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Risk assessment of ice-melter reagents for urban plants

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Abstract. The paper assessed the phytotoxicity of the most frequently used ice-melter reagents in Moscow (sand and salt mixture, anti-freeze reagent based on a composition of calcium and sodium chloride, technical salt), snow with varying degrees of contamination of the remnants of ice-melter reagents, as well as soil after the snow cover melting. The toxicity assessment was carried out in the samples taken on the lawns along the roads in nine administrative districts of the city in places with the same anthropogenic load. The test object is oat seeds (*Avena sativa*), as a sensitive biotest showing the most stable and reproducible data compared to seeds from other crops. Salt solutions of reagents with dilution rates of 1, 2, 4, 6, 8 and 10, melted snow and soil extracts were used for biotesting. The phytotoxic effect was determined by comparing the average root length of control and prototype seeds. It was found that all studied ice-melter reagents have a pronounced toxic effect on oat plants even at tenfold dilution. The phytotoxic effect of snow and soil polluted with ice-melter substances, which in turn inherits the chemical composition of snow cover after its melting, was shown.

Introduction

As an important factor in road safety, anti-icing of road pavements also has a negative impact on all components of the urban environment. Current ice-melter reagents - are multi-component chemicals consisting of a set of salts of both organic and inorganic origin [1], most of which contain sodium and calcium chlorides. Sodium chloride and calcium chloride salt solutions formed as a result of ice and snow melting, when they get into the soil, cause salinization of the soil cover [2]. In turn, changes in soil properties can suppress plant growth and development. Thus phytotoxic action of ice-melter reagents is shown both on an organismal level (extinction of roots, twisting of leaves, withering of a plant, etc.), and on cellular level (change of structure of chloroplasts, decrease in the starch content, infringement of process of photosynthesis) [1, 3].

The purpose of this work was to assess the degree of phytotoxicity of various ice-melter reagents, as well as snow and soil contaminated during their application.

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Objects and methods

The objects of research were selected:

1) the most commonly used ice-melter reagents in Moscow (sand and salt mixture, solid multi-component anti-freeze reagent based on a composition of calcium and sodium chloride ($CaCl_2$+NaCl), technical salt (NaCI). General characteristics of ice-melter reagents are presented in Table 1;

2) the snow samples contaminated with ice-melter reagents;

3) the soil after snow melting.

Table 1. General characteristics of ice-melter reagents

Name	Aggregate composition	Component composition	Chemical composition	Operation temperature	Hazard class in terms of impact on the human body
Sand and salt mixture	solid	combined	sand -70% NaCl – 30%	from -12 °C to -15 °C	3 -moderately dangerous. It has no harmful effect on the undamaged skin, but when it hits skin wounds, it impairs their healing
$CaCl_2$+ NaCl	solid	chemical	$CaCl_2$- 20% NaCl – 80%	from -12 °C to -15 °C	3 -moderately dangerous. It has an irritant effect on the mucous membranes of the upper respiratory tract and eyes. Systematically irritates and dries the skin
Technical salt	solid	chemical	NaCl – 93% Ca^{2+} - 0.8% Mg^{2+}- 0.8% K^{+}- 0.9% SO_4^{2-} - 2.2% Fe_2O_3 – 0.1%	from -12 °C to -15 °C	3 -moderately dangerous. It has no harmful effect on the undamaged skin, but when it hits skin wounds, it impairs their healing

Snow and soil samples were taken in nine administrative districts of the city: North-East Administrative District (NEAD), East Administrative District (EAD), South East Administrative District (SEAD), South Administrative District (SAD), South Western Administrative District (SWAD), Western Administrative District (WAD), North West Administrative District (NWAD), Northern Administrative District (NAD), and Central Administrative District (CAD) at the same points on the lawns along roads and sidewalks in places with the same anthropogenic load in December 2018 and April 2019 (Figure 1). Control "conditionally clean" samples were taken in the national park "Losiniy ostrov", where the presence of ice-melter reagents was completely excluded.

