Influence of the saline waters of the flowing well on the chemical composition of water and bottom sediments in the Irtysh river and its tributary (Aremzyanka river)

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Abstract. The article presents data on the influence of waters from the self-flowing wells in the floodplain of the Aremzyanka river of the first order inflow on the chemical composition of the water in the large transboundary Irtysh river in the south of the Tyumen region (Tobolsk District). The article shows the excess of the background of various elements in the bottom sediments of the studied rivers. The number of ions in the water of the Aramzyanka river is 2 times higher in comparison with the main river. The paper discusses the impact of saline water from a flowing well on a freshwater ecosystem, its components.

1. Introduction
The state of the water bodies of the Ob-Irtysh basin is determined by both the natural features of the hydrographic network and the economic activity. The main problems in the field of protection and use of water resources of the Irtysh river basin are their low quality and water content. At the same time, in the period of 1950-1980s, during exploration works in the territory of the Tyumen region, a large number of exploration wells were drilled. For 30 years after their decomposition, the reservoir mineralized waters through them uncontrollably pour out and gush into the basin of the Irtysh River and its tributaries, which include the Aremzyanka river [1], [2].

This right-bank inflow flows into the Irtysh River at 576 km from the mouth at the border of the following 2 areas (Tobolsk and Uvat). In the left-bank part of the Aremzyanka River on the terrace above the floodplain 9 km from the mouth, one of these wells is No. 36 RG, with a flow rate of 1000 m³/day and a temperature of 73°C. There is a transformation of the natural state of the rivers as a result of the outpouring of saline water from such wells to the riverbed rivers’ ecosystem [2], [3]. Meanwhile, no one takes into account the effect of saline water from the wells when assessing the state of large watercourses, since this issue is poorly studied, which increases the relevance of our research.

In this regard, the purpose of the work is to determine the effect of saline waters on the chemical composition of the waters and bottom sediments of the Aremzyanka and Irtysh rivers.
2. Materials and Methods
Studies of the hydrochemical regime of the Irtysh and Aremzyanka rivers and the chemical composition of bottom sediments (BS) were carried out during the autumn low seasons in 2013, 2017, 2018. The concentration of elements in the bottom sediments was compared with background values for the south rivers of the Tyumen region [4]. River water and bottom sediments were sampled using standard methods in accordance with GOST 8.563-2009 [5] and GOST 31861-2012 [6]. For sampling of bottom sediments, a Petersen scooper bottom with a capture area of 0.025 m² was used. Chemical analysis of water, bottom sediments and the heavy metals content in them, and other elements were carried out in accredited laboratories of the TKNS UB RAS, FSUE “Gosrybtsentr” (Russia).

3. Results
As a result of studies on the rivers’ hydrochemical regime, we found that during the period under study, the sum of the main ions in the Irtysh River in Tobolsk and Uvat districts averaged 197.68 and 190.60 mg/l, respectively (Table 1).

Table 1. The chemical composition of the Irtysh and Aremzyanka rivers in September 2013, 2017, and 2018.

