CONTINUOUS EMISSIONS MONITORING SYSTEMS (CEMS)

Emissions Trading Scheme

Technical Brief

Surat (Gujarat), India
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TABLE OF CONTENTS

GLOSSARY OF TERMS

Abdul Latif Jameel Poverty Action Lab South Asia: Academic implementation partner of the project, referred to as “**J-PAL SA**”.

CEMS: Refers to Continuous Emission Monitoring Systems.

Gujarat Pollution Control Board: The environmental regulator for the State of Gujarat, hereinafter referred to as the “**GPCB**”, government implementation partner of the project.

Industry or plant: Refers to industrial facilities under the CEMS pilot, belonging to sectors: Chemicals (i.e., dye intermediates), Paper, Sugar and Distilleries or Textiles.

Principal Investigators: The Project is headed by four principal investigators – Prof. Michael Greenstone (University of Chicago), Prof. Rohini Pande (Yale University), Dr. Nicholas Ryan (Yale University) and Dr. Anant Sudarshan (University of Chicago).

Project or Pilot: The Continuous Emissions Monitoring Scheme implemented in partnership with the Gujarat Pollution Control (GPCB), set up in a phased-in randomized control trial setting. This is referred to as the “**Pilot**” or the “**Project**”.

Randomized Control Trial: Method of evaluation of the project, hereinafter referred to as “**RCT**”.

SPCB: Refers to State Pollution Control Boards.

Status Quo Regulation: Status quo regulation refers to the command-and-control framework by which GPCB has historically regulated industrial pollution. In the status quo, an SPM concentration limit is imposed at the level of 150 mg/Nm^3 per industrial stack. Any plant found emitting above this limit during a physical inspection by GPCB is subject to stringent and punitive regulatory action.

EXECUTIVE SUMMARY

This report summarizes learnings from a pilot project to install Continuous Emissions Monitoring Systems (CEMS) for reporting industrial emissions in solid fuel burning factories in Surat, Gujarat. The pilot was implemented as a randomized control trial in a sample size of 373 plants. Continuous monitoring systems were gradually rolled out to all plants in phases, with assignment to a phase being conducted by lottery. This allowed for a rigorous evaluation of impacts through a comparison of early phases (with CEMS) and later phases (without CEMS).

During the intervention, data on particulate emissions was sent in real-time to the Gujarat Pollution Control Board (GPCB), the key implementing partner of the study. The motivation for installing CEMS was to help to reduce reliance on frequent manual monitoring, providing significant long-term cost and time savings, as well as increasing the reliability of readings. Because CEMS transform the visibility that regulators have into the pollution emitted by factories, CEMS may improve the ability to monitor firms, allowing regulatory standards to be better targeted and enforced. However, CEMS do impose small additional costs on industries and have been widely mandated by India’s Central Pollution Control Board. As such, evaluating their effectiveness is of immediate policy relevance.

In addition to any direct benefits, the installation and connection of CEMS is a necessary first step to introducing several forms of modern regulation, including market-based regimes. Regulations such as emissions trading schemes have the potential to allow the government to lower regional water and air pollution at a lower economic cost than under conventional command-and-control regimes.

The results observed at the end of the pilot evaluation period have been mixed, though largely positive. Regulator interactions with plants were found to increase, at least with regards to sending letters and warnings. Pollution over the course of the experiment dropped significantly across the sample but factories with CEMS did not emit less than their counterparts without these devices. One possible reason is that plants in later phases anticipated that their emissions would soon become visible and thus took early action. It is also possible that better data by itself does not suffice to reduce pollution. In fact, CEMS devices did enable new regulation: following the installation of monitoring technology, the Gujarat Pollution Control Board introduced India’s first pilot emissions trading scheme in Surat.

1 MOTIVATION

Air pollution now poses one of the most severe public health challenges in India.[1] Beyond impacts on mortality and life expectancy, new research has pointed to the generalized health risks of air pollution, suggesting that the effects of poor air quality may extend to reduced crop yields, lower labor productivity, and decreased cognitive skills.[2] In other words, the apparent trade-off between environmental protection and economic growth is something of a Hobson's choice—economic growth cannot continue without cleaning up the air and water.

Existing command-and-control approaches to environmental regulation in India have been criticized as being ineffective in controlling industrial emissions, while creating large compliance costs. For instance, in Maharashtra, University of Chicago researchers digitized over 13,200 regulatory pollution tests spanning a period between September 2012 and February 2018, finding that over half exceeded regulatory limits.[3]

One reason why pollution from the manufacturing sector poses a particularly thorny challenge to understaffed environmental regulators in India is the difficulty of monitoring a large number of highly polluting but relatively small factories. In most Indian states, officials from the State Pollution Control Boards (SPCBs), or accredited laboratories, perform in-person environmental inspections of plants. This process of manual sampling at industries is time consuming and laborious. SPCBs face severe capacity constraints to carry out these inspections regularly and as a result, pollution information is infrequently collected, and therefore not necessarily representative of the plant's true emissions.

[1]Balakrishnan, Kalpana et al. 2019. "The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017" Lancet Planet Health 3: e26–39. DOI: 10.1016/S2542-5196(18)30261-4.

[2]Bharadwaj, Prashant, Matthew Gibson, Joshua Graff Zivin, and Christopher Neilson. 2017. "Gray Matters: Fetal Pollution Exposure and Human Capital Formation" Journal of the Association of Environmental and Resource Economists 4(2): 505–542. DOI: 10.1086/691591.

Burney, Jennifer and V. Ramanathan. 2014. "Recent climate and air pollution impacts on Indian agriculture." Proceedings of the National Academy of Sciences of the United States of America 111(46): 16319-16324. DOI: 10.1073/pnas.1317275111.

Chang, Tom Y., Joshua Graff Zivin, Tal Gross, Matthew Neidell. 2019. "The Effect of Pollution on Worker Productivity: Evidence from Call Center Workers in China." American Economic Journal: Applied Economics 11(1): 151–172. DOI: 10.1257/app.20160436.

[3]Greenstone, Michael, Santosh Harish, Rohini Pande, and Anant Sudarshan. 2018. "The Solvable Challenge of Air Pollution in India." Proceedings of the India Policy Forum 14: 1–40.

In addition to the quantity of data available through manual sampling, there are also concerns around quality. A large, randomized control trial in the state of Gujarat documented systematic weaknesses in manual methods of monitoring in the state, drawing attention to biases and corruption in the data, infrequent measurement, and a practice of targeting the worst polluters but not all violators (Duflo et al. 2013; Duflo et al. 2018). The Gujarat Pollution Control Board was able to reduce some of these problems through an innovative change in the rules governing how accredited laboratories were paid for doing manual audits. Nevertheless, many of these challenges remain.

