

Interpretation and Communication of Short-term Air Sensor Data: A Pilot Project

Background

Low-cost portable air quality sensors are becoming increasingly available to the public and there is a need to help people interpret air quality concentrations that are collected and reported in increments as short as 1 minute. To provide guidance to the public and to sensor manufacturers on the appropriate interpretation and communication of 1-minute sensor data, EPA's Office of Air and Radiation and Office of Research and Development are conducting a pilot project that uses short-term data from the Village Green Project and regulatory monitors to develop short-term scales and associated messages about potential personal exposure, for ozone (O₃) and particulate matter (PM_{2.5}) (<http://bit.ly/VillageGreenPilot>). This summary describes how EPA analyzed and interpreted available short-term data that are the basis for both the scales and the messages. This information is intended to help the public understand what a 1-minute sensor reading may indicate in terms of local air quality and pollutant exposures. The Village Green Project is a community-based activity to demonstrate the capabilities of new real-time monitoring technology that makes data available online and by smartphone (<https://www.epa.gov/air-research/village-green-project>). EPA is using Village Green sites for the pilot project because they are streaming 1-minute data of known quality.¹

In order to help the public understand the short-term air quality data being recorded on a sensor, EPA developed categories representing a low-medium-high scale corresponding to 1-minute sensor readings. Categories representing the different "breakpoints" were assigned different messages that provide information about how the short-term concentration may be related to overall local air quality and personal exposure. EPA is testing the effectiveness of the breakpoints and messages that are described in this paper during a spring-summer 2016 pilot project. After concluding the pilot project, EPA may refine the breakpoints and/or messages as appropriate, with a goal of making the scales and messages available to air quality sensor developers later in 2016. The breakpoints and messages may also be periodically refined based on additional data or user feedback.

The low-medium-high scales and messages described in this paper are based on analyses of U.S. air quality data and on pollutant concentrations near sources in the U.S.; as such, they are appropriate only for use in the U. S. This information is intended to help users understand air quality data and associated exposures, and provide a tool for planning activities. EPA cautions that the sensor breakpoints are not to be used for regulatory purposes.

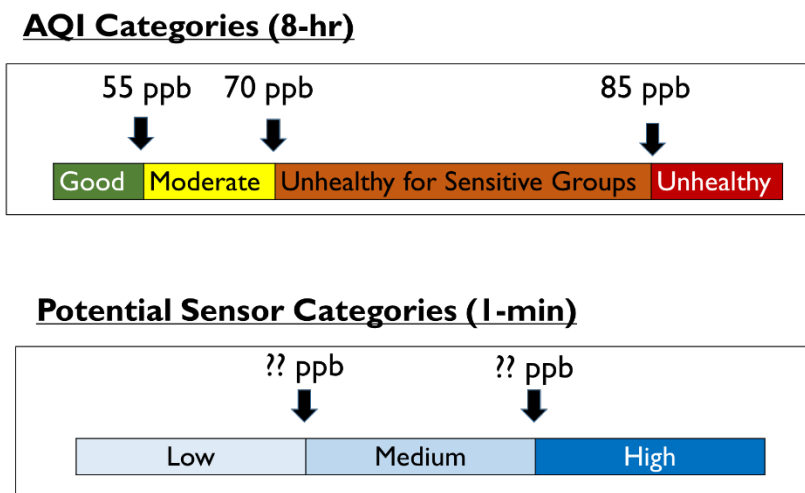
Conceptual Approach to Selecting Numeric Sensor Scales and Associated Messages

A primary challenge to interpreting the significance of 1-minute air quality concentrations is that health studies do not support linking 1-minute O₃ or PM_{2.5} exposures to adverse health effects. Consistent with the available health evidence, EPA's existing standards and tools that interpret air quality – the national ambient air quality standards (NAAQS) and the Air Quality Index (AQI) -- are based on longer exposure periods, such as eight and 24 hour averages. Therefore, it is not appropriate to directly compare a 1-minute O₃ or PM concentration from a sensor to the level of the NAAQS or to AQI breakpoints. In addition, there is an inconsistent relationship between 1-minute O₃ and PM_{2.5} ambient concentrations and ambient concentrations with longer averaging times for which we have health information. Consequently, the potential health implications of 1-minute sensor readings are not clear.

