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POLLUTION OF "AKMENĖS CEMENTAS" VICINITY: ALKALIZING MICROELEMENTS IN SOIL, COMPOSITION OF VEGETATION SPECIES AND PROJECTION COVERAGE

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Abstract. The article presents the results of the research pertaining to forest litter and the composition of peat topsoil microelements, as well as the composition and projection coverage of undergrowth, herbaceous and bryophyte species specific to the vicinity of the cement factory "Akmenės cementas" are presented. Increased amounts of strontium, barium, titanium, manganese, copper, chromium, nickel and boron in forest litter and the upper 10 cm peat layer (up to 6 km from the pollution source) were established. 53 plant species were observed. The greater part (75–81%) of them are vascular plants. It was indicated that the diversity of vegetation species at different distances (0.5–1.0, 3.0–3.5 and 5.5–6.0 km) from the pollution source varies. Species of broadleaved trees and shrubs (*Quercus robur* L., *Betula pendula* Roth., *Frangula alnus* Mill., *Corylus avellana* L.), resistant to the impact of alkaline dust, are more outspread near the pollution source. Nearby the pollution source (0.5–1.0 km), *Campylium stellatum* Lange and *Campylium sommerfeltii* Lange, were found. At the farthest distances from the plant, the typical for *Myrtillo-oxalidosa* site type moss *Hylocomium splendens* (Hedw.) Schimp., *Rhytidiadelphus triquetrus* (Hedw.) Warnst, and herbs *Epilobium palustre* L., *Vaccinium myrtillus* L., *Moehringia trinervia* (L.) Clairv. were observed. Total coverage of vegetation species varied from 35.5±1.9% at the closest to the pollution source distance to 19.6±2.1% at the 3.0–3.5 km distance. It is significantly ($p < 0.05$) less in comparison to the control (51.9±2.2%). The greatest part (43–72%) of the coverage in different squares of the vegetation study consisted of herbs and undergrowth plants.

Keywords: cement dust pollution, alkaline microelements, herbaceous, bryophytes, undergrowth, species composition, projection coverage.

1. Introduction

Changes in the atmosphere and soil due to human activities, especially industrial pollution, have a considerable impact on many ecosystems. Atmospheric deposition of toxic mass and alkalizing substances has become an important environmental problem. Soil contamination is the global problem of industrial environment and agricultural technological processes, to which no universal solution has been found yet (Baltrėnas *et al.* 2010; Juostas and Janulevičius 2009; Jankaitė 2009). Countless soils around the world are contaminated with heavy metals. In Lithuania, there are wide analyses of air pollutants such as NO_x, CO_2 (Juostas and Janulevičius 2009) or particulate matter (Vyzienė and Girgždys 2009). Anthropogenic pollution emissions can be controlled by various biofilters (Baltrėnas and Zagorskis 2010). For soil remediation from heavy metals, mathematical modelling can be used (Jankaitė 2009).

With increasing environmental pollution and its effects on nature, many ecosystems were undergoing transformation. Forest ecosystems situated close to pollution sources suffer the greatest impact as the concentration of harmful substances in the local pollution zone often exceeds permissible amounts. Up to 1980, environmental pollution has resulted in a significant decrease of biodiversity in anthropogenized or semi–natural ecosystems. This particularly concerns the species of vascular plants as well as diversity of ground vegetation (Tylianakis *et al.* 2008). Changes of the structure, composition of species and health condition of plant communities are especially characteristic of forest ecosystems locally and on a regional scale (Hendriks *et al.* 1997; Ozolinčius, Stakėnas 1999; Juknys *et al.* 2002). Significant damages of tree stands have been determined in different regions of northwestern Europe (Innes, 1998; Fischer *et al.* 2007). Most scientists state that decline of forest condition is caused by a complex of various factors, but the main factor causing large scale forest damage is environmental pollution, and other negative factors just strengthen the impact of pollutants (Kandler, Innes 1995; Nihlgard 1997; Klap *et al.* 2000). In forests of Germany and the Czech Republic that have been severely damaged by anthropogenic pollution, an invasion of nitrophilous and gramineous plants (Schmidt 1993; Bobbink *et al.* 1998) has been attributed not only to the environmental eutrophication due to nitrogen deposition (Kral 1990; Schmidt 1993), but also to a competitive exclusion of characteristic species due to thinning of tree crowns and to attenuation of the trees (Jones 1989; De Vries *et al.* 2003).

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Changes in the chemical composition of forest soil and impact of these changes on species composition of plant communities considering the direct effect of cement dust were observed in the vicinity of cement plants of Estonia (Liblik *et al.* 2003; Mandre 1995), northern Lithuania (Armolaitis *et al.* 1999) as well in Ukraine (Ворон 2002). As a result of fluxes of fly ash, the precipitation in north-east Estonia was often alkaline with pH reaching up to 7.5–9.5; alkaline factor has caused essential changes in environmental conditions in bogs, plant cover and species composition (Karofeld 1994).

Investigations of ground vegetation changes of due to atmospheric deposition was performed making a comparison of the vegetation structure of analogous ecosystems by pollution gradient (control method) or analyzing the changes of plant species composition time-wise (Schmidt 1993).

The condition of damaged forest ecosystems started to improve locally and on regional scale at the beginning of 1990s as the result of reduced environmental pollution (Hendriks *et al.* 1997; Ozolinčius, Stakėnas 1999; Juknys *et al*. 2002; De Vries *et al.* 2003; Fischer *et al.* 2007).

The impact of long-term cement dust alkalizing pollution on forest vegetation has not yet been investigated in Lithuania. Before now the investigations in the vicinity of "Akmenės cementas" factory were related to analyzing of tree radial increment and assessment of forest ecosystems health condition. The questions of Scots pine radial growth dynamics, changes peat soil features and communities of pedobionts due to the alkalizing impact of "Akmenės cementas" pollution (Stravinskienė, Kubertavičienė 2001; Stravinskienė, Erlickytė-Marčiukaitienė 2009; Armolaitis *et al.* 2003), analyzing of Scots pine needles surface characteristics (Kupčinskienė, Huttunen 2005) were tackled.

