Medical Waste as a Source of Antibiotic Contamination in Wastewater

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Abstract. In modern conditions of the coronavirus pandemic, the amount of medical waste is sharply increasing, among which antibiotics that enter the environment from various sources are among the most hazardous from an environmental point of view. The article analyzes the sources of antibiotics coming with hospital wastewater. The majority of medical institutions for the population of our region have no local treatment facilities and antibiotics transit through them. The aim of this paper was to collect and analyze information on medical waste in medical institutions of the Baikal region as a source of antibiotics in water bodies and to assess environmental risks. Based on information on the procurement of antibiotics for medical institutions in the Irkutsk Region, it was established that the sources of pollution of natural waters with antibiotics are wastewater from agricultural enterprises, medical institutions, and home first-aid kits. The total amount of antibiotics circulating in the Irkutsk Region reaches 9.2 tons, the residual concentration of antibiotics in wastewater from various sources ranges from 0.3 to 3.9 mg/L. The hazard quotients for drinking water contaminated with antibiotics are of medium and low categories.

1. Introduction
In modern conditions, when the SARS-CoV-2 virus is spreading on the planet infecting and killing millions, the amount of medical waste is sharply increasing. The term “medical waste” includes any waste generated as a result of the activities of medical institutions or medical and preventive measures carried out by the population (completely or partially consisting of human or animal tissues, blood or other body fluids, excrement, pharmaceuticals, bandages, items of medical care, etc.).

Of the total amount of waste coming from health care activities, approximately 85% is ordinary non-hazardous waste comparable to household waste. The remaining 15% are considered hazardous materials that can be infectious, chemical or radioactive. Among the hazardous waste are infectious waste contaminated with blood and other body fluids, waste from patients in isolated wards; chemicals, in particular laboratory sample solvents, disinfectants, pharmaceuticals, expired, unused, contaminated drugs and vaccines. High-income countries generate, on average, up to 0.5 kg of hazardous waste per hospital bed per day; while low-income countries produce an average of 0.2 kg.
Medical waste in most countries of the world has long been classified as highly hazardous waste. The problem is that the amount of medical waste is on a steady upward trend, especially now in connection with the pandemic. Medical waste is the main source of harmful chemical, chemical-biological and biological elements coming into the environment. These are primarily drugs and chemicals - solid and liquid chemicals; disinfectants; toxic substances; expired or falsified medicines; cytotoxins.

A particular hazard is created by the uncontrolled flow of antibiotics into the environment, since microorganisms become resistant to them and the effectiveness of treatment decreases sharply. The problem of pharmaceutical waste and antibiotic resistance today is very acute in the world, in Russia and the Baikal region in particular [1,2].

Most health care facilities lack an organized system for collecting, storing, transporting and disposing of drug residues; as a rule, they are drained into the city-wide drainage system. Wastewater contaminated with antibiotics is treated at treatment facilities, but they are not completely removed, and they transit and enter natural water bodies. For example, 14 antibiotics were found in wastewater after treatment facilities, including sulfonamides, tetracyclines, fluoroquinolones, macrolides, cephalixin, lincomycin and trimethoprim [3-11].

In the Baikal region, not a single health care facility has local treatment facilities for the treatment of hospital effluents, and the entire mass of pharmaceuticals after their use ends up in the sewage system and further in surface waters.

The aim of this paper was to collect and analyze information related to medical waste from healthcare facilities in the Baikal region as a source of antibiotics in water bodies, followed by an assessment of environmental risks for the population of the region.

2. Materials and Methods
The objects of the study were medical institutions in the city of Irkutsk. We analyzed the initial data: background information on the amount of antibiotics passing through the pharmacy network in Irkutsk; the number of patients passing through hospitals; information on the procurement of antibiotics in hospitals in Irkutsk.

The forecast assessment of the environmental risk for the population of the Irkutsk Region was carried out in accordance with the methodology recommended by the American Environmental Protection Agency [1].

3. Results of the Study and Discussion
Studies have found that antibiotics are widely used in general hospitals, their share in the total number of pharmaceuticals ranges from 30 to 50%. They are used to prevent infectious complications in surgery, as well as in the treatment of pneumonia (against staphylococaceae bacteria), syphilis (treponema pallidum), tuberculosis (mycobacterium tuberculosis), salmonellosis (against bacteria from the genus salmonella), skin infections, etc. The range of antibiotics purchased from trade organizations in the Irkutsk Region includes 37 trade and 28 international non-proprietary items.