In this context, technology may offer a promising solution to the problem of information availability and data quality. Continuous Emissions Monitoring Systems use instruments that are designed to be installed in the smokestack of factories and to continuously measure the concentration (or mass) of air pollution released by the factory. Because CEMS devices supply real-time data on emissions[4] from the industrial stack, they dramatically improve the frequency and quantity of particulate emissions data available to regulators. More broadly, CEMS data allows regulators to calculate the total mass of a pollutant released over time, necessary to implementing modern market-based regulation. As such, it is possible that the use of CEMS may also encourage new regulatory instruments.

In 2013, the Central Pollution Control Board (CPCB), and affiliates at J-PAL, South Asia and the University of Chicago, jointly drafted and released the first CEMS specifications in India for low-cost and accurate pollution monitoring.[5] These specifications were designed to produce data that could form the basis of market-based regulatory frameworks such as cap and trade schemes. In February 2014, the CPCB mandated the installation of CEMS in 17 categories of highly polluting industries, following which this pilot was implemented in collaboration with the Gujarat Pollution Control Board (GPCB). A brief timeline of the key steps taken towards CEMS integration can be found in Appendix 1.

[4]Although CEMS can measure several pollutants, the project described here focused on the continuous measurement of suspended particulate matter.

[5]Central Pollution Control Board, 2013. "Specifications and Guidelines for Continuous Emissions Monitoring Systems (CEMS) for PM Measurement With Special Reference to Emission Trading Programs." URL.

2 HOW DO CEMS WORK?

A CEMS for particulate emissions consists of a network of hardware devices and software programs that link monitored industrial plants to the environmental regulator in a manner that allows emissions data to be securely transmitted at regular intervals. The CEMS hardware components required at each industry site consist of the following:

1. Particulate matter CEMS analyzer and flow meters to measure the mass of pollutants emitted.
2. Data logger unit for saving records at the industry-site, in case of internet failure.
3. Data Acquisition System (DAS), normally consisting of a computer at the industry site and a server at the regulator site.
4. Software to visualize and analyze the CEMS emissions data.

The CEMS analyzer for particulates is a device that relates the physical properties of emissions from a factory chimney to the concentration (or mass flow rate) of suspended particles in the air. For example, optical devices measure the attenuation in the intensity of a laser beam sent through smoke. An alternative technology exploits the so called ‘tribo-electric’ effect and relies on measuring the electric charge induced by the movement of particles near a probe.

These approaches to measurement are “indirect” since they measure a property of the gas that is used as a proxy for the presence of solid particles. Therefore, these devices must first be calibrated against manual readings that directly measure the weight of particles in a specified volume of exhaust. In other words, an electrical signal generated by the analyzer must be mapped to a value of particulate emissions. Typically, this mapping is obtained by fitting a linear model relating a set of manual measurements taken at different levels of boiler loads (typically eight readings) to the corresponding measures of current produced by the analyzer.

3 SCOPE OF THE CEMS PILOT

The Continuous Emissions Monitoring System (CEMS) pilot was implemented in 373 highly polluting industries in Surat. With a city population of 5 million and metropolitan population of 6.5 million, Surat is the second largest city in Gujarat and home to 15% of the state’s small-scale industrial units, most of which are in the textile sector. Besides Surat city, the industrial clusters included Pandesara, Udhna, Sachin, Palsana, Kadodara-Vareli and Jolva-Tantithaiya. As indicated in Figure 1, all firms are located within 30km of the city center, and thus their emissions were expected to affect ambient pollutant concentrations for a large sub-population. With a population density in the Surat Metropolitan Area (which encompasses the industrial clusters in the sample) of 4,065 persons/km2, a crude estimate of the number of people in a 20 km radius affected by industrial emissions is 7.9 million. This rough calculation underscores the case for improved emissions monitoring and regulation by showing the substantial number of lives exposed to poor air quality and who would benefit from improved environmental regulation.

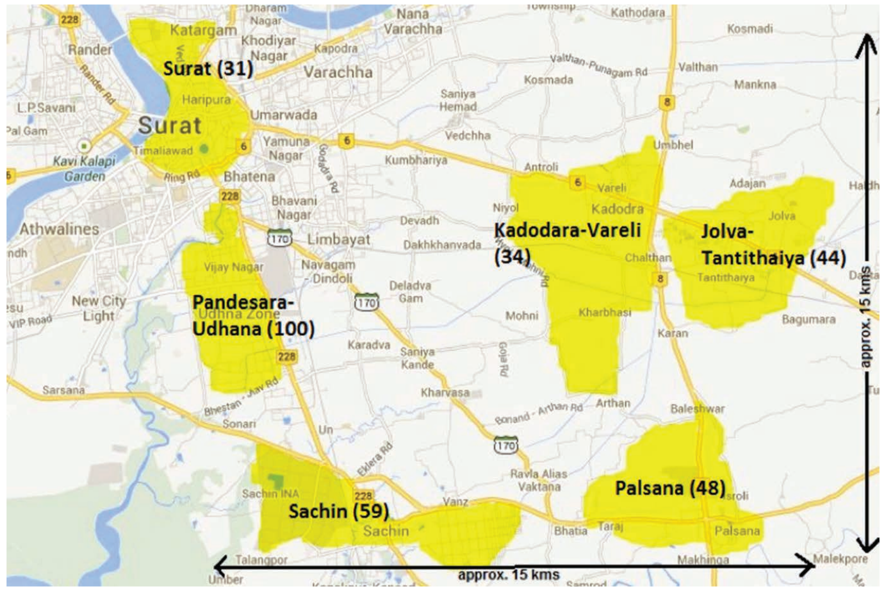


Figure 1: Surat industrial clusters in the CEMS study

The pilot used a randomized phase-in design to evaluate the effects of mandating CEMS installation on different outcomes of interest including (i) PM emissions from industry and (ii) regulator actions taken on industrial plants. Plants in the sample were randomly assigned into treatment and control groups. The former group of industries was required to install CEMS, whereas the latter formed an identical comparison group under the status quo regulation. Figure 2 illustrates the design of the pilot study.

