Studying Drinking Water Quality and its Change During Transportation through Samara Water-Supply Facilities

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Abstract. The paper investigates changes in water physico-chemical composition and its physical indicators through \( \zeta \)-potential in residential buildings in eight administrative districts of Samara. The results are processed by the methods of mathematical statistics and presented at the 0.05 level of importance. The sampling points for water in the city districts were chosen with the aid of random numbers tables. It was determined that the quality of drinking water was stable and consistent with the existing standards in Zheleznodorozhniy, Samarskiy, Leninskiy, Octyabrskiy, Kirovsliy, Sovetskiy and Promyshlenniy districts of Samara. The following indicators were taken into account: pH, colour, turbidity, alkalinity, general rigidity, content of ions \( \text{Ca}^{2+} \), \( \text{Mg}^{2+} \). It was also established that drinking water in Kuibyshevskiy district (with all other excellent indicators) had increased mineralization due to the natural hydrological conditions of the water inlet. Some change in the size of zeta-potential of the water was detected during its transportation through the existing water-supplying networks of the city. It was shown that the link between zeta-potential and various kinds of contamination in drinking water is underexplored and requires further detailed study.

1. Introduction
Water management of Samara mega-city is unique in its technological and operational difficulties induced by the significant decline in requisite water discharge in recent years. It is also characterized by long and worn-off networks, different types of water supply sources and initially accepted technologies for water treatment [1-7].

2. Relevance
Historically, Samara network has four main sources of water treatment: pumping-filtration plants (PFP \( \# 1 \), \( \# 2 \) and \( \# 3 \)), urban water supply station (UWSS), water inlets and water purification systems (WPS) in Krasnoglinskiy district. PFP \( \# 1 \) provides its water to Sovetskiy, Octyabrskiy, Zheleznodorozhniy, part of Kirovskiy and Promyshlenniy districts of Samara. PFP \( \# 2 \) provides water to Kirovkiy district, and to the greater part of Promyshlenniy and krasnoglinskiy districts . UWSS brings drinking water to Samarskiy, Leninskiy and partially Kuibyshevskiy districts, and PFP \( \# 2 \) carries water to the rest of Kuibyshevskiy district of Samara. PFP \( \# 1 \) and PFP \( \# 2 \) technological and high-altitude schemes are described in Paper 1 [1].

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Urban water supply station (UWSS) was built in 1956 in the old city on the bank of the river Volga. The installed power capacity of waste-disposal plants is 50000 m\(^3\) of water per day. Actual average water supply to consumers varies from 20 to 30000 m\(^3\).

Pumping-filtration plant №3 (PFP №3) is located in Samarskoe Zarechie. It was put into operation in 1999. PFP №3 complex consists of 19 linearly located wells in the first bottom of the Samara river, deferrization station and ten quick filters. The actual water delivery to the network is 25-30 thousand m\(^3\) per day, depending on the time of year.

Water from all treatment facilities of Samara meets requirements mentioned in Paper 8 [8]. The purpose of this study is to examine changes in drinking water physical-chemical composition during its transportation not only via the city's piped network but also (and especially) via in-house systems of Samara by measuring its electrokinetic potential. This research develops at a higher level the work which began in 2012 [2]. It studied the effectiveness of coagulation process with different reagents at PFP №1.

Zeta-potential (ZP, \(\zeta\)-potential) is the most important indicator of pollution sustainability degree (mainly of colloidal dispersion). It is known [9] that with the increase in ZP value, the system stability also increases. It is accepted that ZP value equal to 25-30 mV is a boundary value. At this value the process of particles coagulation begins [10]. Thus, the range from 0 to 30 mV is the best way to facilitate water purification processes through coagulants and (or) flocculants.

The determination of \(\zeta\)-potential value is complicated by the complexity of the process of its determining and by the absence of available factory fabricated instruments. Researchers working at the Water Supply and Wastewater Chair designed a device [3] working at amperometrical method of determining electrokinetic mobility of particles [9]. This device is based on former works by S.M. Chudnovskiy [11,12]. The calculation of zeta-potential was carried out according to the equation of Helmholtz-Smolukhovskiy [9, p. 201]. ZP value measurements were taken five times on each sample of water. The results were processed by methods of mathematical statistics at 0.05 level of importance according to the methodology introduced in Paper 13 [13].