The aim of research was to analyse the alkalizing microelements in peat soil, species composition and coverage of forest undergrowth, herbaceous at different distances from the pollution source.

2. Methodology

2.1. Study area

The study area is situated near the "Akmenės cementas" cement factory in Naujoji Akmenė (56°40' N, 22°87' E) district in the northern part of Lithuania. "Akmenės cementas" is the largest company in the Baltics and one of the largest cement and slate factories in Europe.

It began operating in 1952. At the times of prosperity (the beginning of the 70s of the 20th century) the amount of pollutants discharged into the atmosphere consisted of 27 thou. tons of sulphur dioxide (SO_2), 9–10 thou. tons of cement dust, 8.5 thou. tons of nitrogen oxides (NO_x), 1 thou. tons of ash and other solid particles annually (Armolaitis *et al.* 1999). At the beginning of the 1990s, due to industrial decline emissions gradually decreased. In 1989–1991 annual emissions amounted to 60–70 thou. tons. During the transition period, annual emissions decreased due to reduced of plant production and improved production technology. In 2006, emissions comprised about 6.3 thou. tons. Recently, annual emissions of this factory failed to exceed 4–5 thou. tons (Stravinskienė, Erlickytė-Marčiukaitienė 2009).

"Akmenės cementas" is surrounded by the forests belonging to Naujoji Akmenė forestry of Mažeikiai forest enterprise. Research was performed in drained 65–75–year–old Scots pine (*Pinus sylvestris* L.) stands of 0.7 stocking level, III site class, located at distances of 0.5–1.0, 3.0–3.5 and 5.5–6.0 km in the direction of prevailing south-westerly winds (Table 1), growing on the peat soils of transitional bog (*Terri-Fibric Histosols* $-P_2^{\,l}$) in *Myrtillo-oxalidosa turfuso-siccata* forest type (Karazija 1988), characterised by a high absorptiveness of different pollutants. Control Scots pine (*Pinus sylvestris* L.) forest stands with analogical dendrometric parameters were chosen in the site that had no local pollution, located at the distance of 10.0–12.0 km in the direction of non-prevailing winds.

2.2. Sampling design and vegetation anglysis

The sample plots were established along a 6.0 km transect running to the east from the plant. Apart from the pollution level, Scots pine (*Pinus sylvestris* L.) stands and site types in sample plots were relatively similar.

The analysis of physical-chemical characteristics of peat soils and vegetation analysis was carried out from 2005 to 2008 in sampled observation plots at three locations (0.5–1.0, 3.0–3.5 and 5.5–6.0 km) along the study transect in the direction of prevailing winds (Fig. 1). In each distance (observation plot) and control at 3 places, applying the method of American Forest Health Monitoring (Tallent-Halsell 1994), four vegetation study sites (subplots) with a radius of 7.32 m were allocated systematically. Totally, in all observation plots and control 48 vegetation sample squares (microplots) were distinguished. In each microplot 3 vegetation sample quadrates (area of 1 m^2) were selected (Fig. 2).

Table 1. Dendrometric characteristics of forest stands at the study sites in the vicinity of "Akmenės cementas" and control

Observation plot (distance from the plant), km	Species composition	Age, years	Mean height, m	Mean diameter, cm	Stoking level	Site class	Direction from the plant
I (0.5–1.0)	10P	70	20	22	0.7	III	East
II (3.0–3.5)	10P+B	75	23	24	0.7	III	East
III (5.5–6.0)	9P1B	65	21	21	0.7	III	East
Control (10.0–12.0)	9P1B	70	24	24	0.7	III	South-west

Note: P – Scots pine (*Pinus sylvestris* L.), B – downy birch (*Betula pubescens* Ehrh.)

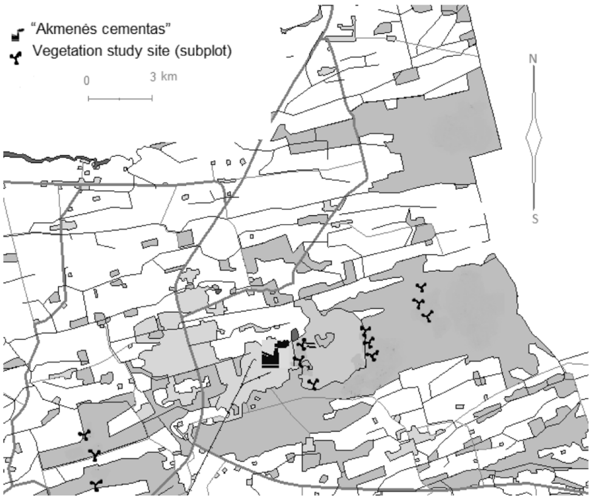

Fig. 1. Location of study sites in vicinity of "Akmenės cementas" and in control forest stands

