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# PROFILE VARIABILITY OF LITHIUM CONTENT IN SOILS OF SELECTED FOREST ECOSYSTEMS

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A b s t r a c t. The distribution of total lithium content with depth was studied in soils of selected forest ecosystems, with regard to their physicochemical properties and possible anthropogenic impact. The six soil profiles, representing forest soils, were selected for the study: Udipsamments formed from sandr sand, eolian sand and alluvial sand, and Haplorthods Humic formed from eolian sand, Dystrochrepts formed from alluvial silt and Eutrochrepts formed from boulder loam.

The total Li content was determined after previously dissolving the samples in a mixture of concentrated acids: hydrofluoric and nitric ($HF+HNO_3$). The content of Li in solutions was determined using the FAS method on PU-9100 X Philips spectrometer. The total lithium content in studied soils under investigations occurs in range of 1.63 to 229.68 mg $kg^{-1}$ and was considerably lower in organic horizons (1.63-8.07 mg $kg^{-1}$) than in mineral (17.58-229.68 mg $kg^{-1}$). The concentration of lithium in subhorizons of forest litter increases according to the litter decomposition degree (Ol<Of<Ofh). The Li concentrations found in all forest soils formed from sand were much higher than its natural content in surface mineral horizons of arable soils 1.30-56.00 mg $kg^{-1}$.

The total lithium content in studied soils was negative statistically correlated with the content of organic carbon (-0.6062), silt and clay fraction (-0.7131 and -0.6322), hydrolytic acidity (-0.5222), sum of exchangeable bases (-0.6196) and cation exchange capacity (-0.6277).

K e y w o r d s: lithium, forest soils, content.

## INTRODUCTION

Lithium is the alkali metal of the subgroup I a with the single electron in outermost energy level (oxidation $^{+}1$), resulting in highly reactive chemical behaviour. Lithium has a relatively small ionic radii (0.082 nm) and ionic potential, and in geochemical processes is likely to replacement ions having sufficient similarity in radii: $Mg^{+2}$, $Fe^{+2}$, $Al^{+3}$ and $Ti^{+4}$. Lithium differs crystalochemically from the other alkali metals, like Na, K, Rb and Cs, and does not follow them in geological processes [6,7].

Lithium occurrence in 1500 minerals, for instance: spodumene $LiAlSi_2O_6$, lepidolite $K_2Li_3Al_4Si_7O_2(OH, F)_3$, petalite (Li, Na)$AlSi_4O_{10}$, litiofilite Li(Mn, Fe)$PO_4$ and amblygonite LiAl(F, OH)$PO_4$ [1]. Lithium is concentrated in the uppermost part of the lithosphere, and its highest level is in acidic igneous rocks (30 mg $kg^{-1}$), sedimentary argillaceous sediments (60 mg $kg^{-1}$), and also in coals (world-wide average 65 mg $kg^{-1}$).

Lithium content in soils at the world-wide scale ranged from 1.3 to 56 mg $kg^{-1}$. The lowest Li amounts are in organic and sandy soils and the highest in rendzinas and chernozems (common range 6-105 and 10-175 mg $kg^{-1}$). Soils in Poland contain 5-40 mg $kg^{-1}$ of lithium [7]. Increased levels of lithium is mainly of anthropogenic origin, and is seldom observed. High Li concentration were reported in soils of Legnica-Głogów Basin 730 mg $kg^{-1}$ [9].

Lithium is easily mobile in soils, and thus its great fraction is leached down to ground waters. The distribution of lithium in soils is highly correlated with the content of clay fraction (<0.02 mm). All other soils parameters, such as organic matter, cation exchange capacity, base saturation, and pH, are of a much less importance [7]. Lithium is not bioconcentrated element [6].

Lithium influenced many physiological functions of plants; it affects growth, morphogenesis and leaves movement as well [2].

The purpose of the investigation was to determine the distribution of lithium in forest soil profiles. Emphasis was placed on the evaluation of the nature of lithium with respect to soil properties (pH, organic carbon content, cation exchange capacity and texture) and possible anthropogenic impact.

