Increasing the efficiency of the process of snow mass utilization from the urban infrastructure and reducing the negative impact on the environment through the introduction of an installation for the utilization of snow mass

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Abstract. The article raises the problem of the maintenance of the urban area in winter, namely, the problem of disposal of snow masses from the urban area. The article describes the main disadvantages of the existing snow-melting systems for the utilization of city snow mass and are encouraged to develop an installation for melting of snow, functioning at the expense of power consumption. The developed installation allows to reduce the noise level during its operation, to exclude the influence of exhaust gases on the environment, therefore, to improve the environmental safety of the urban infrastructure.

1. Introduction

The characteristic climatic conditions of the Russian Federation raise a number of problems which associate with the development of the urban areas in the winter in most regions of the country [1]. There are often problems associated with the environmental safety of urban infrastructure. In most works, it is proposed to solve it by reducing emissions of harmful substances with exhaust gases of vehicles [2,3,4,5,6,7,8]. However, studies that are aimed at the utilization of snow mass without the use of exhaust gases are not enough [9,10,11].

In every city there are regulations about the rules of urban areas. These standards marked the period when it carries out snow removal, permissible time of storage and highlights the environmental danger of snow masses and requirements for their utilization. The problem is the complexity of compliance with these standards. This causes a reduction in traffic, an increase in the number of accidents and violation of environmental safety [12].

Currently, the trend of urban growth is increasing every day, which, in turn, causes an increase in the area of landfills for snow. This is an expensive process due to the technical and environmental requirements that are imposed on the design of the urban environment [13, 14, 15]. The main requirement is the need to take into account the influence of a large volume of melt water in the spring on urban infrastructure facilities. Therefore, the continuous system of utilization of an urban snow-melting plant is actively developing and being introduced now.

On the territory of the Russian Federation mobile snow-melting systems that operate at the expense of energy which is obtained from the combustion of liquid fuels is widespread, relative to similar systems that operate at the expense of power consumption. First of all, this is connected with the design of plants for the utilization of snow mass, the structural feature of which is the simplicity of the technological scheme. The process of melting is carried out when exposed to an open flame on the snow mass.

Typically, the process of melting city snow mass flows in a metal container, which is called a melting chamber. The combustion products of diesel fuel or natural gas heat this chamber. Further, the cooled combustion products are discharged into the atmosphere.

A typical snow melting system is shown in Figure 1 [16,17]. It includes a receiving chamber (melting chamber) 1 is a metal structure with an inlet 3, a heat generator 2 that contains a burner and a mixing chamber, a channel for gaseous fuel and a cooled coolant outlet. The inner walls and the lower part of the inclined chamber and the outer walls are located by the exhaust jacket 4. The exhaust jacket closes the heating of the hot gas of the bottom wall of the receiver. The snow mass melts in the funnel during the heating of the chamber wall. The liquid that is formed by melting on inclined walls flows through the outlet pipe 5. The heated gas from the mixing chamber is supplied to the chamber of the exhaust jacket by melting.

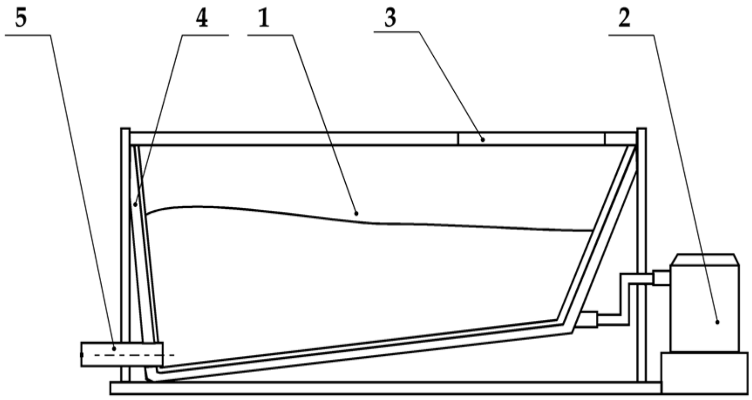

Figure 1. Snow melting system.

