Challenge of integrated low-cost emission monitoring system into a digital information system

A M Simbolon¹, J A Fatkhurrahman², A Mariani³, I R J Sari⁴*, Syafrudin⁴, Sudarno⁴

¹ Department of Environmental Engineering, Universitas Diponegoro, Semarang, Indonesia
² Department of Environmental Engineering, Institut Teknologi Bandung, Bandung, Indonesia
³ Center of Industrial Pollution Prevention Technology, Ministry of Industry
⁴ Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia
⁵ Department of Education Management, Universitas Negeri Semarang, Semarang, Indonesia

ikha.rasti@gmail.com

Abstract. The emission from industry has become a significant problem in Indonesia. Usually, the enterprise uses an accredited testing laboratory to conduct emission tests to report its process's environmental performance. In contrast, this testing was accurate, but it cannot visualize whole time emission from one method. This year, the Covid-19 pandemic also gained some difficulties in environmental evaluation in the industry, including emission performance evaluation. Some big companies may have expensive continuous emission monitoring that can substitute manual laboratory testing. Some other, the small and medium scale industry did not have this system. There is a possible development of an integrated low-cost emission monitoring system in the small-medium scale industry. The low-cost gas sensor rapidly develops and gets more accurate. An engineering scenario of integrating low-cost emission monitoring systems into digital information systems could be developed under some challenges, instrumentation, calibration, and regulative support. By applying this scenario, periodical emission concentration can be evaluated periodically to support air quality management policy.

1. Introduction
The negative effect of emission from industry becomes a significant problem for air quality as industrialization growth year by year in Indonesia. Several emission contaminants could have a negative impact both for health and the environment [1]. Sulfur dioxide, nitrogen oxide, and carbon monoxide were major gases emitted from the industrial burning process. At the same time, particulates will follow as emission with coarse and fine particulates diameters, including PM 1, PM 2.5, and PM 10. Gaseous emission could damage the human respiratory system and cardiovascular system. There will be lung function degradation affected by long term exposure of sulfur dioxide, while nitrogen dioxide as secondary emission of nitrogen oxide will cause chronic lung disease [2]. High-level carbon monoxide in blood will extenuate hemoglobin-oxygen binding capability that might cause death if more than 1000 ppm captured in blood [3]. Sulfur dioxide and nitrogen oxide could damage the environment by
producing an acid condition in the rain, then descend as acid rain that reduces material strength [4], grind soil fertility, and degradation of biodiversity [5].

Emission negative effect spin Government of the Republic of Indonesia to regulate several emission regulations to confine emission from each industrial sector. They have to report emission evaluation from each burning process to the Ministry of Environmental and Forestry (MoEF) once in six months by SIMPEL (Electronic Evaluation System of Ministry of Environmental and Forestry). It is a manual report based on digital form input for each industry. In 2018, MoEF regulated Onlimo (Online Monitoring) for wastewater quality monitoring from several major industrial sectors in Indonesia. While this regulation has settled for wastewater, MoEF just started to adopt an online emission report based on continuous emission monitoring system (CEMs) integrated with a digital information system named SISPEK (Continuous Industrial Emission Information System). It started to regulated for power plant industry in 2019 to apply this integrated system. Both CEMS and SISPEK are a costive system for small and medium-scale sectors since each industry could invest their high capital cost for each CEMs on every industrial burning process [6]. Also, expensive maintenance operation costs each year; this is an abusive situation since many small and medium-scale industries still struggle to fulfill emission monitoring unit requirements [7].

The needs for low-cost emission monitoring systems integrated into a digital information system are urgent. At the beginning of 2020, a Covid-19 pandemic stopped testing laboratory activity from conducting emission tests in the industry. This condition leads to delays in emission and air quality reports for the industry that did not have CEMS reported to SISPEK in their process. Delay in emission report is quite alarming in potential hand hazards of air pollution from the emission process. Researchers have found that a low-cost emission monitoring system could be adopted for this purpose of emission report. Fat Kathurrahman et al. (2019) show that using a low-cost ammonia sensor can evaluate and control ammonia emission from the medium-scale crumb rubber industry [8]. They used a cheap metal oxide sensor to read ammonia concentration from the drying process, integrated with Arduino based microcontroller to control debit from wet scrubber activity. Wet scrubber effectivity optimization based on this system can measure ammonia emission in real-time. They also develop a low-cost particulate sensor to control the wet scrubber process to gain its efficiency [9].