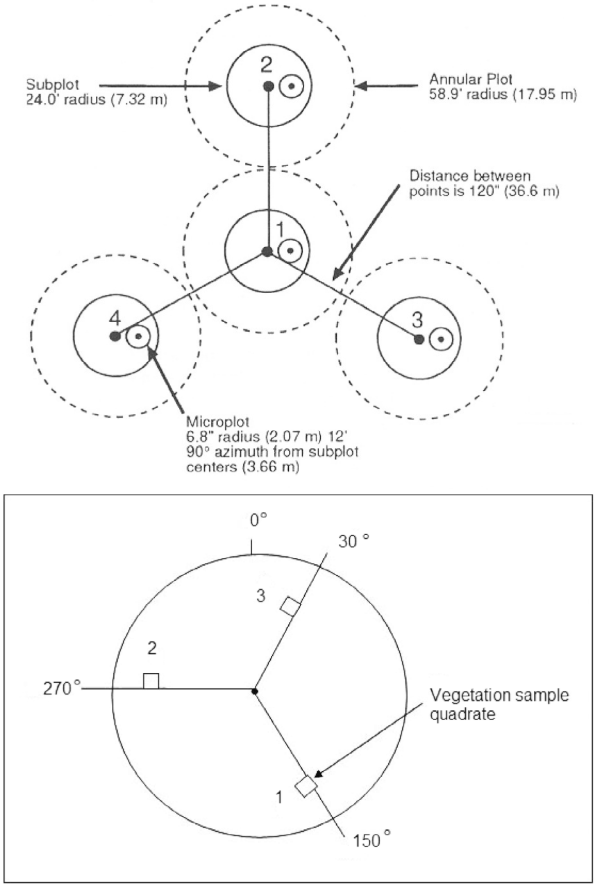

Fig. 2. Scheme of American Forest Health Monitoring study site (top) and location of vegetation sample quadrates (bottom) in vegetation sample microplot (Tallent-Halsell 1994)

All undergrowth species (trees and shrubs) up to the height of 0.6 m, the number of herbaceous and bryophyte species, as well as their projection covering (%) in 144 vegetation sample quadrates in total were ascertained.

Forest litter, 0–10 cm and 10–20 cm peat layer soil samples were collected, prepared and analysed according to widely using in chemical analysis techniques (Manual on Methodology ... 1994; Агрохимические методы ... 1975, etc.). Forest litter and peat layers soil samples at all observation plots at different distances from the pollution source and control forest stands were taken in three replications in 2007. In total, 36 samples of forest litter and peat soil from observation plots and control area were taken. Amounts of strontium, barium, titanium, manganese, copper, chromium, nickel and boron were evaluated. Nomenclature of vascular plants is presented according to Z. Gudžinskas (1999), bryophytes – according to I. Jukonienė (2003). "Statistica" and "Microsoft Excel" software were applied for statistical analysis and presentation of data.

3. Results and discussion

3.1. Study of peat soil microelement composition

Studies on soil nutrient composition have shown that emissions from "Akmenės cementas" contain the alkalizing substances. Alkalizing impact of the emissions increases the amount of strontium, barium, titanium, manganese, lead, copper, chromium, nickel and boron.

At the farthest distance from the pollution source peak amounts of strontium, barium, titanium, manganese (in observation plots I and II 1050±25 mg/kg and 1100±50 mg/kg correspondingly) were found in the upper 10 cm layer of peat soil. At the depth of 10–20 cm amounts of microelements were 2–3 times lower, while forest litter according to the accumulation of microelements occupies an intermediate position. Strontium, barium, titanium and manganese are the principal microelements in the cement dust. At the farthest distances from the factory (observation plot III) the amount of microelements decreases (Fig. 3).

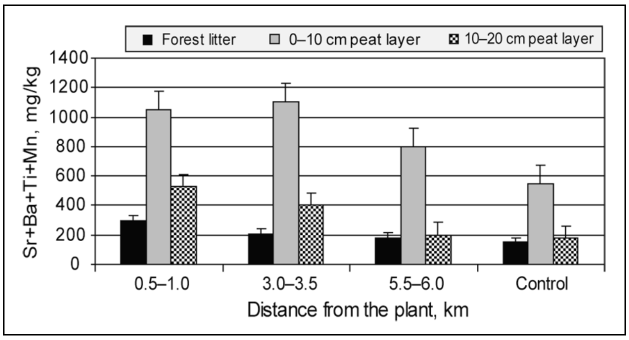

Fig. 3. Microelement (strontium, barium, titanium, manganese) content in peat soil in vicinity of "Akmenės cementas"

Most amounts of nickel, chromium, copper and barium were found close to the plant (observation plot I – 46±4.9 mg/kg) and at the distance 3.0–3.5 km (observation plot II – 48±4.3 mg/kg) in the upper 10 cm layer of peat. At the depth of 10–20 cm their amounts are 4.6–10 times lower, while forest litter according to the accumulation of these microelements occupies an intermediate position – amounts of microelements 1.5–2 times less than in the upper 10 cm layer of peat. Further away from the plant their amounts decrease. At the distance of 5.5–6.0 km from the chemical plant the amount of nickel, chromium, copper and boron in forest litter and peat soil is similar to control (Fig. 4). The dust of calcium and magnesium neutralizes acid peat soils. This leads to alkalization of peat soil and forest litter. During the process of alkalinisation, both harmful (aluminium, manganese, cadmium, lead) and useful (barium, phosphorus, copper, cobalt) for plants elements become active.

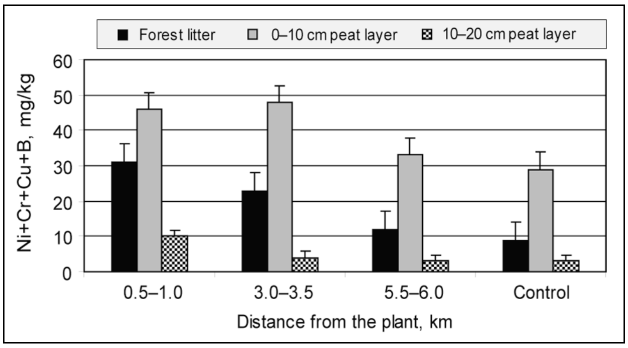

Fig. 4. Microelement (nickel, chromium, copper, boron) content in forest litter and peat soil in vicinity of "Akmenės cementas"

Comparing to the results of our previous analysis (Stravinskienė, Kubertavičienė 2001, the results of this study indicates decreased amounts of microelements in all observation plots. Significant (20–30%) decrease of strontium, barium, titanium and manganese amounts was estimated in forest litter and upper 10 cm peat layer at observation plots I and II (till 3.5 km from the factory). At the farthest distance (5.5–6.0 km) the reduction of amounts is less and similar to the control.