Main disadvantages of such structures are:

- small distance between the outer surface of heat exchangers;
- the need for frequent stops melting process because of the cleaning system from debris;
- high complexity of the recycling process, the availability of fuel reserves, the use of which, the pollution of environment with combustion products.

In the modern world, the problem of preserving a clean environment, which casts doubt on the future prospects of the spread of snowmelt systems, is acute and contributes to increasing emissions of pollutants into the atmosphere [18].

2. Results and Discussion

To date, the latest technical developments have serious standards of environmental safety. The conducted studies revealed a significant level of snow pollution in the city [12]. The average values of pollutants are different and are presented in Table 1.

Table 1. Average values of typical contaminants in urban snow mass.

Substances	Dimension	Value
Suspended substance	mg/l	121 – 732
BOD_5	mg/l	2.48-7.61
Ammonium nitrogen	mg/l	0.33-9.6
Chlorides	mg/l	16.11-338.2
Sodium	mg/l	13.76-442.4
Potassium	mg/l	22.3-110.9
Iron	mg/l	0.68-1.45
Manganese	mg/l	0.11-0.67
Zinc	mg/l	0.013-0.09
Lead	mg/l	15.23-37.23
Oil	mg/l	1.4-50.2
Synthetic surfactants	mg/l	0.23-1.012

Their magnitude depends on the urban area. In the snow samples, suspended substances, organic compounds that are not susceptible to oxidation, and solid salt for flour were observed. The chloride content exceeded the permissible concentration by 7-15 times. The amount of sulfates exceeded 3.5 times. The maximum allowable concentration of ions of toxic metals (manganese, iron, copper, cobalt, lithium, zinc, molybdenum, cadmium) exceeded the maximum allowable concentration up to 46 times. The content of phenols and petroleum products exceeded the maximum allowable concentration, respectively, from 1 to 4 and from 25 to 150.

The analysis identified the following pollutants: suspended substance, chlorides, oil products. The averaged concentrations of suspended, which matter equal to 426.5 mg/l, is presented in 27% of cases. The concentration of oil, equal to 25.6 mg/l, is presented in 33% of cases. The concentration of chlorides, equal 177.2 mg/l, is presented in 28% of cases.

The developed installation for the utilization of urban snow mass as a primary energy source uses electricity. This makes it possible to eliminate exhaust fumes during plant operation, which is an important advantage in comparison with similar installations that operate on hydrocarbon fuels. Thus, the use of this unit allows to significantly reduce the negative impact of the operation of the snow melting unit on the environment.

As a result of the study of the problem, a new approach emerged to address the negative impact of the snow utilization facilities on the environment and the Grodsk infrastructure. Thus, the work suggests the development of an installation for the utilization of urban snow. The main purpose of the plant being developed is to intensify the process of melting city snow, provide low energy costs and increase environmental safety in the disposal of snow.

The installation solves the problem of recycling urban snow masses from the urban area. This problem leads to an increase in the traffic flow, a reduction in the number of accidents and pollution of the environment. The development of an installation for urban snow reclamation is a specialized project designed for the active process of melting urban snow mass due to the use of electricity. The electrical energy used in the installation is converted into microwave electromagnetic radiation. This allows during the snow melting to clean and drain the resulting water melt. The scheme of the developed installation of snow melting is shown in Figure 2.

