Chapter 2
Acute and Chronic Phytotoxicity of Subarctic Urban Soils and Industrial Wastes

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Abstract Soil degradation is a combination of natural and anthropogenic processes that lead to changes in soil functions, quantitative and/or qualitative deterioration of composition and properties, and a decrease in the natural and economic significance of lands. The state of the soil cover in Russia is far from satisfactory, and in some areas even critical. The Murmansk region is highly industrialized and urbanized region in the Arctic zone. We have tested the acute and chronic phytotoxicity of various industrial materials (expanded vermiculite, nepheline waste and quartz waste), urban and suburban soils of industrial, traffic and recreational zones, soil of urban farm, and conditionally background soil. The water-soluble, plant available, and acid-soluble metal fractions were analyzed. To assess the acute toxicity of industrial wastes, pre-grown hydroponic lawns from *Lolium* spp. were used, and the duration of the experiment was 7 days. The chronic toxicity was assessed using marigolds (*Tagetes* spp.), after 28 and 60 days. The highest level of metals was found in soils of the suburban zone near the plant of nonferrous metallurgy and in the traffic zones, but it was revealed that the presence of nutrient elements in high concentrations can partly neutralize the toxic effect of these soils. Phytotesting showed that the weak

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acceleration of roots to the substrate after 3–7 days of exposition is the express indicator of the presence of high concentrations of toxic metals in the substrates and an unfavorable pH level. Thus, we propose the following low-cost algorithm for the rapid field assessment of soil phytotoxicity in the Subarctic: testing of acute phytotoxicity using hydroponic lawns; testing of chronic phytotoxicity using marigolds in case when acute phytotoxicity is absent; the chemical analysis of mobile fractions of heavy metals and nutrients only for soils which revealed the toxic effect to develop the recommendations for improving soil quality or to make decision about their replacing.

Keywords Lawn · Marigold · Phytotoxicity · Urban soil · Industrial waste · Subarctic

2.1 Introduction

Various pollutants are released into the environment in large quantities. Industrial activity, poor agricultural practices and urbanization accelerate environmental pollution. Soil pollution is currently attracting considerable public attention as the problem is growing rapidly, especially in highly industrialized regions of the World. Heavy metals are among the most hazardous substances in the soil environment due to their high persistence and toxicity to biota. In soil, heavy metals tend to be strongly adsorbed to the soil matrix and, unlike organic pollutants, are not degraded by microorganisms or by chemical oxidation. The accumulation of heavy metals in the soil can reduce crop yields, cause disease, affect food security and impede sustainable development (Minisha et al. 2021).

Remediation of sites contaminated with heavy metals using chemical or physical methods is a complex task. Phytoremediation is a "low-tech, high-efficiency" purification method that can be used as an alternative to expensive methods. Numerous studies have been carried out aimed at developing an effective and economical way to restore soils contaminated with heavy metals (Alkorta et al. 2004; Erakhrumen 2007). However, in the conditions of polar latitudes, the accumulation of biomass during the year is slow and extremely uneven, which significantly affects the efficiency of such technologies. There are environmental-friendly technologies for the remediation of soil objects using mining waste, the products of which have an acid-neutralizing ability and sorption properties (Slukovskaya et al. 2018). This technology has been tested on the territory of the Subarctic in the impact zone of a copper–nickel plant, but mining wastes have various composition and should be tested before the use in remediation.

Environmental hazard assessment of soils and industrial substrates could be carried out by quantitative methods based on comparing the physicochemical composition with the permissible content of pollutants, and by qualitative assessment accounting the reaction of organisms in biotesting. Physicochemical approach cannot provide a comprehensive assessment of soil toxicity due to the antagonistic or synergistic action of different chemical elements and also has such limitations as costs and labor.

Biotesting methods are based on the organism response to the negative impact of pollutants, and they can provide reliable information about the quality of the substrate (Timofeeva 2011). One of the biotesting methods determines the acute and chronic toxicity of controlled objects for plant organisms. The toxicity criterion is a reliable quantitative change in parameters of testing organisms, based on which a conclusion about the soil toxicity is made.