The insoluble cement dust deposited on a wet leaf or needle forms crust, which pushes the sheet surface and changes light, temperature and water treatment of the plant tissues. Solid particles, clogging the stomates of leaves or needles modify the transpiration rate and reduce the intensity of photosynthesis (Mandre 1995). Alkalizing dust causes changes of the metabolic processes, resulting in abnormal growth and development, leading to extinction of some plant species (Annuka 1995).

Studies in the vicinity of Kunda cement plant in northern Estonia confirm that alkalisation of forest ecosystems and changes of soil, soil water, precipitation, etc. are expressed as changes of the species composition and growth of trees and plant communities considering the direct effect of cement dust (Mandre 1995; Liblik *et al.* 2003). Studies in Lithuania have shown that moving away from the factory adverse impact of pollutants on the soil cover reliably decreases (Armolaitis *et al.* 2003).

3.2. Species composition and projection coverage of ground vegetation

This research described features of ground vegetation species composition and coverage in the vicinity of cement factory alkalizing pollution. Study of ground vegetation showed that the total number of plant species at different observation plots at different study year differed insignificantly. On an average, 53 plant species were found. The greater part (75–81%) of them consisted of vascular plants. The number of herbaceous and bryophytes in different distances from the chemical plant was increasing from on an average 40, at a distance of 0.5–1.0 km from the plant, to 43 at a distance of 5.5–6.0 km. The number of herbs species at the closest distance is 27±2.4. The average number of herbaceous species was regularly increasing depending on the distance from the plant (Fig. 5). At the farthest distance the total number of herb species increased to 33±2.8 (Table 2).

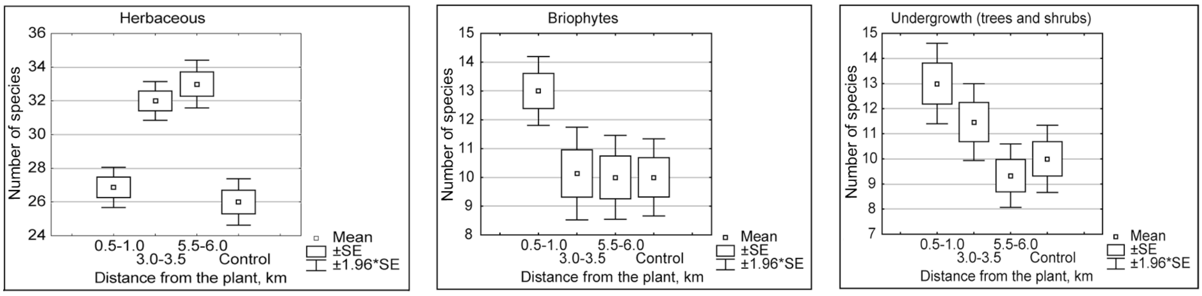

Fig. 5. The average number of herbaceous, bryophyte and undergrowth species at different distances from the pollution source

Table 2. Mean abundance and projection coverage of vegetation in vicinity of "Akmenės cementas"t

Distance from the plant, km	Number of species			
	Herbaceous	Bryophytes	Undergrowth	All species
0.5–1.0	27±2.4	13±2.3	13±3.5	53±2.7
3.0–3.5	32±2.7	10±3.2	12±3.0	54±2.9
5.5–6.0	33±2.8	10±3.0	10±2.4	53±2.7
Control	26±2.7	10±2.6	10±2.6	46±2.6

Distance from the plant, km	Projection coverage, %			
	Herbaceous	Bryophytes	Undergrowth	All species
0.5–1.0	22.2±2.9	14.6±2.3	5.2±0.7	35.5±1.9
3.0–3.5	12.8±2.7	17.2±3.0	2.2±0.4	19.6±2.1
5.5–6.0	12.7±3.1	35.2±3.3	3.1±0.7	32.8±2.4
Control	22.1±3.2	28.6±2.7	3.6±0.8	51.9±2.2

Number of herbaceous species in the observation plots significantly ($p < 0.05$) differed from that of the control. The main indicator species of *Myrtillo-oxalidosa* site type, i.e. *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L., appeared only at farther distances, whereas in the area polluted by alkaline dust, nitropfhilic species typical of more fertile site types, such as *Rubus idaeus* L., *Rubus caesius* L., *Epilobium angustifolium* L., *Cirsium oleraceum* (L.) Scop., *Poaceae* sp. herbs were seen more frequently. In the most polluted area *Calamagrostis canescens* (Weber) Roth, *Oxalis acetosella* L., *Rubus idaeus* L., *Rubus saxatilis* L. and *Galium mollugo* L. were widespread. *Fragaria vesca* L., *Rubus idaeus* L., *Galium mollugo* L., *Epilobium angustifolium* L., *Cirsium oleraceum* (L.) Scop. were abundant in all vegetation sample quadrates (Table 3).

Table 3. Herbaceous plant species and their projection coverage (%) at different distances from the pollution source and control forest stand (an average data from 36 vegetation sample quadrates at each distance and control)