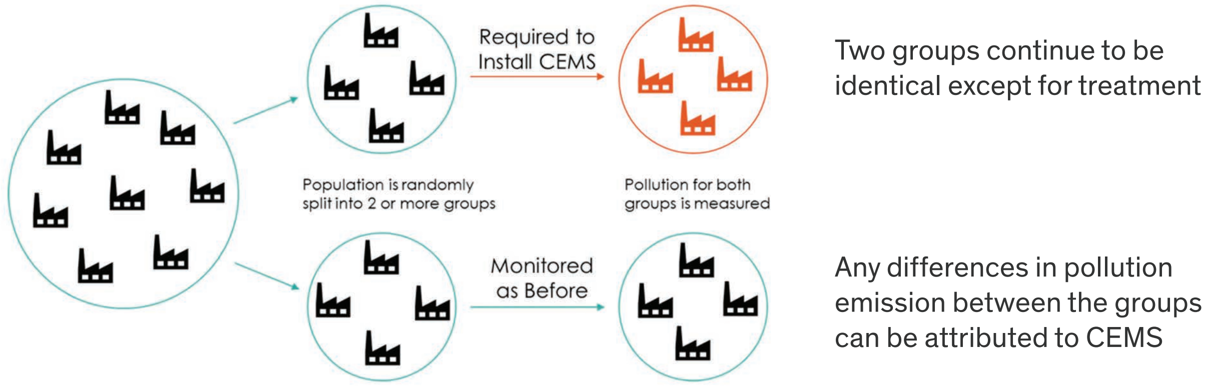


Figure 2: Experimental design of CEMS intervention

The primary question the evaluation aimed to answer was whether PM-CEMS installations reduce SPM pollution from factories. Real-time data on emissions from the industrial stack greatly increases the frequency and quantity of particulate emissions data available to both regulators and industry. As a result, the polluting behavior of plants becomes more visible, and so factories transmitting this data to the regulator may be inclined to reduce emissions to avoid possible penalties. Therefore, we might expect lower overall PM emissions for industries in the treatment group (with PM CEMS) relative to those in the control group (without PM CEMS).

A secondary question of the evaluation was whether regulator behavior changes with access to high quality emissions data. The outcome of interest here is regulatory action on offending units. A CEMS regime could help reduce reliance on frequent manual monitoring by the regulator and lower their costs. By making data available at a high frequency and for all factories, regulators may be enabled to act against violators in a more systematic manner.

To compare treatment and control plants, pollution tests using manual sampling methods were conducted at baseline and endline. Data on the costs of operating pollution abatement equipment was also collected through detailed firm surveys at baseline and endline. In addition, all interactions between the GPCB and plants (such as show-cause notices, industrial plant visits) were tracked as a measure of regulator behavior.

SAMPLE SELECTION

The study sample of 373 industries was made up of predominantly small-scale, textile units situated in and around 30-km of the Surat city. The experimental sample was selected in collaboration with the GPCB based on a set of scientific and objective criteria. The following parameters were used to shortlist these industries:

a. 'Red' Category Industries using Solid Fuel. Red category industries have high pollution potential, with those burning solid fuel have the highest concentration of PM emissions.
b. Proximity to Surat. Participant industries were chosen within a 30km radius of the Surat city centre.
c. Feasibility of CEMS Installations in Stacks. Industrial stacks that qualify the minimum stack diameter for installation of electric probes (per "Revised CPCB Guidelines for Continuous Emissions Monitoring Systems, G.S.R. 96(E) January 29, 2018) were selected under the programme.

The evaluation initially began with a small group of pilot installations in 11 factories, intended to carry out technical tests of different CEMS devices. This first phase was followed by random assignment of the remaining sample of plants to one of three experimental treatment groups. Each treatment group of firms was mandated to install PM CEMS and begin sending CEMS data to the regulator in a staggered manner or in other words, across three phases, numbered II, III, and IV. Therefore, plants without CEMS connections who were assigned to later phases, served as a control group for the plants in Phase II who installed CEMS first. The main evaluation used Phase II as a treatment and Phase IV as a control.
Table 1 indicates treatment assignment and phase-wise status of the rollout.[6]

Table 1: CEMS Phased Roll-out and Treatment Assignment

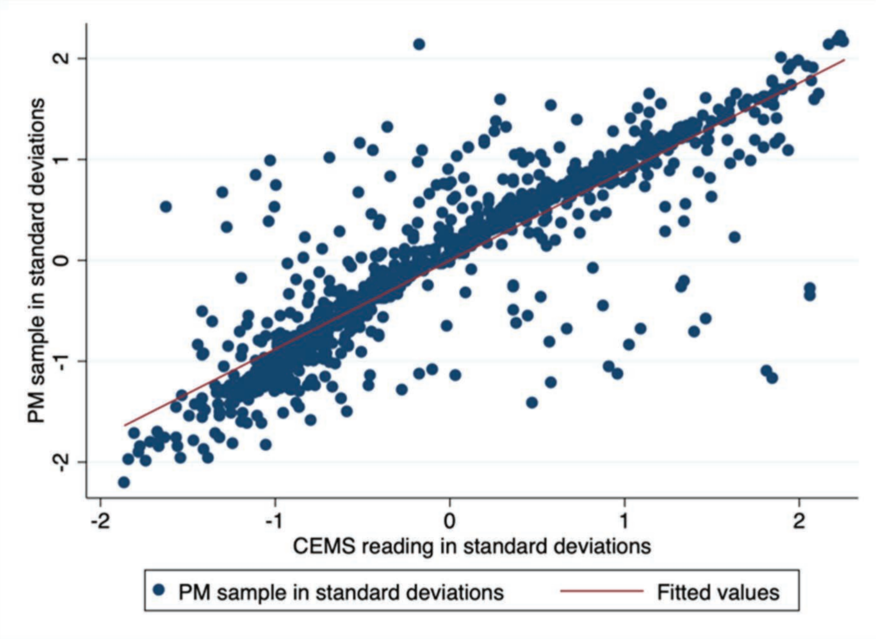
Roll-out Phase	Treatment Assignment	Number of Industries
I	Pilot	11
II	Treatment	141
III	Buffer	82
IV	Control	139

[6]During the baseline, 11 firms from the treatment and 11 firms from the control reported being permanently closed, so they were not surveyed. At the endline, 13 more firms from the treatment closed and 7 from the control permanently closed. The eventual sample used accordingly reduced.

4 DATA TRANSMISSION AND ACCURACY

The calibration process of CEMS devices involves comparing CEMS readings against manual sample measurements. In Figure 3, we plot the correlation between CEMS readings and the PM manual samples in standard deviations. There is a high correlation between the two, validating the basis of using these devices to measure emissions.

Figure 3: Correlation between CEMS reading and manual PM Sample



CEMS data ideally provides an account of minute-wise emissions data generated by CEMS devices throughout an entire day. In practice, plants may cease transmitting data for several reasons, including technical faults, internet outages, poor maintenance, power outages and so on. Figure 4 shows the evolution of data availability over the course of the project.

