Evaluation of the applicability of measurement techniques to determine the quality of drinking and industrial water used in galvanic production

M I Grichukha and E A Kremcheev

St. Petersburg mining University, 2, Line 21 V.I., Saint-Petersburg, 199106, Russia

E-mail: ilona.g.l@yandex.ru

Abstract. The scientific project «Evaluation of the applicability of measurement techniques to determine the quality of drinking and industrial water used in galvanic production» is devoted to the problems of improving the structure of the methodological base in the production laboratories of enterprises, ensuring its uniformity and efficiency. The paper presents a multi-criteria analysis of measurement methods.

1. Introduction

Nowadays, the regulatory framework for the measurement of water quality indicators is extensive. Sanitary rules and regulations (SRR) 2.1.4.1074-01 [2] and GOST 9.314-90 [6] normalize the content of more than 32 indicators of water quality, which include:

- for drinking water:
  1) summary indicators;
  2) inorganic substances;
  3) organic substances;
- for technical waters:
  1) summary indicators;
  2) inorganic substances.

In addition GOST 27384-2002 [7] regulates the measurement errors of the indicators of the composition and properties of water.

In order to determine the amount of concentration of normalized components in the samples used standardized and certified measurement techniques. The number of such measurement methods is more than 30 units. Moreover, the methods regulate the procedure for determining the concentrations of both a single component in the sample and a set of components. At the same time, there is no regulated list of methods for measuring the quality of drinking water and technical water used in galvanic production. The difficulty of the list creation is that the use of measurement techniques is voluntary.

2. Water quality

The requirements for the quality of drinking water and industrial water used for galvanic production are different [8]. The determination of the quality of drinking water is measuring indicators such as: hydrogen index, total mineralization, total hardness, oxidation of permanganate, petroleum products,
surfactants, phenolic index, aluminum, barium, beryllium, boron, iron, cadmium, manganese, copper, molybdenum, arsenic, nickel, nitrates, mercury, lead, selenium, strontium, sulphates, fluorides, chlorides, chromium, cyanides, zinc and pesticides. In addition, the quality of drinking water is determined by microbiological, parasitological and organoleptic characteristics.

During the determination of the quality of technical water used in galvanic production, the following parameters are measured: hydrogen index, total mineralization, total hardness, sulfates, chlorides, nitrates, phosphates, ammonia, petroleum products, chemically consumed oxygen, residual chlorine, surfactant, iron, copper, nickel, zinc, chromium trivalent, electrical conductivity.

The requirements for the quality of technical water are generally higher than for the quality of drinking water. In addition, the requirements for the quality of technical water are tightened with increasing its category. Thus, for example, the maximum permissible concentration (MPC) of pollutants for the first category of technical water may coincide with the MPC for drinking water, while the MPC for the third category of water is several times tougher.

According to the Federal state budgetary institution "North-West Department for Hydrometeorology and environmental monitoring" [3] the metals and organic substances MPC overage found in samples taken to determine the quality of drinking water in January 2019 at St. Petersburg. These data were obtained in the laboratories of Roshydromet using measurement techniques (MT), which are selected by this organization. The data on the percentage of samples with exceeding the MPC of metals displayed in the source is not correct. Figure 1 shows the result of the analysis of 50 samples taken in January 2019. On the basis of the grades the MPC of polluting substances, which are established to provide guidance to [1] and criteria extremely high pollution and high pollution, which is established by the Order of Russian meteorological service [5], Russian meteorological service established cases of high pollution of surface water, as the concentration of manganese in several samples exceeded the MPC at 30–50 times [4]. It was also noted as general, the excess MPC of heavy metals, phosphorus, easily oxidized organic substances on BPCs, organic substances on chemically consumed oxygen.