In contrast, another research described a digital platform to monitor CO, NOx, and CO2 pollution from road traffic emission using low-cost sensors and raspberry pi to send the data into electronic databases in SQL format [10]. Based on reality, the possibility of the low-cost sensor for environmental quality measurement growth, as the development of a cheap microcontroller from the beginning of the 2000s. Almost previous research did not study how to integrate monitoring systems into digital information-based system analysis. With some integration with data transmission into a server, it can be applied as a digital information system, even though it will be a more complex field. A fundamental challenge needs to be conquered once we develop low-cost environmental monitoring; instrumentation, calibration, coverage, processing, and incentivization [11]. This challenge may differ in Indonesia since different industrial habits and regulations exist between countries and need to be concluded later.

2. Methodology

Within this Covid-19 pandemic, the industry in Indonesia faces difficulties in environmental reports and evaluation. They depend on the testing laboratory that has several limitation activities during the pandemic. Industry, regulatory agency, and research and development agency need to settle a new approach in applying environmental monitoring systems, including low-cost emission monitoring integrated with the digital information system. It needs to be used through the whole industrial sector, including small and medium scale industries. If this approach is successful, it can be developed by participatory-based monitoring and emission maps for the entire industrial sector in Indonesia. Finally, this development of low-cost emission monitoring systems could be powerful tools for environmental research, enabling measurement at the industrial community scale. At the same time, accuracy and stability demands may vary.
When a low-cost sensor is used as an integrated emission monitoring system into a digital information system, these engineering scenarios can be applied. The low-cost sensor may be connected to an electronic detection module. An esp32 board or Arduino can be used as a cheap detection module. From the detection module, data reading from the sensor was then transmitted into an internet gateway. An open source-based microcomputer like raspberry pi could be used as an internet gateway by considering future development. It is still in progress development by the manufacturer, high capability, Linux based operating system, universal and adaptive into much connectivity data transmission formats like JSON and SQL database format. Data from this gateway then transmitted into the database server, including an alternative option. It can be connected to a regulated SISPEK server with fulfilling their requirement. Internally, it can be integrated into a digital dashboard with an information system under web application or mobile information system in android or iOS. The whole scheme of this suggested engineering scenario of low-cost emission monitoring integrated into a digital information system could be described below.

![Diagram](https://via.placeholder.com/150)

**Figure 1.** Schematic engineering scenarios of low-cost emission monitoring system; 1. emission source, 2. interference eliminator, 3. the gas pump, 4. detection module, 5. internet gateway, 6. sensor array, 7. drain, 8. database server.

Various data transmission could be settled using this scenario, direct data transmission into the server, then tabulated into SQL database, or adding security data transmission using data encryption is possible to make this system more reliable.

3. **Results and discussion**

As we mentioned above, some outlined challenges need to be discussed in detail, which can be concluded into three significant challenges, calibration, instrumentation, and regulation support for this scenario could be vastly applied to the industrial community and accepted by the regulator.

3.1 **Calibration**

We have to state that the low-cost sensor will have weaknesses in stability and accuracy [12,13]. Stability problem may occur and needs periodic calibration more frequent to diminish this problem [14]. There are two principles in low-cost sensor calibration; exposing sensors with constant standard gas calibration or co-located with the same sample matrix read by reference instrument [15,16]. Multiple points exposing the sensor with standard gas calibration can be selected for calibration. A gas dilution system to make various gas concentrations would be the best method to test the linear correlation between the sensors' attention in many variations. This linear correlation is stated as the correlation
between the actual value of gas concentration in every sensor data response. The sensor calibration scheme using the gas calibration standard could be seen in figure 2.

