

17. During spill of raw materials or finished product, they are processed by environmental sorbent glauconite modified by biosurfactants PS-17. The fire on the installation should be extinguished after disconnecting electricity with glauconite modified by biosurfactants PS-17, with carbon dioxide fire extinguishers, water system with fire water supply enterprises, foam, powder, superheated steam, fire blanket, firefighting and others. Containers, tank trucks, sleeves during filling and draining of waste petroleum products regenerated should be grounded. One time per year the soil of enterprise should be regenerated with the ecological sorbent glauconite modified by biosurfactants with normal use 2.2 kg per m<sup>2</sup> at pollution of soil by substances at the level of the MPC, 22 kg per m<sup>2</sup> with significant pollution (10 MAC) or 220 kg per m<sup>2</sup> with high level of pollution (100 MAC). Along the perimeter of the enterprise must create sorption-filtration engineering geochemical 3-ply barrier with thickness of 10 cm for ratio glauconite-grained sand — 30:50; 70:30, and 30:20, respectively. Not allowed to spill the regenerated oil on the ground, in the water and sewerage network.

**Conclusions.** Technological regulations for regeneration of waste fuel oil include the plums raw materials from rail tank car to ground capacity; downloading of the cub heaters; distillation of the mixture; condensation, cooling and storage of derived distillate and residues; shipment of finished products. The semi-finished 180 and 350 are used for own needs as fuel, and fuel oil 100 brands produced as commodity product. Fuel oils not neutralized by glauconite are belong to 3 class of danger, while after neutralization by glauconite modified by biosurfactants PS-17 — to 4 class of danger.

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### COMPARISON OF ACCUMULATION OF NUTRIENTS IN SHOOTS OF HERBACEOUS PLANTS IN FOREST SPRING NICHES

**Introduction.** Seasonal variability of the environment and different needs of plants during their life span decide about the dynamic character of the relationship plant — environment, especially in ecosystems of marshy land, where underground waters flowing out on the surface create specific conditions for development of the marshy land plants. Specific nature of underground waters introducing a specific ion load to ecosystem [1] and their high level stimulate swamping of the area and development of rich plant species [2]. Plants of marshy meadows by retention, uptake and accumulation of a series of nutritional components, play a very important role in formation of chemical character of waters [3]. In recent years, the composition of species of forest vegetation which in a substantial way modifies physical and chemical properties of waters [4] contributing at the same time to their purification has drawn special attention. Interactions between water, vegetation and the soil in mid-forest spring niches are very close and anisotropic.

The aim of the study was to compare ten species of herbaceous plants of forest spring niches as to accumulation of N, P, K, Mg, Ca, Zn, Cu, Ni, Mn, Fe, Sr and Al. The content of macro- and microelements was analyzed, considering each component separately and in an integrated way, comparing the demand of the examined species for nutritional components.

**Main part.** The research was done in the upper course of Kamienna Creek which is the left side tributary of River Slupia situated in the northern part of Poland within Leśny Dwór Forest Inspectorate area (54°19'N; 17°10'E). It is the area of average annual precipitation of about 770 mm and average annual air temperature of 7.6°C. The area of the catchments of Kamienna Creek is nearly wholly covered by forests with spatially diverse species composition, with the dominance of beech, pine and spruce trees in its plateau part and common alder (*Ainus glutinosa*) at the bottom of the valley. The 40-86 years' old common alder (*Alnus glutinosa* Gaertn) constituted the layer of trees within a given marshy land, which grew on domed bogs consisting of the wood and sedge peat [5]. In the examined spring niche the

presence of 106 species of vascular plants was discovered, 17 species of moss and 8 species of liverworts. At the area of headwater marshy meadow there were, among others: *Galium palustre* L., *Lycopus europaeus* L., *Solanum dulcamara* L., *Cardamine amara* L., *Chrysosplenium alternifolium* L. and *Scirpus sylvaticus* L.