![Number of samples with MPC overage](image)

**Figure 1.** Graphical interpretation of the number of samples exceeding the MPC

According to these data, it can be concluded that the priority for St. Petersburg is the measurement and control of such water indicators as:

- heavy metal;
- phosphorus;
- easily oxidized organic substances according to BPCs;
- organic matter on chemically consumed oxygen.
3. Water use
Water users include municipal services and various organizations, enterprises and factories. Water supplier at St. Petersburg is SUE Vodokanal St. Petersburg (Vodokanal), which intakes water from different points of the city. There are 5 water intake stations at St. Petersburg:

- Main water supply station (MWSS);
- Northern water supply station (NWSS);
- Southern water supply station (SWSS);
- Volkovskaya water supply station (VWSS);
- Water treatment plants (WTP) g. Kolpino.

Purified water from these supply stations supply utilities and enterprises [9], including galvanic production enterprises [10]. After receiving from Water and Sanitation Authority, industrial consumers purify the water to a technical state and use it in production processes. At the exit from the production process MPC of pollutants in water are exceeded several times, and before discharge into the sewer, it requires pre-treatment. All stages of water transfer and use are accompanied by monitoring of water quality indicators, and, consequently, are needed in the methodological basis for measuring these indicators. Water quality indicators are monitored at the following points:

- at the entrance of the water station;
- at the output of distribution stations;
- at the entrance of the enterprise (where water comes from Water and Sanitation Authority);
- at the outlet of the treatment plant at the enterprise (if the water comes with indicators worse than required in the production);
- at the exit of the production process;
- at the outlet of the treatment plant before the effluent of used water into the sewer.

Effective monitoring of water quality indicators requires a methodological framework that can be used at all stages of monitoring.

The purpose of this study is to select the optimal measurement methods for the determination of metal ions in water used for the needs of housing and communal services and galvanic production enterprises.

According to the guidance document (GD) on "The organization and carrying of regime observations of the state and pollution of surface waters of the land" [1] monitoring of surface waters should be carried out at regular intervals and within a specified time. These parameters are defined by the normative document on Sanitary-epidemiological rules and standards of SRR [2], in addition, the number of samples taken within 1 year is established. In this regard, the cost of monitoring should be economically justified, that is, the assessment of indicators of the quality of drinking water and technical water should be carried out with minimal time and financial resources. Despite the fact that GD [1] and SRR [2] indicate the frequency and timing of surface water monitoring, there is no regulated list of water quality indicators MT.

According to the above mentioned aspects, the measurement methods must meet the following requirements: to ensure ease of experimental data processing, the specified accuracy of the results, technical and economic efficiency.

4. Research methodology
In order to achieve the purpose of the study, we turn to the system analysis. The following tasks are performed during the research:

- selected relevant MT that are appropriate for the accuracy and measuring range;
- the methods of measuring the efficiency are analyzed, that is, the efficiency indicators and efficiency criteria are selected;
- the results are processed;
- the best option is chosen.
5. Research results
As a result of the selection of measurement methods to determine the content of copper and manganese the documents are selected to the analysis of the effectiveness. The list of these documents is presented in tables 1 and 2.

| Table 1. Methods for measuring mass concentrations of manganese in water |
|---------------------------------------------------------------|
| Name of the method |  |
| 1 | ERFD* 14.1:2:4.139-98 QCA of waters. Methods of measurement of mass concentrations of cobalt, nickel, copper, zinc, chromium, manganese, iron, silver, cadmium and lead in samples of drinking water, natural water and wastewater by atomic absorption spectrometry |
| 2 | ERFD 14.1:2:4.143-98 QCA of waters. Method of measurement of mass concentrations of aluminum, barium, boron, iron, potassium, cobalt, magnesium, manganese, copper, sodium, nickel, strontium, titanium, chromium and zinc in drinking water, natural water and wastewater by the method of ISP-spectrometry |

*Environmental regulatory federal documents.