![Figure 2. Schematic design of calibrating low-cost sensor using gas calibration standard; 1. nitrogen, 2. gas calibration standard, 3. nitrogen valve, 4. gas calibration valve, 5. gas dilution system, 6 with a low-cost sensor.](image)

An alternative method, the co-location method, correlates the sensor response with a reference instrument, as stated by Fatkhurrahman et al. (2020) [17]. This method needs the same emission sample flow between the low-cost sensor and reference instrument. Data should be tabulated in synchronous time, so linear correlation could be made between these two instruments, as seen in figure 3.

![Figure 3. Schematic design of calibrating low-cost sensor using co-location method; 1. emission source, 2. low-cost sensor instrument, 3. reference instrument or a gas analyzer.](image)

Both methods can be used as low-cost sensor evaluation since Lin et al. (2015) also stated that much low concentration level of the low-cost gas sensor shown good correlation compared to its reference instrument, also Spinelle et al. (2017) for field calibration of several sensors shown useful linear and multilinear regression of low-cost sensor compared to its reference instrument [18,19].

### 3.2 Instrumentation
Instrumentation used in emission monitoring could be derived into several classifications; for laboratory testing, they will use portable and mobile emission monitoring instrumentation. It is a standard and accurate instrument that is periodically calibrated in the calibration laboratory. The testing laboratory then issued a laboratory report to the industry as emission evaluation, which is a grab sampling report and does not cover periodical evaluation report. Several large-scale industries applied fixed CEMs that capable of real-time and continue emission reports through an online system. This online system could
be integrated into the digital information system internally and externally to the regulation agency through MoEF’s *SISPEK*. Our research, therefore, focused on low-cost emission sensors as integrated emission monitoring through developed digital information systems as a previous study of [8,20] create in the Center of Industrial Pollution Prevention Technology (BBTPPI) under the Ministry of Industry (MoI).

![Figure 4](image)

**Figure 4.** (a) Typical whole instrument data of low-cost particulate sensor correlated to reference instrument, (b) time series of the fitted low-cost particulate sensor by linear approximation between sensidyne instrument as a reference and sharp gp2y1010 as a low-cost instrument for particulate reading, picture authorized taken from [21].

Besides fulfilling this engineering scenario, besides calibration, a reference instrument is also one key to the successful application of this low-cost sensor for emission monitoring. Reference instrument reading could be one of the standard low-cost sensor stability readings from the original emission source to be evaluated thoroughly.

### 3.3 Regulative support

The development of low-cost sensors as emission monitoring needs to be supported by each related stakeholder like MoEF and MoI. As we see, there are also many low-cost sensors available on the market by now with diverse specifications and sensitivity. Both ministries need to standardize a low-cost sensor to guarantee accuracy, stability, lifetime, and calibration method. Research and development of low-cost sensors also need to be supported, as there is an Indonesian researcher whose research in developing achievable gas sensors [22,23]. Standardization on data transmission and connectivity standards also needs to be made to gain trust for this entire system, including data security and encryption. Finally, regulative support by giving some incentives could be an option to increase industrial participation using this low-cost emission monitoring system. One of these incentive options could be integrated into the Green Industry policy as MoI regulated it. Some incentives could be supported for this program, like permit systems, taxes on emission, charges, subsidies, and a combination of tax-subsidy [24]. Collaboration between MoEF and MoI needed to create air quality management, including research, supports air quality control both for industry and the environment. In the future, we could use this system as a data inventory of emissions from the entire industrial sector in Indonesia. In the hand of that mitigation, databases and emission maps could be developed much better.

### 4. Conclusion

Some research proves that a low-cost environmental monitoring system could be established to resolve costly environmental monitoring systems besides pandemic situations that faced a lack of ecological testing due to physical distancing activities. An engineering scenario could be developed by utilizing a low-cost sensor to monitor emission from the industrial process, integrated with a digital information system. It can be a solution to the internal evaluation of the environmental quality and external evaluation since MoEF has to settle *SIMPEL* and *SISPEK* for environmental reporting. Some challenges
on calibration, instrumentation, and regulative support could be the best option to achieve an integrated monitoring system through a digital information system.

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