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INFLUENCE OF CEMENT DUST ON SELECTED PROPERTIES OF SOILS AND THE MORPHOLOGY OF PINE (*Pinus sylvestris* L.) NEEDLES FROM THE FOREST STANDS IN THE SURROUNDINGS OF "LAFARGE" – CEMENT PLANT IN BIELAWY

WPŁYW PYŁÓW CEMENTOWYCH NA WYBRANE WŁAŚCIWOŚCI GLEB ORAZ BUDOWĘ MORFOLOGICZNĄ IGIEŁ SOSNY POSPOLITEJ (*Pinus sylvestris* L.) Z FITOCENOZ OTACZAJĄCYCH ZAKŁADY CEMENTOWO-WAPIENNICZE „LAFARGE" W BIELAWACH

Abstract: In the present research the impact of cement dust emitted by cement plant Lafarge S.A. – in Bielawy on soil and forest stands were investigated. Selected physicochemical properties of soils and the morphology of Scots pine needles were studied. The soils in the vicinity of the cement plant have elevated pH and contained $CaCO_3$ in the surface horizons due to alkaline dust accumulation. Shoots and needles of Scots pine were covered with thin layer of cemented dust. Pine needles from trees near the dust emitter were shorter and more narrow than needles from the trees beond the dust impact. Thus, pine trees in the vicinity of cement dust emitter have lower assimilation surfaces that might cause the lowering of photosynthesis process.

Keywords: cement dust, soil, Scots pine (*Pinus sylvestris* L.)

Numerous studies describe the damage done by acidic air pollution to forest areas in industrial regions [1–4]. The impact of alkaline air pollution on forests stands is much less recognized.

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The cement production process is accompanied with the emissions of considerably amount of dust. Thus, cement industry is a source of environmental pollution with alkaline dusts. Cement dusts influence the ecosystems including soil and plants, cause the imbalances in soil nutrients and reduce biodiversity. In some varieties of Portland cement (and in cement dust) traces of toxic metals such as chromium and lead are common. Elevated metal contents might also effect the plant cover and soil in the area being under the cement dust impact [5].

In the last decades, cement production has been rising in Poland and the problem is increasing. The objective of the study was to assess the impact of emitted cement dusts on selected soil properties and the condition of pine forest stands, particularly the morphology of pine needles, in the vicinity of cement plant Lafarge S.A. in Bielawy.

Materials and methods

The study area is situated at the central part of Poland, the relief is flat and the age of Scots pine stand is 20 years.

For the study soil samples and pine needles from pine forest stands nearly Lafarge Cement Plant in Bielawy have been sampled. Scots pine needles are used for monitoring environmental pollution [6, 7]. Soil from two soil profiles: typical podzolic soil (profile P1) located on the edge of pine forest and arable lessive soil (Profile P2) located near the forest in the direct vicinity of cement plant, were investigated. Soil samples from each soil horizon was analysed. The texture of the soils was determined using Boyoucose–Cassagrandč method with Proszynski modification and soil pH was measured in H_2O and 1 M KCl on pH-meter. Content of organic carbon was determined according to Tiurin method, basic exchangeable cations and cation exchange capacity – acc. to Kappen's method and calcium carbonate concentration – using Scheibler's method.

Plant material: pine needles of different age was sampled from *Pinus sylvestris* L.

Morphological features of plant material (after the segregation of needles in the laboratory on 3 group: one year old, two years and three years old) were characterized on the base of biometric data such as length and width of the needles. The surface area of needles was calculated assuming that each individual needle is cylinder shaped. Biometric data were collected and interpreted using computer programme DIGISHAPE (Cortex Nova 2005).

All analysis were made in triplicate, arithmetic mean values are presented in the paper.

Results and discussion

The results of the study on soil and plant material are presented in Table 1, 2 and 3, respectively. The most prominent effect of dust emissions in the investigated area is the elevated soil pH, which was in the range 5.99–7.26, with the highest values at the surface horizons: 7.22 and 7.26. Alkaline effect is not only restricted to the surface soil. Deeper samples showed elevated pH values, too – Table 2.