Phytotesting in an express laboratory version (seed germination in contact with an aqueous soil extract or soil in a humid chamber), carried out in a short period (4–5 days), is known as acute phytotoxicity (Blok et al. 2008), when a longer vegetation experiment (3–6 weeks) in known as chronic phytotoxicity (GOST R ISO 2010).

One suitable plant organism for assessing the degree of toxicity may be the genus *Tagetes* L. (*Asteraceae*) or marigold which is an annual plant 20–30 cm high and widely distributed throughout the World (Politi et al. 2016). The reproduction rate of marigolds is high, the life cycle is short, growth is fast and the root system is well developed (Chatterjee et al. 2012; Goswami and Das 2017; Chintakovid et al. 2008; Sathya et al. 2020). *Tagetes* L. is very popular due to its ease of cultivation and wide adaptability, including poor soils (Coelho et al. 2017). Marigolds show rapid phytoextraction of heavy metals from the soil during their initial growth phase (Choudhury et al. 2016). *Lolium multiflorum* L. was used to assess acute phytotoxicity. The plant is one of the valuable grass species for fast creation of plant communities due to its rapid growth and high biomass, which is necessary for phytoremediation of contaminated areas in harsh climatic conditions (Slukovskaya et al. 2018). Biological reclamation of disturbed areas and industrial dumps, as well as greening of urban spaces in the Subarctic climatic conditions, often requires quick decision-making on the choice of an action strategy and, in particular, such parameters as the composition of soil constructions and plant assortment. In this regard, the purpose of the work was to substantiate the method of field phytotesting of acute and chronic toxicity of urban soils and mining wastes with varying degrees of pollution, applicable in the Subarctic zone.

2.2 Materials and Methods

2.2.1 Characteristics of Industrial Wastes and Urban Soils

Samples were collected from the depth 0–15 cm from different land-use zones in the Murmansk region, Russia (NE Europe).

2.2.1.1 Industrial Zone

Tested substrates were sampled from the depositions of different mining wastes.

Expanded vermiculite (**IV**) (LLC Kovdorlyuda, Kovdor) with a particle size of 1–2 mm was obtained from the vermiculite concentrate of the Kovdor deposit by firing at 500–550 °C in an electric modular trigger furnace designed by Nizhegorodov (Kremenetskaya et al. 2020). The initial sample was a typical vermiculite for the Kovdor deposit with a noticeable admixture of phlogopite. Vermiculite chemical composition (wt%): SiO_2 (30.9), MgO (27.0), Al_2O_3 (9.6), Fe_2O_3 (5.3), CaO (4.0), Na_2O (3.3), K_2O (0.9), C (0.5), H_2O (7.7). The acidity of the water extract was 8.97.

Quartz waste (**IQ**) (JSC Olkon, Olenegorsk) was formed during the processing of ferruginous quartzites, and the production of iron ore concentrate (Suvorova et al. 2012). After the enrichment of iron ores, fine-grained waste was formed, millions of tons of which were annually deposited into the tailings. The annual mass of waste disposal is 53936401 tons/year. Chemical composition (wt%): SiO_2 (66.8), Fe_2O_3 (19.7), CaO (4.8), Al_2O_3 (4.0), MgO (2.9), K_2O (0.9), Cl (0.25), MnO (0.24), TiO_2 (0.2), S (0.14), P_2O_5 (0.07). The acidity of the water extract was 8.07.

Nepheline waste (**IN**) (LLC Lovozersky Mining and Processing Plant, Revda) was formed after the extraction and processing of loparite ores, followed by the production of a concentrate of rare earth metals, as well as niobium and tantalum. The annual mass of waste disposal is 397413 tons/year. The content of elements in the sample (wt.%): Na (9.08), K (2.98), Ca (0.89), Mg (0.25), Mn (0.18), Al (10.57), Fe (4.4), Sr (0.19). The acidity of the water extract was 8.89.

