Measuring of industrial emission parameters

M V Volkodaeva, O A Taranina, V A Kuznecov
Saint-Petersburg Mining University, 2, 21st Line, St Petersburg, 199106, Russia
E-mail: m_vladi_v@mail.ru

Abstract. The current system for estimating an air pollution level in the Russian Federation is based on the calculation of the maximum concentrations of pollutants reduced to a 20-minute time interval. The maximum ground level concentration of a pollutant, $C_{\text{max}}$, mg·m$^{-3}$, is calculated by the formula, which includes both reference values and parameters determined by the results of instrumental measurements. Measuring off-gas parameters from the air pollution source requires simultaneous monitoring of all parameters for 20 minutes. Deviation from this requirement and carrying out measurements not simultaneously can lead to errors in the estimation of emission efficiency. Continuous Emission Monitoring System can cope with such a task the significance of which increases after approval of the Federal Law 7-FZ "On Environmental Protection". These systems allow getting the real picture of pollutant emissions into the atmosphere, and in case of exceeding parameters, immediately make decisions in order to reduce the negative impact on the environment.

1. Introduction
At present, the main source of air pollution is emissions from industrial enterprises. According to the state report of the Ministry of natural resources and environment on the state of the environment of the Russian Federation, in 2016 they accounted for 55% of all pollutants, or 17,349,300 tonnes of pollutants [1].

The current system for estimating the air pollution level is based on the calculation of the maximum concentrations of pollutants reduced to a 20-minute time interval, and comparison between calculated pollutant concentrations and the corresponding maximum permissible one-time concentration (MPC OT) [2]. To do this, it is necessary to determine the maximum one-time concentrations of pollutants in the emissions from sources for a period of 20 to 30 minutes using an instrumental or computational method. It should be noted that there are no definitions of the concept of an instrumental method or a computational method, and both methods are based on measurements [3].

2. Maximum ground level concentration of pollutants
The maximum ground level concentration of pollutants, $C_{\text{max}}$, mg·m$^{-3}$, is calculated by the following formula:

$$C_{M} = \frac{A \cdot M \cdot F \cdot m \cdot n \cdot \eta}{H^{2} \cdot 4 \sqrt{\nu \Delta T}}$$ (1)
where $M$ - the average emission efficiency of each pollutant from the source of air pollutant, g·s$^{-1}$, for 20 to 30 minutes;

$\Delta T$ - temperature difference of the effluent gas and atmospheric air, °C;

$H$ - height of the source of air pollutant, m;

$V_1$ - seconds volume flow rate of effluent gas, m$^3$·s$^{-1}$;

$F$ - nondimensional coefficient that takes into account the sedimentation rate of the considered pollutant in the atmospheric air and depends on the particle size and the emission cleaning factor;

$A$ - coefficient depending on the distribution of air temperature over the height of the troposphere;

$m$ and $n$ - coefficients that take into account the emission conditions from the source;

$\eta$ - coefficient that takes into account the influence of the local landscape.

The coefficients $F$, $A$, $m$, $n$ and $\eta$ are reference values and they can be found in [2]. But the value of the emission efficiency or the volume flow of waste gases is calculated based on the data obtained directly by instrumental measurements.

So the volume flow of effluent gas, $V_1$, m$^3$·s$^{-1}$, is calculated by the following formula:

$$V_1 = \frac{\pi D^2}{4} w_0$$  

(2)

where $D$ - diameter of the outlet of the source of air pollutant, m;

$w_0$ - the average speed of the effluent gas output from the mouth of the source of air pollutant, m·s$^{-1}$.

At the same time, the flow rate is the parameter that is subject to instrumental measuring. It should be noted that the linear dimensions of the source of air pollutant appearing in formulas (1) and (2) can be the reason for the overestimated values of the effluent gas volumes, if they are inaccurately measured.

Emission efficiency is the amount of matter emitted into the atmosphere per time unit [4]. The pollutant emission efficiency from a stationary source of emissions, $M$, g·s$^{-1}$, in most cases, is calculated by the following formula:

$$M = C_{pe} V_1 \cdot 10^{-3}$$  

(3)

where $C_{pe}$ - concentration of pollutants in the measuring section of the exhaust duct, mg·m$^{-3}$;

$V_1$ - second volumetric flow of effluent gas through the measuring section, m$^3$·s$^{-1}$;

$10^{-3}$ - conversion constant mg in g.