With regulators and industries both receiving calibrated (hence, more reliable) real-time emissions data, a variety of tools were developed to enable each stakeholder to use this data for effective action. These include:

1. An interactive user-based website and mobile application, which allows regulators to easily identify and quickly react to offending units.
2. A mobile application to enable plants to track hourly trends in their emissions and consult experts to solve problems as they arise. This also allows device vendors to monitor the performance of their devices and alert industries when a maintenance visit is required.
3. Weekly/monthly reports to provide more detailed insights into overall and industry-wise performance over different periods of observation.
4. Development of performance indicators which allow the regulator to place units on a gradient of severity and efficiently target resources using a pre-defined set of performance-based actions.

5 INTEGRATING CEMS INTO THE REGULATORY FRAMEWORK

The project team worked with GPCB to develop an action framework for treatment firms to characterise non-compliant industry behaviour based on two parameters: Data Availability and PM Emissions. Designed to target the worst performing firms, a feature of the framework was that it offered a graded set of actions, which escalated in severity with the level of non-compliance. See Appendix 2 for a complete description of the CEMS Action Framework.

Ratified and implemented in April 2018, the framework initially saw a staggered implementation with GPCB sending auto-generated SMS/emails to firms that were either not sending data or reporting high levels of pollution. Continued poor performance was tied to other actions, starting from in-person meetings, then site-visits with manual pollution testing, and finally legal show-cause notices. Table 2 shows the number of times different steps in the action matrix have been implemented by the regulator both in Treatment and Control up to January 2020.

Implementing the framework in Phases I and II of the study helped achieve significant improvements in data availability as evident from Figure 4, which shows data reporting from CEMS for the period of Jan 2018 to July 2019. The implementation of the regulatory framework was also extended to plants in Phases III and IV of the evaluation starting December 2019, following the conclusion of the main experimental evaluation.

Figure 4: CEMS Reporting in Treatment firms from Jan 2018 – Jul 2019

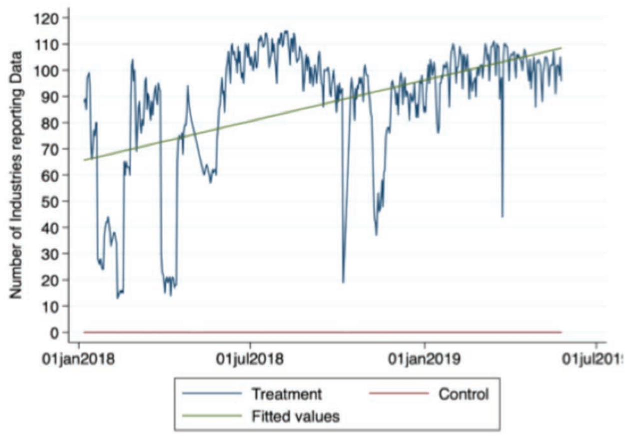


Table 2: Actions taken by GPCB in response to CEMS data

Treatment Assignment	*Month*	*SMS Warning*	*Letter*	*In-person Meeting*	*On-site Inspection and Pollution Test*
Treatment (Phase II)	Mar – Aug 2018	306	166	20	-
	Sep'18 – Feb'19	400	257	121	22
	Mar'19 – Sep'19	440	267	24	5
	Oct'19 – Jan'20	141	119	23	-
	Feb`20 – Mar`20	81	54	-	-
Control (Phase IV)	Dec 2019	13	17	-	-
	Jan 2020	15	15	18	-
	Feb – Mar 2020	-	-	-	-

6 IMPACT

To measure key outcomes of interest, a detailed firm-level quantitative survey was developed and administered as baseline and endline surveys. The survey instrument had a general section to collect data on firm fuel consumption, production and revenues to understand the scale of operations within the firm, and a technical section to collect information on all emission sources and the operating and maintenance costs of abatement measures installed. A first round of firm level surveys (baseline) was conducted in late 2014 before industries in the sample were identified. A second round (midline) was conducted in 2016, just before the CEMS installation, and the endline survey was conducted between December 2018 and March 2019. The period between the first and second surveys involved an extended amount of technology testing and technical problem-solving. At the time of starting the project CEMS devices were rare in India, resulting in several challenges in implementation.

For the pollution analysis, data from manual PM sampling, CEMS data and 'Ringelmann tests' was used. A Ringelmann test refers to a visual method of monitoring plant emissions by comparing the color of smoke against a graded color-scale on an index card. Ringelmann tests are cruder and more imprecise than in-person pollution testing but have the advantage of requiring no interaction with the plant, thus eliminating the possibility of strategic changes in behavior when being tested. These tests are also low-cost and therefore can be repeated frequently, unlike manual samples. Each Ringelmann round consists of a period of approximately two weeks in which surveyors are visiting firms. Four Ringelmann rounds were conducted before the treatment started and nine rounds were conducted after the implementation of the treatment.

GPCB administrative data between 2014 and 2019 was used to analyse the treatment effect on the probability of inspections and legal actions conducted after the implementation of the treatment in April 2018.

RESULTS

A balance check of key characteristics for plants in the study sample is presented in Table 3, showing that these plant characteristics are balanced across treatment and control groups.