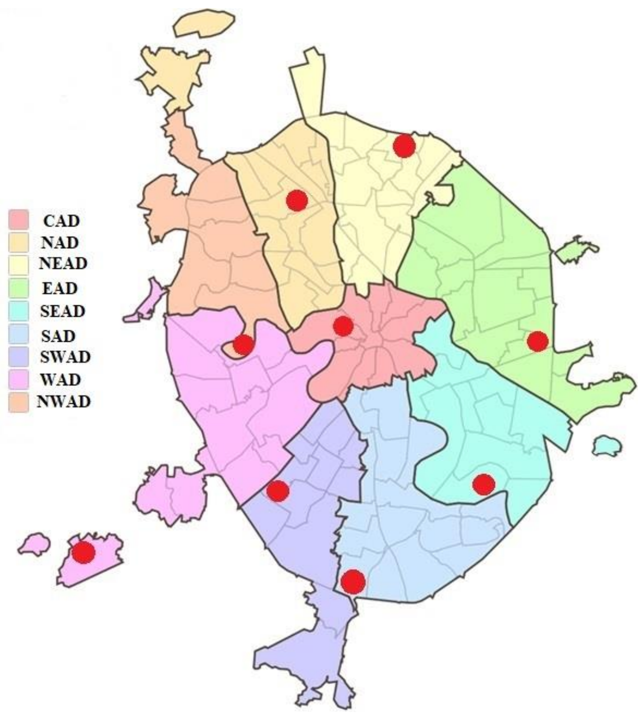

Fig. 1. Sampling map

Phytotoxicity was evaluated using bioassay on the biological effect of saline solutions on oats (*Avena sativa*) of ice-melter reagents salt solutions (at dilution of R=1, 2, 4, 6, 8 and 10), melted snow and soil extraction. Oat seeds used as test plants provide the most stable and reproducible data compared with seeds from other crops (peas, cucumbers, wheat, carrots, etc.) [4]. In Petri dishes with mugs of filter paper 25 oats seeds were placed and 5 ml of the studied solution were added. In the control sample (K) during testing of ice-melter reagents and snow the substrate for germination of seeds was distilled water (pH=6), in the experience with soil samples - "conditionally clean" soil extract. All samples were kept at a temperature of 20-23 °C for 7 days. After this period, the length of the roots of the seedlings in the control and experimental samples was measured, and the root of the maximum length was the object of measurement for each seed.

The toxic effect was determined by comparing the test function of the control and experimental seeds.

Results and discussion

Biotesting of samples of ice-melter reagents currently used in Moscow has shown that all the ice-melter reagents studied in the work have a pronounced toxic effect on oat sprouts even at tenfold dilution of the solution (Fig. 2).

Snow, as the main storage medium in winter, serves as a reliable indicator of atmospheric pollution. However, in contrast to the permanent snow cover, which is formed in parks, public gardens and remote areas of the city during the winter season, in the pollution of snow regularly removed from highways and sidewalks, ice-melter reagents make the main contribution, and the impact of atmospheric deposition is negligible.

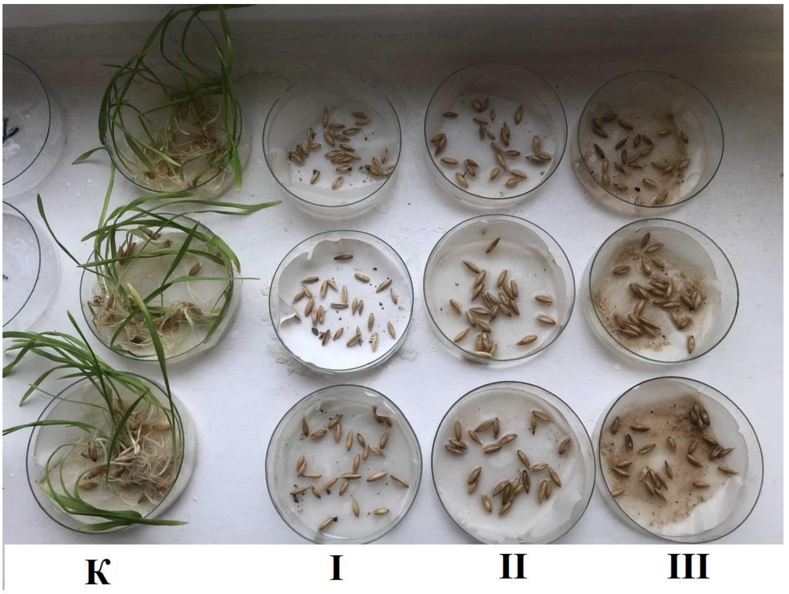

Fig.2. Inhibition of oat seed root growth by solutions of ice-melter reagents (R=10)
(K-control; I- technical salt; II- $CaCl_2$+NaCl; III- sand and salt mixture)