2.2.1.2 Urban and Suburban Zone

Soils were collected from three industrial cities in Murmansk region, Russia: Monchegorsk, Apatity and Kirovsk.

Soil of industrially polluted zone (degraded podzol) (**PD**) was sampled from the suburban territory near JSC Kola MMC, Monchegorsk. This area is located on the industrial wasteland and is highly polluted. The proportion of element content in the mobile fraction for potentially toxic metals was (%): Cu (58.1), Ni (44.7), Pb (36.4), Fe (26.5), Al (20.2). The acidity of the water extract of the soil was 4.2–4.8, the content of organic carbon-1.3%, the carbon content of humic acids-0.35%, the content of total nitrogen-0.07%, of which 2.5–4.0 mg/kg of nitrate nitrogen and 0.8 mg/kg of ammonium nitrogen (Ivanova et al. 2021).

Soils of traffic zone were sampled from the territory near the administration building of Monchegorsk (**TM**) and a roadside site in Apatity (**TA**) (Saltan et al. 2021). The total composition (wt.%) of the soil in Monchegorsk: Na (4.02), Mg (1.3), Al (8.35), Si (71.3), P (0.4), K (2.13), Ca (2.4), Mn (0.16), Fe (9.7), Co (0.008), Ni (0.08), Cu (0.06), Zn (0.02), Pb (0.004). The acidity of the water extract was 6.78. The composition of the soil sample in Apatity (wt.%)—Na (4.2), Mg (1.5), Al (8.7), Si (68.9), P (0.1), K (3.7), Ca (3.06), Mn (0.13), Fe (8.97), Co (0.008), Ni (0.13), Cu (0.42), Zn (0.1), Pb (0.004). The acidity of the water extract is 6.23.

Soils of recreational zone: Soil sample was taken in the city park of Kirovsk (**RK**). The total composition of the sample (wt.%): Na (4.75), Mg (0.81), Al (13.33), Si (62.1), P (1.1), K (3 0.04), Ca (3.4), Mn (0.14), Fe (11.27), Co (0.003), Ni (0.02), Cu (0.03), Zn (0.02), Pb (0.008). The acidity of the water extract is 5.79.

Soils of urban farming zone: The soil sample was taken from the farm field of the Polar Experimental Station of the Vavilov All-Russian Institute of Plant Genetic Resources (**UF**). The total composition of the sample (wt.%): Na (5.06), Mg (1.14), Al (13.88), Si (60.44), P (0.5), K (2.33), Ca (3.89), Mn (0.15), Fe (12.51), Co (0.003), Ni (0.017), Cu (0.03), Zn (0.014), Pb (0.002). The acidity of the water extract was 6.15.

Soils of background zone: Soils were sampled at the experimental site of the Polar Alpine Botanical Garden-institute (**BG**). The total chemical composition of the sample (wt.%): Na (5.3), Mg (0.97), Al (14.4), Si (61.06), P (0.15), K (4.73), Ca (2.48), Mn (0.17), Fe (10.6), Co (0.003), Ni (0.013), Cu (0.028), Zn (0.02), Pb (0.001). The acidity of the water extract was 5.79.

2.2.2 Phytotoxicity Testing

To test the acute toxicity of samples of industrial wastes, seeds of annual ryegrass (*Lolium multiflorum* L.), manufacturer: Agroprogress, class Izorskii RS-1 were used. Hydroponic carpet lawns were previously grown during 7 days in the 1 cm layer of expanded vermiculite on the plastic tray. After this, turfs were layered on the moistened industrial wastes. Test parameters—assessment of root development and growth to the substrate were evaluated after 7 days of the experiment. The acute phytotoxicity of samples of soils and wastes from industrial zone was assessed using *Lolium multiflorum* L. since this plant was used in the technology of remediation of industrially disturbed areas using mining waste as the dominant species of grass cover and was proven to be resistant to harsh climatic conditions of Arctic and Subarctic (Slukovskaya et al. 2018).