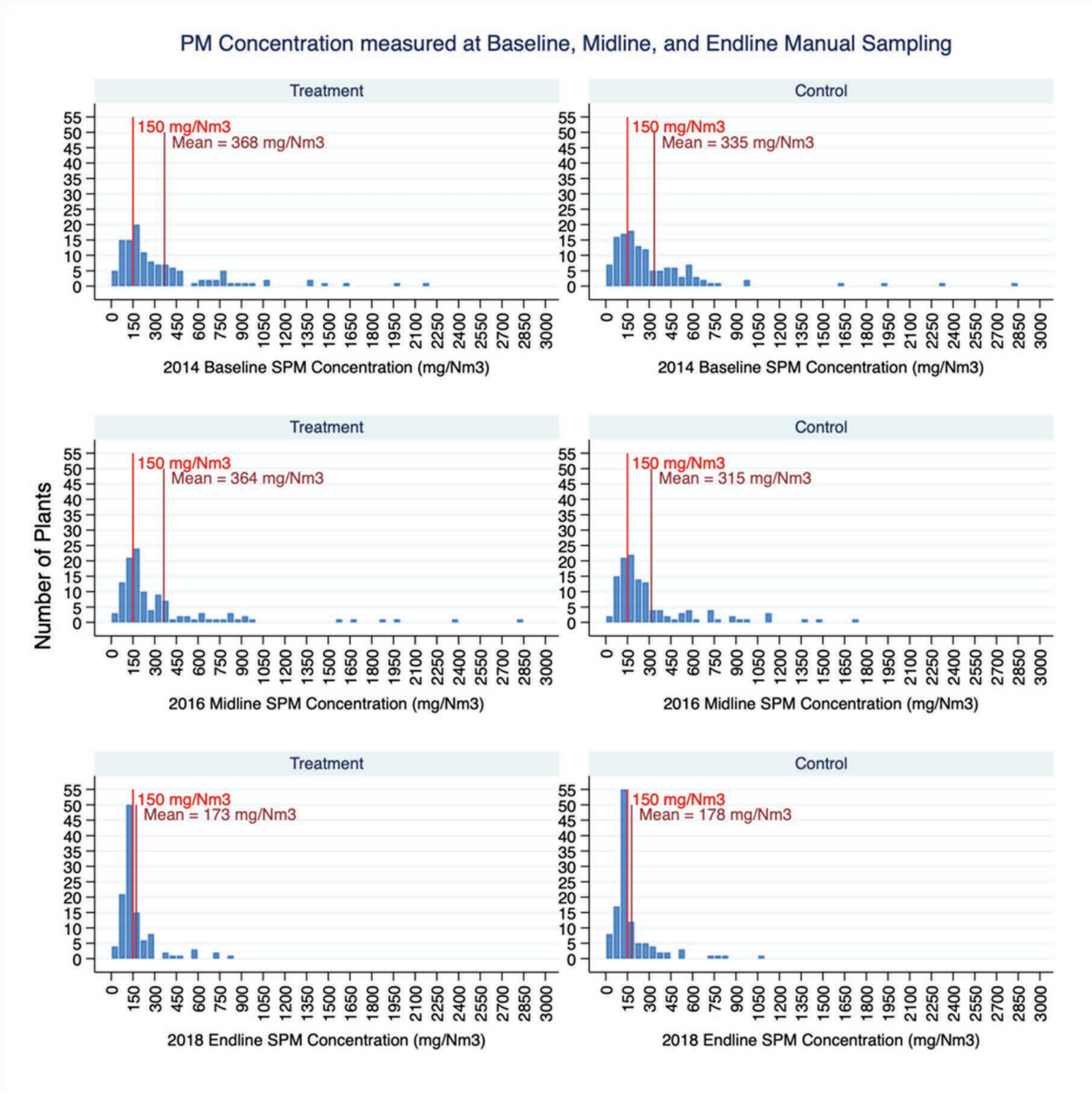
Table 3. Balance check of key plant characteristics at baseline

Panel A: Baseline Plant Characteristics	**Control Mean**	**Treatment Mean**	**Difference**	**p-value**
Asset Value (Excluding Land)	802.81	626.69	176.12	0.40
Gross Sales Revenue Annually	4182.33	2933.72	1248.61	0.28
Employment	261.63	235.21	26.42	0.39
Boiler Capacity	11.48	6.17	5.30	0.26
Thermopack Capacity	17.64	32.81	-15.17	0.60
Observations	128	130	258	
Panel B: Baseline Abatement Behaviour	**Control Mean**	**Treatment Mean**	**Difference**	**p-value**
Operating Cost	7.20	7.24	-0.04	0.97
Maintenance Cost	2.25	2.15	0.09	0.77
Capital Cost	25.85	25.12	0.73	0.92
Recent Modifications Cost	0.07	0.40	-0.32*	0.06
Number of Cyclone	4.16	4.11	0.05	0.81
Number of Bag Filter	2.53	2.69	-0.16	0.59
Number of ESP	0.27	0.16	0.10	0.55
Number of Scrubber	3.12	2.70	0.42	0.14
Observations	128	130	258	
Panel C: Baseline Pollution Emissions	**Control Mean**	**Treatment Mean**	**Difference**	**p-value**
Ringelmann Mean Score	1.62	1.72	-0.09*	0.10
PM Concentration	335.10	368.10	-33.00	0.50
Observations	128	130	258	

Notes: Columns (1) and (2) show means. Column (3) shows the difference among the means, and column (4) shows the p value. . *p<.10, **p<.05, ***p<.01.

The first observation of interest in the results is that over the course of the experiment, all plants—across both treatment and control—reduced pollution (Figure 5). The average PM concentration at baseline was 354 mg/Nm³ with a standard deviation of 384, across the entire sample. The average PM concentration at endline was 173 mg/Nm³ with a standard deviation of 152, across the entire sample. At endline sampling, 31% of plants were out of compliance with the regulatory standard of 150 mg/Nm³, reduced from 71% of plants at baseline. Only 18% of plants at endline sampling had a PM measurement greater than 1.5x the regulatory standard, reduced from 50% of plants at baseline.

Figure 5: Distribution of PM at baseline, midline, and endline by Treatment

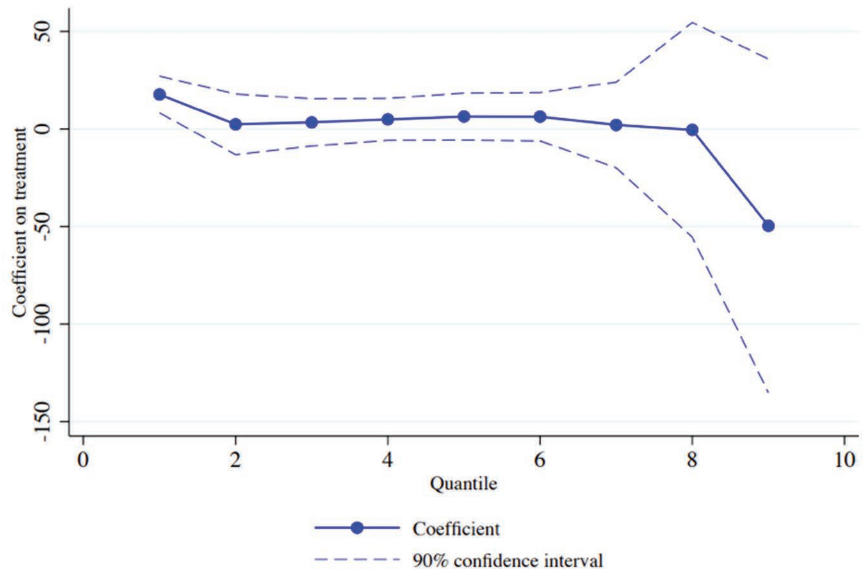


INDUSTRY POLLUTION

Although pollution in the population as a whole reduced from baseline to endline, there was little evidence that treatment plants were cleaner than those in the control. Figure 6 shows results from a quantile treatment effect regression, plotting the difference in quantiles of the distribution of particulate matter emissions, between treatment and control groups. There is little evidence that the pollution levels in plants with CEMS are lower than those without CEMS, across most of the distribution. It is possible that very high pollution plants did reduce emissions under CEMS, but this result is too imprecise to state with confidence.

Why might this be the case, even though the regulator is receiving superior information from the treatment group? One reason could be that the population as a whole reduced pollution due to other factors and once factories were in compliance with the fixed standard (150 mg/Nm3 concentration of particulates in emissions), they had no further incentive to reduce. In other words, CEMS by itself creates no incentive for factories to do more than just about comply with the regulatory standard.

