IOP Conf. Series: Materials Science and Engineering **262** (2017) 012217 doi:10.1088/1757-899X/262/1/012217

# Metrological Support in Technosphere Safety

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**Abstract**. The principle of metrological support in technosphere safety is considered. It is based on the practical metrology. The theoretical aspects of accuracy and errors of the measuring instruments intended for diagnostics and control of the technosphere under the influence of factors harmful to human beings are presented. The necessity to choose measuring devices with high metrological characteristics according to the accuracy class and contact of sensitive elements with a medium under control is shown. The types of additional errors in measuring instruments that arise when they are affected by environmental influences are described. A specific example of the analyzers application to control industrial emissions and measure the oil and particulate matter in wastewater is shown; it allows assessing advantages and disadvantages of analyzers. Besides, the recommendations regarding the missing metrological characteristics of the instruments in use are provided. The technosphere continuous monitoring taking into account the metrological principles is expected to efficiently forecast the technosphere development and make appropriate decisions.

The technosphere is an area of the biosphere that surrounds man in the form of synthesis of nature and technology. It is created as a result of the vigorous transforming activity of man.

When creating the technosphere [1], man strives to improve the comfort of his habitat and ensure his protection from external influences. However, in this case the technosphere conditions, along with the positive influence, have a negative impact on man and the surrounding natural environment.

At present, due to the increase in anthropogenic loads on the technosphere, one of the most urgent problems is monitoring [2] of the part of the technosphere, to which people are the most exposed.

The paper considers metrological support for the measurement of physical factors with harmful impacts on humans.

For the permanent monitoring and analysis of the actual state of the technosphere, it is necessary to have highly accurate and highly sensitive technical diagnostic and measurement tools [3].

The practice shows that different methods and tools of measurement are used to assess the degree of pollution of the technosphere due to various harmful factors. High results in the determination of technosphere contamination are achievable only due to the availability of measuring instruments with high metrological characteristics.

Metrology is known to be a science of measurements, methods and means of ensuring their unity, and ways to achieve the required accuracy.

Depending on the purpose, three sections of metrology are distinguished: theoretical, legal, and applied ones.

The paper pays the main attention to the practical metrology issues (practical application of theoretical metrology developments and provisions of the legal metrology), because the tools that provide diagnostics and control of the technosphere are based on general principles of the practical metrology [4].

When choosing a tool, depending on the task, an important point is the measurement method, which is the basis of the measuring process. The measurement method is generally divided into direct and indirect measurements. The results of the direct measurement are found directly from the experimental data, and the result of indirect measurements are found from the known functional dependence of the measured value on the unknown physical quantity, taking into account the experimental data estimated by direct measurements.

Any measuring device generally has a primary converter built on a certain measuring principle. The primary converter based on the method of contiguity with the controlled environment can be contact and non-contact. In recent years, measuring instruments with sensitive elements that do not contact (remote ones) with the object of measurement have been the most common ones.

Accuracy which determines the proximity of the measurement result to the true (effective) value of the measured physical quantity [5] is one of the important metrological characteristics of any meter. In other words, the accuracy is the quality of measurement. The measurement error, which is divided into absolute, relative, and reduced, is the reciprocal of the accuracy.

The absolute error $\Delta$ is defined as

$$\Delta = X - X_{tr}$$

where $X$ is the measured value of the physical magnitude, $X_{tr}$ is the true value of the measured magnitude. To calculate the relative error $\delta$, one can use the expression

$$\delta = \frac{\Delta}{X_{tr}} 100\%$$

The reduced error $\gamma$ of the measurement result is calculated according to the formula

$$\gamma = \frac{\Delta}{X_f} 100\%$$

where $X_f$ is the fiducial value of the measuring device.

The property of technical measuring tools is defined by the sensitivity $S$, which can be expressed as

$$S = \frac{\Delta Y}{\Delta X}$$

where $\Delta X$ is the change of the input signal at the input of the meter, $\Delta Y$ is the change of the output signal of the meter.

Depending on influencing factors (for example, temperature and/or humidity of the environment), any measuring device has basic (instrumental) and additional errors [6]. The additional error, in contrast to the basic error, occurs when environmental influencing factors change from their normal values.