## MATERIALS AND METHODS

The six soil profiles, representing forest soils, were selected for the study (Fig. 1):

- "Szumiąca" profile - Udipsamments formed from sandr sand (Ol-Of-AEes-ABv-Bv-BvC-C), Bory Tucholskie region;
- "Stryszek" profile - Udipsamments formed from eolian sand (Ol-Of-AEes-Bv-BvC-C), Kotlina Toruńska region;
- "Chełmno" profile - Dystrochrepts formed from alluvial silt (Ol-A-ABbr-B1br-B2br-C), Ostrów Panieński Reserve;
- "Dębiny" profile - Eutrochrepts formed from boulder loam (Ol-Of-A-B1br-B2br-B3br-C), Brda Valley;
- "Kluki" profile - Haplorthods Humic formed from eolian sand (Ol-Of-AeEes-Bh-Bfe-Bfegg-CG), Słowiński National Park;


**Fig. 1.** Location of sampling sites.

- "Włocławek" - Udipsamments formed from alluvial sand (Ol-Of-Ofh-AEes-ABv-Bv-BvC-C), Nitrogen Works "Włocławek" protection zone.

Soils were sampled from each soil horizons and subhorizons. The soil samples were air dried and mildly ground to pass through 1 mm sieve. Organic samples were homogenized before the analyses.

The total Li content was determined after previously dissolving the samples in a mixture of concentrated acids: hydrofluoric and nitric [4]. The content of Li in solutions was determined using the FAS method on PU-9100 X Philips spectrometer.

Lithium content was analysed in three replicates; of each soil sample mean values are presented. The precision of the method was confirmed using reference material TILL-3 for Li determination [3].

Physicochemical properties of soils were determined by commonly used in soil science procedures.

Relationships among Li content and pH, organic carbon, clay content and cation exchange capacity of soil were evaluated by statistical calculations using “Statistica 5.0 PL” programme.

## RESULTS AND DISCUSSION

The profile distribution of total lithium and selected properties of the soils studied are presented in Table 1. Total Li concentrations ranged from 1.63 to 229.68 mg $kg^{-1}$. Lower amounts of lithium were observed in organic horizons - 1.63-8.07 mg $kg^{-1}$, what suggest weak biological accumulation [6]. Organic matter contents in soil profiles was found to be not a crucial factor determining the total concentration of lithium in soil horizons. The total content of lithium in soils is negatively correlated with organic carbon (Table 2). The concentration of lithium in subhorizons of forest litter increases according to the litter decomposition degree (Ol<Of<Oh).

The total lithium content in the mineral horizons ranged between 17.58-229.68 mg $kg^{-1}$ (Table 1). The highest concentration of this element was detected in mineral horizons of soils profiles “Szumiąca, “Stryszek, “Kluki and “Włocławek, formed from sand (59.84-229.68 mg $kg^{-1}$). Lower amounts of Li were observed in mineral horizons of soil profiles “Chełmno and “Dębiny formed from alluvial silt and boulder loam (Fig. 2).

The lithium concentrations found in all forest soils formed from sand were much higher than its natural content in surface horizons of arable soils. The mean lithium content in world’s soils ranged from 1.3 to 56 mg $kg^{-1}$ [7,8]. Average lithium in light sandy soils of Poland is 4.2, whereas in heavy loams is 14.8 mg $kg^{-1}$. The geometric mean for lithium in all surface mineral soils is 5.5 mg $kg^{-1}$ [6].

Kośla *et al.* [8] have reported that with growing acidity (pH), the level of lithium content was growing up also. The lithium content in studied soils was negative correlated with the hydrolytic acidity ($r=-0.5222$) (Table 2). In soils of Poland the content of Li shows the significant correlation with the granulometric soil fraction [7]. The total lithium content in the examined soils was negatively correlated with the content of silt and clay fraction (Table 2). The total lithium was also negative statistically correlated with the sum of exchangeable bases ($r=-0.6196$) and cation exchangeable capacity ($r=-0.6277$).

The extremely wide range of lithium concentrations for these few studied forest soils illustrates the need to undertake further investigation on Li status of soils in Poland.

