The scientific and technological standards adaptation principles to waste water existing treatment facilities

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Abstract. The use of the scientific and technological documentation (STD) in the new facilities design and construction allows the modern technological and technical solutions use proven by operating practices that ensure the treated wastewater regulatory quality. However, the questions about the application of STD and modern construction materials at existing wastewater treatment plants, as well as being in commissioning mode remain.

Based on the physical survey materials of existing wastewater treatment plants using statistical models, it was shown that the infiltration and rain effect flows on the contaminants' composition transported through the sewage collector is insignificant and should not be taken into account, and when choosing a re-technology scheme for treatment facilities polluted stream, i.e. concentrated wastewater.

Introduction

The scientific and technical documentation [1] (STD), introduced in 2018 in the Russian Federation into the wastewater treatment practice, recommend their use in various wastewater treatment plants from small to very large with concentrations of pollutants from low to highly concentrated.

The scientific and technical solutions providing the standard quality of treated wastewater are given in practice for the STD application in the new facilities design and construction. At the same time, the questions about the application of STD to existing wastewater treatment plants, as well as being in the mode of commissioning remain.

When preparing the materials for the STD development the authors [1,2,3] statistically processed the results of a survey of the state and quality of wastewater treatment for 2 years (2015–16) for over 300 treatment facilities in the Russian Federation. It was noted that less than 10% of the 1st category facilities (wastewater consumption over 20 thousand m$^3$ / day) use modern technologies to remove nitrogen and phosphorus, there is a tendency for this share to increase with increasing wastewater consumption, but not fundamental.

- less than 10% of them use modern technologies ensuring the nitrogen and phosphorus removal, there is a tendency to increase this share with an increase in wastewater consumption, but it is not a fundamental one;
- about 30% of the facilities have after-treatment facilities, but these facilities vast majority effectiveness is very low;
- environmentally safe UV disinfection ahead of its development technology for removing nitrogen and phosphorus, reaching 20% of the objects’ total number;
- the greatest progress was achieved in the transition to mechanical dewatering of sediments - it is used by more than 40% of all the objects and 75% of the operating system with a capacity of over 100 thousand m³/day.

None of the surveyed objects use special technologies for the urban wastewater (UWW) treatment from industrial pollution (heavy metals, synthetic surfactants, petroleum products, phenols). The same applies to the dissolved mineral pollution (chlorides, sulphates, total mineralization).

For the objects of the 2nd category (5–20 thousand m³/day), the effective technological solutions predominant absence for the nutrients’ removal was also noted.
- buildings with biofilters built in the 50-60s (36%);
- structures with aerotanks similar in technology and design used on larger objects (24%);
- buildings with compact installations (prefabricated), built in the 70s and 80s (12%);
- new facilities built in the last 20 years with more or less modern technologies (6%).

The new facilities’ state and results are very different, because a significant proportion of them are based on the projects containing gross errors, or not provided for proper operation.

A significant part of them failed due to clogging, loading and lack of necessary repairs.

Main part

One of the compelling reasons for the wastewater treatment plant unstable operation is, along with the disruption to the wastewater treatment plant operation, the discrepancy between the actual pollutants’ concentrations in the wastewater and the calculated concentrations incorporated in the project.

In this regard, the additions development to STD for the existing regimes adaptation in the conditions of historically established sewage treatment plants to modern technologies and cleaning standards is relevant. The studies on a number of existing wastewater treatment plants in the south of the Russian Federation have been conducted.

The changes in the costs and pollutants concentrations in wastewater entering the period of rainfall in the sewage network through the leakage of wells manholes, occurs due to groundwater infiltration [4].

The value of additional inflow $q_{ad}$, l/s, can be determined by [4]

$$q_{ad} = 0.15L\sqrt{m_d},$$

where $L$ is the total length of pipelines to the calculated structure (pipeline section), km; $m_d$ is the maximum daily precipitation amount, mm.

To determine the wastewater concentrations drift in collectors during the rainy period, the data for the city of Rostov-on-Don and the city of Stavropol were used.

The total length of water disposal networks in Rostov-on-Don is 1,354 km [5]. The maximum daily amount of precipitation is 100 mm, therefore, the value of the additional inflow will be 2031 l/s. If we assume the duration of rain is 1 hour, then the additional inflow will be 7311 m³. The sewage treatment plant capacity in Rostov-on-Don (D) (the sum of two lines) is 4,40000 m³/day, the average hourly flow rate is 18,333 m³/hour, i.e., the increase in consumption due to rainwater inflow will be 40%.