They included 10 representative species of herbaceous plants characterized by the highest frequency and density, growing on three domed bogs. The samples of above ground shoots were taken three times during the growing period (May, July and September) in the years 2012—2014. The content of total N content was specified by the Kjeldahl method and phosphorus by the molybdenum method after mineralization in the mixture of 98% H<sub>2</sub>SO<sub>4</sub> and 30% H<sub>2</sub>O<sub>2</sub>. To determine metallic elements, the plant samples were digested in the mixture of 65% HNO<sub>3</sub> and 30% H<sub>2</sub>O<sub>2</sub>. In obtained solutions the content of K, Mg, Ca, Zn, Cu, Ni, Mn and Fe was specified by means of a method of the atomic absorption spectrometry method (AAnalyst 300, Perkin Elmer, USA) as well as Al and Sr by the method of atomic emission spectrometry with microwave induced plasma (Agilent 4100, MP-AES, Australian). The wavelengths at which the various metals were detected are as follows: K 769.9 nm, 202.6 Mg, 422.7 Ca, 213.9 Zn, 324.8 Cu, 232.0 Ni, 279.5 Mn, 248.3 Fe, 283.3 Sr and 396.1 Al. All analytical measurements were made in triplicate. The demand of the examined species for nutritional components was described by application of ANE method (*Accumulation Nutrient Elements*) [6]. Hierarchical cluster analysis (Ward's method) was used to classify plant species based on the nutrients contents in shoots.

Uptake of nutritional elements from the soil solution by plants is to large extent due to the factors dependent on the plants and soil characteristics [7]. The main factor deciding about the availability of macronutrients for plants is the reaction of soil. High dampness and slight acidification of peaty soils in the examined headwater marshy meadow invited accumulation of macro- and microelements in the shoots of the plants. The content of macro- and microelements in shoots of plants was arranged into decreasing series depending on species:

- Ajuga reptans*: K > Ca > N > Mg > P > Fe > Al > Mn > Sr > Zn > Ni > Cu;
- Caltha palustris*: K > Ca > N > Mg > P > Fe > Sr > Mn > Al > Zn > Cu > Ni;
- Carex echinata*: K > N > Ca > Mg > P > Fe > Mn > Al > Zn > Sr > Cu > Ni;
- Geranium robertianum* : K > Ca > N > Mg > P > Fe > Al > Sr > Mn > Zn > Cu > Ni;
- Gymnocarpium dryopteris*: K > N > Ca > Mg > P > Fe > Mn > Al > Sr > Zn > Cu > Ni;
- Mentha aquatica*: K > N > Ca > Mg > P > Fe > Al > Mn > Sr > Zn > Cu > Ni;
- Scirpus sylvaticus*: K > N > Ca > P > Mg > Mn > Fe > Al > Zn > Sr > Ni > Cu;
- Solanum dulcamara*: K > N > Ca > Mg > P > Fe > Mn > Al > Sr > Zn > Ni > Cu;
- Urtica dioica*: Ca > K > N > Mg > P > Fe > Mn > Sr > Al > Ni > Zn > Cu;
- Valeriana officinalis*: K > N > Ca > P > Mg > Fe > Al > Mn > Sr > Zn > Ni > Cu.

The examined plant species accumulated substantial quantities of components, which indicated that they constituted an effective protective barrier for the waters flowing across the peat swamp. The plants accumulated from 1 754.3 to 2 934.8 mmol<sub>c</sub>/kg of all components while microelements constituted from 99.39% to 99.71%. The summary content of macro- and microelements in the examined species of herbaceous plants decreased in the line series: *Urt\_dio* > *Cal\_pal* > *Ger\_rob* > *Sol\_dul* > *Aju\_rep* > *Val\_off* > *Men\_aqu* > *Sci\_syl* > *Gym\_dry* > *Car\_ech*. The highest sum of nutrients was found in the shoots of *Urtica dioica*, and the lowest in the case of *Carex echinata*. Nitrogen participation in the examined species constituted 42.6% — 52.9% of that sum, phosphorus 2.9% — 14.2%, potassium 19.1% — 34.9%, magnesium 7.0% — 24.8% and calcium 4.8% — 8.5%, and total microelements constituted from 0.29% in the shoots of *Caltha palustris* to 0.67% in the shoots of *Valeriana officinalis*. Fe showed high participation in the sum of the microelements (20.9% — 51.6%), Al (17.3% — 40.6%) and Mn (8.4% — 28.9%), which indicates excessive uptake of these components by plants.