Water samples were taken in accordance with the requirements of All Union State Standard (GOST) P 51593-2000 "Drinking water". OOO "SCS", being an accredited laboratory, collected samples from clean water reservoirs of pumping-filtration plants (CWR PFP), from pumping stations (PS) and from water-pumps (WP) of the centralized supply system, in accordance with the program [14], developed on the basis of the requirements of Sanpin 2.1.4.1074-01 [8] and state sanitary and epidemiological legislation [15-16], established by the Federal Service for consumer and human rights supervision of the Samara region.

Besides, researchers working at the Water Supply and Wastewater Chair collected water samples from residential buildings (with sampling points being water taps of apartments) in various parts of the city. The selected samples were analyzed according to methodologies [17-19] on the same day. The analysis was performed in the accredited hydrochemical laboratory of the Water Supply and Wastewater Chair. Such indicators as turbidity, alkalinity, pH, calcium and magnesium ions were considered during the analysis. Summarized results of studies are shown in Table 1 (with only a few selection points in four districts of the city). The temperature of the selected water samples (except indicators marked with *) correspond to the time of analysis of these samples in the hydrochemical laboratory of the Water Supply and Wastewater Chair.

For residential buildings of Kuibyshevskiy district, it was found out that the rate of colour of the water samples was 3.8 times greater in autumn than in summer, while in other areas, the colour in summer was 1.3-1.5 times greater than it was in autumn. Colour of the water and its pH met the requirements of Sanpin [8] in all city districts. Values of zeta-potential in residential buildings were as follows: in Zheleznodorozhnyi district it changed from 127.3 ± 16.0 to 158.2 ± 9.0 mV, in Samarskiy district it hanged from 147.1 ± 6.0 to 154 ± 3.0 mV. In Leninskiy district, ZP values decreased from 177,0 ± 2.3 (Molodogvardeyskaya st., 194) to 115,2±14,5 mV (Molodogvardeyskaya st., 207). In Octyabrskiy district they decreased from 193.2 ± 10.0 (at Sampling Point 9) to 123.0 ± 6.6 mV.
Table 1. General characteristic of drinking water in *residential buildings* in Samara districts.