It is known that ammonium nitrogen is practically not contained in groundwater and rainwater, therefore, its concentration in wastewater during rains should decrease. For example, if an average concentration of ammonium nitrogen in wastewater 40 mg/l is taken, then during the rain it can drop to 28 mg/l (30%).

The precipitation graphs in Stavropol and Rostov-on-Don are shown in Figures 1 and 2 respectively [4,5].
Similar conclusions were obtained for the city of Stavropol conditions: the length of sewage networks is 338 km [6], the maximum daily amount of precipitation is 100 mm, the capacity of treatment facilities is 134957 m³ / day [6]. Average hourly consumption will be 5623 m³. In this case, the dilution effect (1825/5623 = 0.32) of the rain inflow is also about 30%.

Table 1 presents the ammonium nitrogen actual concentrations values in the wastewater in the months of maximum and minimum rainfall.

| Name | Months with minimum rain/snowfall | Months with maximum rain/snowfall |
|------|-----------------------------------|----------------------------------|
|      |                                   |                                  |
To determine the significant differences in the ammonium ions concentrations in wastewater entering the treatment plant in the months of maximum and minimum rainfall, the “normalized deviation” the statistical indicator was used [7].

The ammonium wastewater nitrogen concentration normalized deviation tabular value in Stavropol with the number of invariant n = 4, and a significance level of 5%, is 3.18, for the conditions in Rostov-on-Don with n = 16 and a significance level of 5%, - 2.13.

The normalized deviation calculated values were compared to the table values: if the normalized deviation calculated value does not exceed the table value, then it can be concluded that all values belong to the same statistical population and the differences are insignificant (Table 2), i.e. the infiltration and rainwater effect on the composition of pollution transported through the sewage collector is insignificant. This, in turn, means that no additions are made to STD during the rainfall period.

Table 2. The normalized deviation calculations results (n1 = 4, n2 = 16)

| Name of the settlement | Average value | Standard deviation | Normalized deviation | Maximum deviation |
|------------------------|---------------|---------------------|----------------------|-------------------|
| Stavropol 2016 and 2017 for March and June | 44.15 | 9.11 | 3.18 | 1.48 |
| Stavropol 2016 for March and June | 40.6 | 1.56 | 12.71 | 0.71 |
| Stavropol 2017 for March and June | 47.7 | 14.0 | 12.71 | 0.71 |
| Rostov-on-Don 1st stage 2016 | 28.43 | 2.29 | 3.18 | 1.12 |
| Rostov-on-Don 1st stage 2017 | 30.18 | 2.92 | 3.18 | 1.13 |
| Rostov-on-Don 2nd stage 2016 | 28.68 | 2.61 | 3.18 | 1.16 |
| Rostov-on-Don 2nd stage 2017 | 31.8 | 1.65 | 3.18 | 1.39 |
| Rostov-on-Don 2 stages for 2016 | 28.05 | 2.31 | 2.36 | 1.28 |
| Rostov-on-Don 2 stages for 2017 | 30.99 | 2.36 | 2.36 | 1.56 |
Further, the ammonium nitrogen actual concentrations deviations in the wastewater from the calculated values, carried out according to BC 32.13330.2012 [4], are analyzed.

Wastewater from the cities of Stavropol, Rostov-on-Don and the village of Kuzhelevskaya was taken as the comparison objects. The treatment facilities of these settlements, in accordance with the classification of STD, are classified as large, average and small. The number of residents in Stavropol in 2018 is 433,931 people, in Rostov-on-Don - 1,130,305 people, in the village of Kuzhelevskaya - 30,000 people.

Table 3 shows the costs of wastewater entering the sewage treatment plant, specific wastewater disposal, taking into account that 40% of the residents use the central sewage system in the village of Kuzhelevskaya.

### Table 3. The residents number distribution in Stavropol by year

| Name of the settlement | Sewage treatment plants capacity, thousand [m³ / day] | Specific drainage, [l/day pers] |
|------------------------|-----------------------------------------------------|---------------------------------|
| Rostov-on-Don          | 440                                                 | 407.0                           |
| Stavropol              | 135                                                 | 323.0                           |
| Kuzhelevskaya          | 2.7                                                 | 225                             |

The actual content of pollution in the wastewater treatment plants in the settlements under consideration and their estimated concentrations are compared, based on the specific pollutants from one resident per day (Table 4).

Table 4 presents the main pollutants concentrations calculated indicators in the wastewater, taking into account which the design organization is developing a technology for the wastewater treatment.