To assess the chronic phytotoxicity of samples, we used erect marigolds (*Tagetes patula* L.), manufacturer: AELITA (GOST 12260-81). *Tagetes* L. is the most common plants used in urban landscaping and they are able to grow and blossom in soils of good quality in the Subarctic. Marigolds were preliminarily germinated on filter paper in Petri dishes for three days before planting in tested samples. The duration of the experiment for the samples of the industrial zone was 28 days of vegetation, for the samples of the urban zone—60 days. The test parameters are the length of aboveground plant organs, water balance and the content of chlorophylls a and b in plant leaves. The experiments were carried out in triplicate, and the results were processed statistically ($p < 0.95$). The content of chlorophyll a, b and water band index (WBI) was determined using a SpectraVue Leaf Spectrometer CI-710 s. WBI is the index used for the assessing of water stress and related to them indicators, i.e., productivity determination, etc.

Phytotesting was carried out in laboratory conditions at air temperature of 20–22 ºC. Plants were grown in a well-ventilated room using both daylight and artificial lighting.

2.2.3 Methods of Soil and Waste Analysis

To determine the pH, 5 g of soil and mineral samples was placed in 50 ml of distilled water, and the pH of the suspensions was measured after 1 h using an Expert-001 pH-meter-ionomer liquid analyzer with an ESL-63-07SR glass laboratory electrode and auxiliary laboratory silver chloride electrode EVL-1M3.1.

The total content of heavy metals (HM) and content of their acid-soluble and water-soluble fractions were analyzed. Total content of metals was determined after autoclave microwave decomposition in the SW4 system in the DAK 100 autoclaves (Berghof, Germany). A mixture of HF and HNO_3 concentrated acids was used to decompose the soil samples. Content of water-soluble fraction (WSF) was determined after treatment of fresh soil (10 g) with deionized water (50 ml), shaking (1 h) and filtering using membrane filter with pore size 0.45 μm. For samples of urban and suburban soils, the content of acid-soluble metal fraction (ASF) was determined after treatment of air-dried soil (1 g) with 0.2 N HCl (50 ml), mixing (1 min), shaking (15 min) and filtering through 'blue ribbon' filter paper with pore size 2–3 μm. For industrial zone samples, a stronger 1N HNO_3 acid was used to obtain acid-soluble metal fraction. Solutions were analyzed using a Perkin Elmer ELAN 9000 DRCe inductively coupled plasma mass spectrometer. Multielement calibration solutions Inorganic Ventures (USA) (IV-STOCK-29, IV-STOCK-21, IV-STOCK-28) were used for the instrumental calibration. For quality control, standard reference materials were used: CRM-SOIL-A (High purity standards, USA), GSO 7126-84 Bil-1, GSO 902-76 SP-2, GSO 903-76 SP-3, SDPS, SKR -1 (Russia).

2.3 Results

2.3.1 Characteristics of Industrial Wastes

The assessment of the chemical properties of mineral substrates was carried out based on the results of determining the water-soluble, available to plants and acid-soluble fractions of chemical elements (Table 2.1).

