Operational control methods of wastewater turbidity

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Abstract. The article identifies the optimal method of operational control of wastewater turbidity generated during the production of water-dispersion paint material.

Introduction
The rapid growth in the production of water-based (waterborne and water-dispersion) paint materials (PM), compared to organic-based paint compositions has been observed in recent decades, due to the environmental advantages of using water as a dispersion medium and solvent [1].

Currently, to improve the environmental friendliness and efficiency of paint enterprises, it is important to develop methods for operational control of waste composition at different stages of wastewater treatment. Express control directly in the production process during the wastewater (WW) formation allows you to obtain the necessary information about the WW concentration and treatment methods.

The wastewater composition generated during the production of water-dispersion paints is variable and varies widely depending on the product type produced at a particular moment.

Material and technique
As is known, the composition of water-dispersion paint material (PM) includes numerous components of organic and inorganic nature, such as dispersions of copolymers with different monomeric composition, dispersants, organic and inorganic pigments and fillers, thickeners, antifoamers, preservatives, and others, all manner of compositions that constitute a mixture of several organic compounds. Suspension, which is wastewater in excess of high turbidity after washing the paint equipment, sedimentation extremely stable due to the appropriate technology of grinding pigments and fillers. The PM composition contains anti-flocculating additives that ensure the irreversibility of such a suspension for quite a long time [2]. Such drains do not meet sanitary standards and the rules for their reception into the city sewage system and create the danger of collectors clogging and as a result, possible failure of the municipal sewage system.

Solving the problem of wastewater treatment generated during the PM production is a difficult task for a number of reasons, one of which is the operational control of the effluent composition, the need to locate a local treatment station next to the production. Hence the requirement for a station compactness, as well as the possibility of its modernization if the effluent composition changes.
Successful resolution of this problem will reduce the environmental risks of modern enterprises and ensure the further development of the paint industry [3, 4].

In order to identify the method of operational control of wastewater turbidity, wastewater of various PM productions was considered [5-7]. The particle size of fillers and pigments, as well as the floccules formed during coagulation was estimated using an optical microscope Labomed-3, («Labor microscopes») with 100x lens and a digital camera Olympus.

The content of organic substances in wastewater was estimated using IR-spectrum obtained using the FSM-1201 IR-Fourier spectrometer with the prefix MNPVO-36 (prefix of multiple disperse total reflection of the horizontal type with a cuvette of zinc selenide) ("Monitoring"). Microscopic technique was originally used for a better understanding of the pollutants nature and further selection of purification method. However, it is necessary to take into account the microscopy possibility to control objects of at least 0.5-1 μm. Nevertheless, the microscopy method is convenient for qualitative determination of the suspension form; in addition, it is operational, since it requires minimal time for its implementation.

Even smaller particles in dispersed media are detected by other methods, for example, turbidimetry, i.e. turbidity meter [8].

Modern technologies for controlling dispersed media use the main physical effect of the heterogeneities presence and concentration - transparency in the spectral region of certain radiations. Differences in the optical effects of the radiation interaction with a homogeneous medium and heterogeneities make it possible to obtain reliable data on the media. For continuous measurements of the finely dispersed media concentration where solids content is 100 mg/l or less, optical concentration meters are most effective and promising [9]. They perceive nephelometers that constitute dispersed radiations by the disperse medium sideward or turbidimeters that constitute radiations having passed through it. Nephelometers use the dependence of informative scattering radiation on a certain angle to the flow direction of the acting radiation. Information-measuring devices for determining turbidity, as well as particle concentration and distribution are built on this basis. In their nature, nephelometers are the means of relative measurements that require the presence of certain turbidity standards. These standards in form, size and particles distribution, as well as the refractive index should be strictly consistent with the characteristics of the controlled fluid.

Optical turbidity measurement method is based on the dependence of the scattering coefficient on the size, shape, particles number and the difference in the refractive indices of the medium and particles. Its essence is as follows: if a luminous flux is transmitted through the turbid medium, then a part of the light is scattered by suspended particles and the higher the concentration of suspended matter in the controlled medium a large proportion of light is scattered. In this case, a measure of the suspended particles concentration is the attenuation of the light flux intensity transmitted through the layer of the controlled medium [10].

To control the dispersed medium concentration (undissolved suspended particles) in liquids, this method is used quite widely. Turbidimeters are used to control turbidity, which is a complex characteristic of the solid medium content. The measuring range of the device allows to work with media from low to high turbidity degrees (but not more than 1100 FNU) [11]. Use conditions and a manufacturer determine turbidity controls devices [12]. Conventionally, they are divided into laboratory, portable and mobile. Accordingly, the higher the class of the device, the more accurate the measurement it can provide, however, in this case, mobility decreases with increasing mass and size characteristics. Special cuvettes are used for placement of heterogeneous media samples. Probe Sampling and transportation are carried out using samplers that to some extent improves the limited turbines mobility but does not completely solve the problems of express control. Embedded fiber optic sensors are used in industrial designs of modern turbidimeters. These sensors are not applicable for mobile monitoring systems.