The basic instrumental error is found according to the accuracy class of the measuring instrument. The accuracy class is a generalized metrological characteristic determined by the limiting values of the permissible basic and additional errors. The most common form for errors for modern measuring instruments is the expression

$$\Delta_l = \pm(a + bX)$$

where $\Delta_l$ is the limit of the basic absolute error containing additive ($\pm$ $a$) and multiplicative ($\pm$ $bx$) components.

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For the additive $\Delta_{add}$ and the multiplicative $\Delta_m$ errors, one can write

$$\Delta_{add} = Y_0 - Y_{0_{nom}}$$

$$\Delta_m = Y - Y_{nom}$$

where $Y_o$ is the value of the output value at zero value of the input signal of the meter; $Y_{o\ nom}$ is the nominal value of the output value at zero value of the input value; $Y$ is the value of the input value.

In the measuring technology the determination of the limiting value of the additional error is reduced to the transformation of the basic instrumental error $\Delta_o$ and the value of the changing factor (temperature, humidity, and ambient pressure) influencing the measurement result.

The analysis of air in the atmosphere during emissions is carried out using automatic gas analyzers which allow continuously monitoring the concentration of harmful substances in industrial emissions. If the readings of the gas analyzer do not exceed the maximum permissible concentrations, the emissions are generally recognized as being maximum permissible and the enterprise is declared environmentally safe and receives emission allowance.

Nowadays, there exists the List of gas analyzers for control of industrial emissions, which are approved for use in 2017 [7]; they are analyzers intended for measuring air pollutants concentration in industrial emissions, registered in the State Register of Measuring Instruments, and examined at the Atmosphere Research Institute. The list includes the names of gas analyzers and the methods for measuring pollutants concentration in industrial emissions along with indications of the developing organizations. The measurement ranges, the operation principles of the instruments, and the measured components are also described.

Unfortunately, this document does not specify accuracy classes or measurement errors in the part of the basic and additional errors of these measuring analyzers, as well as methods of measurement. For example, the Russian (produced by OJSC "KOT", St. Petersburg) optical gas analyzer designed to control the concentration of suspended particles in the waste gas with a measurement range of 0.5-7g/m$^3$ is mentioned without indication of the accuracy class, ambient temperature range, and other metrological characteristics (sensitivity). The same can be said about foreign analyzers - for example, a DuPont Type 460 photometric analyzer (France) designed to control $O_2$ and $SO_2$ with measurement ranges of 0-3; 0-21 % and 0-0.5; 0-1.5% respectively.

The lack of some metrological characteristics of measuring tools often does not allow of evaluating the prospects of using a particular meter. Moreover, one cannot calculate both the basic and additional measurement errors without the accuracy class and/or temperature range of the measuring instrument operation. That makes the application of a particular device to solve a particular problem a big question.

One of the main components of the technosphere is the water sphere.

Industrial wastewater appears to be the main pollutant of water bodies. The paper [8] describes a waste water pollution analyzer STOK-101 (registered in the State Register) which is designed to measure the content of oil and solid suspended particles pollutants. The principle of the analyzer consists in the introduction of ultrasonic oscillations to the waste water and measurement of them reflected from the particles of oil and solid suspended particles. The analyzer contains a measuring unit, a power supply unit, and ultrasonic sensor. The sensor contains a transmitting piezoelement and a receiving one separated by electric and acoustic screens, which provides high control sensitivity. According to its technical specification, the analyzer can measure the contamination from 15 to 200 mg/l. The relative error is ± 15 %. The temperature of the operation medium and the environment ranges from 5 to 40 ° C.

According to the above technical characteristics, it is possible to estimate the additional error of this analyzer due to the influence of ambient temperature, humidity, and pressure on the result of the measurement. The absence of the accuracy class does not allow of determining the basic measurement error to the full. There is also no measurement method in the list of technical characteristics.

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In general, to minimize errors in measuring the physical parameters that characterize the state of the technosphere, the measuring instruments must be metrologically certified and have the self-check capability and digital output to connect modern recording devices, for example, computers. It makes sense to use radio wave, acoustic, and lidar primary converters providing remote monitoring and analysis as sensors. By virtue of the introduction of innovative technologies, it is desirable to use intelligent measuring devices to monitor the state of the technosphere, which permit to make correct prediction and online decisions.

The results listed above can be used to diagnose and monitor the state of various ecological systems exposed to factors harmful to humans. Using these results, one can take decisions aimed at optimal management of the processes which take place not only in the technosphere but in other spheres.

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