¹Jiao, W., Hagler, G.S.W., Williams, R.H., Sharpe, R.N., Weinstock, L., and Rice, J. Field assessment of the Village Green Project: An autonomous community air quality monitoring system. *Environ. Sci. Technol.* 2015, 49, 6085-6092.

While it is not appropriate to directly compare 1-minute sensor readings to either the level of the NAAQS or to AQI categories, it is appropriate to set 1-minute sensor breakpoints such that, to the extent possible, sensor messages received over a given time period are consistent with concurrent messaging based on longer-term pollutant concentrations (e.g., messages related to the NAAQS and the AQI). For example, a 1-minute sensor reading in the “Low” category should primarily correspond to a longer-term average pollutant concentration below the level of the NAAQS, and a 1-minute sensor reading in the “High” category should primarily correspond to a longer-term average pollutant concentration above the level of the NAAQS. Figure 1 illustrates the conceptual relationship between the AQI categories and potential sensor categories for O₃.

Figure 1. Conceptual relationship between the AQI categories and potential sensor categories for O₃



Analytical Approach for O₃ Sensor Scale and Messages

To inform the identification of O₃-specific sensor breakpoints and messages, we analyzed the relationship between 1-minute O₃ concentrations and 8-hour average O₃ concentrations. Based on this analysis, we considered how sensor readings could relate to the O₃ NAAQS and to the O₃ AQI categories.

To develop the low-medium-high scale for O₃, EPA examined 1-minute O₃ concentrations from 18 sites with regulatory-quality data (4 Village Green locations and 14 Federal Reference Method (FRM) monitors). In total, there were 7.6 million observations over 823 days.


A statistical analysis was conducted to examine: (a) how 1-minute O₃ concentrations are related to 8-hour average concentrations, and (b) how these 8-hour average concentrations relate to the level of the O₃ NAAQS and to the O₃ AQI categories. The statistical analyses are described in separate summaries, which can be found at <http://bit.ly/SensorScalePilot>. Based on the analysis for O₃ EPA determined that:

- 1-minute sensor readings in the range of 0 to 59 ppb would best represent a “Low” sensor message, because analyses indicate that the corresponding 8-hour average concentration would almost always be below the level of the O₃ NAAQS and in the “good” or “moderate” AQI category;
- 1-minute sensor readings in the range of 60 to 89 ppb would best represent a “Medium” sensor message, because analyses indicate that the corresponding 8-hour average concentrations would mostly correspond to the “moderate” AQI category and sometimes to the “unhealthy for sensitive groups” AQI category;

- 1-minute sensor readings in the range of 90 to 149 ppb would best represent a “High” sensor message, because analyses indicate that the corresponding 8-hour average concentrations would almost always be above the level of the O₃ NAAQS and in the “unhealthy for sensitive subpopulations” or “unhealthy” AQI category; and
- a “Very High” category, while expected to be a very rare occurrence, would be represented by 1-minute readings of 150 ppb or higher, which could indicate very high O₃ concentrations, or could also indicate a malfunctioning sensor.

Pilot O₃ messages for the various sensor categories are shown in Table 1.

Table 1. Pilot version: 1-minute O₃ readings

Pilot Version* 1-Minute O₃ Readings <i>(Not for regulatory purposes)</i>	
Low 0-59 ppb	Enjoy your outdoor activities.
Medium 60-89 ppb	If medium readings continue, use the Air Quality Index to plan outdoor activities.
High 90-149 ppb	If high readings continue, consider adjusting outdoor activities, especially if you are sensitive to ozone. Check the Air Quality Index to find out.
Very High >150 ppb	If high readings continue, consider adjusting-outdoor activities. Check the Air Quality Index to find out. Very high readings may mean the sensor is not working properly.
	Sensor may be offline. Check the Air Quality Index.

* May be refined as data sources are periodically updated.

Analytical Approach for PM_{2.5} Sensor Scale and Messages

To develop PM_{2.5} sensor categories, we built off of the approach used for O₃, but the available 1-minute data from Village Green benches for PM_{2.5} were more limited than for O₃ (only 5 monitors) and varied considerably based on location and source influence (e.g., fireworks and wildfires). By comparison, there is a robust dataset of high quality 1-hour monitoring data for PM_{2.5}, which led EPA to conduct a statistical analysis that considered the relationships between 1-hour and 24-hour PM_{2.5} average concentrations rather than relying on the 1-minute PM_{2.5} data. This analysis evaluated 1-hour PM_{2.5} air quality data from 386 sites with FRM monitors for the years 2012 – 2014, which included ~ 7 million 1-hour averages over 1,096 days. EPA took this longer exposure time into account when developing the sensor messages for PM_{2.5}. Specifically, the “Low” and “Medium” sensor messages correspond to sensor readings that stay in the same range for an hour or more, not for just a few minutes as could occur when an emissions source is temporarily nearby.