Figure 6: Treatment effects for different quantiles of plant pollution



EXPENDITURES ON REDUCING EMISSIONS

Measurements of pollution during a one-time survey present only a snapshot of environmental performance. It is also useful to see if the expenditure of plants on pollution abatement equipment changes. Table 4 shows results from a regression of different outcomes on an indicator for belonging to the treatment group. Specifically, the analysis considered the number of installed Air Pollution Control Devices (APCDs), their capital cost, and operation and maintenance costs.

The first column shows an OLS regression for estimating the treatment effect of being required to install CEMS, on the number of APCDs a firm had at the endline, controlling by the number of APCD the firm had at the baseline. Columns (2) and (3) consider capital costs and operating and maintenance costs of such equipment.

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The point estimate of the number of APCDs is positive, indicating more pollution reduction equipment, but this finding is imprecise and statistically insignificant. In line with this, capital expenditure on such hardware is also higher in plants that installed CEMS but again the effect is too small to draw strong conclusions. Overall there is little reason to conclude that factories required to install CEMS early behaved differently from those without these devices (required to install them later).

Table 4: Treatment Effects on Abatement Cost

	(1) Number of APCDs	(2) Capital Cost	(3) Op and Maintenance
Treatment	0.24	4.59	-2.25
	(0.18)	(8.02)	(5.29)
# APCDs Baseline	0.85***		
	(0.12)		
Capital Baseline		0.11**	
		(0.05)	
Op and Main Baseline			1.30***
			(0.33)
Industrial-Cluster FE	Yes	Yes	Yes
No. of Obs.	229.00	234.00	234.00
R-Squared	0.52	0.04	0.16
Mean	4.84	35.60	26.05

REGULATOR ACTIONS AND PLANT INTERACTIONS

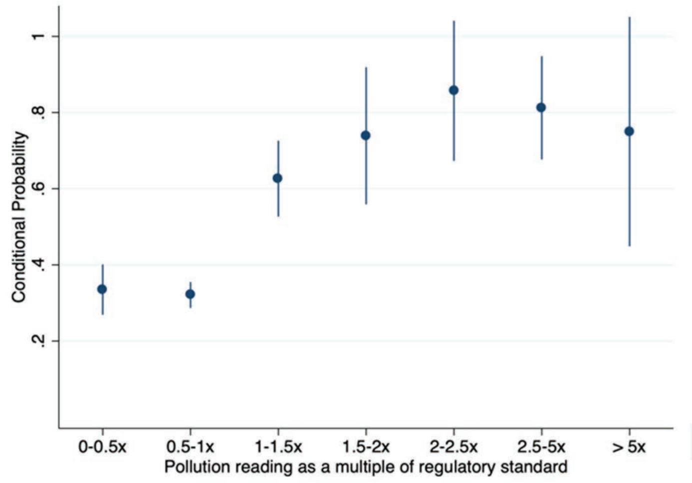
If factories installing CEMS did not reduce pollution relative to those without, one reason might be that the regulator did not use CEMS data to guide decision-making. Administrative data was collected and used to analyze the nature of plant-regulator interactions in the two groups, including in-person inspections carried out by the regulator. These inspections can form legally admissible evidence of over-pollution that may be followed by a show-cause notice or other actions.

There were two main findings:

1. The GPCB did increase the number of warnings sent to plants based on their CEMS emissions levels. There were also about 27 percent more inspections in factories with CEMS relative to the control group.
2. Although inspections increased, these additional visits were not concentrated in the most polluting plants. Previous research has shown that the chain from a legally admissible inspection to eventual reductions in pollution involves several steps (show cause notices, replies by plants, assessments of these responses, eventual actions in court), and inspections lead to reductions in pollution only for very highly polluting plants (Duflo et al 2018). This may explain why, although more visits were made to plants, eventually this did not translate to reduced pollution (in the treatment, relative to control).

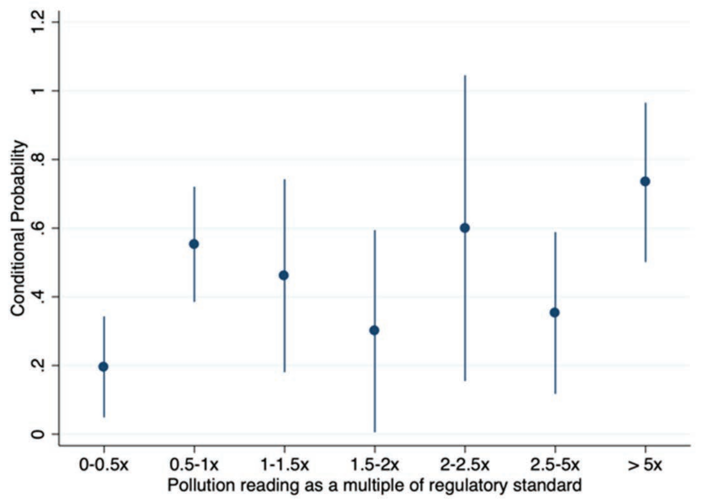
Why did inspection visits to highly polluting factories not increase with CEMS data? In Figures 7 and 8, we show how the probability of receiving a legal notice from GPCB varies with (i) PM concentration samples taken manually during an inspection, and (ii) the average PM concentration reported by CEMS during that period. Figure 7 shows the regulatory response to manual air pollution samples measured at different levels of noncompliance during regulatory inspections. On the y-axis is the conditional probability of a plant receiving a legal action 6 months after a GPCB inspection, given the pollution measurement taken manually at the time of the inspection. Pollution readings are shown in multiples above the regulatory standard of 150 mg/Nm^3. For example, the conditional probability of receiving a legal action given that your plant's pollution measurement during a regulatory inspection in the last 6 months was 2.5 to 5 times the regulatory standard, is approximately 80%.

Figure 7: Getting a legal action based on PM sample during an inspection



In contrast, Figure 8 shows the regulatory response to manual air pollution samples measured at different levels of noncompliance by CEMS. On the y-axis is the conditional probability of a plant receiving a legal action during the 3 months before a regulatory inspection, given the average CEMS readings during those 3 months. For example, the conditional probability of receiving a legal action given that your average CEMS reading in the 3 months before a regulatory inspection was 2.5 to 5 times the regulatory standard, is less than 40%. The probability that GPCB will take regulatory action against a plant is still much more strongly correlated to a manual sample taken during a site inspection than to CEMS readings.

