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Ionic composition of drinking water and its influence on the value of its zeta potential (ZP)

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Abstract. The authors demonstrate the dependence of ZP on the value of water ionic composition, characterize test water physical and chemical composition and introduce thorough analysis of the obtained results. In order to reveal a complete picture of water quality, they also define such additional parameters as test water pH, temperature, turbidity and alkalinity in the course of the research. The study proves that all studied water parameters correspond to SanPiN 2.1.4.1074-01 Standard "Drinking water. Hygienic requirements for the quality of water in centralized drinking water systems. Quality control. Sanitary rules and regulations". The paper also presents mathematical dependences between the ζ-potential and the content of anions and cations in the test water with the accuracy of approximation R2 not less than 0.83.

1. Introduction
The research aims to establish the degree of dependence of the electrokinetic potential (ζ-potential, ZP) on the ionic composition of water. To achieve these goals the researchers fulfil the following tasks: sampling of tap water from four sampling points of Samara water supply network; determination of the teas water physical and chemical composition and its Zeta potential; results processing and analysis.

2. Problem specification
Zeta-potential value in the test water samples was carried out while using the installation created by the Department of Water Supply and Wastewater Treatment of Samara State Technical University (see Fig. 1) adopting the methodology described in Paper [1]. All measurements were made on the basis of amperometric method of electro-kinetic mobility determination [2]. The ZP value was determined from five water samples while using the Helmholtz-Smoluchowski equation [3].

The researchers firstly connected the unit to a DC source, then poured the distillate into the chamber to verify the readings accuracy (that should be within 0,0÷0,1 A). After testing the readings with the distillate, the test solution was poured into the cell. To measure the values of the oxidation-reduction potential of pure samples and salt solutions the authors used ORP-meter 2069 produced by "Kelilong", its operating range being ±1999 mV at 0-50°C and inaccuracy of ±5 mV. In addition to the main indicators, to obtain a complete picture of the teat water quality, sensory data as well as harmful substances value was collected in accordance with the Rules stated in Paper [4]. The obtained results were compared to MAC norms [6].

3. Methodology
To determine the turbidity of water the researchers used photovoltaic concentration colorimeters KFK-2MP. Determination of alkalinity was carried out according to the procedure set out in All Union State Standard (GOST) 31957-2012 Water. The methods for determination of alkalinity and mass concentration of carbonates and hydro carbonates" [7]. Concentration of chloride ions was determined by the method described in All Union State Standard (GOST) 4245-72 "Drinking Water. Methods for determination of chlorides "[8]. General rigidity concentration was determined according to the procedure de-scribed in All Union State Standard (GOST) 31954-2012 "Drinking Water. Methods for determining rigidity" [5]. Determination of calcium ions content was carried out according to the procedure described in All Union State Standard (GOST) 23268.5-78 "Mineral drinking water, medical-table and natural table water. Methods for determination of calcium and magnesium ions [9].

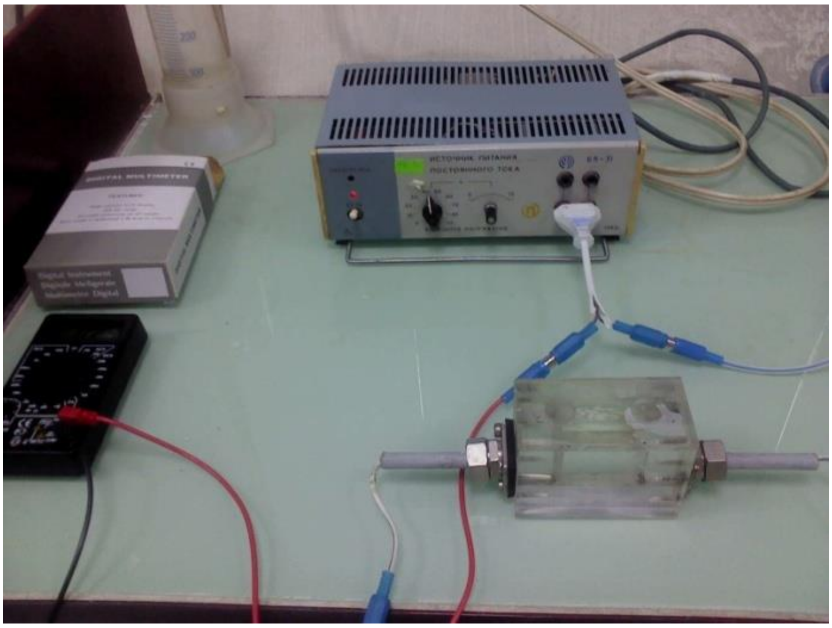

Figure 1. General view of the device for measuring the ZP value.