Table 2.1 Results of chemical fractionation of mineral substrates

Concentration, mg•kg^{-1}

Sample	Na	Ca	Mg	Al	Fe	P	K	Mn	Cu	Ni	Zn	Si	S
Water-soluble fraction													
PD	18	*63*	*18*	7.75	7	1.375	9	0.65	**11**	**3.1**	0.12	20	**85**
IQ	18	*58*	*16*	3.3	7.25	1.15	11	0.32	0.22	0.07	0.1	13	18
IN	88	0.2	0.7	2.52	1.4	12.25	5	0.03	0.24	0.024	0.17	9	0
Plant available (1 M $CH_3COOH + NH_4OH$, *single extraction*) *fraction*													
PD	10	22	6	**427**	**110**	4.75	17.75	1.1	**175**	**6.75**	0	32	**300**
IQ	9	*1100*	11	4	37	0	16.5	12.75	0.142	0.217	4.75	2	32
IN	**1100**	202	8	**470**	22	*52.5*	*150*	*32.25*	0.825	0.177	*10*	*515*	0
Plant available (1 M $CH_3COOH + NH_4OH$, *second + third extractions*) *fraction*													
PD	12	35	6	**700**	**187**	13.25	15.5	5.75	**102.5**	**4.35**	0.15	77	**42**
IQ	11	*390*	11	2.4	28	0	15.25	6.25	0.375	0.065	1.65	5	0
IN	925	77	3	**625**	57	*28.5*	*77.5*	*14.75*	0	0.105	*4.25*	*430*	0
Acid-soluble (1N HNO_3) *fraction*													
PD	26	392	72	**4450**	**825**	117.5	20.5	14.75	**200**	**13.75**	11.5	1675	45
IQ	24	725	67	60	190	222.5	20.5	4.07	0	0.127	7	80	57
IN	**17,575**	*2450*	57	**32,450**	590	*1300*	*5050*	*102.5*	0	0	31	*44,850*	**1000**

Note Elevated levels of elements that may be significant for the substrate toxicity are highlighted in color, a negative effect is bold, a positive effect is italic

Extremely high concentrations of plant available fraction of such elements as Na, Al, P, K and Mn were obtained for IN substrate. High concentrations of the first two elements can have a negative effect on plant growth, and the last three are nutrients that can be beneficial for plants. The IQ substrate contains high concentrations of Ca and is depleted in both nutrients and toxic metals. Naturally, the highest level of metals is characteristic of PD, in which, there are no elements in elevated concentrations that can neutralize the negative impact, primarily of Cu, Ni and sulfates.

2.3.2 *Study of Phytotoxicity of Industrial Wastes*

2.3.2.1 Acute Phytotoxicity

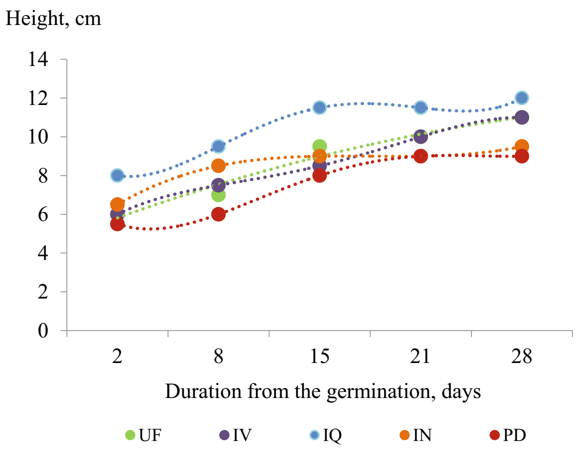
The appearance of plants and roots after exposure for 14 days is presented in Table 2.2. As a result of the express test, it was revealed that the complete growth of the roots of *L. multiflorum* occurred in experiments with expanded vermiculite and agricultural soil, which were characterized by the most optimal pH values. Growth of mini lawns to other mineral substrates was not noted. The degree of development of the root system was assessed by visual inspection in points from 1 to 10, where 1 is the absence of roots growth, 3 is very weak growth, 8–9 is good growth and 10 is excellent growth (Table 2.2). In the variant with nepheline waste (IN), an active development of the root system occurred (10 points), for IV, this indicator was 9 points, for UF and IQ—8 points. The most toxic was the contaminated podzol soil (3 points). The results obtained correspond to the results of the chemical analysis of the substrates. The lack of growth of mini lawns reflects the presence of high concentrations of toxic metals (PD) in the substrates and unfavorable pH levels (IN and IQ), and the development of the root system correlates with the availability of nutrients (IN).

Thus, the mini lawns test makes it possible to compare the acute toxicity of different substrates and assess the possibility of their turfing and root development.