### Table 4. The number of pollutants per inhabitant (SP32.13330.2012, Table. 19)

| Indicator                  | The amount of pollutants per inhabitant, g / day |
|----------------------------|--------------------------------------------------|
| Suspended substances       | 65                                               |
| BOD unclarified fluid      | 60                                               |
| Total Nitrogen             | 13                                               |
| Volatile ammonia           | 10.5                                             |
| Total Phosphorus           | 2.5                                              |
| Phosphorus phosphate       | 1.5                                              |

The calculated concentrations of pollutants in the wastewater of the specified settlements (Table 5) were determined using the data [4] and Internet resources www.gks.ru, www.fedstat.ru [8.9]. It was taken into account that 40% of the residents use centralized sewage in the village of Kuzhelevskaya.

Compared the actual content of pollution in the wastewater treatment plants in the settlements under consideration and their estimated concentrations, based on the specific pollutants from one resident per day (Table 5).

### Table 5. Estimated and actual concentrations of pollutants in the wastewater of Stavropol, Rostov-on-Don, Kuzhelevskaya

| Indicator                  | Estimated and actual concentrations of pollutants |
|----------------------------|--------------------------------------------------|
| Stavropol                  | Rostov-on-Don, Kuzhelevskaya                      |
| Nitrogen ammonium salts    | [mg / dm³]                                       |
Calculated values | 208.1 | 159.0 | 289.0  
Actual values (average for 2017 and 2016) | 27.6 | 237.8 | 309.0  
Deviation from the calculated value% | +24 | +33 | +6.5  

BOD₅ unclarified fluid, [mg O₂/dm³]  
Calculated values | 192.1 | 146.8 | 267.0  
Actual values (average for 2017 and 2016) | 202.6 | 224.2 | 279.0  
Deviation from the calculated value% | +5.18 | +34.5 | +4.3  

Volatile ammonia, [mg/dm³]  
Calculated values | 33.6 | 25.6 | 47.0  
Actual values (average for 2017 and 2016) | 47.7 | 30.6 | 85.0  
Deviation from the calculated value% | +29.6 | +16.4 | +44.7  

Phosphorus phosphate, [mg/dm³]  
Calculated values | 7.7 | 6.0 | 6.7  
Actual values (average for 2017 and 2016) | 3.2 | 2.6 | 6.0  
Deviation from the calculated value% | -58% | -56.7 | 10.4  

Discussion  
Higher concentrations of pollutants in the incoming wastewater, compared with the calculated, can be explained by the processes occurring in the reservoir inside which conditions are formed that facilitate the waste microorganisms to carry out uncontrolled pollutants transformation.

At the same time, the smaller the capacity of the treatment plant and the higher the coefficient of unevenness, and, consequently, the duration of the stay of wastewater in the reservoir, the greater the difference between the calculated and actual pollutant concentrations values.

Comparing the calculated and actual concentrations of pollutants (Table 5) with the wastewater pollution ranges according to STD (Table 6), it should be noted that the same waters can be classified as low, medium and highly concentrated.

Table 6. The main pollution concentration ranges in initial city sewage

| Pollutants | Sewage contamination ranges, mg / dm³ |
|------------|---------------------------------------|
|            | low concentrated wastewater | medium concentrated wastewater | concentrated wastewater | under the influence of industrial wastewater |
| BOD₅       | 208.1 | 159.0 | 289.0 |
| Actual values (average for 2017 and 2016) | 27.6 | 237.8 | 309.0 |
| Deviation from the calculated value% | +24 | +33 | +6.5 |
| BOD₅ unclarified fluid, [mg O₂/dm³] | 192.1 | 146.8 | 267.0 |
| Actual values (average for 2017 and 2016) | 202.6 | 224.2 | 279.0 |
| Deviation from the calculated value% | +5.18 | +34.5 | +4.3 |
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| Phosphorus phosphate, [mg/dm³] | 7.7 | 6.0 | 6.7 |
| Actual values (average for 2017 and 2016) | 3.2 | 2.6 | 6.0 |
| Deviation from the calculated value% | -58% | -56.7 | 10.4 |
Then the choice of the technological scheme of re-technologization of wastewater treatment plants for practical implementation should be carried out according to the most polluted stream purification technology, i.e., concentrated wastewater, understanding in advance its greater cost compared to less polluted waters.

Summary
1. When calculating the municipal wastewater treatment technological schemes according to STD statistical models, the infiltration and rainwater effect on the pollution composition transported through the sewage collector is insignificant and should not be taken into account.
2. When choosing a re-technologization scheme for sewage treatment plants, the most polluted stream purification technology, i.e., concentrated wastewater, should be adopted for practical implementation.

References
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