Table 1

Soil texture

Horizon	Depth [cm]	The percentage of the particle fractions ∅ [mm]					
		2–0.1	0.1–0.05	0.05–0.02	0.02–0.005	0.005–0.002	< 0.002
Site P1							
Ap	0–35	78	11	3	2	1	5
Ees	35–50	80	8	3	2	1	6
Bhfe	50–120	90	6	3	1	—	—
C	< 120	78	6	2	2	1	11
Site P2							
Ap	0–38	73	11	6	3	1	6
Eet	38–93	89	4	1	1	—	5
Bt	93–120	72	9	2	3	2	12
C	< 120	53	15	7	7	2	16

Normal pH in soils of the region classified as podzolic soils or luvisols is 4.5–5.0. High soil pH values indicate evident anthropogenic influence of cement dust emission rich in $CaCO_{3.}$ Previous study [8] showed that parent material as well as soil from the upper horizons does not contain calcium carbonate. Cement dust contains high level of calcium carbonate and calcium oxide; other oxides like potassium silica and aluminium are also present.

Calcium oxide is very reactive and with water forms calcium hydroxide – alkaline compound responsible for the damage of the plant tissue. Calcium is described as the element tracer of the pollution due to the cement industry [9]. The pH of the cement dust is about 12.0. The average monthly emission of dust from the Lafarge plant is 13.2 g/m^2.

Naturally acid soils sorrounding the cement plant in Bielawy are rich in base exchangeable cations. The ratio of alkaline cations to the total cation exchange capacity ranged from 83 % to 99 % with the maximum at the surface horizons – Table 2.

Excess of base cations in naturally acid soils are considered to originate from the cement dust. The impact of cement dust accumulation was higher in site P2 located closer to the emmiter – Table 2. Similar observation have been made in area polluted by cement emissions in Niepolomnice [10]. In studied soils near Bielawy the consequence of alkalization might be significant due to sandy texture of the soils – Table 1. In soils enriched in alkaline cement dust the effect similar to overliming was reported [11, 12]. It is well documented that soil pH raising leads to decrease of microelements phyto-availability. Kreutzer [13] reported boron deficiency and damage of the mycorrhizae in pine forest.

Elevated pH observed in soils in the vicinity of Lafarge plant might lower the amount of other needed nutrients even considered to be tolerant to low soil nutrients like Scots pine [14].

Table 2

Physico-chemical properties of soils

Horizon	Depth [cm]	pH		Hh [mmol(+) · kg^{1}]	$CaCO_3$ [%]	C-org. [g · kg^{1}]	S [mmol(+) · kg^{1}]	T [mmol(+) · kg^{1}]	V [%]
		H_2O	KCl						
Site P1									
Ap	0–35	7.26	6.44	3.40	< 1	6.6	49.4	49.7	99
Ees	35–50	6.21	6.39	2.20	< 1	—	11.5	13.7	83
Bhfe	50–120	6.23	6.49	3.00	< 1	—	74.5	77.9	95
C	< 120	6.21	6.29	4.10	< 1	—	67.5	71.6	94
Site P2									
Ap	0–38	7.22	6.40	1.90	5.9	4.5	113.6	117.0	97
Eet	38–93	6.02	6.51	1.50	5.0	—	25.5	27.0	94
Bt	93–120	5.99	5.89	2.60	< 1	—	78.0	80.6	96
C	< 120	6.12	5.90	6.70	< 1	—	108.0	114.7	94