| Indicators | Units | Irtysh river | Aremzyanka river, Tobolsk district | Aremzyanka river, Uvat district, n = 2 | The estuary of Aremzyanka river, 2018, n = 3 | MFC | Background (Tura River) |
|------------|-------|--------------|-----------------------------------|----------------------------------------|--------------------------------------------|-----|-------------------------|
|            |       | Tobolsk district, 2013, 5 stations, n = 15 | Uvat district, 2013, 2 stations, n = 6 | Above the estuary, 2017, n = 2 |                                      |     |                         |
| O₂         | mg/l  | 872 – 11.07 | 8.98 – 9.96 | 9.24 | - | 9.87 – 11.04 | 9.43 | 100% 100% |
| pH         | units | 8.75 – 9.14 | 8.78 – 9.13 | 8.94 | 7.7 – 7.69 | 7.7 | 7.54 | 6.5-8.5 6.5-8.5 |
| Ca²⁺       | mg/l  | 43.26 – 61.86 | 38.75 – 49.38 | 48.1 – 68.14 | 58.12 | 40.08 – 64.13 | 49.43 | 180 - |
| Mg²⁺       | mg/l  | 5.40 – 7.72 | 4.83 – 6.16 | 20.66 – 24.5 | 22.48 | 18.23 – 20.66 | 19.44 | 40 - |
| Na⁺ / K⁺   | mg/l  | - | - | - | - | - | - |
| HCO₃⁻      | mg/l  | 96.0 – 113.53 | 101.20 – 111.0 | 286.8 – 280.7 | 283.7 | 183.1 – 250.2 | 207.5 | - - |
| CO₃²⁻      | mg/l  | 1.88 – 2.55 | 1.93 – 3.09 | 1.23 | - | - | - |
| Cl⁻        | mg/l  | 14.70 – 16.28 | 15.55 – 16.14 | 38.29 – 38.30 | 38.3 | 28.4 – 31.9 | 29.5 | 300 14.80 |
| SO₄²⁻      | mg/l  | 20.70 – 26.33 | 20.6 – 26.0 | 3.65 – 4.56 | 4.11 | 4.56 – 7.30 | 6.08 | 100 9.60 |
| Σion       | mg/l  | 85.87 – 220.78 | 149.2 – 241.0 | 428.5 – 436.1 | 432.3 | 287.9 – 377.3 | 319.0 | <1000 - |
| Total hardness | 0.0200* ppm | 1.95 – 2.79 | 1.75 – 2.19 | 4.4 – 5.1 | 3.5 – 4.8 | - | - |
| N/NH₄⁺     | mg/l  | 0.53 – 0.73 | 0.79 – 1.12 | 0.74 – 0.77 | 0.36 – 0.77 | 0.40 | 0.35 |
| N/NO₃⁻     | mg/l  | 0.008 – 0.017 | 0.011 – 0.019 | 0.101 – 0.103 | 0.102 | 0.038 – 0.127 | 0.071 | 0.02 0.014 |
| N/NO₂⁻     | mg/l  | 1.0 – 1.18 | 1.03 – 1.24 | 1.57 – 1.79 | 1.68 | 0.44 – 1.63 | 1.16 | 9.10 0.27 |
Note: Background values for sodium group, while the concentration of turn, this leads to a change of the bicarbonate class of the calcium group with the chloride class of the RG well into the Aremzyanka ion sum was played by bicarbonates, chlorides, calcium, magnesium ions occurs (dilution) in the mouth area and sodium.

It has been shown [2] that downstream of the well, this indicator amounted to 432.2 mg/l, a decrease in the concentration of ions occurs (dilution) in the mouth area – 319 mg/l. The most important role in the formation of the ion sum was played by bicarbonates, chlorides, calcium, magnesium, and sodium ions. It has been shown [2] that the salt ions coming from the catchment area of the Cherkashinskaya 36 RG well into the Aremzyanka river have a significant impact on the ion composition of river waters. In turn, this leads to a change of the bicarbonate class of the calcium group with the chloride class of the sodium group, while the concentration of Na and Cl increases significantly. These ions in the water have a high migration capacity [7], while entering the river in large volumes.

Table 2. Heavy metals in bottom sediments of the Irtysh and Aremzyanka rivers in September 2013, 2017.

| Indicator, mg/kg | Irtsh river | Tobolsk district | Plot (stream) of the water inflow into the Aremzyanka river, n = 3 |
|-----------------|-------------|------------------|-------------------------------------------------------|
|                 | Tobolsk       | Estuary, 2017, | Above the water inflow into the Aremzyanka river, n = 3 |
|                 | district, n = 3 | n = 6 | n = 2 | n = 3 |
| Ni              | 2.50–22.14    | 20.0–46.0 | 6.20–15.0 | 5.40–47.0 |
|                 | 10.70         | 33.0     | 10.60    | 21.13    |
| Cu              | 1.49–15.89    | 3.90–4.60 | 0.77–3.40 | 3.10–8.20 |
|                 | 5.90          | 4.30     | 2.09     | 5.60     |
| Zn              | 4.39–41.45    | 10.0–11.0 | 7.60–11.0 | 0.56–11.0 |
|                 | 17.90         | 10.50    | 9.3      | 5.92     |
| Cd              | 0.04–0.69     | 0.23–0.33 | 0.20–0.22 | 0.32–0.55 |
|                 | 0.18          | 0.28     | 0.21     | 0.45     |
| Pb              | 0.33–109.20   | 4.20–5.30 | 1.40–3.0 | 5.40–16.0 |
|                 | 40.35         | 4.75     | 2.20     | 9.37     |

