Analysis of protection of the northern Kazakhstan cities from surface runoff waters

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Abstract. The purpose of the research is to determine the amount of surface runoff formation in the cities of the northern Kazakhstan region and to improve the urban environment quality with rational use of surface runoff of meltwater and rainwater. The goal is achieved by analyzing the features of atmospheric water management on the example of the city of the Republic of Kazakhstan. Ecosystem solutions in the field of integrated management of surface wastewater as a measure of adaptation to climate change are considered. The atmospheric runoff level is analyzed, an integrated approach to surface runoff management and a nature-oriented landscape for decentralized water resources management are proposed. A project has been designed for city safety and mobility. Indeed, in recent years, the spread of sustainable development approaches and the transition to a "green" economy has led to a change in the basic concepts of territorial management of natural resources and environmental protection. This is caused by the fact that the ecosystem approach has become widely used in the management of biological and physical systems. The ecosystem approach is based on the idea that all ecosystem components are closely interconnected, and changes in one component can lead to negative consequences for the others. In this way, the ecosystem approach helps to ensure more efficient use of resources, improve the quality of life of the population, and protect the environment.

1 Introduction

Surface runoff is the process of water moving over the earth surface, which usually occurs as a result of rain or snowmelt. Water, without being absorbed into the soil, flows down over the surface of the earth, forming flows, streams, and rivers. Surface runoff can cause land flooding and soil erosion. To analyze the surface runoff, it is necessary to collect data on the land forms, precipitation, climate, and geological characteristics, for this we take the city of Rudny as a basis.

The city of Rudny is located in the Kostanay region, mainly located in the steppe zone of the Trans-Urals. The land area of the Rudny settlement within the city limits is 2013 hectares, including residential and public buildings - 1316 hectares, industrial and storehouse and public utility buildings located within the residential territory - 73 hectares, transport, communications, engineering communications within the residential territory -

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470 hectares, public use (streets, roads) - 50 hectares, parks, squares, boulevards - 104 hectares, the scheme is shown in Figure 1 [1].

Fig. 1. Map of the city of Rudny.

2 Materials and Methods

Determination of quantitative characteristics of surface runoff from the catchment area consists in determining:

- average annual and maximum daily volumes of surface runoff (rain, snowmelt) used in
- the calculation of the standards of MAD and storage tanks;

The annual volume of surface wastewater generated in the catchment area is defined as the sum of surface runoff for the warm (April–October) and cold (November–March) periods of the year from the total catchment area of the facility according to the formula:

$$W_Y = W_R + W_M, \quad (1)$$

where W_R, W_M is the average annual volume of rainwater, meltwater, in m^3.

The average annual volume of rainwater (W_R) and meltwater (W_M), in m^3, is determined by formulas (1) and (2) clause 5.2. Recommendations of construction regulations of the Republic of Kazakhstan 4.01–03–2011 Water disposal. outdoor networks, and structures [2].

$$W_R = 10 \times h_R \times \Psi_R \times F, \quad (2)$$

$$W_R = 10 \times 238 \times 0{,}575 \times 2013 = 2\ 754\ 790{,}5\ m^3$$

$$W_M = 10 \times h_M \times \Psi_M \times F, \quad (3)$$

$$W_M = 10 \times 98 \times 0{,}600 \times 2013 = 1\ 183\ 644\ m^3$$

$$W_Y = 2754790{,}5 + 1183644 = 3\ 938\ 434{,}5\ m^3$$

where F is the nominal runoff area, in ha;
h_R is the precipitation layer for the warm period of the year, h_R = 238 mm (determined according to the Table 3.2 of the SP RK 2.04–01–2017 "Construction climatology" [3]);

h_M is the precipitation layer for the cold period of the year, h_M = 98 mm (determined according to theTable 3.1 of the SP RK 2.04–01–2017 "Construction climatology" [3]);

Ψ_R – the total coefficient of rainwater runoff is determined as a weighted average according to the instructions of clauses 5.2.3–5.2.4 of the Recommendations to the Construction Regulations of the Republic of Kazakhstan 4.01–03–2011 Water disposal, outdoor networks, and structures [2].