**Table 1.** Physical and chemical properties and total lithium content in investigated soils

| Horizon | Thick-ness (cm) | Hydrolytic acidity cmol(+)kg-1 | Corg. (%) | Sum of exchangeable bases cmol(+)kg-1 | Cation exchange capacity cmol(+)kg-1 | Fraction <0.02 mm(%) | Fraction <0.002 mm(%) | Li mg kg-1 |
|---|---|---|---|---|---|---|---|---|
| Profile "Szumiąca" | | | | | | | | |
| Ol | 8-2 | 54.00 | 49.39 | 28.07 | 72.32 | - | - | 1.63 |
| Of | 2-0 | 61.92 | 39.53 | 20.84 | 83.61 | - | - | 3.07 |
| AEes | 0-10 | 6.75 | 1.84 | 0.38 | 7.17 | 10 | 8 | 155.89 |
| ABv | 10-25 | 3.27 | 0.55 | 0.21 | 3.50 | 5 | 2 | 229.68 |
| Bv | 25-62 | 1.50 | 0.17 | 0.21 | 1.72 | 4 | 2 | 115.60 |
| BvC | 62-102 | 0.78 | 0.03 | 0.20 | 0.99 | 1 | 1 | 113.74 |
| C | 102-150 | 0.39 | 0.01 | 0.31 | 0.70 | 1 | 1 | 107.87 |
| Profile "Stryszek" | | | | | | | | |
| Ol | 9-4 | 107.28 | 54.93 | 26.96 | 132.91 | - | - | 4.19 |
| Of | 4-0 | 132.72 | 45.27 | 12.02 | 144.62 | - | - | 5.08 |
| AEes | 0-16 | 4.50 | 0.98 | 0.80 | 5.39 | 3 | 2 | 202.42 |
| Bv | 16-50 | 2.67 | 0.40 | 0.87 | 3.55 | 3 | 3 | 139.10 |
| BvC | 50-78 | 1.29 | 0.04 | 0.47 | 1.77 | 3 | 2 | 125.46 |
| C | 78-150 | 0.81 | 0.04 | 0.49 | 1.31 | 1 | 0 | 84.54 |
| Profile "Chełmno" | | | | | | | | |
| Ol | 5-0 | 10.80 | 37.53 | 70.52 | 81.92 | - | - | 8.07 |
| A | 0-25 | 2.04 | 2.60 | 17.05 | 19.23 | 34 | 15 | 19.48 |
| ABbr | 25-40 | 0.33 | 0.96 | 16.42 | 16.79 | 34 | 16 | 17.58 |
| B1br | 40-55 | 0.18 | 0.75 | 14.82 | 15.02 | 29 | 6 | 18.85 |
| B2br | 55-70 | 0.40 | 0.76 | 15.96 | 16.38 | 33 | 13 | 18.60 |
| C | 70-150 | 0.21 | 1.00 | 20.53 | 20.75 | 40 | 20 | 30.56 |
| Profile "Dębiny" | | | | | | | | |
| Ol | 8-5 | 42.72 | 47.56 | 37.82 | 84.82 | - | - | 2.81 |
| Of | 5-0 | 58.08 | 46.61 | 32.23 | 92.89 | - | - | 3.44 |
| A | 0-31 | 4.57 | 0.52 | 4.49 | 9.11 | 18 | 6 | 22.64 |
| B1br | 31-40 | 3.67 | 0.14 | 13.27 | 17.11 | 23 | 12 | 38.39 |
| B2br | 40-80 | 2.95 | 0.16 | 13.82 | 16.78 | 26 | 16 | 44.37 |
| B3br | 80-105 | 2.32 | 0.06 | 12.57 | 14.89 | 24 | 13 | 37.54 |
| C | 105-150 | 1.75 | 0.07 | 14.05 | 15.81 | 23 | 13 | 31.37 |
| Profile "Włocławek" | | | | | | | | |
| Ol | 6-3 | 119.36 | 45.76 | 17.83 | 137.19 | - | - | 4.56 |
| Of | 3-1 | 112.94 | 38.75 | 3.92 | 116.86 | - | - | 4.06 |
| Ofh | 1-0 | 69.32 | 21.27 | 2.44 | 71.76 | - | - | 4.78 |
| AEes | 0-4 | 10.51 | 0.94 | 0.04 | 10.55 | 9 | 5 | 95.55 |
| ABv | 4-24 | 6.62 | 0.31 | 0.04 | 6.66 | 6 | 4 | 74.81 |
| Bv | 24-63 | 2.74 | 0.10 | 0.03 | 2.77 | 6 | 5 | 59.84 |
| BvC | 63-86 | 2.15 | 0.05 | 0.03 | 2.18 | 2 | 2 | 110.82 |
| C | 86-150 | 1.87 | 0.02 | 0.02 | 1.89 | 1 | 1 | 109.38 |