Table 2.2 Root appearance and development of the root system of *Lolium multiflorum* L

Index	IQ	IN	PD	UF	IV
Appearance					
Growth to the substrate	No	No	No	Yes	Yes
Roots development	8 points	10 points	3 points	8 points	9 points

Fig. 2.1 Height of *Tagetes patula* L. in the experiment with industrial wastes



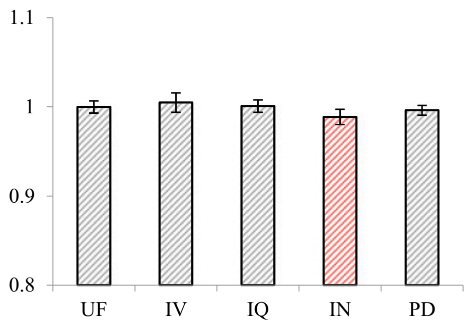
2.3.2.2 Chronic Phytotoxicity

Phytotesting with marigolds showed that the least favorable substrate for plant growth and development is degraded podzol, which is characterized by the highest content of Cu and Ni (Fig. 2.1). The maximum height of marigolds on the degraded podzol reached 9 ± 0.5 cm at the 21st day of vegetation. The greatest height of marigolds was present in the experiment with quartz tails (IQ)—12 ± 0.5 cm. In comparison with the control soil sample, experiments with mineral substrates were characterized by the best results due to the high content of macronutrients such as Mg and Ca.

The results of the study of water balance index (WBI) are presented in Fig. 2.2. This index is designed to assess the moisture content in vegetation. The water content is an important indicator; high humidity is characteristic of healthy vegetation. WBI is used for water stress analysis, productivity determination, fire hazard analysis, irrigated land management, etc. (Penuelas et al. 1995; Champagne et al. 2003).

The lowest WBI values were in the experiment with nepheline waste (IN), and the rest of substrates had almost the same optimal level.

Fig. 2.2 Water band index of *Tagetes patula* L. in the experiment with industrial wastes



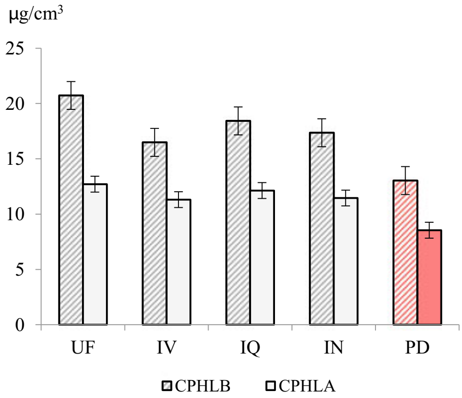


Fig. 2.3 Chlorophyll content in the leaf blade of *Tagetes patula* L. in the experiment with industrial wastes

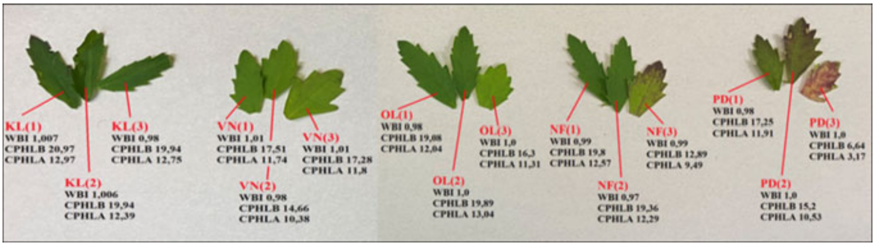


Fig. 2.4 Image of leaf blades of *Tagetes patula* L. analyzed on a leaf spectrometer

The maximum value of chlorophyll content in the leaf blade belonged to the marigolds grown on the control soil (Fig. 2.3). The minimum content of chlorophylls was noted in the experiment with degraded podzol, which was also reflected in the visual inspection of the leaves (Fig. 2.4).

2.3.3 Characteristics of Urban Soils

The hydrophysical characteristics, acidity and content of carbon and nitrogen compounds of urban soils are given in Table 2.3, the results of chemical analysis—in Table 2.4.