| Mn     | 89.34–723.40 | 309.0–331.0 | 65.0–121.0 | 234.0–5480.0 |
|--------|--------------|-------------|------------|--------------|
|        | 262.5        | 320.0       | 92.0       | 2021.0       |
| Fe     | -            | -           | 21290.0    | 2775.0–6529.0 |
|        | -            | -           | 4152.0     | 5745.0       |
| Se     | -            | -           | 5.70–7.10  | 2113.0–3102.0 |
|        | -            | -           | 6.20       | 1561.50      |

Note: Background values for the bottom sediments are taken according to [4].
In the study of bottom sediments, for the south rivers of the Tyumen region, the excess of the background of the maximum levels of Ni in the stream flowing into the river Aremzyanka from the well, and the content of Ni is exceeded in 3.5 times in the river Aremzyanka, 1.8 times in the Irtysh river. The values of Mn are higher in 18.8-1.1 and 4.0-2.5 times, respectively. In the bottom sediments of the Irtysh River, the excess over the background is observed in Pb (8-10 times) and Zn (2-1.4 times) in the Uvat and Tobolsk districts (Table 2).

It should be added that the reservoir water, in addition to chlorides, which accumulate in bottom sediments, also contains fluorine, iodine, bromine, boron, strontium, and barium in concentrations significantly exceeding the MPC. At the same time, these components are not controlled by anyone either in the water or in the bottom sediments.

4. Discussion
The ongoing pollution of bottom sediments of the Irtysh river by specific toxic substances, including heavy metals, is associated with transboundary transport from overlying areas (Omsk region, Kazakhstan, PRC). Also, the pollution of bottom sediments is associated with the river fleet and the removal of pollutants from those floodplain areas where various enterprises operate, as well as the discharge of polluted wastewater in the catchment area [8].

In turn, according to [9], the composition of bottom sediments of the lower Irtysh consists in the increased content of those elements whose minerals are resistant to weathering, and floodplain soils have a high content of biogenic cadmium and zinc, alluvial soils-chromium, and nickel. It was shown [9] that the accumulation of trace elements in the bottom sediments of the Irtysh is 1.3-1.6 times more than in the soils of the floodplain, in which the tributary is located (Aremzyanka river). Anthropogenic halogenesis for watercourse functions is a problem with practically unexplored consequences [10], [11]. According to researchers, it has been shown [12] that salinization changes the fundamental physicochemical nature of the soil-water environment, increasing ion concentrations and disrupting the existing chemical equilibrium and solubility of minerals. At the same time, elevated concentrations of dissolved substances, especially sulfates, change the biogeochemical cycle of the main elements, including carbon, nitrogen, phosphorus, sulfur, iron. Also, an increase in the concentration of salts and sulfide causes physiological stress in the biota of floodplain lands, and ultimately can lead to significant changes in natural communities and related ecosystem functions [10-13]. For example, it was established [14] that the ionic stress caused by salinization has an inhibitory effect on both aerobic and anaerobic mineralization of organic substances. For the carp fish [15] and invertebrate hydrobionts [16], it was shown that as a result of changes in salinity, their behavior may change. Also, a decrease in reproductive adaptation of the plankton crustaceans to natural and anthropogenic stressors is observed [17].

5. Conclusion
Thus, our research clearly shows the difference in the chemical composition of the water and bottom sediments of the main Irtysh river and its first-order tributary (Aremzyanka river), which is affected by the mineralized iodine-bromine water of the flowing well. In the studied area of the Aremzyanka river, the number of ions, as well as the chloride content, exceeds these indicators of the Irtysh River in 3 times.

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