Like soil, pine trees are affected by cement dust. Hard incrustation of cement was observed on entired exposed surface of pine trees including bark, branches and needles. The main visible pollution generated by the cement industry on the vegetation corresponds to the dusts. Visual estimation showed that shoots and leaves (needles) of trees from the vicinity of cement plant are covered by a white thin layer of cement. Adhesive properties of alkaline dust favour formation a sort of incrustation on the leaf surface. Detailed study showed that. Young needles were longer and have larger surface area (Table 3, Fig 1). Thus, the negative effects of emission were more pronounced in older 2–3 years old needles. Site P2 was located closer to the source of dust emission compared with the site P2, and the reduction of length and width of pine needles from site P2 was larger than from P1, less affected site – Table 3. Other authors [15] reported very low amounts of available manganese and available phosphorus in soils affected by cement dust.The plant reactions differ in their rates of development and weaking the plant communities. Pine forest vegetation in the studied area is adapted to very acid soil, soil alkalization must negatively impact the whole ecosystem.

Table 3

Morphology of the pine needles

Age of the needles	Surface area [mm^2]	Width [mm]	Length [mm]
Site P1			
I*	256.13	1.43	82.18
II	250.32	1.45	80.10
III	208.96	1.48	74.04
Site P2			
I	169.39	1.20	63.35
II	171.59	1.58	51.98
III	158.17	1.34	59.13

* I, II, III, one year, two years and three years old, respectively.

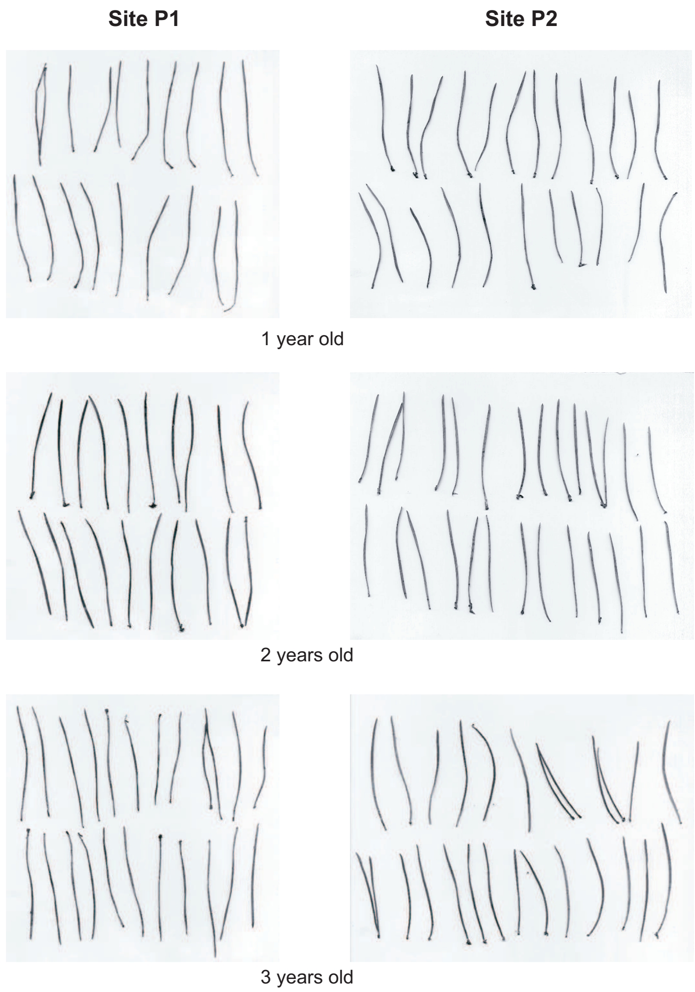

Fig. 1. Pine needles from investigated area

Brandt and Rhoades [16] report significant reduction in lateral growth of deciduous species: *Acer rubrum* and *Quercus rubra* in the cement dust-affected area as compared with control site. Foliar chlorosis, leaf scorch and general decline in growth and vigor was also observed.

The coniferous ecosystems are particularly sensitive to air contamination. Other authors observed a decrease in moss species and changes in the life cycle of mosses near the cement plant [17].