After adopting formazin as a model primary standard, turbidity units became known as formazin turbidity units - FTU (formazin turbidity units - FTU). American Public Health Association (APHA)
and American Water Works Association (AWWA) were the first to use formazin as a primary turbidity standard in the 13th edition of the Standard Methods for the Examination of Water and Wastewater. The U.S. Environmental Protection Agency (USEPA) defines the primary standard somewhat differently, using terms that meet the standards for presenting USEPA results.

The standard concept in turbidimetry is somewhat blurred due to differences in the definitions used by USEPA, APHA, AWWA and those given in the "Standard methods". The concepts of "primary standard" and "secondary standard" were introduced for clarity in the 19th edition of Standard Methods. The primary standard is defined in them as a standard that is prepared by the user precision, from controlled starting materials under controlled environmental conditions. In turbidimetry, the only standard that meets these requirements is formazin prepared directly on a laboratory bench.

"Standard methods" define a secondary standard as a manufacturer standard (or an independent inspection organization), such that instrument calibration for this standard gives (within certain limits) results equivalent to those produced by the user formazin calibration. There are various types of secondary standards, including an industrial assortment of 4000 formazin suspensions. NTU, stabilized formazine suspensions and industrial microspheres suspensions of styrene copolymer and divinylbenzene.

Since the styrene-acrylic dispersion, which in its colors is similar in properties to the suspension of styrene copolymer and divinylbenzene microspheres, that is a base for the turbidimeter calibration, this makes it possible to use the turbidimetry method as the main one.

The definition of super high turbidity is usually the measurement when it is impossible to determine the particles concentration by the nephelometric method. In devices with a light path in the sample of 1 inch, the nephelometric sensor signal begins to decrease when turbidity reaches about 2000 NTU. Starting at such a level, the turbidity increase will result in the signal decrease of the nephelometric detector. However, to determine the turbidity in such samples, there are other ways: by transmitted light, by direct scattering and by backscattering. The amount of transmitted light and diffused forward is inversely proportional to the turbidity increase and give good results up to the order values of 4000 NTU. At turbidity values of more than 4000 NTU (using a standard 1 inch cell) the signal from the transmitted or diffused light is so small that it is comparable to the noise level, i.e. instrument noise becomes the main source of interference. On the other hand, the signal from the backscatter sensor increases in proportion to the turbidity increase. It has been shown that backscattering detection is effective for determining turbidity in the range of 1000 to 1000 NTU (and above). The backscatter sensor signal is very small and is lost in the instrument noise below 1000 NTU. The detectors combination can be used to detect turbidity from minimum to ultra-high values.

The definition of ultra-high turbidity is widely used for example to control the components content such as titanium dioxide in paints.

When determining ultra-high turbidity, the measuring cell greatly influences the accuracy. The cell is not perfectly round and the wall thickness is not constant. These two factors have a significant impact on the turbidity definition and especially on the backscatter definition. To reduce cell influence, it is necessary to perform several measurements at different cell orientations. Recommended positions are 0, 90, 180 and 270 degrees relative to the mark. Measurements must be performed using the same sample preparation method. Measurements should be taken at regular intervals after mixing the sample in order to achieve maximum measurements reproducibility. The obtained values should be averaged, and the averaged value should be taken as the true value.

The definition of ultra-high turbidity is commonly used to monitor production control. The user must first establish the relationship between the turbidity and various conditions of the process. Sample is diluted to determine the dependence and the turbidity is determined at each dilution. The turbidity-dilution dependency graph is built. The slope of the approximating straight line shows the dependency nature. If the slope is large (greater than 1), then the fit is good and the potential interference with the measurements is minimal. If the slope is small (less than 0.1), then there are
interferences that affect the measurements. In this case, the sample should be diluted until the slope begins to increase. If the slope is close to zero or negative, then turbidity is too great, or interference is too strong. The sample should be diluted again.

In determining ultra-high turbidity, color can be a major hindrance. Possible solution in case of color interference is to dilute the sample significantly. Alternative method identify the absorption spectrum of samples and determine turbidity at wavelengths that the sample does not absorb. The use of wavelength 800 - 860 nm is effective because most colored compounds found in nature absorb light at this wavelength only slightly [13].

The ability to determine turbidity in the range of ultrahigh values provides a simple physical characteristic for a large number of samples and processes. In general, each process is unique, and some effort is required to accurately characterize the sample and its properties through turbidimetric (nephelometric) measurements.

Summary
To solve the problem in operational control of industrial waters turbidity obtained in the production of water-dispersion paints, the turbidimetry method is the most technologically and economically acceptable for small industrial paint enterprises. Since the styrene-acrylic dispersion, which in its colors is similar in properties to the microspheres suspension of styrene copolymer and divinylbenzene that is used to calibrate the turbidimeter, this makes it possible to use the turbidimetry method as the main one.

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