Species	Projection coverage (%) at distance from the factory, km			Control
	0.5–1.0	3.0–3.5	5.5–6.0	
Aegopodium podagraria L.	0.04	0.03	0.00	0.00
Angelica sylvestris L.	0.00	0.13	0.00	0.00
Athyrium filix-femina (L.) Roth	0.00	0.03	0.04	0.00
Calamagrostis canescens (F. H. Wigg.) Roth	13.00	0.15	0.05	0.10
Carex digitata L.	0.83	0.00	0.01	0.69
Carex elongata L.	0.13	0.58	0.00	0.00
Carex lasiocarpa Ehrh.	0.00	0.00	0.23	0.31
Cerastium holosteoides Fr)	0.00	0.00	0.04	0.00
Chamerion angustifolium (L.) Holub	0.08	0.20	0.08	0.00
Circeae alpina L.	0.00	0.00	0.04	0.00
Cirsium oleraceum (L.) Scop.	0.23	0.13	0.03	0.00
Dactylis glomerata L.	0.00	0.00	0.48	0.00
Deschampsia cespitosa (L.) P.Beauv.	0.03	0.00	0.38	0.23
Elymus caninus L.	0.03	0.03	0.00	0.03
Epilobium angustifolium L.	0.43	0.53	0.09	0.27
Epilobium montanum L.	0.00	0.08	0.10	0.10
Epilobium palustre L.	0.00	0.03	0.49	0.52
Festuca gigantea (L.) Vill.	0.03	0.05	0.18	0.00
Fragaria vesca L.	0.78	4.00	0.53	0.01
Galium boreale L.	0.03	0.00	0.00	0.00
Galium mollugo L.	0.13	0.13	0.20	0.10
Geum rivale L.	0.15	0.10	0.00	0.00
Hieracium vulgatum Fr.	0.00	0.07	0.00	0.00
Hypochaeris maculata L.	0.00	0.08	0.00	0.00
Luzula pilosa (L.) Willd.	0.00	0.00	0.00	0.14
Lycopus europaeus L.	0.09	0.00	0.00	0.00
Maianthemum bifolium (L.) F.W.Schmidt	0.03	0.00	0.05	1.10
Malaxis monopfyllos (L.) Sw.)	0.00	0.04	0.00	0.00
Moehringia trinervia (L.) Clairv.	0.00	0.00	0.23	0.27
Moneses uniflora (L.) A.Gray	0.00	0.00	0.57	0.00
Mycelis muralis (L.) Dumort.	0.08	0.20	1.63	0.00
Nardus stricta L.	0.00	0.15	2.05	0.00
Orthilia secunda (L.) House	0.00	0.03	0.00	0.00
Oxalis acetosella L.	3.28	0.08	0.03	6.50
Paris quadrifolia L.	0.09	0.00	0.02	0.00
Poa trivialis L.	0.00	0.00	0.15	0.10
Platanthera bifolia (L.) Rich.	0.00	0.00	0.06	0.00
Ranunculus repens L.	0.00	0.00	0.00	0.39
Rubus caesius L.	0.13	1.75	0.00	0.00
Rubus idaeus L.	2.30	1.58	1.13	0.10
Rubus saxatilis L.	1.09	0.33	0.00	2.40
Solanum dulcamara L.	0.09	0.00	0.00	0.00
Sonchus oleraceus L.	0.03	0.00	0.00	0.00
Stellaria graminea L.	0.00	0.00	0.90	0.10
Taraxacum officinale F.H.Wigg.	0.05	0.15	0.18	0.00
Torilis japonica (Houtt.) DC.)	0.00	0.07	0.00	0.14
Trientalis europaea L.	0.00	0.00	0.00	0.39
Tussilago farfara L.	0.03	0.10	0.30	0.00
Urtica dioica L.	0.03	0.35	0.00	0.35
Vaccinium myrtillus L.	0.00	0.00	0.55	6.20
Vaccinium uliginosum L.	0.09	0.03	0.00	0.02
Vaccinium vitis-idaea L.	0.00	0.93	0.40	0.70
Valeriana officinalis L.	0.00	0.00	0.08	0.00
Veronica chamaedrys L.	0.00	0.00	0.03	0.12
Viola canina L.	0.00	0.40	0.00	0.00

Eight plant species specific to this zone, i.e. *Carex digitata* L., *Lycopus europaeus* L., *Galium boreale* L., and fertile soil indicators – *Aegopodium podagraria* L., *Maianthemum bifolium* (L.) F.W.Schmidt, *Urtica dioica* L., *Sonchus oleraceus* L., and *Solanum dulcamara* L. were found in the observation plot I. Coverage of these species decreased at greater distances from the plant.

According to the results of soil liming experiments (Kreutzer 1995; Kostikov *et al.* 2001), due to increased soil pH, the concentration of nitrogen compounds in the soil has augmented. The spreading of nitrophilic species has been recorded in most cases when liming of soils leads to an increase in soil pH (Rodenkirchen 1992; Dulière *et al.* 2000). Our research indicated that with increasing distance from the plant, the coverage of nitrophilic species decreases. It can be explained by the fact that with increasing distance from the source of alkalizing pollution, soil pH decreases.

At greater distances from the factory the projection coverage of *Nardus stricta* L., *Epilobium montanum* L., *Mycelis muralis* (L.) Dumort. has increased. At the distance of 5.5–6.0 km from the pollution source (observation plot III), plant species, such as *Stellaria graminea* L., *Carex lasiocarpa* Ehrh., *Dactylis glomerata* L., *Moehringia trinervia* (L.) Clairv., and *Poa trivialis* L. were observed.

The number of species in observation plots in the polluted area was higher by 13–15% than that in the control observation plot (see Table 2). These differences were caused by reduced soil acidity due to the alkalizing impact of emissions. The number of bryophyte species was changing insignificantly, meanwhile that of herbaceous was potentially growing.

The investigated Scots pine stands were similar by the richness of the undergrowth. The undergrowth species composition corresponded to the control, where its species comprised about one fifth (21.7%) of the total number of observed species. Evaluation of the undergrowth vegetation species composition showed that in vicinity of alkalizing emission impact, such deciduous species as *Corylus avellana* L., *Frangula alnus* Mill., *Quercus robur* L., *Betula pendula* Roth, considered as resistant plants to such pollution type, were existing here. These results confirm the data of other researchers (Annuka 1995) that some deciduous species, like *Corylus avellana* L., *Quercus robur* L., *Frangula alnus* Mill., *Betula pendula* Roth are resistant to alkalizing pollution.

Salix myrsinifolia Salisb., tolerant fertile and moist soils, was observed at the farthest distance. The number of undergrowth trees and shrubs species decreased as the distance from the alkalizing pollution source increased and varied from 13 at the closest distance to 10 at the farthest distance from the plant.

