEMS	online continuous emission monitoring system
SPCB	State Pollution Control Board

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Control panel of a CEMS installation

Image: Sanjeev K Kanchan/CEEW

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