Based on the analysis of antibiotic purchases by three hospitals in Irkutsk, it was found that in 2020 333.72 kg of antibiotics were supplied and used. The amount of medicines consumed during treatment depends not only on the number of beds, but also on the specifics of the services provided. Thus, Irkutsk City Clinical Hospital No. 1 during the pandemic was converted into a covid hospital and the consumption of medicines was 6 times higher than that in the Irkutsk Regional Clinical Hospital. Irkutsk Regional Clinical Hospital has an in-patient facility for 1200 beds, which is two times more than that in Irkutsk City Clinical Hospital No. 1 with 615 beds.
Table 1. Consumption of antibiotic medicines in hospitals of Irkutsk in 2020, kg

| Pharmaceutical          | City Hospital No. 10 | City Hospital No. 1 | Regional Hospital |
|-------------------------|----------------------|---------------------|------------------|
| Total antibiotics supplied | 35.51                | 227.24              | 70.97            |
| Including               |                      |                     |                  |
| Azithromycin            | 1.65                 | 10.5                | 6.38             |
| Amoxicillin             | 2.4                  | 0.7                 | 15.0             |
| Ampicillin              | 1.4                  | 1.5                 | 16.2             |
| Ciprofloxacin           | 2.4                  |                     | 16.0             |
| Vancomycin, powder      | 1.4                  | 1.4                 | 1.7              |
| Levofloxacin            | -                    | 20.625              | -                |

If we assume that all purchased antibiotics were used by hospital patients, then we can calculate the amount of medicines that entered the hospital effluent with the waste products of patients (urine and feces). According to [11], 50-80% of antibiotics that enter the body leave it through human excretion. In our calculation, we took the value of 65%.

Having taken in the calculations the total amount of antibiotics used in 143 hospitals in the Irkutsk Region, we established that 9240.16 kg of antimicrobial drugs entered the sewage system.

According to the data in [11], in developed countries, hospitals discharge from 400 to 1200 liters of water per bed daily. Having taken the daily water consumption for 1 bed-day of 800 liters and statistical information on the bed capacity in the Irkutsk Region, we were able to calculate the volume of hospital wastewater in the Irkutsk Region.

It has been established that the daily discharge of hospital wastewater in the region is 19,312 m$^3$, and the annual volume will be 7,048,880 m$^3$, which is 4.4% of the total volume of domestic wastewater in the region.

The work assessed the contribution of the main source of antibiotics, wastewater, coming in water bodies of the Irkutsk Region (Table 2).

Table 2. Amount of antibiotics entering the wastewater of the Irkutsk Region

| Source                          | Volume of wastewater discharged from the source per year, million m$^3$ | Mass of antibiotics entering the wastewater per year, t | Antibiotic content in the wastewater, mg/L |
|---------------------------------|------------------------------------------------------------------------|------------------------------------------------------|-------------------------------------------|
| Agricultural facilities         | 98,215,650                                                             | 383.115                                              | 3.9                                       |
| Medical organizations           | 7,048,880                                                              | 9.24                                                 | 1.31                                      |
| Medicines from home first aid kits | 178,266,456                                                           | 0.054                                                | 0.307                                     |

During the forecast assessment of the environmental risk for the population of the Irkutsk Region according to the methodology recommended by the American Environmental Protection Agency, it was found that the hazard quotients calculated for the standard consumption of drinking water at the minimum and maximum concentrations of antibiotics (dilution of 1:10 and 1:1000) belong to medium and low categories (Table 3).
According to the accepted classification, the risks according to the hazard quotient (HQ) are as follows: the level of risk is minimal, if HQ < 0.1; the level of risk is low, if HQ = 0.1 - 1.0; the level of risk is medium, if HQ = 1.0 - 5.0; the level of risk is high, if HQ = 5.0 - 10.0, and the level of risk is extremely high, if HQ > 10.0.

**Table 3.** Predicted value of the hazard quotient for the consumption of drinking water contaminated with antibiotics

| Source of water                          | Predicted value of the hazard quotient for the minimum concentration | Predicted value of the hazard quotient for the maximum concentration |
|-----------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|
| Springs and wells                       | 0.9                                                                 | 5.2                                                                 |
| The Angara River downstream             | 0.1                                                                 | 1.5                                                                 |
| of the wastewater discharge             |                                                                     |                                                                     |

4. **Conclusion**

It has been established that significant sources of pollution of natural waters with antibiotics are wastewater from agricultural enterprises, medical institutions, and home first-aid kits.

The total amount of antibiotics circulating in the Irkutsk Region reaches 9.2 tons, the residual concentration of antibiotics in wastewater from different sources ranges from 0.3 to 3.9 mg/L.

The hazard quotients for drinking water contaminated with antibiotics belong to medium and low categories.

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