To calculate the single-time ground level concentrations of the pollutants, an average (during 20 minutes) of the emission efficiency of each pollutant from the source of air pollutant into the atmosphere is taken. For that purpose the concentration of the considered pollutant, reduced to a 20-minute time interval, is used. To obtain this level, it is necessary to carry out instrumental measurements either using various gas analyzers or using measurement techniques based on chemical analysis. To date, about 600 methods for measuring various pollutants in industrial emissions have been registered in the Federal Information Fund for Ensuring the Uniformity of Measurements in the section "Information on Certificated Measuring Techniques (Methods)" [5]. Instrumental measuring of the pollutant concentrations in off-gases from the source of air pollutant suggests a 20-minute sampling with simultaneous monitoring of all the above parameters [6]. Deviation from this requirement and carrying out measurements not simultaneously, but successively can lead to errors in the estimation of emission efficiency since the technological processes at the plant may not be constant, and the effluent gas parameters may change in time.
In addition to the above temperature, it is also necessary to control the effluent gas pressure and humidity, since the measured concentration of pollutants in subsequent calculations must be reduced to normal conditions: \( T_0 = 273 \, \text{K}, \, P_0 = 760 \, \text{mm Hg}, \) dry gas [7]. Disregard of this requirement can lead to significant errors in calculating the pollutant emission efficiency. This fact specifically refers to the calculation of the concentration of water vapor in the effluent gas, since the temperature and pressure in the effluent gas are in many cases measured, and the humidity of the effluent gas is taken into account in very rare cases. These parameters of the effluent gas must be measured at the same places of the flue, where the concentration of pollutants is measured, including the flow speed.

3. Continuous Emission Monitoring System

As we have previously stated during the instrumental measuring, the concentration of pollutants in industrial emissions all parameters should be reduced to a 20-minute averaging interval. This fact suggests conducting parallel measuring of the component concentration in the off-gas and all parameters, including temperature, pressure and humidity. This requirement is not always fulfilled at the plant. This task is solved by the system of continuous emission monitoring or CEMS. This system has been successfully used for more than 20 years to monitor industrial emissions in the USA. And in accordance with federal legislation (EPA standard CFR 40, parts 60 and 75), it should be installed on power plants operating on organic fuel with a capacity of more than 25 MW [8]. These systems allow monitoring primarily greenhouse gases, as well as particulate matter. Based on the results of the measurements, a report is compiled and submitted to the US Environmental Protection Agency (EPA).

Adaptation of such systems for Russia production facilities becomes important due to approval of the Federal Law 219-FZ "On Environmental Protection" [9]. Section 9 article 67 of this law requires to equip stationary pollutant sources in the first danger class from 01.01.2019 with automatic tool measuring of emissions volume or mass (the objects of the first danger class are those that have a significant negative impact on the environment [9]). These continuous monitoring systems will have to collect data on the status of plant effluent gases and transfer data to the State Data Fund of the State Environmental Monitoring or to the state authorities of a subject of the Russian Federation that carry out state environmental monitoring.

At present various manufacturers offer emission monitoring systems that allow continuous monitoring of the following parameters of effluent gases: temperature, pressure and velocity, as well as concentrations of the following substances: sulfur dioxide, sum of nitrogen oxides, nitrogen dioxide, carbon monoxide, carbon dioxide, oxygen, ammonia, hydrogen sulphide, hydrogen fluoride, hydrogen chloride, methane, total sulfur, suspended particles [10, 11, 12]. This list of components is determined due to their negative impact on the ecosystem and humans. In addition to the listed substances, systems can control organic compounds, which are most toxic, for example, methane, acid, ethane, hexane, formaldehyde. Systems for continuous emission monitoring can be implemented for various industries: mining and processing enterprises, thermal power plants, metallurgical plants, oil and gas industry plants, etc.

Figure 1 shows a scheme of Continuous Emission Monitoring System. Sensors for monitoring temperature, pressure, humidity, dust are installed directly on the stack, and there are also sampling probes. The information processing center is at the bottom. Via the heated channel, a sample enters the sample preparation unit, where it is filtered, dried, diluted, and cooled if applicable. Then the sample enters the gas analyzer unit. These can be IR-Fourier spectrometers, gas chromatographs, electrochemical analyzers, spectrofluorimeters. Information obtained from gas analyzers and sensors located on the stack is processed on a personal computer (PC) located nearby. Data can be sent directly to the operators controlling the technological process and in case of deviation from normal levels, employees can make quick decisions. Data can also be received by the State Data Fund.
Figure 1. Scheme of continuous emission monitoring system

Such systems allow controlling emissions from several air pollution sources simultaneously. At the same time, information collection and processing units can be located in a single analytical center located on the territory of the plant, which provides for full monitoring of information on the state of air pollution source.

4. Conclusion
The installation of a system for the continuous emission monitoring at plants, including devices that measure the concentrations of pollutants in effluent gases, as well as other parameters (temperature, humidity, velocity, etc.), and combining them into a single network for monitoring industrial emissions make it possible to control all effluent gases parameters at the same time and in real time. These systems allow one to monitor all deviations from the normal operation of the equipment and, if necessary, interfere quickly with the technological process. But most importantly, these systems allow one to see the real picture of atmosphere pollutant emissions and, in case of exceeding parameters, immediately make decisions in order to reduce the negative impact on the environment.

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