Soil samples differ in the content of organic carbon, availability of mobile nitrogen, actual and exchangeable acidity. According to the availability of phosphorus and potassium, all samples are classified as highly endowed. The TM and UF samples had the highest content of NO_3 which is likely related to the input of mineral fertilizers as a part of planting maintenance activities. The TM and TA samples from traffic zones are characterized by the high content of mobile Cu and Ni, which is related to the proximity to the nonferrous factory (TM) or logistic factor—transportation of

Table 2.3 Characteristics of urban soil samples

Land-use zone	Urban farm	Background	Recreational	Traffic, city center	Traffic, divine lane
Index	UF	BG	RK	TM	TA
Bulk density, kg/dm^3	0.88	1.05	0.41	1.01	0.63
Humidity of field samples, %	21.45	23.23	50.94	18.98	36.42
Humidity of air-dried samples, %	2.82	2.67	3.61	1.57	2.29
Loss of ignition, 900 °C	14.01	5.52	20.58	8.51	17.98
Field water capacity, %	67.49	39.83	135.29	51.14	96.71
NH_4^+, mg/kg	3.9	4.8	2.1	2.1	0.9
NO_3^-, mg/kg	145.9	34.7	18.1	253.6	21.9
C, %	6.2	3.4	9.3	3.5	8.3
N, %	0.3	0.1	0.5	0.2	0.3
H, %	1.1	0.9	1.4	0.7	1.2
pH (H_2O)	6.15	6.42	5.79	6.78	6.23
pH (KCl)	4.81	5.1	4.33	5.94	4.6
Eh	216	266	209	208	242

contaminated substrate from sand career to other towns of the region (TA). The BG sample is characterized by a high content of Al due to the natural soil properties of Podzols.

2.3.4 Phytotoxicity of Urban Soils

The results of the assessment of chronic toxicity of urban soils are presented in Fig. 2.5.

The most toxic was the soil with a high content of Cu and Ni (TA, traffic zone in Apatity), where the plants died on the first day of vegetation. High levels of Cu and Ni were also found in the TM soil, where however the presence of calcium and phosphorus partly neutralized the metal toxicity. The background (BG) soil was more toxic than the TM soil due to the high content of mobile Al, about 2 wt.%; plant height on the last growing day was 6.3 ± 0.5 cm.

Table 2.4 Chemical composition of urban soil samples

Sample	Na	Mg	Al	Si	P	K	Ca	Mn	Fe	Co	Ni	Cu	Zn
Total content, wt.%													
UF	2.26	0.51	6.21	27.03	0.22	1.04	1.74	0.07	5.60	15	80	134	66
BG	2.47	0.45	6.76	28.53	0.07	2.21	1.16	0.08	4.96	14	61	132	97
RK	1.81	0.31	5.08	23.66	0.42	1.16	1.28	0.05	4.29	12	78	132	83
TM	1.89	0.61	3.92	33.43	0.17	1.00	1.13	0.07	4.58	38	**378**	**305**	113
TA	1.57	0.58	3.33	26.34	0.04	1.45	1.17	0.05	3.43	29	**513**	**1609**	**390**
Acid-soluble fraction (0.2 N HCl), mg/kg													
UF	195	445	5850	1860	*2130*	*820*	*4800*	133	1105	1.7	6	19	25
BG	390	295	**19,500**	7100	*785*	*375*	*2650*	160	645	1.4	4	12	13
RK	355	340	8050	1105	*5250*	*540*	*13,650*	131	1145	1.2	11	18	56
TM	142	430	3350	2030	*1985*	*230*	*6450*	78	1080	4.7	**105**	**200**	41
TA	1200	585	4900	3850	*350*	*700*	*4050*	43	840	9.3	**265**	**1500**	32
Water-soluble fraction, mg/kg													
UF	10	1.4	0.6	4.3	2.9	41	5.9	0.04	0.24	0.001	0.008	0.030	0.005
BG	10	0.7	**9.3**	13.7	0.7	16	3.6	0.15	1.38	0.008	0.050	0.245	0.208
RK	7	0.4	1.1	9.4	0.7	14	2.3	0.02	0.57	0.000	0.009	0.034	0.010
TM	10	2.5	0.7	2.9	2.5	14	15.3	0.02	0.57	0.001	0.119	0.132	0.009
TA	15	0.5	1.7	30.0	0.3	7	1.3	0.02	0.87	0.003	0.070	0.796	0.075