Ψ_M is the total coefficient of meltwater runoff from residential areas and sites of enterprises, considering snow removal and water losses due to partial absorption by permeable surfaces during thaws, we accept 0.6 according to paragraph 5.2.5 of the Recommendations of the Construction Regulations of the Republic of Kazakhstan 4.01–03–2011 Water disposal, outdoor networks, and structures [2].

In total, for the year on the territory of the city of Rudny, the average annual surface volume of urban water runoff is 3 938 434.5 m^3. Part of the generated surface runoff is absorbed by undeveloped soil areas, feeding groundwater, increasing their level and the possibility of flooding the city territory. The other part goes to the lower reach of Parkovaya Street, further flowing into the Tobol River, bringing with it pollutants such as organic matter, petroleum products, specific chemical compounds.

For a long period of time, sections of urban areas are flooded, which interferes with traffic on the roads, causes inconvenience to pedestrians, and can lead to flooding of basements and underground utilities. It is interesting to note that the volume of surface runoff being drained increases every year, this is due to an increase in the average runoff coefficient from urban areas, since over time the area of roads and sidewalks, roofs of buildings and structures increases due to a decrease in the green areas, adjacent territories, and undeveloped territories. In addition, there have been changes in climatic conditions that have affected the precipitation characteristics: the average precipitation intensity has increased, snow melting has begun in a short time, respectively, the consumption characteristics of rain and melt runoff have increased, which affects the functioning of storm sewer systems.

On the territory of the city of Rudny, the total length of the storm sewer is 4.6 km [1].

The amount of pollutants transferred from residential areas by surface runoff depends on many factors, such as population, landscaping, type of surface coverage, traffic intensity, frequency of street cleaning, as well as the presence of industrial enterprises and the level of emissions into the atmosphere.

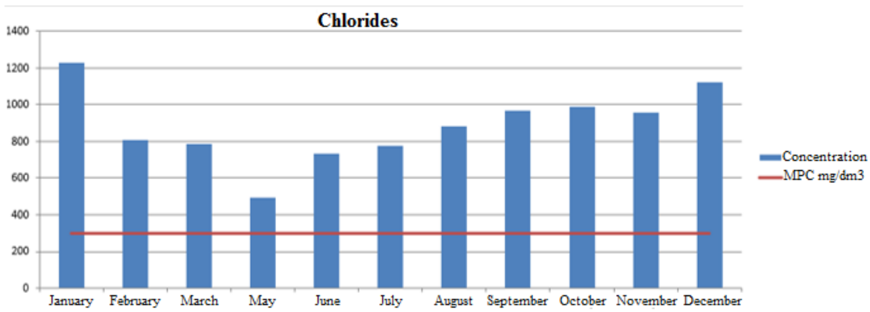
The concentration of the priority pollutants in the rain runoff depends on the precipitation layer thickness and the duration of the period without precipitation. When rainwater is drained, the concentration of pollutants changes. The maximum concentrations are observed at the beginning of the runoff until the maximum flow rate is reached, after which their concentration decreases sharply [9].

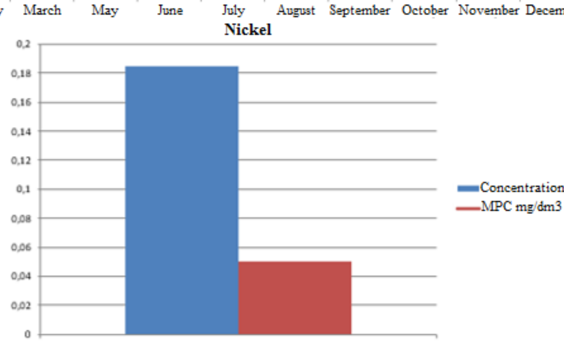
In residential areas, the main sources of surface runoff pollution are various factors, such as soil erosion, washing of lawns and open soils, dust, household waste, animal metabolic byproducts, as well as leaves, grass seeds, shrubs, and trees. In addition, the surface runoff may include components of road surfaces and construction materials stored in open storehouses, as well as petroleum products that may get into the surface due to malfunctions of vehicles and other equipment. Taken as a whole, all these pollution sources contribute to the formation of surface runoff quality in urban settlements [20].