The calculation of ζ-potential was carried out by using five water samples at a significance level of $q = 0.05$ according to the methods described in Paper [10]. The order of experiments was randomized while using a table of random numbers. PH measurements were carried out by KELILONGPH-009 Device. The dry sediment was evaporated by the "Drinking Water. The method of determining the content of dry sediment" methodology. For measuring and mixing solutions, the researchers used BIONITPROLINE pipette dispenser and Termo_1-10 ml.

4. Results
The obtained results analysis showed that Zeta potential value is directly proportional to the concentration of *magnesium ions* in the water, *sulphates and water chromacity index*. The dependence of the change in the value of ZP on the concentration of *calcium, magnesium and chloride ions* in water stands out. It can be assumed that the value of water chromacity indirectly affects the ZP value, because the chromacity itself depends on the presence of iron and humic acids in the water, that is, most likely, they affect the value of ZP. This phenomenon requires further study.

The results are summarized in Table 1 and Figures 2-7.

The analysis of the data given in Table 1 proves that all studied water parameters correspond to SanPiN 2.1.4.1074-01 Standard "Drinking water. Hygienic requirements for the quality of water in centralized drinking water systems. Quality control. Sanitary rules and regulations".

Table 1. Generalized parameters of test water quality.

Sampling Date	Averaged values at *q = 0.05*					Physico-chemical indicators of the test water quality									
	time, s	current, mA	particle velocity, cm/s	electrophoretic mobility, cm^2/s	D.P., mV	Ca^{2+}, mg/dm^3	Mg^{2+}, mg/dm^3	pH	turbidity, mg-EQ/dm^3	chromacity, deg.	Cl^-, mg/dm^3	SO_4^{2-}, мг/дм^3	$(Na+K)$, mg/dm^3	turbidity, mg-EQ/dm^3	rigidity, mg-EQ/dm^3
Belorusskaya, 96															
25.12.15	7.45	5.41	0.617	0.000025	35.84	11.6	3.5	6.9	0.20	11.60	12.0	364.8	367.7	6.0	15.1
27.01.16	7.36	5.39	0.625	0.000026	36.41	11.5	3.6	6.8	0.23	11.50	12.1	364.9	367.8	5.9	15.1
01.07.16	7.56	5.38	0.608	0.000025	35.52	11.6	3.5	6.9	0.30	11.54	12.2	364.7	367.6	5.8	15.1
08.07.16	7.43	5.42	0.619	0.000025	35.87	11.7	3.6	6.8	0.35	11.60	12.1	364.8	367.51	5.9	15.3
Belorusskaya, 92															
21.12.15	7.21	4.52	0.638	0.000031	44.33	10.9	4.1	6.8	0.22	11.54	7.21	365.1	368.0	6.0	15.0
25.12.15	7.19	4.36	0.640	0.000032	46.08	11.1	4.2	6.9	0.25	11.53	7.19	364.9	367.8	5.8	15.3
27.01.16	7.27	5.29	0.633	0.000026	37.56	11.2	3.8	6.9	0.31	11.29	7.27	364.2	367.1	5.8	15.0
01.02.16	7.30	4.68	0.630	0.000030	42.28	11.1	4.68	6.8	0.32	11.36	7.30	364.1	367.0	5.9	15.78
Belorusskaya, 18															
21.12.15	7.53	4.62	0.611	0.000029	41.52	11.0	4.10	6.8	0.21	11.55	11.0	601.6	603.2	6.0	15.1
25.12.15	7.52	4.64	0.612	0.000029	41.40	11.1	4.20	6.8	0.23	11.56	11.1	601.2	602.8	5.9	15.3
27.01.16	7.65	4.63	0.601	0.000029	40.78	11.3	3.80	6.9	0.32	11.49	11.4	601.7	603.6	5.8	15.1
01.02.06	7.52	4.62	0.612	0.000029	41.58	12.0	4.10	6.8	0.33	11.58	11.1	601.5	603.2	6.2	16.1
Belorusskaya, 17															
21.12.15	7.48	4.59	0.615	0.000030	42.08	11.3	4.31	6.9	0.20	11.54	7.48	599.9	602.8	5.9	15.61
27.01.16	7.55	4.57	0.609	0.000029	41.87	11.2	4.29	6.9	0.22	11.53	7.55	598.9	601.8	5.9	15.49