The phytotoxic effect of contaminated ice-melter reagents snow samples can be considered proven in samples taken in the territory of 6 administrative districts of the capital (NEAD, SAD,WAD, NWAD, NAD, CAD) (Table 2). According to the results of biotesting, the most pronounced phytotoxic effect is exhibited by samples taken in the North West Administrative District (55.9%) and the Northern Administrative District (59.7%).

Table 2. Characteristics of the effect of salt solutions of anti-icing agents on oat seeds (snow)

Sample number	Average root length, mm ($p<0.05$)	Ratio of average length to control, %	Phytoeffect, %	Test reaction
К (control)	68.9 ± 2.9	100.0	0	Standard
I (NEAD)	49.2 ± 3.1	71.3	28.7	Braking effect
II (EAD)	81.4 ± 4.7	118.0	0	Adverse effect is absent
III (SEAD)	69.6 ± 2.8	101.0	0	Adverse effect is absent
IV (SAD)	45.9 ± 1.7	66.5	33.5	Braking effect
V (SWAD)	69.2 ± 5.2	100.3	0	Adverse effect is absent
VI (WAD)	52.6 ±4.3	76.2	23.8	Braking effect
VII (NWAD)	30.4 ± 2.6	44.1	55.9	Braking effect
VIII (NAD)	27.8 ± 3.5	40.2	59.7	BRAKING effect
IX (CAD)	47.1 ± 4.7	68.2	31.8	braking effect

This is probably due to violation of the established norms of distribution and technology of road surface treatment with ice-melter reagents and, as a result, the entry of pollutants into green areas. For example, the density of treatment with solid ice-melter reagents should not exceed 30-50 g/m^2 at air temperature from -4 °C to -8 °C [5]. However, this norm is violated everywhere, and, according to expert estimates, the salt load on the territory of the city in recent years reaches 500 thousand tons [6].

Soil samples taken in various districts of Moscow, contaminated with ice-melter reagents, also have a toxic effect on higher plants. In this case, the maximum values of inhibition of root growth were noted in soil samples on the territory of the Central Administrative District (39.5%) and Southern Administrative District (42.4%) (Table 3).

Table 3. Characteristics of the effect of salt solutions of ice-melter reagents on oat seeds (soil)

Sample number	Average root length, mm ($p<0.05$)	Ratio of average length to control, %	Phytoeffect, %	Test reaction
К (control)	68.9 ±3.5	100.0	0	Standard
I (NEAD)	57.0 ± 3.6	82.7	17.3	Standard
II (EAD)	78.4 ± 1.9	113.7	0	Adverse effect is absent
III (SEAD)	68.7 ± 3.5	99.6	0.4	Standard
IV (SAD)	39.7 ± 2.5	57.6	42.4	Braking effect
V (SWAD)	53.7 ± 1.8	77.9	22.1	Braking effect
VI (WAD)	79.4 ± 5.8	115.2	0	Adverse effect is absent
VII (NWAD)	43.1 ± 4.7	62.5	37.5	Braking effect
VIII (NAD)	46.0 ± 4.1	66.7	33.3	Braking effect
IX (CAD)	41.7 ±3.9	60.5	39.5	Braking effect

Conclusions

Thus, the use of ice-melter agents in the streets of Moscow has a negative impact on the condition of green areas of roadside territories.

Phytotoxic effect has not only solutions of used ice-melter reagents, but also snow contaminated with salts, as well as the soil, inheriting the chemical composition of the snow cover.

The results obtained indicate the need to take measures to optimize the use of ice-melter reagents, to tighten control over their consumption and compliance with the requirements of their application technology.

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