| Sampling location | Sampling Date | Sampling Date | Values of indicators |
|-------------------|---------------|---------------|----------------------|
|                   |               | ZP, mV        | pH | temperature, °C | Colur, grad. | Turbidity, mg/dm³ | alkalinity, mmol/d m³ | Total rigidity, mg-eq/d m³ | Calcium, mg-eq/dm³ | Magnesium, mg-eq/dm³ |
| Zheleznodorozhniy district | | | | | | | | | | |
| 1. Partizanskaya st., 56* | 12.05.16 | 151.0±10.0 | 6.8 | 17 | - | 2.20 | 2.6 | 4.6 | 2.6 | 2.0 |
| | 07.12.16 | 127.3±16.0 | 6.5 | 17 | - | 0.08 | 3.0 | 4.6 | 3.3 | 1.3 |
| Kievskaya st., 12 (NSP,70)** | 20.10.16 | - | 6.9 | 12.1 | 11.6 | <1.0 | - | 4.1 | - | - |
| | 06.12.16 | - | 6.9 | 6.0 | 12.7 | <1.0 | - | 4.1 | - | - |
| Samarskiy district | | | | | | | | | | |
| 2. Samarskaya st., 61* | 28.04.16 | 152.0±10.0 | 7.0 | 20 | - | no val. | 3.0 | 4.3 | 3.0 | 1.3 |
| | 14.07.16 | 147.1±6.0 | 6.5 | 21 | - | 0.76 | 2.1 | 3.6 | 2.6 | 1.0 |
| | 19.11.16 | 154.5±3.0 | 6.6 | 19 | - | no val. | 2.3 | 3.5 | 2.3 | 1.2 |
| Leningradskaya s 106 (BPK) ** | 04.05.16 | - | 7.5 | - | 18.2 | 1.61 | - | 4.8 | - | - |
| | 03.11.16 | - | 7.5 | 10.2 | 11.4 | <1.0 | - | 4.8 | - | - |
| Leninskiy district | | | | | | | | | | |
| 3. Molodogvardeyskaya st., 207* | 27.01.16 | 115.2±14.5 | 7.0 | 20 | - | 0.78 | 2.2 | 5.1 | 4.0 | 1.1 |
| | 01.02.16 | 134.7±5.3 | 7.0 | 24 | - | 0.78 | 2.2 | 5.2 | 4.3 | 0.9 |
| | 28.07.16 | 153.5±9.7 | 6.5 | 25 | - | 0.08 | 2.4 | 4.0 | 3.0 | 1.0 |
| Molodogvardey skaya st., 209 (NSP-82/2) ** | 28.01.16 | - | 7.5 | - | 9.7 | 1.03 | - | 4.8 | - | - |
| | 29.02.16 | - | 7.5 | - | 10.0 | 1.25 | - | 4.8 | - | - |
| | 27.07.16 | - | 7.5 | - | 16.8 | <1.0 | - | 4.8 | - | - |
| Oktyabrskir district | | | | | | | | | | |
| 4. Novo-sadavaya s 25* | 27.01.16 | 166.1±9.9 | 7.0 | 20 | - | 0.56 | 3.2 | 5.8 | 3.4 | 2.4 |
| | 01.02.16 | 123.0±6.6 | 7.0 | 20 | - | 0.55 | 3.3 | 5.8 | 3.5 | 2.3 |
| Novo-sadovaya st., 25B (NSP- 45) ** | 20.01.16 | - | 6.9 | - | 14.3 | <1.0 | - | 4.1 | - | - |
| | 20.02.16 | - | 6.9 | - | 16.4 | <1.0 | - | 4.1 | - | - |
| Kirovskiy district | | | | | | | | | | |
| Krasnopresnenskaya st., 2* | 26.07.16 | 205.9±6.5 | 6.6 | 24 | - | no val. | 3.8 | 3.2 | 2.4 | 0.8 |
| Lenin-Krasnopresnenskaya sb. 07.16 a st. (BPK) ** | | | | | | | | | | |
*) – statistics according to samples collected by the researchers of the Water Supply and Wastewater Chair in residential buildings (temperature measured during laboratory analysis).
**) – statistics according to samples collected by the researchers from OOO "SCS" (temperature measured at the moment of taking samples at water supplying facilities).

The highest ZP value was determined in Kirovskiy district (Krasnopresnenskaya st, 123): 205,9 ± 6.5 mV. The lowest value was determined in Leninskiy district (Molodogvardeyskaya st., 207): 115.2±14.5 mV. River-water ZP values were 3-4 times greater than those of artesian water. The rates of water rigidity at sampling points of water inlets fed by the waters of the Volga river (UWSS, PFP № 1 and № 2) complied with the standards [8]. These rates were influenced by Ca2 + salts by 56-83%. Drinking water in Kuibyshevskiy district (with all other excellent indicators) had increased mineralization due to the natural hydrological conditions of the water inlet. It should be noted that the share of Ca2 + salts in the total value of water rigidity was 73-77%.

The analysis of the results showed that water quality remained within acceptable limits but tended to deteriorate in the old housing stock and as it approached the historic centre of the city. It has been found that when the point of water sampling was at its farthest from waste-disposal plants, its ZP value was at its highest and closest to maximum-permissible physico-chemical indicators of water quality.

It is clear that the great length of water network systems and heavy wear and tear of the internal housing systems serve as additional sources of pollution. This conclusion points to the need for water-quality express control (for example, through the use of ZP) not only in water distribution networks and water treatment stations but also in the place where it is consumed, that is directly in residential buildings. In general, water quality corresponded to the standards [8].

3. Conclusions
1. It is shown that the main drinking water quality indicators in Samara correspond to the health standards.
2. It is determined that water zeta-potential changes during water transportation process depending on the distance of the consumer from PFP. Similar to that, water quality changes in terms of the indicators studied. The research demonstrates a heavy dependence of water ZP on its rigidity. It means that that further research is needed.

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