This leads to pollution and contamination of the waters of the Tobol River, which serves as a source of drinking water for the city of Kostanay, and recreational facilities are also polluted and infected, which leads to an increase in the cost of drinking water production or the inability to obtain drinking water with the available equipment of the water treatment plant, to the closure of recreational facilities for quarantine, to the death of fish species, etc. It is impossible to use water for irrigation of agricultural lands and livestock complexes.

In addition to pollution and contamination of water bodies, urban areas are flooded, which leads to damage to the city infrastructure, destruction of water supply networks and systems of sanitary and storm sewers, as well as failure of municipal facilities: flooding of basements of buildings, structures, etc. [8].

The main regulatory document for assessing the water quality of water bodies of the Republic of Kazakhstan is the "Unified System of classification of water quality in water bodies" dated November 9, 2016 [4]. According to this classification , Tobol River belongs to the 5th class. The waters of this water use class are suitable for use for hydraulic power engineering, mining, hydraulic transportat, and are not recommended for other purposes. Figure 2 shows monthly indicators of substances which concentration exceeds the maximum permissible concentration (MPC) of surface waters of the Tobol River [5].





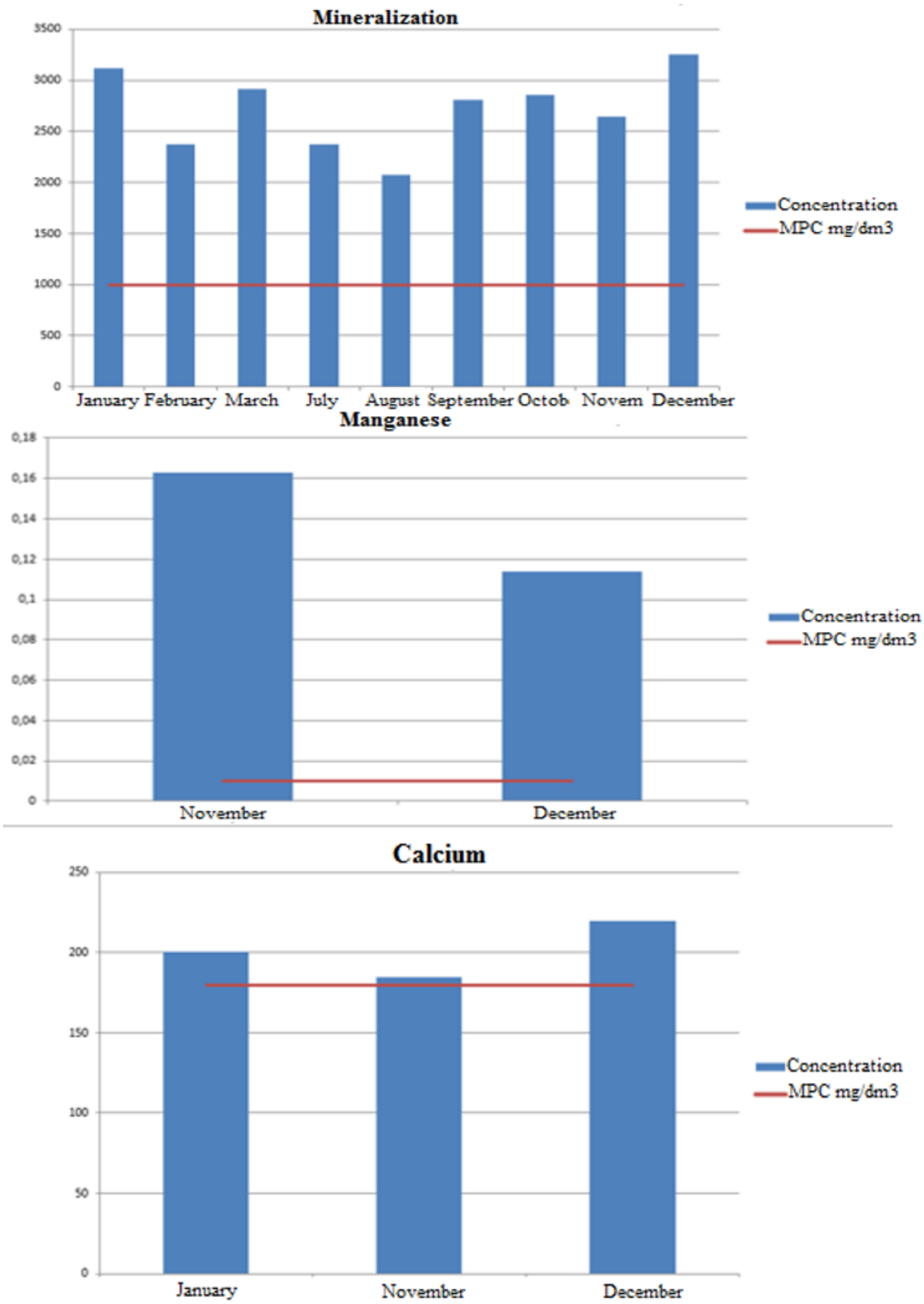


Fig. 2. Concentration of pollutants exceeding the MPC of the Tobol River.

3 Results

To improve the urban environment, it is necessary to develop new approaches to creating and maintaining quality in relation to the removal, treatment, and reuse of surface water runoff from transport communications and public spaces of settlements. At the same time, the created public spaces should provide comfortable conditions for human stay and life. An important element of a comfortable urban environment is an artificially created ecosystem of streets of settlements that meets human needs. Modern streets of settlements should be considered as part of the ecological framework of an urbanized territory [6].

Here are the main methods of managing surface runoff sources, they can be divided into state regulation methods (these are all possible pilot projects, the use of tax charges, fines, fees, the allocation of state subsidies, the introduction of innovative methods in the development of new territories) and structural methods (the organization of rain gardens, retention ponds, the use of porous asphalt or paving slabs, green roofs, arrangement of eco-parking, etc.) [18, 19]. The use of drainage systems is the creation of drainage channels, wells, drainage pipes for the removal of excess surface water in natural and artificial territories [16]. Monitoring of development zones - compliance with land use rules in the development of construction projects, prevention of development of sites with low groundwater levels [7, 14].