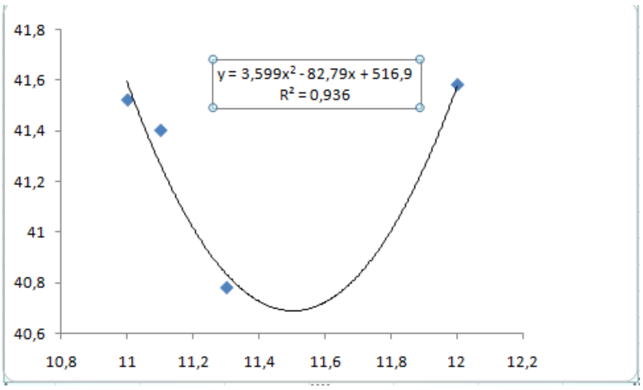

Figure 2. Dependence of ZP value, mV, on the concentration of calcium ions in tap water mg/dm3, sampled at: 18, Belorusskaya street.

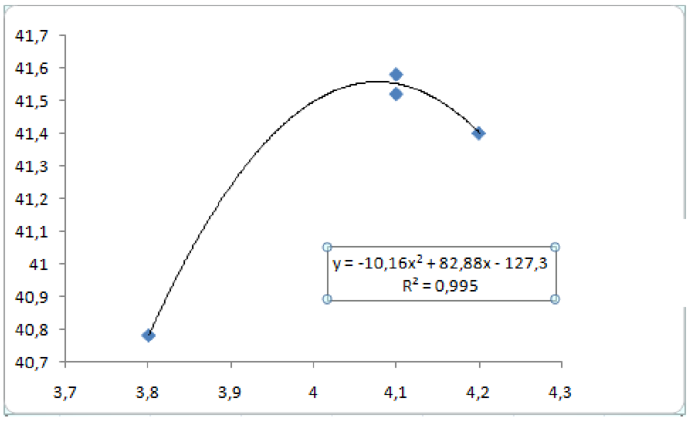

Figure 3. Dependence of ZP value, mV, on the concentration of magnesium ions in tap water mg/dm3, sampled at: 18, Belorusskaya street.

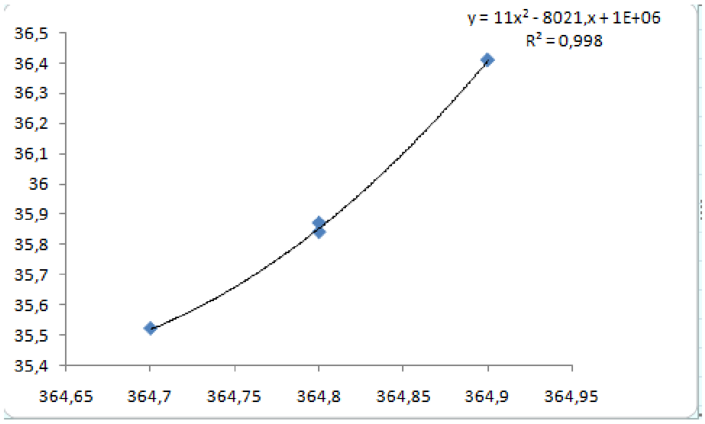

Figure 4. Dependence of ZP value, mV, on the concentration of sulphates in tap water mg/dm3, sampled at: 96, Belorusskaya street.