To compare the examined species of plants as to their accumulative properties in relation to elements, the Ward method was applied, by means of which 3 main groups of species were separated (figure 1). Group A comprised *Sci\_syl*, *Gym\_dry*, *Val\_off*, *Sol\_dul* and *Car\_ech* characterized by a high, summary participation of N, P and K > 81.9% and a relatively low summary participation of Al, Fe and Mn < 75.1%.

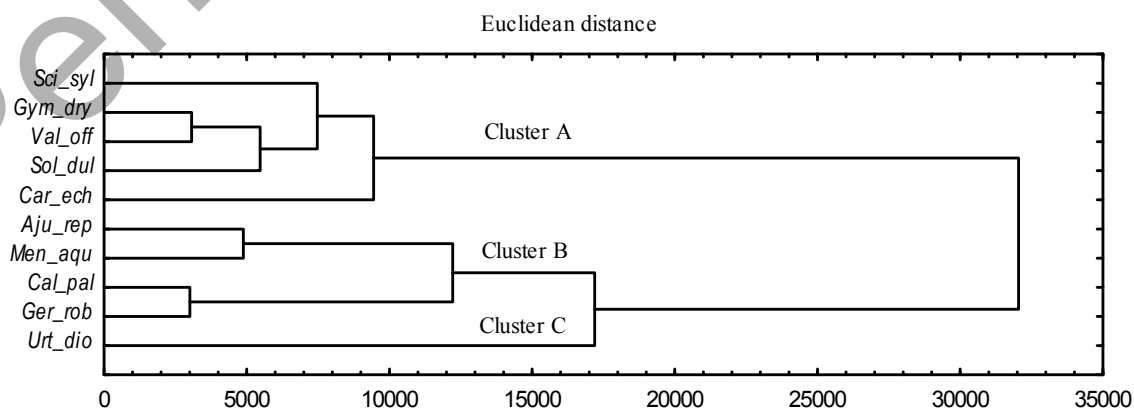


Figure 1 — Dendrogram of hierarchical cluster analysis of elements concentration in shoots of plants in riparian forest

Group B comprised *Aju\_rep*, *Men\_aqu*, *Cal\_pal* and *Ger\_rob* representing medium summary participation of N, P and K in the interval from 73.5 to 77.9% and a high summary participation of Al, Fe and Mn > 84.2%. Group C comprised only *Urt\_dio* outstanding from the examined species of plants by the highest accumulation of components 2 934.8 mmol<sub>c</sub> / kg. However, the summary participation of N, P and K remained at the level of 67.9%, and Al, Fe and Mn at the level of 81.0% in relation to the other species. The applied Ward method indicates similar accumulative properties of the species of plants belonging to the same families (Cluster A: *Sci\_syl*, *Car\_ech* — *Cyperaceae*, Cluster B: *Aju\_rep*, *Men\_aqu* — *Lamiaceae*).

**Conclusions.** High bio-diversity of the plant species in headwater swamp meadows and their diversified accumulative property provide a wide spectrum of the compounds disposed from waters, mostly biogenic ones or heavy metals. The investigated plants can accumulated especially high contents of nitrogen, phosphorus, potassium, iron, manganese and aluminum which make them an excellent choice for phytoremediation and biomonitoring programs.

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