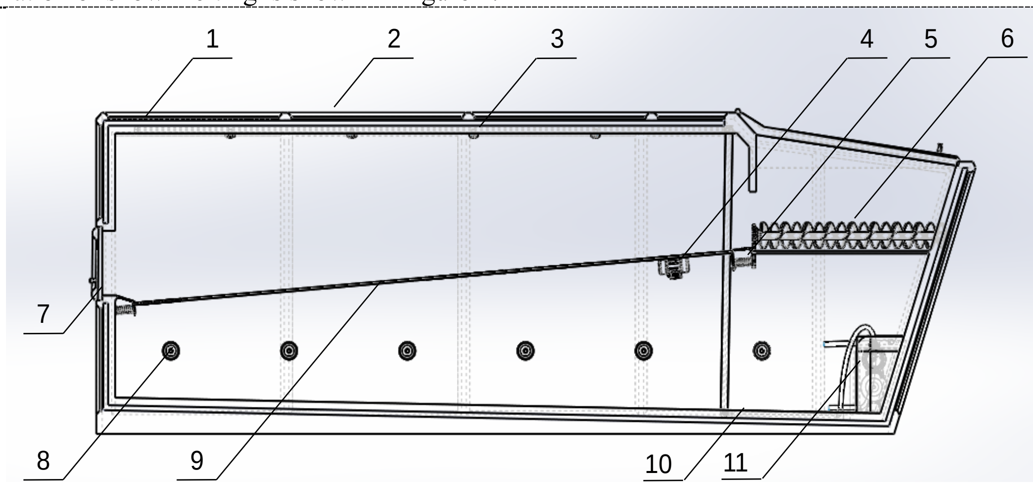

Figure 2. The design of the installation for the utilization of snow: 1 – heat and soundproofing layer, 2 – hull installation, 3 – atomizer, 4 – inertial vibrator, 5 – restraining spring, 6 – screw conveyor, 7 – bunker bulky waste, 8 – electromagnetic emitter, 9 – sifting (protective) grate, 10 – temperature sensor 11 – water distribution pump.

The principle of the installation is based on the progressive process of cleaning and heating the snow mass. It is loaded into the area for receiving and processing snow, which includes a conveyor belt and a storage compartment, where it is subjected to the first stage - loosening and transport of snow mass. The snow mass is weakened due to the rotational-translational motion of the screw 6. Then, in the section for receiving and treating the snow mass, it undergoes preliminary cleaning of the snow cover, which does not contact the transport screw 6. It then interacts with the rigid panel, which provides access to the preliminary cleaning only the snow weakened. In the pre-treatment chamber, the snow mass decreases with the waste.

Further, the mass of snow passes the screening process through the protective grate 9. The sieving process is intensified by using a protective grating 9, which is installed under a slight inclination (150 degrees), and an inertial vibrator. It provides vibration of the protective grid 9. Hydration of the snow mass takes place with the sprayer 3 simultaneously with the sieving process. The moistened and sieved mass of snow enters the melting chamber 9, and the bulk waste that remains on the protective grid enters the waste compartment.

The mixed and purified snow mass is melted in the melting chamber by means of an electromagnetic radiator 8. The water melt enters the water distribution pump 11. Small debris is removed through a special compartment located at the bottom of the unit. 3-D model of installation for the utilization of snow mass is shown in Figure 3.