Mean projection coverage of the undergrowth (trees and shrubs) species varied from 5.2±0.7% at the closest to the pollution source distance to 2.2±0.4% at the 3.0–3.5 km distance. Mean projection coverage of the undergrowth species in control study sites is 3.6±0.8% (Tables 2, 4).

Results of our investigation revealed diversity of plant species composition in the vicinity of alkalizing pollution source due to changes in the chemical status of peat soil (Armolaitis *et al.* 2003). Other authors (Mandre 1995; Mäkipää 1995; Kannukene 1995) have described that the impact of pollution on soil chemical structure changes are better expressible in ground vegetation (herbaceous, bryophytes, lichens, etc.) than in forest trees. In the changed herbal communities, plant species that tolerate acid substrates and are typical for some forest types are inhibited, while neutrophilic and calciphilic species become dominant. With the increasing distance from the pollution source and decreasing influence of emissions species composition of bryophytes has changed gradually: 13±2.3 species nearby the plant (observation plot I), 10±3.2 and 10±3.0 species at farther distances correspondingly. The average number (10±2.6) of bryophyte species in contol study sites was similar to its number at observation plots II and III (Tables 2, 5).

Table 4. Undergrowth (trees and shrubs) species and their projection coverage (%) at different distances from the pollution source and control forest stand (an average data from 36 vegetation sample quadrates at each distance and control)

Species	Projection coverage (%) at distance from the factory, km			Control
	0.5–1.0	3.0–3.5	5.5–6.0	
Betula pendula Roth	2.09	0.12	0.70	0.12
Corylus avellana L.	0.14	0.15	0.69	0.61
Crataegus monogyna Jacq.	0.08	0.00	0.00	0.00
Euonymus verrucosus Scop.	0.00	0.08	0.00	0.07
Frangula alnus Mill.	0.00	0.11	0.09	1.03
Fraxinus excelsior L.	0.00	0.00	0.08	0.00
Picea abies (L.) Karst.	1.09	0.41	0.00	0.00
Pinus sylvestris L.	0.13	0.67	0.51	0.45
Populus tremula L.	0.07	0.00	0.15	0.00
Quercus robur L.	0.05	0.05	0.05	0.00
Rhamnus cathartica L.	0.05	0.09	0.00	0.03
Ribes nigrum L.	0.23	0.00	0.00	0.08
Rosa canina L.	0.00	0.08	0.00	0.00
Salix caprea L.	0.07	0.00	0.17	0.00
Salix cinerea L.	1.12	0.12	0.00	0.14
Salix myrsinifolia Salisb.	0.00	0.00	0.47	0.00
Sorbus aucuparia L.	0.06	0.19	0.09	1.00
Viburnum opulus L.	0.02	0.05	0.00	0.07

Table 5. Briophyte species and their projection coverage (%) at different distances from the pollution source and in control forest stand (an average data from 36 vegetation sample quadrates at each distance and control)

Species	Projection coverage (%) at distance from the factory, km			Control
	0.5–1.0	3.0–3.5	5.5–6.0	
Brachythecium curtum (Lindb.) Lange et C.E.O.Jensen	0.08	0.00	0.00	0.00
Brachythecium mildeanum (Schimp.) Schimp. ex Milde	0.00	0.00	0.78	0.00
Bryum capillare Hedw.)	4.03	0.08	0.18	0.10
Calliergonella cuspidata (Hedw.) Loeske	5.03	0.10	0.00	0.00
Campylium sommerfeltii (Myrin) Lange	0.93	0.00	0.00	0.00
Campylium stellatum (Hedw.) Lange et C.E.O.Jensen	1.10	0.00	0.00	1.00
Dicranum montanum Hedw..	0.00	0.10	0.00	0.00
Eurhynchium pulchellum (Hedw.) Jenn.	0.58	4.28	10.25	4.00
Eurhynchium striatum (Hedw.) Schimp.	0.03	0.63	0.15	0.00
Fissidens osmundoides Hedw.	0.03	0.03	3.25	7.80
Hylocomium splendens (Hedw.) Schimp.	0.00	1.65	0.38	0.10
Plagiomnium affine (Blandow) T.J.Kop.	0.00	0.10	0.18	0.00
Plagiomnium cuspidatum (Hedw.) T.J.Kop.	0.93	0.00	0.65	0.00
Plagiomnium undulatum (Hedw.) T.J.Kop.	0.10	0.00	0.00	0.00
Plagiothecium Schimp.	0.04	0.00	0.00	7.10
Pleurozium schreberi (Brid.) Mitt.	0.08	0.08	0.00	0.00
Pseudoschleropodium purum (Hedw.) M.Fleisch.	0.00	0.00	0.58	1.90
Rhytidiadelphus triquetrus (Hedw.) Warnst.	0.00	0.00	0.08	0.00
Thuidium philibertii Limpr.	0.02	0.01	0.78	0.00

The dominant bryophyte species, such as *Calliergonella cuspidata* (Hedw.) Loeske, *Plagiomnium affine* (Blandow) T.J. Kop.), *Plagiomnium undulatum* (Hedw.) T.J. Kop.), and *Eurhynchium striatum* (Hedw.) Schimp.), are nonspecific to *Myrtillo-oxalidosa turfuso-siccata* site type. Neaby the plant (0.5–1.0 km), in most cases, scraggy, sparse bryophytes were found on the stumps of trees. It was estimated (Økland 1995; Dulière *et al.* 2000) that alkaline dust affected the moss at first, then grasses and woody plants. *Calliergonella cuspidata* (Hedw.) Loeske was sufficiently abundant and covered over 9% of this observation plot area.

Species, which tolerate alkaline and carbonized substratum, like *Campylium stellatum* (Hedw.) Lange et C.E.O. Jensen and *Campylium sommerfeltii* (Myrin) Lange were found here. *Eurhynchium striatum* (Hedw.) Schimp., *Plagiomnium undulatum* (Hedw.) T.J. Kop., and *Campylium stellatum* (Hedw.) Lange and *Thuidium philibertii* Limpr were observed rare.