For the application of structural methods of controlling surface waters, it is necessary to select stable phytocompositions that will be adapted to the unfavorable conditions of the urban environment (limited space, gas pollution, soil fertility, etc.) [11].

Here are examples of perennial plants that are suitable for creating self-sustaining compositions and are able to adapt to the conditions of the Kazakhstan territory [13]: Daylily Hemerocallis hybrid, Rudbeckia fulgida, Iris setosa, Aster x fricartii Mönch, Lysimachia clethroides, Sedum telephium, Campanula lactiflora, etc.

Figure 3 shows one example of the use of surface runoff waters in combination with herbaceous perennials in urbanized areas.

Fig. 3. Use of surface runoff waters and perennial plants in urban environment.

The ability of perennial plants to self-renew allows to get more yield without wasting time and money on sowing new seeds or planting new plants. It can also be useful for creating natural landscapes and ecological systems. The cost-effectiveness of perennial herbaceous plants is manifested in the fact that they require less attention and care than annual crops. They do not need an annual planting campaign or regular feeding, which saves resources and labor costs [10].

The advantages of using herbaceous perennials are longevity and ability to self-seeding and growth, economy, aesthetics, environmental friendliness, reliability and ease of care. The lifespan of perennial herbaceous plants can reach several decades, and sometimes more than a hundred years, which saves time and resources of annual planting, this will also allow to have more stable and beautiful gardens and parks [12].

The aesthetics of perennial plants can be very diverse and beautiful. They can create cozy corners in the garden or park, as well as serve as a basis for creating floral arrangements and borders. The environmental friendliness of perennial herbaceous plants is manifested in the fact that they can serve as a food source and shelter for animals and insects [15]. They are also able to improve the soil and air quality in the environment. Reliability and ease of care of perennial plants are manifested in the fact that they usually do not require special knowledge and skills for growing and caring for them.

4 Conclusion

The goal set in the study has been achieved, calculations show that a volume of surface runoff water of about 4 million m^3 is formed in the city per year, methods of using surface runoff in the form of drainage systems and perennial plants adapted to urban conditions are proposed, which will create an attractive appearance for streets and reduce dust and noise. This will make it possible to reduce the cost of street cleaning and maintenance of green spaces, as well as increase the environmental safety of the city.

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