Sewage treatment technology for mining-and-smelting enterprise

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Abstract. The paper considers problems related to efficient treatment of sewage falling into natural surface water of a reservoir, making the latter technogenic. This treatment consists in creating an artificial ecological system in the way of a pollutant flow, based on the ability of individual biota links to absorb contaminants. The paper evaluates the ecological state of the environment exposed to intensive technogenic effect, produced by a mining-and-smelting enterprise. As for the context, the paper is relevant for the countries with a robust mining-and-smelting and industrial system, and for development of “green economy” in such countries.

1. Introduction
In natural waters, biocoenosis links (for instance, higher water plants) can create conditions that reduce concentration of ingredients in water by means of various physical and chemical processes. It is widely known that some biota links are capable of absorbing contaminants [1-7]. Effects of individual biota links, jointly, are one of the factors that can be used for treatment of sewage falling into a water reservoir, and for regulation of natural water quality.

2. Reference and methodology
The paper uses methods of environmental monitoring, graphical modeling, and bioindication. Also, the paper is based on rich reference and results of monitoring studies.

3. Results and discussion
Middle Ural is a so-called “area of minor rivers and lakes”, while geologically, it has lots of mineral ores. Started 300 years ago, development of mineral resources and ore treatment brought Ural to the whole new stage. Nowadays, the economy of the region is mostly based on mining-and-smelting industry [8]. The bulk of rivers and lakes are located nearby the industrial facilities, being sewage receivers. In fact, all of them are technogenic reservoirs with contaminant concentration exceeding limits by tens and hundreds of times.

Severskoye Reservoir was chosen a model facilities for studying treating ability of the higher water plants; the reservoir is exposed to the effect produced by a copper mining-and-smelting enterprise located at the Gumyoshevsky mine in the area Polevskoy (a city in the Sverdlovsk Region).

Today, the pilot in-situ leaching system is operating at the Gumyoshevsky mine; copper mining goes through feeding leaching solutions (water solutions of technical sulfuric acid 10-30 g/dm3) to the split-level grid of extraction and injection wells. When unloading wells, three major pollutant flows are formed, which fall into the Zhelezyansky gulf (a part of the Southern gulf of the Severskoye...
Reservoir, see Figure 2). Entering water reservoirs, sewage changes the composition of natural waters, having negative impact on the environmental state of surface waters [8-20].

Present-day environmental situation was evaluated during monitoring which included state assessment of environment component. For that, 230 surface water samples, 60 samples of soil, and 60 samples of plants were extracted. The contamination level of these components was assessed through comparing pollutant concentration thereof with criterion values.

The analysis of the results showed the following:
1. Environmental state of the topsoil was formed with abandoned waste piles (positive forms) and plant-filled old quarries of the Gumyoushevsky mine that started copper mining in 1702. Among heavy metals having polluting effect on the area, copper is on top, exceeding limits by 2-3 times (see Figure 1). Figure 1 shows that the highest copper concentration in soil is recorded in Zhelezyansky gulf of the Severskoye Reservoir. In plants, copper concentration does not exceed any limits across the whole area.

![Figure 1. Copper Concentration: a) in soil (mg/kg), b) in plants (mg/kg).](image)

Note: AC is the assessment criteria that involves MPCs maximum permissible concentrations), and background. ACs of the environment component state were based on combination of maximum permissible and background concentrations. If values of maximum permissible and background concentrations are almost equal, MPCs are used as ACs. If maximum permissible and background concentrations differ significantly, the latter are used as ACs.

2. Surface waters are waters of the Southern gulf of the Severskoye Reservoir. As mentioned above, contaminants fall into the reservoir with industrial sewage formed during in-situ leaching processes; first off, they enter the Zhelezyansky gulf, which is a part of the Southern gulf. Chemical analysis of 154 water samples extracted from 7 section lines of the Southern gulf (Figure 12) showed highest excess over MPCs for the following components: 100MPC for copper, 5MPC for zinc; in 76 samples extracted from three sewage flows falling into the Zhelezyansky gulf, over-limit values came to the following: 2,140MPC for copper, 4,604MPC for zinc.

The data acquired lead to the conclusion that the Southern gulf is actually technogenic, with water quality formed by technogenic localized sewage flows.

This is proven by the environmental and hydrobiological research of the Southern gulf of the Severskoye Reservoir, during which the species composition, development pattern, and structural and functional properties of the fish fauna were studied. In total, 24 perch, 14 breams, 13 pikes, 5 roaches, 2 idees, and 1 crucian carp were caught. By analyzing the fish fauna data, it was found that, despite fair food supply in the reservoir, growth pace was assessed as medium or low. Copper concentration in bone tissue (5.35 mg/kg) exceeds the value for fish of other reservoirs (4 mg/kg); in
70.2% of the catch was characterized by toxicosis in destruction of tail fin rays and sores. These data indicate that this environment is very toxic for fish. Thus, surface waters have the most severe impact which deteriorates the environmental situation in the area of the effect produced by the mining-and-smelting enterprise.