The typical for *Myrtillo-oxalidosa* site type bryophyte species, such as *Hylocomium splendens* was found in observation plot II, while *Rhytidiadelphus triquetrus* – only on the farthest (5.5–6.0 km) distance from the cement factory. Their projection coverage has increased in the farthest areas and they were becoming more viable under these conditions. One of the main indicator species of this site type *Pleurozium schreberi* at the farthest distance from the pollution source was not detected at all.

The similar results were obtained in Estonia – at the lowest cement factory impact zone *Rhytidiadelphus triquetrus* (Hedw.) Warnst.) was observed and *Pleurozium schreberi* declined also (Kannukene 1995). At the farthest distances an indicatory species of *Myrtillo-oxalidosa* site type *Rhytidiadelphus triquetrus* (Hedw.) Warnst. was observed. At observation plots II and III the total number of bryophyte species decreased to 10 and equal to the number of these species in the control forest stand (Table 5).

The coverage of mosses increased with increasing distance from the plant: as the first observation plot compared with the third, at the latter coverage increased by two times. At a distance of 5.5–6.0 km it was the highest (35.2±3.3%) among all study sites. In the areas closer to the factory (observation plots I and II; 14.6±2.3% and 17.2±3.0% correspondingly), the projection coverage of bryophytes was significantly less ($p < 0.05$) compared with the coverage on the farthest distance and control (28.6±2.7%) study sites (Fig. 6).

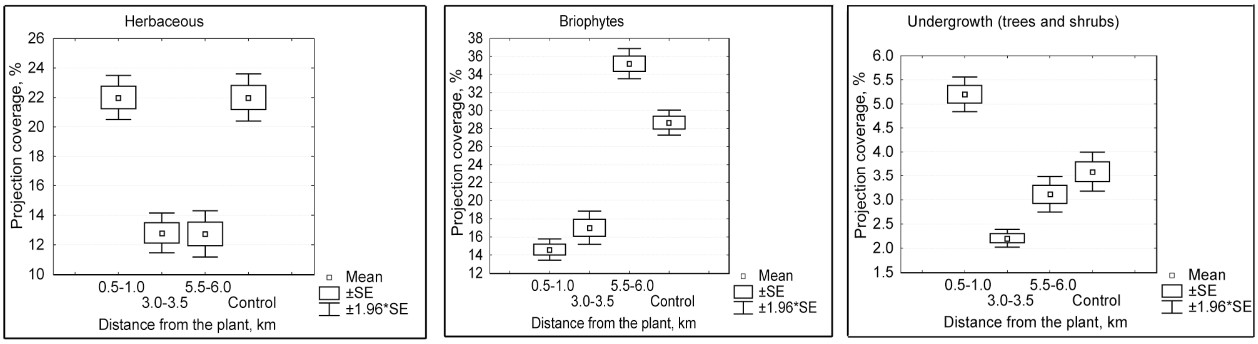

Fig. 6. Mean projection coverage % of vegetation species at different distance from the pollution source

According to the results of our investigation, total projection coverage of vegetation further away from the chemical plant was changing unevenly. The greatest part of coverage consisted of herbs and undergrowth plants. The total coverage of all ground vegetation species varied from 35.5±1.9% in the most polluted area to 19.6±2.1% at the 3.0–3.5 km distance from the pollution source. It is significantly less ($p < 0.05$) as compared to control study sites (Table 2, Fig. 6).

The coverage of undergrowth tree and shrub species was significantly greater ($p < 0.05$) at observation plot I as compared to the control. The projection coverage of herbaceous was reliably greater in the closest to the pollution source observation plot ($p < 0.05$), while in more distant observation plots it was lower as compared to the coverage in observation plot I and control study sites.

4. Conclusions

1. Studies on soil nutrient composition have shown that emissions (dusts and ashes) of "Akmenės cementas" cement factory contain the alkalizing substances. Alkalizing impact of emissions increases the amount of strontium, barium, titanium, manganese, lead, copper, chromium, nickel and boron in forest litter and peat soil.
2. Peak amounts of nickel, chromium, copper and barium are found nearby the cement factory and at the distance 3.0–3.5 km in the upper 10 cm layer of peat. At the depth of 10–20 cm their amounts are 4.6–10 times lower; while forest litter according to the accumulation of microelements occupies an intermediate position.
3. 53 plant species were found; most of them (75–81%) vascular plants. The number of herbaceous species in different observation plots was increasing from 27±2.4 (at a distance of 0.5–1.0 km from the plant) to 33±2.8 (5.5–6.0 km). The number of bryophyte species at the closest to the plant distance is 13±2.3, the number of undergrowth tree and shrub species – 13±3.5.
4. At the farthest distance from the pollution source the total number of bryophyte species decreased to 10±3.0. The undergrowth species structure corresponded to the control, where it species comprised about 21.7% of the total number of ground vegetation species.
5. The main indicator species of the reference peaty *Myrtillo-oxalidosa* site type *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. appeared only at farthest distances, while nearby the plant more frequently occurred species typical for more fertile site types, such as *Rubus idaeus* L., *Rubus caesius* L., *Epilobium angustifolium* L., *Cirsium oleraceum* (L.) Scop., *Poaceae* sp. herbs.
6. In the vicinity of the most intensive pollution, such herbal species as *Calamagrostis canescens* (Weber) Roth, *Oxalis acetosella* L. and *Rubus saxatilis* L., *Galium mollugo* L., *Fragaria vesca* L., *Rubus idaeus* L., *Galium mollugo* L., *Epilobium angustifolium* L., *Cirsium oleraceum* (L.) Scop. in all vegetation study sites are widespread and prevalent. Nearby the cement factory attributable to calcicole plants *Campylium stelatum* (Hedw.) Lange et C.E.O. Jensen and *Campylium sommerfeltii* (Myrin) Lange were found.
7. Total coverage of all ground vegetation species varied from 35.5±1.9% at the closest to the pollution source distance to 19.6±2.1% at the 3.0–3.5 km distance from the plant. It is significantly less comparing to control (51.9±2.2%).
8. Projection coverage of bryophytes was increasing moving away from the plant and at a distance of 5.5–6.0 km it was the highest (35.2±3.3%) among all study sites.
9. At the farthest distance from "Akmenės cementas", typical for this forest type mosses *Hylocomium splendens* (Hedw.) Schimp., *Rhytidiadelphus triquetrus* (Hedw.) Warnst. were observed; their projection coverage has increased with the increasing distance from the cement factory.