| Table 2. Methods for measuring mass concentrations of copper in water |
|---------------------------------------------------------------|
| Name of the method |  |
| 1 | ERFD 14.1:2:4.139-98 QCA of waters. Methods of measurement of mass concentrations of cobalt, nickel, copper, zinc, chromium, manganese, iron, silver, cadmium and lead in samples of drinking water, natural water and wastewater by atomic absorption spectrometry |
| 2 | ERFD 14.1:2:4.140-98 QCA of waters. Methods of measurement of mass concentrations of beryllium, vanadium, bismuth, cadmium, cobalt, copper, molybdenum, arsenic, nickel, tin, lead, selenium, silver, antimony and chromium in samples of drinking, natural and wastewater by atomic absorption spectrometry with electrothermal atomization |
| 3 | ERFD 14.1:2:4.143-98 QCA of waters. Method of measurement of mass concentrations of aluminum, barium, boron, iron, potassium, cobalt, magnesium, manganese, copper, sodium, nickel, strontium, titanium, chromium and zinc in drinking water, natural water and wastewater by the method of ISP-spectrometry |

Figure 2 explains the possibility of using the selected techniques at different stages of galvanic processing. In this case, the analysis of content of pollutions in water can be divided into 4 stages:
- stage 1 – at the entrance of the enterprise (where the water comes from the Vodokanal);
- stage 2 – at the outlet of the treatment plant at the enterprise (if the water comes with indicators worse than required in the production);
- stage 3 – at the exit of the production process;
- stage 4 – at the outlet of the treatment plant before the effluent of used water into the sewer.

The color indicates the stages of galvanic production at which it is possible to determine the concentrations of pollutants using appropriate techniques. The figure shows that all of these methods are suitable for use at each stage of galvanic production.

| Elements | Stages | 1 stage | 2 stage | 3 stage | 4 stage |
|----------|--------|---------|---------|---------|---------|
| Cuprum   |        | 1,00    | 0,30    | 30,00   | 3,00    |
| Manganese|        | 0,10    | 0,10    | 0,10    | 0,30    |

| MT        |        |         |         |         |
|-----------|--------|---------|---------|---------|
| ERFD 14.1:2:4.139-98 |   | |         |         |
| ERFD 14.1:2:4.140-98 |   | |         |         |
| ERFD 14.1:2:4.143-98 |   | |         |         |

Figure 2. Analysis of the applicability of MT at various stages of galvanic production

For clarity and ease of evaluation of measurement methods according to the economic efficiency,
Table 3 presents data on water quality standards, error rates, the total cost of equipment and materials, as well as the time spent on holding a water sample for each MT.

As a result of the MT analysis the following conclusions are made:

- measuring the copper in water samples is more economical in financial and time costs to use ERFD 14.1:2.4.140-98;
- measuring the manganese in water samples is less in financial costs to use ERFD 14.1:2.4.139-98.

Despite the fact that in ERFD 14.1:2.4.139-98 sample holding time exceeds 4 times than in ERFD 14.1:2.4.143-98, the use of ERFD 14.1:2.4.139-98 justified comparative indicator of money savings of almost 1 million rubles.

**Table 3. Evaluation of measurement methods by criteria**

| The criterion | Measurements of the COPPER concentrations | Measurements of the MANGANESE concentrations |
|---------------|-------------------------------------------|--------------------------------------------|
|               | Standard for COPPER | ERFD 14.1:2.4.139 | ERFD 14.1:2.4.140 | ERFD 14.1:2.4.143 | Standard for MANGANESE | ERFD 14.1:2.4.139 | ERFD 14.1:2.4.140 | ERFD 14.1:2.4.143 |
| Measuring range, mg/dm³ | 1 | 0.01–1 | 0.04–1 | 0.1 | 0.05–0.5 | 0.05–0.5 |
| Error, % | 25 | ±25 | ±25 | ±25 | 25 | ±25 | ±25 |
| Financial costs, ₽/element | – | 1 828 588.00 | 1 561 086.00 | 3 237 481.00 | – | 1 828 588.00 | 3 237 481.00 |
| The time required to extract samples, min | – | 40–60 | 10–15 | 10–15 | – | 40–60 | 10–15 |

**References**

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[8] Barkan M., Kornev A. 2018 Development of new technological solutions for recovery of heavy nonferrous metals from technogenic waste of electroplating plants and sludge of water treatment systems Eastern-European Journal of Enterprise Technologies, Volume 2, Issue 10-92, 17-24
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