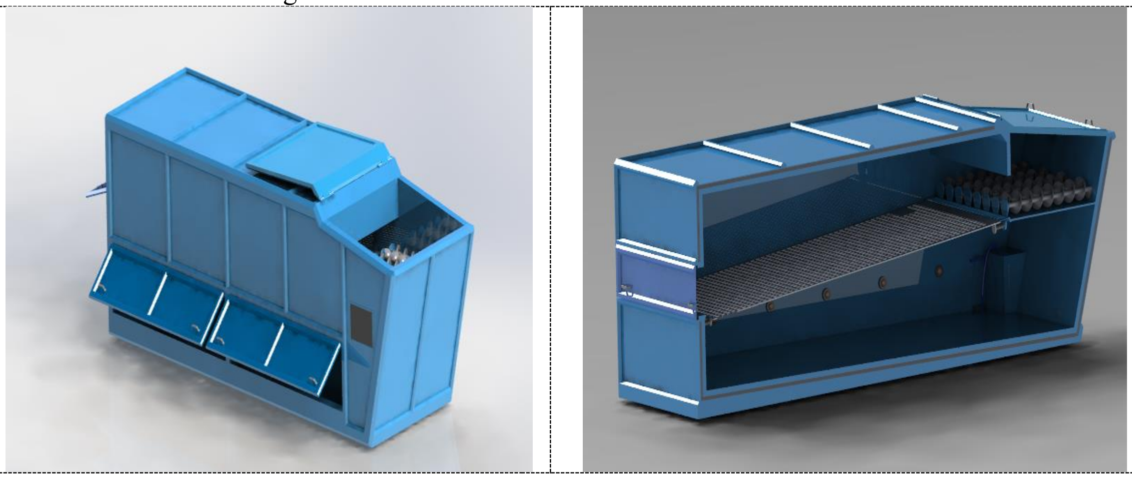

Figure 3. 3-D model of installation for the utilization of snow mass.

The purpose of creating the 3-D model of the installation is not only the development of modern design, but also the calculation of the minimum costs for its production and the theoretical evaluation of the possibility of implementing the melting process of the snow mass. Technical characteristics of the installation for the utilization of snow mass are shown in Table 2.

Table 2. Technical characteristics of the installation for the utilization of snow mass.

Parameter	Value
Performance in the snow, m^3/hour (t/h)	15 (1.05-1.55)
Electricity consumption, kW·h (MJ)	30 (108)
Dimensions, m	6.2·2.3·2
The volume of the chamber melting, m^3	5.4
Volume load snow, m^3	4.1
Water discharge, m^3/hour	4.65-6.95

Indicators of "performance in the snow m3/h» and «discharge of water m3/h" have variable values due to differences in density of the snow mass in the melting process of snow.

The main novelty is the use of a water distribution system (irrigation and drainage) and melting based on electromagnetic effects as the primary source of electricity, which solves the main problem from the point of view of the energy consumption of the melting process of snow. This is to ensure the phase transition of the solid phase into the liquid. The efficiency of melting is due to the nature of the propagation of electromagnetic radiation. In the proposed design of the installation, it acts directly on the entire volume of snow mass and interacts with water molecules, which cause a resonance effect. This increases the frequency of vibrations of polar molecules and causes the appearance of thermodynamic reactions that provide an intense thermal environment.

The urban snow mass is an adsorbent and contains oil products, heavy metals, household waste, de-icing materials and so on. The change in heat capacity and density of pure snow mass with the addition of pollutants causes a change in its melting temperature. Therefore, the work also included studies of interfacial heat transfer processes in the melting of urban snow mass. During this stage of the experiment, we found that the use of heat exchangers in a local thermal system increases the melting time of contaminated snow compared to a pure analogue. The use of electromagnetic radiation reduces the melting time with the content of pollutants in the snow mass.

Thus, the developed installation is an effective way of recycling urban snow mass, which contains pollutants.

3. Conclusion

This article describes the scheme and principle of operation of existing installations for the utilization of snow masses. In the course of analyzing their technical characteristics and features, we found that the melting of the snow mass is carried out with the help of gases that are formed during the combustion of hydrocarbon fuels and has a negative impact on the environment. Therefore, we have developed an installation for the disposal of urban snow mass with the use of electromagnetic radiation, which has made it possible to improve the environmental safety of urban infrastructure.

Operation of the developed installation allows:

- to reduce the noise level during the operation of the plant due to the presence of a soundproof layer;
- to remove exhaust fumes during operation, since electricity is the source of energy;
- to use it directly in the urban environment, as the technical characteristics of its operation are consistent with the norms of acceptable noise pollution and environmental safety;
- to increase the plant productivity through the use of screening systems, electromagnetic effects and a humidification system and the melting process;
- improve the quality of the process of cleaning urban snow from debris because of the presence of a two-level system.

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