Based on the assessment of the relationship between 1-hour PM_{2.5} average concentrations and 24-hour average concentrations, EPA determined that:

- Sensor readings in the range of 0 to 29 µg/m³ that continue for 1 hour or more would best represent a “Low” sensor message, because analyses indicate that the corresponding 24-hour average concentrations would be in the “good” or “moderate” AQI category for PM_{2.5};

- Sensor readings in the range of 30 to 69 $\mu\text{g}/\text{m}^3$ that continue for 1 hour or more, would best represent a “Medium” sensor message because the corresponding 24-hour average concentrations would generally be in the “moderate” or “unhealthy for sensitive groups” AQI category (although some corresponding 24-hour average concentrations would fall into the “good” or the “unhealthy” category).


For the “High” and “Very High” $\text{PM}_{2.5}$ sensor categories, an approach different from O_3 was taken in recognition of the fact that, unlike O_3 , $\text{PM}_{2.5}$ can be directly emitted by an emission source. Proximity to an emission source is an important consideration because high short-term spikes in local $\text{PM}_{2.5}$ concentrations can occur. For that reason, for the “High” and “Very High” sensor messages, EPA focused on the ranges of $\text{PM}_{2.5}$ concentrations that can occur near common emission sources (e.g., diesel buses). This approach was taken in recognition that $\text{PM}_{2.5}$ concentrations vary widely near emission sources, from less than 100 $\mu\text{g}/\text{m}^3$ to several thousand $\mu\text{g}/\text{m}^3$, and that sensor readings in these concentration ranges are possible when emissions sources are nearby.

To reflect the lower end of the range of $\text{PM}_{2.5}$ concentrations often found near emission sources, EPA determined that:

- 1-minute sensor readings for PM in the range of 70 to 499 $\mu\text{g}/\text{m}^3$ would best represent a “High” sensor message, because a user may encounter this level of $\text{PM}_{2.5}$ near sources, and
- a “Very High” message would be represented by 1-minute readings higher than 500 $\mu\text{g}/\text{m}^3$ that could indicate either a nearby emission source or that the sensor is not working properly. A $\text{PM}_{2.5}$ concentration higher than 500 $\mu\text{g}/\text{m}^3$ is expected to be a very rare occurrence, but could occur at times in extreme situations such as a wildfire.

Associated sensor scale messages for low $\text{PM}_{2.5}$ concentrations are, therefore, intended to be consistent, to the extent possible, with messages a user would see when checking the AQI, similar to the rationale for the O_3 sensor messages. The “High” and “Very High” $\text{PM}_{2.5}$ messages alert the user that an emissions source may be near the sensor. The messages also take into consideration the fact that very high ambient $\text{PM}_{2.5}$ concentrations can occur under some circumstances (such a fires), so advice is given to check the AQI for the daily forecast or any other alerts about unusual local air quality. The pilot $\text{PM}_{2.5}$ messages are shown in Table 2.

Table 2. Pilot version: 1-minute $\text{PM}_{2.5}$ readings

Pilot Version* 1-Minute $\text{PM}_{2.5}$ Readings <i>(Not for regulatory purposes)</i>	
Low 0 - 29 $\mu\text{g}/\text{m}^3$	Enjoy your outdoor activities.
Medium 30 - 69 $\mu\text{g}/\text{m}^3$	If medium readings continue (for an hour or more), use the Air Quality Index to plan outdoor activities.
High 70 - 499 $\mu\text{g}/\text{m}^3$	You may be near a source of particle pollution like dust, smoke or exhaust. Check the Air Quality Index to plan outdoor activities.
Very High > 500 $\mu\text{g}/\text{m}^3$	You may be near a source of particle pollution like dust, smoke or exhaust. Check the Air Quality Index to find out if you should adjust outdoor activities. Very high readings may mean the sensor is not working properly.
	Sensor may be offline. Check the Air Quality Index.

* May be refined as data sources are periodically updated.