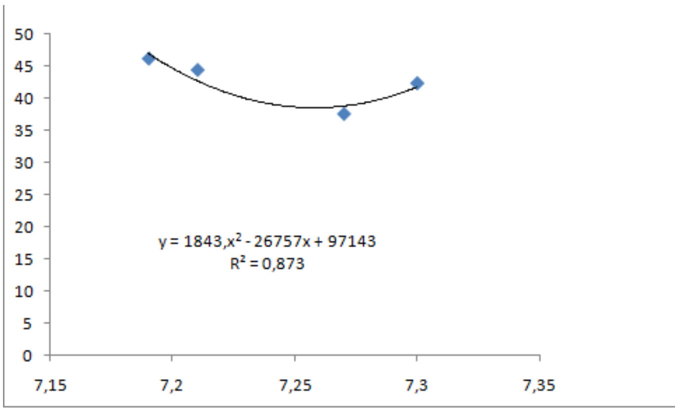

Figure 5. Dependence of ZP value, mV, on the concentration of chlorides, in tap water mg/dm3, sampled at: 92, Belorusskaya street.

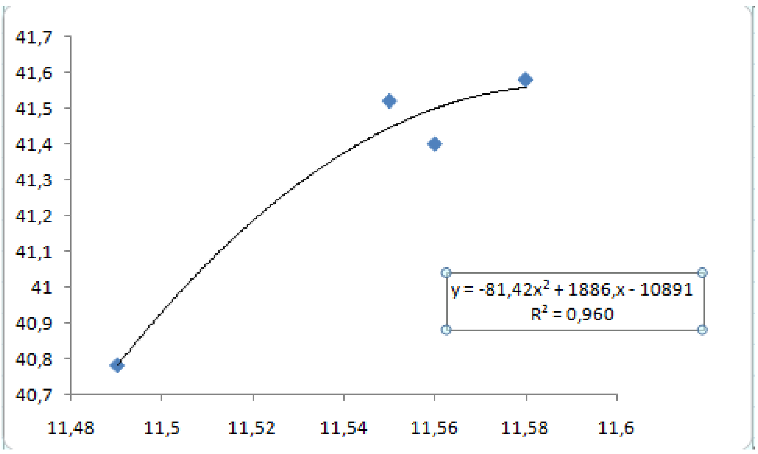

Figure 6. Dependence of ZP value, mV, on the chromacity, deg., in tap water, sampled at: 18, Belorusskaya street.

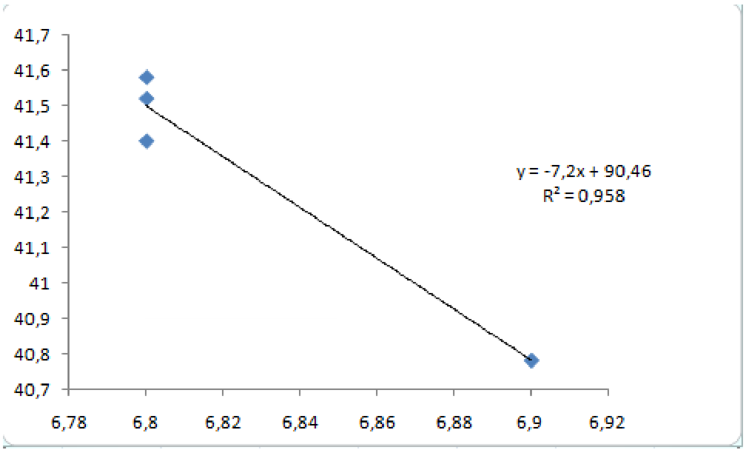

Figure 7. Dependence of ZP value, mV, on the chromacity, deg., in tap water, sampled at: 18, Belorusskaya street.

Figures 2-9 show strong connections between Zeta potential values, water rigidity and concentration of Mg^{2+}, Ca^{2+}, SO_4^2, Cl^- ions in test water. The accuracy of the approximation here ranges from 0.873 to 0.998.

5. Conclusions

Zeta potential value shows a strong dependence on Ca2+, Mg2+, SO2-4, Cl-,Na+K ion concentration in test water and on water chromacity index and its pH, as R2 here is greater than 0.7 in almost all the cases. Graphs of the remaining indicators, where R2 is significantly less than 0.7, indicate that they do not have a significant impact on Zeta potential value.

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