Figure 8: Getting a legal action based on PM CEMS readings



7 IMPLEMENTATION LESSONS AND CHALLENGES

The CEMS infrastructure in Surat has overcome several implementation challenges. This section outlines some of the key process findings instrumental to the successful implementation of PM-CEMS in Gujarat.

MANAGING DELAYS IN THE ADOPTION AND ROLL-OUT OF CEMS

The technical framework of the PM-CEMS based monitoring system consists of a network of hardware devices and software programs that interlink regulated industries to the regulator in a manner that allows emissions data to be securely transmitted at regular intervals. However, issues such as regulatory capacity-crunch combined with infrastructural constraints at the industry level, caused delays in the adoption and roll-out of CEMS technologies. Steps taken to rectify some of these issues are:

1. **Regulatory documentation to aid the continuity of essential operations**: The transfer of senior Pollution Control Board personnel led to considerable delays in the rollout and implementation of the CEMS program. Institutionalizing program protocols and extensive documentation of all regulatory communication have aided the continuity of essential operations.

2. **Stakeholder cooperation built through engagement**: Initial resistance to CEMS installation by industries was resolved through joint meetings between GPCB Surat and the Industry Association to encourage non-compliant industries to install CEMS. Numerous workshops and meetings were conducted to increase knowledge on CEMS technologies. Incrementally building the support of the Industry Association became invaluable in accelerating cooperation at non-responsive industries.

3. **Minimizing technological constraints at industry**: Poor internet connection, obsolete PC configurations, and pervasive unlicensed operating systems were a major challenge to initial roll-out of CEMS. These issues were minimized through intensive follow-up by GPCB and suggestions that industries install an independent broadband connection, purchase a data card or upgrade the PC hardware.

BUILDING INDUSTRY AND REGULATORY CAPACITY

The first step to adopting an accurate and reliable CEMS technology is selecting a device (or combination of devices) that is optimally suitable per the stack characteristics at the industry. However, scouting for the correct technology and ensuring data transmission often requires capacity building at both the industry and regulatory levels. Several steps were taken to ensure technological support to the program.

1. **Collaboration with CPCB to develop technical specification for CEMS**: The appropriate PM CEMS technology is a costly investment for industries and there has been a certain proclivity from industries to scout the technology that is most affordable to them, irrespective of its reliability and accuracy. The CPCB specifications jointly developed with the J-PAL research team, have an in-built technical framework which has helped enforce correct selection and installation of CEMS technologies through a mindset shift towards purchasing effective devices, thereby strengthening the CEMS architecture.

2. **Strengthening the capacity of CEMS technical personnel at Industries**: This has been an organizational constraint in ensuring smooth operations and maintenance of CEMS at industries. Issues like poor sensor maintenance and data unavailability significantly improved when industries were directed to designate and train a CEMS personnel to communicate with the vendor to address or troubleshoot device hardware issues.

3. **Introduction of Comprehensive Maintenance Contracts to bridge Industry-Vendor coordination on CEMS maintenance**: Poorly structured Annual Maintenance Contracts (AMCs) discouraged many industries from renewing their device maintenance contracts, resulting in negligence of the services required to efficiently operate PM-CEMS. The current AMCs in Surat provide few vendor visits for a high price, exclude spare parts and preventative maintenance, and have long repair times. Comprehensive Maintenance Contracts (CMCs) were structured with increased coverage, including vendor liability for CEMS downtime. These CMCs incentivize vendors to resolve CEMS issues quickly and provide industries with long-lasting maintenance and maximum data uptime.

ENSURING ACCURATE AND ROBUST TRANSMISSION OF CEMS DATA

The expertise in CEMS calibrations and data quality is still a constraint, but several steps were taken to rectify the issues encountered. The measures undertaken as detailed below have improved CEMS data quality significantly and have made the data acquisition system (DAS) more reliable and robust.

1. **Ensuring Quality of Calibrations through double-blind sampling**: Calibration of PM-CEMS devices unlike other gaseous pollutants, are conducted through collection of manual dust samples from CEMS installed stacks at Industries. The process which involves an on-site sampling and thimble analysis by environmental labs, contracted by either the industry or CEMS vendor, faces collusion risks resulting in Labs under-reporting manual sampling results, influenced by the industry, vendor or both. To eliminate such issues, a method of double-blind sampling was instituted, where on-site and thimble analysis are conducted by two different labs under GPCB's supervision, thereby minimising the risks of collusion and ensuring the quality of CEMS calibrations.

2. **Minimising data tampering through encryption of CEMS Data Files**: Access to the raw CEMS data (usually stored at the Industry PC) may lead to unobserved tampering of CEMS readings by industry, vendor or environmental labs during calibration. Working with the GPCB IT vendor and CEMS vendors, all locally-stored CEMS data files at the industry PC were encrypted to minimise the risks to data quality and transmission from CSV tampering at individual plants.

3. **Transitioning the GPCB offline server to a cloud-based server resolved data retrieval issues**: Poor internet and low speed at the Gandhinagar server delayed the retrieval of data from plants, that further effected the efficiency of the ETS website and mobile applications hosted on the GPCB server. Subsequently, through consultations with the J-PAL team, GPCB transitioned its offline server to a cloud-based server (AWS) in June 2018, which significantly improved server connectivity, facilitated uninterrupted data retrieval from plants and enabled the industries to access a real-time dashboard to self-regulate their emissions.

4. **Regulatory Actions based on CEMS data helped improve data availability and reduced emissions from plants**: Lack of maintenance of the CEMS infrastructure plagued data availability as well as resulted in occasional abnormal emissions from CEMS. To improve the data availability and quality as well as to act on non-compliant heavy emitters, the project worked with GPCB to formalise an Action Framework for regulating Industries based on CEMS data. The framework was implemented in a staggered manner with GPCB initially targeting the offenders featuring under low data availability and high PM emissions. Auto-generated SMS/Emails were sent from GPCB, followed by regulatory notices and one-on-one meetings, which saw improved data availability from CEMS, and greater awareness among the high-emitters to monitor and self-regulate their emissions.

5. **Ticketing system helped Industries coordinate with the DAHC for resolving CEMS data and device related issues**: A backlog of device and service complaints at industries caused delay in addressing data availability issues by the Data Acquisition and Handling Centre (DAHC) at GPCB. A ticketing system was created with the GPCB IT vendor, for industries and CEMS vendors to log device and service complaints. This system has greatly improved transparency and accountability for both industries and vendors and led to faster response times for CEMS servicing.