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„AKMENĖS CEMENTO“ APLINKOS TARŠA. DIRVOŽEMĮ ŠARMINANTYS MIKROELEMENTAI, AUGALIJOS RŪŠIŲ ĮVAIROVĖ IR PROJEKCINIS PADENGIMAS

V. Stravinskienė

Santrauka

Pateikami miško paklotės ir durpinio dirvožemio mikroelementinės sudėties, trako augalų, žolių bei samanų rūšių įvairovės bei projekcinio padengimo „Akmenės cemento“ aplinkoje tyrimų rezultatai. Nustatyta, kad dėl cemento dulkių nusėdimo miško paklotėje ir durpėse (iki 6 km atstumu nuo gamyklos) yra padidėjęs mikroelementų (stroncio, bario, titano, mangano ir nikelio, chromo, vario, boro) kiekis; dėl cemento dulkių ir pelenų emisijos dirvožemis šarmėjo. Šis procesas lėmė augalijos rūšių sudėties skirtumus 0,5–1,0, 3,0–3,5 ir 5,5–6,0 kilometrų atstumu nuo gamyklos. Aptiktos 53 augalų rūšys; daugumą (75–81 %) jų sudaro induočiai augalai. Arčiausiai (0,5–1,0 km) gamyklos gausiau išplitę šarminėms dulkėms atsparūs *Quercus robur* L., *Betula pendula* Roth., *Frangula alnus* Mill., *Corylus avellana* L. bei kalcifilinės žolės *Campylium stellatum* (Hedw.) Lange et C.E.O. Jensen, *Campylium sommerfeltii* (Myrin) Lange. Toliau nuo gamyklos randamos durpiniam mėlyngiriui būdingos samanos *Hylocomium splendens* (Hedw.) Schimp. ir *Rhytidiadelphus triquetrus* (Hedw.) Warnst.; gausėja šiam miško tipui būdingų žolių rūšių: *Epilobium palustre* L., *Vaccinium myrtillus* L., *Moehringia trinervia* (L.) Clairv. Augalų rūšių projekcinis padengimas kinta nuo 35,5±1,9 % (arčiausiai gamyklos) iki 19,6±2,2 % 3,0–3,5 km atstumu nuo gamyklos, t. y.patikimai ($p < 0,05$) mažiau už kontrolę (51,9±2,2 %). Didžiąją dalį (43–72 %) augalijos projekcinio padengimo sudaro žoliniai ir trako sumedėję augalai.

Reikšminiai žodžiai: tarša cemento dulkėmis, šarminantys mikroelementai, trako, žolių ir samanų rūšių sudėtis bei projekcinis padengimas.

ЗАГРЯЗНЕНИЕ ОКРУЖАЮЩЕЙ СРЕДЫ ЗАВОДА «АКМЯНЕС ЦЕМЕНТАС»: ПОДЩЕЛАЧИВАЮЩИЕ МИКРОЭЛЕМЕНТЫ В ПОЧВЕ, ВИДОВОЙ СОСТАВ И ПРОЕКТНОЕ ПОКРЫТИЕ РАСТИТЕЛЬНОСТИ

В. Стравинскене

Резюме

Представлены результаты исследования состава микроэлементов в лесной подстилке и верхнем слое торфа, видового состава и проектного покрытия подлеска, трав и мхов в окружающей среде цементного завода «Акмянес цементас». Установлено увеличенное количество микроэлементов (стронция, бария, титана, марганца, свинца, хрома, никеля, бора) в лесной подстилке и верхнем (10 см) слое торфа на расстоянии до 6 км от завода. Обнаружено 53 вида растений, большую часть (75–81 %) которых составляют сосудистые растения. Разнообразие растительных видов на разном (0,5–1,0, 3,0–3,5 и 5,5–6,0 км) расстоянии от источника загрязнения меняется. Устойчивые к воздействию подщелачивающей пыли лиственные подлеска *Corylus avellana* L., *Quercus robur* L., *Frangula alnus* Mill., *Betula pendula* Roth распространены вблизи источника загрязнения. Там же найдены виды, характерные для более плодородных типов леса: *Rubus idaeus* L., *Rubus caesius* L., *Cirsium oleraceum* (L.) Scop, *Poaceae* травы. На более удаленном от завода расстоянии (5,5–6,0 км) найдены характерные для леса типа *Myrtillo-oxalidosa* мхи *Hylocomium splendens* (Hedw.) Schimp. и *Rhytidiadelphus triquetrus* (Hedw.) Warnst. Увеличено число видов трав, характерных для этого типа леса: *Epilobium palustre* L., *Vaccinium myrtillus* L., *Moehringia trinervia* (L.) Clairv. Среднее проектное покрытие наземной растительности меняется от 35,5±1,9 % (вблизи завода) до 19,6±2,2 % на расстоянии 3,0–3,5 км от завода. Это достоверно ($p < 0,05$) ниже контрольных данных. Большую часть (43–72 %) составляет покрытие травянистых растений и подлеска.

Ключевые слова: загрязнение цементной пылью, подщелачивающие микроэлементы, видовой состав и проектное покрытие растительности подлеска, трав и мхов.

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