Figure 2. Location of Sewage Flows Falling into the Severskoye Reservoir and Sample Extraction Places. Key Parameters of the Reservoir: Length — 4.5 km; Width — 0.6 km; Depth — 3.5 m; Water Volume — 12.5 million m3. Legend: – localized pollutant flow; – place of surface water sample extraction.

The test was conducted at the experimental botanic site established in the Zhelezyansky gulf of the Severskoye Reservoir. The purpose of this test was to define the character of the water treatment process - absorbing of contaminants by plants. First and foremost, the ability of higher water plants of greater mass to accumulate various mineral ingredients. Table 1 shows the results of evaluation of how higher water plants accumulate ingredients.

Table 1. Accumulation of Ingredients by Higher Water Plants under Intensive Pollution of Natural Waters by Metal Compounds.

| Test Subjects           | Metal Concentration (mg/kg) | Accumulation Coefficient |
|-------------------------|-----------------------------|--------------------------|
|                         | Cd  | Cu  | Pb  | Fe  | Zn  | Ca  | As  |                  |
| Green cattail leaves    | 0.021 | 0.0115 | 0.125 | 1.045 | 0.225 | 5.5  | 0.002 |
| Cattail root            | 0.027 | 0.074 | 0.145 | 7.42  | 0.405 | 3.4  | 0.036 |
| Reed leaves (dying)     | 0.0165 | 0.0305 | 0.115 | 1.365 | 0.48  | 6.5  | 0.0005 |
| Green reed leaves       | 0.0215 | 0.0435 | 0.115 | 6.66  | 0.29  | 2.6  | 0.0029 |
| Reed blossom            | 0.029 | 0.05 | 0.011 | 0.108 | 0.004 | -    | -    |
| Reed stem               | 0.025 | 0.0025 | 0.0105 | 0.0441 | 0.001 | -    | -    |
| Reed root               | 0.2  | 0.1185 | 0.12 | 7.84 | 0.76 | -    | 0.014 |
| Test Subjects           | Cd  | Cu  | Pb  | Fe  | Zn  | Ca  | As  |                  |
| Green cattail leaves    | 17  | 0.02 | 13  | 0.09 | 0.036 | 255  | 0.03 |
| Cattail root            | 22  | 0.15 | 15  | 0.65 | 0.57  | 157  | 0.48 |
| Reed leaves (dying)     | 20  | 0.06 | 12  | 0.12 | 0.68  | 301  | 0.007 |
| Green reed leaves       | 17  | 0.09 | 12  | 0.58 | 0.41  | 12   | 0.03 |
| Reed blossom            | 23  | 0.01 | 0.1 | 0.009 | 0.006 | -    | -    |
| Reed stem               | 20  | 0.005 | 0.1 | 0.004 | 0.001 | -    | -    |
| Reed root               | 16  | 0.237 | 12  | 0.68 | 108   | 278  | 0.18 |
From various environmental systems that are on the way of pollutant sewage flows (pre-reservoir, botanic site with banked earth, oxidation ditch, etc.), we have chosen a bio-plateau. A bio-plateau is a part of a reservoir, located nearby the place of pollutant inflow, covered with higher water plants, not separated from the main water reservoir area via any device.

We have chosen a bio-plateau as it is capable of cleaning a reservoir of localized sewage flows, designed for removing macro- and microcomponents (heavy metals) from a water reservoir — this property fully complies with the characteristics of the reservoir studied.

The modeling of the botanic site (bio-plateau) and studying of the treating ability of the “sewage-receiving” reservoir, in the presence of higher water plants (narrowleaf cat-tail), showed that the concentration of contaminants (copper, zinc, sulfates) is stably decreased to the levels corresponding to requirements for potable and general-sanitary water reservoirs (Table 2).

Thus, studies of operation of an experimental botanic site as a sewage-treatment facility are indicative of high efficiency of such a method for water quality regulation.

**Table 2.** Results of Research of Self-Purification Ability of the Severskoye Reservoir under Effect of URALGIDROMED OJSC (Polevskoy District, Sverdlovsk Region).

| Chemical Element | MPC for Industrial, Potable, and Household Purposes, mg/l | Annual-Average Concentration, mg/l | Input-Output Concentration Difference, mg/l | Self-Purification, % | MPC reached/not reached |
|------------------|----------------------------------------------------------|------------------------------------|---------------------------------------------|---------------------|------------------------|
| Sulfates         | 500                                                      | 4613.72                            | 492.27                                      | 4121.45             | 100 Reached            |
| Zinc             | 5                                                       | 23.02                              | 0.15                                        | 22.87               | 66.66 Reached          |
| Copper           | 1                                                       | 2.14                               | 0.04                                        | 2.1                 | 32.5 Reached           |

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