The cement crust on the needle surface limited also light conditions. Under the dust cover light shortage was detected and as a consequence disorders in physiological processes connected with assimilation was found. Increasing chlorosis and necrosis of needles and decreasing needle sizes was also reported. Changes were also observed in the reproductive phase of Scots pine. The average number of cones on a single tree decreased [9].

Negative effects of cement dust were also reported on crop plants. Significant reduction of shoot length and total leaf area was observed in *Celosia argentea* (spinach) due to cement pollution [18].

Forest in the vicinity of cement plant Lafarge S.A. in Bielawy acts as pollutant sink, suffering from the effects of pollution but also eliminating these effects.

The long-term effect of soil alkalization on forests and the impact of cement layer on physiological processes of vegetation is still not well recognized. Because pine forest is adapted to very acid soil, soil alkalization must negatively impact these areas. In order to forecast and estimate the dynamics of changes it is necessary to continue the study in a longer period time regarding eventually modification in cement technology production, and the installation of dust collecting facilities.

Conclusions

1. Soils under the impact of cement dust contain calcium carbonate of anthropogenic origin and elevated pH compared with the soils beyond the cement plant emission.
2. Exchangeable cations dominate over the acid cations in studied soils and the degree of base saturation of colloidal complex is above 94 %, in spite of other features like eluviation horizons typical for podzolic soil (Profile 1) and lessive soil (Profile 2).
3. Pine needles from the forest stands in the vicinity of cement plant are covered with cement dust.
4. The analysis of morphology of needles show that their length and width are lower than needles sampled from the tree beyond the cement dust impact. The negative effect of cement dust was more pronounced in older needles (3 years old).
5. It is important to plant tolerant tree and shrub species in the forest ecosystem around the cement plant.

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Abstrakt: Celem podjętych badań była ocena wpływu pyłów cementowo-wapienniczych na wybrane właściwości gleb oraz na stan ulistnienia drzewostanów sosnowych w otoczeniu Zakładów Cementowo--Wapienniczych „Lafarge" w Bielawach. Badania przeprowadzono na próbkach pochodzących z dwóch profili gleb uprawnych: gleba bielicowa właściwa (P1) zlokalizowana na skraju lasu sosnowego oraz gleba płowa typowa (P2) – oddalona o 200 m od lasu mieszanego, leżąca w pobliżu emitora. Materiał roślinny stanowiły igły sosny *Pinus sylvestris* L., zebrane z drzew rosnących w sąsiedztwie pól uprawnych, z których pochodziły próbki glebowe. W próbkach glebowych oznaczono uziarnienie, odczyn, C-organiczny, kationową pojemność sorpcyjną oraz zawartość $CaCO_3$. Ocenę materiału roślinnego (po segregacji wg wieku igieł) przeprowadzono na podstawie danych biometrycznych uzyskanych za pomocą programu komputerowy Digishape (Cortex Nova 2005). Analizowane gleby charakteryzują się uziarnieniem odpowiadającym piaskom słabogliniastym (P1) i piaskom gliniastym (P2). Badane gleby mają odczyn lekko kwaśny (pH_{KCl} 5,6–6,5). Poziomy powierzchniowe charakteryzują się wyraźnie większymi wartościami pH, co wynika ze wzbogacenia tych poziomów w $CaCO_3$. Zawartość próchnicy w poziomach Ap była typowa dla gleb badanego regionu i wynosiła 1,14 $g \cdot kg^{-1}$ (P1) i 0,78 $g \cdot kg^{-1}$ (P2). Z analizy biometrycznej igieł sosnowych wynika, że ich powierzchnia oraz długość maleją z biegiem lat, natomiast szerokość rośnie. Materiał roślinny pochodzący z drzew rosnących bliżej emitora charakteryzuje się znacznie mniejszą powierzchnią asymilacyjną. Igły sosnowe były w tym przypadku krótsze i węższe.

Słowa kluczowe: pył cementowy, gleba, sosna pospolita (*Pinus sylvestris* L.)