8 CONCLUSION

The results of this pilot intervention provide some important lessons for policymakers. The project showed that it is inexpensive and technologically feasible for even small plants to install CEMS equipment and send relatively high-quality data to regulators. The technology, therefore, can work in the Indian context. However, if the eventual goal is to use CEMS devices to drive pollution reductions, more steps might be needed than merely forcing plants to install these devices. This conclusion is drawn from the result that although pollution as measured by manual sampling decreased overall from baseline to endline, there was no significant difference in pollution between treatment plants (required to install CEMS) and control (not required to install CEMS). It is important that regulators use this data directly in order to initiate the legal actions that are the main incentive for plants to comply with pollution regulations.

Currently in India, even when CEMS devices are installed and sending data, this information is not by itself legally actionable. Initiating legal action against a plant requires in-person manual testing by the regulator. This is a significant weakness because it means that state pollution control boards continue to privilege manual testing data over the information from continuous emissions monitoring systems, and eventually must spend scarce resources on in-person inspections before any serious pressure can be brought to bear on polluters. In such a context it is likely that minor or moderate violators will see no real difference in regulator actions—they may receive more warnings, as in fact happened, but more meaningful action may continue to be restricted to a subset of heavily polluting firms.

Nevertheless, these weaknesses in a sense merely highlight the failings of command-and-control regulation, which relies on heavy penalties administered through a slow-moving criminal process requiring several steps of regulator-plant interactions. A potentially much more meaningful advantage of introducing CEMS technology is that it enables newer and more effective regulation, not merely that it might improve existing systems.

On this second aspect the CEMS pilot in Gujarat has led to transformative change. Following the installation of these devices and the availability of real-time data, in 2019 the Gujarat Pollution Control Board launched the world's first emissions trading scheme (ETS) for particulate matter, explicitly built on data from these devices. An ETS has the potential to reduce both pollution and industry costs, whilst being nimbler, more transparent, and easier to administer than command-and-control regulation. The evaluation of the impacts of this Emissions Trading Scheme is presently ongoing.

APPENDIX

APPENDIX 1: CEMS EVALUATION TIMELINE

2014 - 2015
- CPCB mandate on CEMS installations
- Sample identification and Baseline survey
- Identification of suitable hardware and software vendors and establishing the Data Acquisition and Handling Center in Surat

2016 - 2017
- Rollout to CEMS1 industries: Installations and Calibration
- Development of interactive website and mobile application
- CEMS Recalibrations

2017 - 2018
- Rollout of the CEMS Action Framework in Treatment firms
- Rollout to CEMS2 industries: Installations and Calibrations
- Ringelmann Surveys

2018 - 2019
- Endline Survey
- Rollout to CEMS3 industries: Installations and Calibrations
- Rollout of the CEMS Action Framework in Control firms

APPENDIX 2: CEMS ACTION FRAMEWORK

The CEMS software generates weekly report with two key metrics:

a) Data-Performance: Indicates the percentage of data transmitted by the CEMS device to GPCB server.

b) PM-Performance: Measured by PM Score which indicates the duration and extent for which reported PM emissions exceeded legal standard.

Actions to be taken

A. DATA PERFORMANCE		
Action	*List of Industries*	*Detailed Criteria*
Regional Office sends auto-generated SMS and email to industry	As per report	Industry is one of 5 with lowest positive data availability and mean data availability is <85% in the *past week* **(OR)** Industry has zero data availability in last one week
Regional Office sends auto-generated email and letter to industry	As per report	Industry is one of 5 with lowest positive data availability and mean data availability is <85% in the *past 2 weeks* **(OR)** Industry has zero data availability in last two weeks
Regional Office meets with industry and CEMS vendor	As per report	Industry is one of 5 with lowest positive data availability and mean data availability is <85% in the *past 3 weeks* **(OR)** Industry has zero data availability in last 3 weeks
Regional conducts site visit and collects stack sample	As per report	Industry is one of 5 with lowest positive data availability and mean data availability is <85% in the *past 4 weeks* **(OR)** Industry has zero data availability in last 4 weeks
Regional Office issues show-cause notice	As per report	Sample results indicate that industrial emissions are higher than the legal standard

B. PM PERFORMANCE		
Action	*List of Industries*	*Detailed Criteria*
Regional Office sends auto-generated SMS and email to industry	As per report	Industry is one of 5 with worst PM performance in the past 1 week and exceedance duration *> 0 hours*
Regional Office sends auto-generated email and letter to industry	As per report	Industry is one of 5 with worst PM performance in the *past 2 weeks and exceedance duration > 0 hours*
Regional Office meets with industry	As per report	Industry is one of 5 with worst PM performance in the *past 3 weeks and exceedance duration > 0 hours*
Regional Offices conducts site visit and collects stack sample	As per report	Industry is one of 5 with worst PM performance in the *past 4 weeks and exceedance duration > 0 hours*
Regional Office issues show-cause notice	As per report	Sample results indicate that industrial emissions are higher than the legal standard

MEDIA COVERAGE


THE TIMES OF INDIA

World's first emission trading scheme yields positive results

Himanshu Bhatt & Kapil Dave | TNN | Oct 24, 2019, 13:13 IST

SURAT/GANDHINAGAR: World's first emission tradi scheme (ETS) for particula matter 10 (PM 10) launched Surat a month ago has sh positive results.

In the one month of its lau on September 15 in 155 industrial units of highly polluted Pandesara area, trading has been done 38 times and the emission ca

Before the ETS pilot, the 155 units were emitting 362 tonnes of carbon per month


BBC NEWS

India air pollution: Will Gujarat's 'cap and trade' programme work?

12 July 2019


NBT नवभारत टाइम्स

गुजरात में पर्यावरण दिवस पर शुरू होगी उत्सर्जन व्यापार योजना

डिसक्लेमर:यह आर्टिकल एजेंसी फीड से ऑटो-अपलोड हुआ है। इसे नवभारतटाइम्स.कॉम की टीम ने एडिट नहीं किया है।

भाषा

Updated: 04 Jun 2019, 08:42:00 PM

अहमदाबाद, चार जून (भाषा) गुजरात सरकार बुधवार को 'उत्सर्जन व्यापार योजना' (ईटीएस)शुरू करेगी। इसके तहत कोई कंपनी अगर निर्धारित सीमा से अपना उत्सर्जन घटाती...


The Indian EXPRESS

In a 'first', Gujarat to launch trading system with incentive for low polluting industries

The programme is being piloted in Surat as it is a densely populated industrial centre where textile and dye mills release a "significant" amount of air pollution.

Written by Prabha Raghavan | New Delhi | June 6, 2019 3:56:31 am

The programme is being piloted in Surat as it is a densely populated industrial centre where textile and dye mills release a "significant" amount of air pollution.


the quint

Gujarat Becomes First Indian State to Launch Emissions Trading

From August, the emissions trading scheme would come into effect for all industrial units in Surat, an official said

THE QUINT

Published: 06 Jun 2019, 8:49 AM IST

ENVIRONMENT

2 min read

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