**Table 1.** Continuation

| Horizon | Thick-ness (cm) | Hydrolytic acidity cmol(+)kg$^{-1}$ | Corg. (%) | Sum of exchangeable bases cmol(+)kg$^{-1}$ | Cation exchange capacity cmol(+)kg-1 | Fraction <0.02 mm(%) | Fraction <0.002 mm(%) | Li mg kg$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| | | | | Profile "Kluki" | | | | |
| Ol | 8-5 | 46.18 | 46.21 | 22.38 | 68.56 | - | - | 4.54 |
| Of | 5-0 | 52.03 | 38.94 | 19.75 | 71.78 | - | - | 20.46 |
| AeEes | 0-16 | 3.75 | 5.31 | 0.74 | 4.49 | 8 | 4 | 70.37 |
| Bh | 16-27 | 0.92 | 0.31 | 0.14 | 1.06 | 5 | 3 | 143.84 |
| Bfe | 27-55 | 0.96 | 0.20 | 0.13 | 1.09 | 3 | 1 | 69.86 |
| Bfegg | 55-78 | 0.74 | 0.09 | 0.12 | 0.86 | 3 | 1 | 82.54 |
| CG | 78-150 | 0.56 | 0.03 | 0.13 | 0.69 | 1 | 1 | 84.39 |

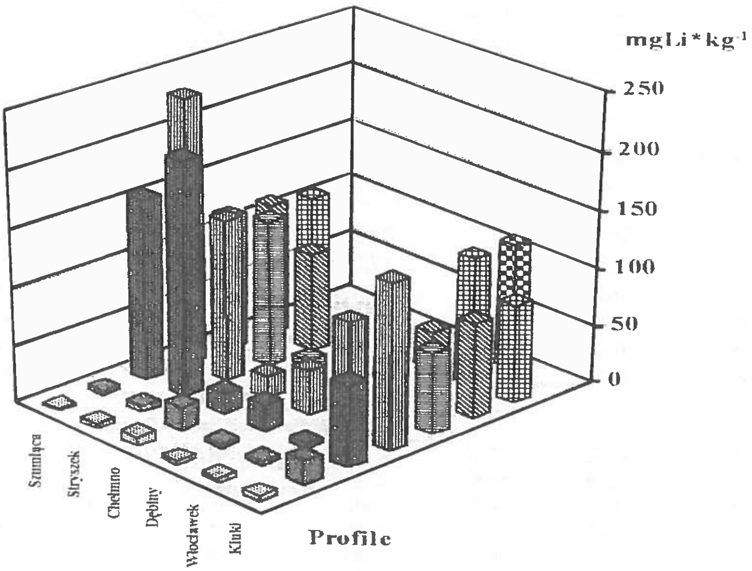


**Fig. 2.** Profile variability of lithium content in forest soils.

## CONCLUSIONS

1. The total lithium content in studied forest soils ranged between 1.63-229.68 mg kg$^{-1}$.

2. Total Li concentrations in organic horizons ranged from 1.63 to 8.07 mg kg$^{-1}$. The concentration of lithium in subhorizons of litter increases according to the litter decomposition degree.

**Table 2.** Coefficients of correlation between total lithium content and some soil properties

| Properties | Correlation coefficients (p=0.05) |
|---|---|
| Hydrolytic acidity | -0.5222 |
| Organic carbon | -0.6062 |
| Fraction <0.02 mm | -0.7131 |
| Fraction <0.002 mm | -0.6322 |
| Sum of exchangeable bases | -0.6196 |
| Cation exchange capacity | -0.6276 |

3. The Li concentrations in mineral horizons of soil profiles formed from sand were much higher then its mean content in arable light sandy soils of Poland.

4. The highest concentration of lithium was detected in soil profiles formed from sand. Lower amounts of Li were observed in soil profiles formed from alluvial silt and boulder loam.

5. The total lithium content was negative statistically with the content of organic carbon, silt and clay fraction, hydrolytic acidity, sum of exchangeable bases and cation exchange capacity.

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