Note Elevated levels of elements that may be significant for the substrate toxicity are highlighted in color, a negative effect is bold, a positive effect is italic

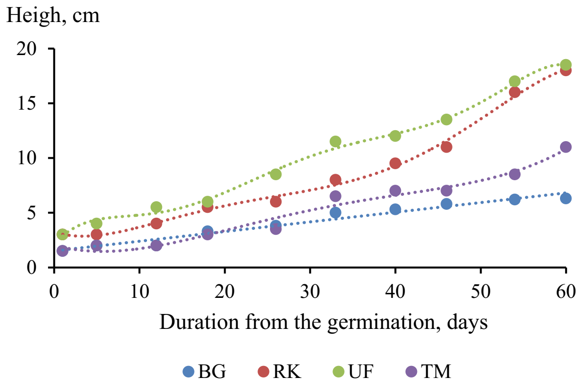


Fig. 2.5 Height of *Tagetes patula* L. in the experiment with urban soils

The chronic toxicity of RK and UF soils was the same; the height of the marigolds was 18.5 ± 0.5 cm at the end of the experiment. The RK soil sample contained mobile Ni and Al, but also contained mobile Ca, which is known to reduce the toxic effect of metals.

2.4 Conclusions

Existing enterprises and an increased regional background for the content of heavy metals in several regions of the Russian Arctic zone require the preservation of natural vegetation, regular planting of greenery and maintaining a high quality of vegetation cover. In the Murmansk region, there are mining enterprises that store thousands of tons of waste, which can be used in the technologies of restoration of industrially polluted and poor urban soils. These products contain layered materials that have high sorption activity with respect to metals, a high specific surface area and the ability to retain moisture and are available in quantities sufficient to the remediation of large areas.

Complex study of the chemical properties of urban soils and industrial wastes and phytotesting of their acute and chronic toxicity using test plants *Lolium multiflorum* L. and *Tagetes patula* L.) shown that the use of these species provide an adequate assessment of the complex phytotoxicity effect of the analyzed materials. At the same time, the data on the chemical composition mainly on the content of mobile forms of the components is needed for the development of recommendations for improving soil quality.

The assessment of acute and chronic phytotoxicity showed the high toxicity of podzol soil from the suburban area of the city Monchegorsk located near the nonferrous plant. This soil contains high concentrations of metals and is depleted in nutrients for essential plants, which are also able to neutralize the toxic effects of metals. The most active development of the root system was observed in variants with expanded vermiculite, nepheline waste and quartz waste. Therefore, these wastes can be easy remediated and also used as components of soil constructions on the areas with lost soil cover.

Phytotesting of urban soils from different land-use zones of three subarctic cities showed that the most toxic was soil with a high content of mobile copper and nickel from the traffic zone of Apatity town, where all plants died. Another tested soil from traffic zone of Monchegorsk town also contained a high concentration of copper and nickel, but this soil was highly provided with phosphorus and calcium, which levels the toxicity of metals.

Thus, we propose the following algorithm for the rapid field assessment of soil phytotoxicity in the Subarctic:

(1) The testing of the acute phytotoxicity (5–7 days) by the root attachment to soil of pre-grown hydroponic lawns from *Lolium* spp.
(2) The testing of chronic phytotoxicity (21 days) using marigolds (*Tagetes* spp.) in case when roots of grasses demonstrated the growth in tested substrate.
(3) The chemical analysis of mobile fractions of heavy metals and nutrients for soils which revealed the toxic effect to take measures to improve the quality of such soils or decide to replace them.

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