LITTER TRANSFORMATION IN A BOREAL SPRUCE FOREST AS A KEY ELEMENT OF ECOSYSTEM FUNCTION ASSESSMENT UNDER THE EFFECT OF AERIAL POLLUTION IN THE KHIBINY MOUNTAINS (MURMANSK PROVINCE, RUSSIA)

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Abstract

Effect of aeolian dusting containing phosphates on the structure and biogeochemical cycles in the litter has been studied in mountain spruce forest (MSF) situated under pollution and in unpolluted foothill spruce forest (FSF).

Total element content was higher in litterfall of MSF, as compared with FSF. Ash content in the litter of MSF exceeded that in the FSF almost four times, P concentration in litter in MSF was almost 23 times as higher, Al concentration - 12 times, and Fe - 6 times.

Though productivity and litterfall was lower in MSF stand, litter stock here was almost twice as large. It can be accounted by prevailing processes of humification in MSF litter, with prevalence of fulvic acids portion that may be responsible for the lower rate of litter destruction in MSF, as well as for the higher content of elements N, Ca, Al, Fe.

Low ratio of C to total elements content revealed for MSF suggests that elements accumulate in the illuvial horizon and pozol formation is weak.

Specific hydrothermal conditions combined with additional element input due to the dust emission from apatite processing factory resulted in the specific course of soil formation where the litter composition and transformation processes are of crucial importance

Introduction.

Terrestrial ecosystems structural inventories depend on abiotic environment (that includes hydrothermic and topographic characteristics, properties of soils, etc.) and may essentially change its habitat, that is the case of coniferous forest, where tree layer by means of litterfall influences soil quality and undergrowth composition. Quantity and chemical composition of forest litterfall, microbial and invertebrate's population and biomass in the soil, rate and course of organic mater destruction, intensity of soil leachates infiltration depend on ecological conditions of habitat. Gases and dust emission cause pollution-induced changes of the ecological conditions, which influense litter transformation.

The purpose of this investigation is to explain the influence of spruce (*Picea obovata* Ledeb.) on the process of podzolic soils formation under different ecological conditions, and investigate the effect of aeolian dusting on the litter transformation processes, which determine soil formation processes.

Area of investigation. Murmansk Province is the most northwestern area of Russia, situated between 66˚ N and 70˚ N. All the area belongs to the Baltic shield, and bedrock's consists mainly of granites, granite gneiss's and granulites. Northern boreal (spruce and pine) forest cover most part of Murmansk province, and podzolised soils prevail here.

Khibinsky Mountains, the highest in Murmansk province (highest point at 1200 m a.s.l.) represent alkaline paleozoic intrusion, the richest type of bedrock. Phosphate-containing deposits (apatite) of Khibinsky Mountains are referred as the largest phosphate ore in the world. The explored reserves in Khibinsky Mts. are about 4 161 million tons. A stock of about 2 280 millions tons of ores is extracted now by four mining factories, and only 16% of ores could be quarried from deposits. The design productivity of all mining factories is 46.6 million tons of ores every year, but real productivity varied from 58.3 million tons in 1989 to 28 million tons in 2000. Only apatite is totally extracted from ores, and the most prominent amount of accompaniment minerals are stored in tails, in amount of about 15-20 tons every year. The mechanism of Khibinsky Mountains ecosystems pollution mainly is airborne transport of silt and sand during dusting storms, when up to 20 Kiloton of sand can be blown away and transported to the distance up to 10 km (1).

Two types of spruce-dominated forest were studied in central part of Murmansk province. One (foothill spruce forest, **FSF**) was situated in 20 km to the south from Khibinsky Mountains, on the Imandra lake eastern shore, on the slope of morainic hill at 155 m a.s.l. The second forest stand (mountain spruce forest, **MSF**) is situated in central part of Khibinsky Mountains, at 340 m a.s.l., on the territory of Polar-Alpine Botanical Garden Reserve.

Climate of area investigated is influenced by warm Halfstream, and is less continental than at the same latitude to the east, and is characterized by mild winters and cool summers. Much of precipitation falls during August and September. The snow cover normally lasts from the middle of October to the April- end of May, and in MSF the winter lasts one month longer. Climate of the mountain area differs from foothill area essentially (Tabl.1)

Tabl. 1. Climatic data for areas of FSF and MSF stands (according to the measurements conducted during 1974-1994). Soil temperature was measured at the depth of 10 cm, snow depth was measured in April.

Stand	Annual mean t°C	Mean January t°C	Mean July t°C	Temperature sum above 10°C	Soil temperature sum above 10°C	Annual mean precipitation	Snow depth (cm)
FSF	-1.2	-11.3	13.4	607	767	556	71
MSF	-1.5	-9.9	12.4	572	1240	1214	138

MSF is situated under milder and more humic conditions, which resulted in an increase of period for biogenic activity in the soil. But summer is shorter and cooler here, that caused decrease of productivity and total litterfall amount per year. (Tabl. 2)

Methods

Forest stands were described according to the Braun-Blanquet approach (5). Trees were counted on the stand 10x10 m, and the chest-high diameter was measured. Age of trees was determined by tree-rings, cores taken at the breast height. Standing crop and net production of field and ground layer were sampled by harvesting 30 cm-wide sods from one trunk to another, in crossing directions, sods were then collected to determine litter stored amount. Alive roots, not-destroyed pieces of bark, cones and twigs were removed, and litter portion was stirred to prepare sample for decomposition rate analysis. Litter moisture was determined as a weight loss after drying.To analyse the rate of decomposition the litter samples were put into glass-fibre bags 20x25 cm, three replicate samples for each of four years of following taking out, and bags were burrowed into the litter horizon. Bags were taken out in fall every year, litter was oven-dried at 80°C, weighted, and analysed. Litter infiltrates were collected using polyethylene lysimeters. Leachates samples were taken out one or two times per month, that depends on the rainfalls. Chemical analysis was carried out by routine procedure used in Russian pedology. This involved determination of leachates reaction, litter and leachates total nitrogen (macro Kjeldahl method), organic carbon (Ponomareva-Plotnikova method, (3)), nutrient (P, Al, Fe) and ash content (Bobritskaya, modified by Popovtzeva method (4)).

Results and Discussion.

Plant communities. FSF stand belongs to association _Eu-Piceetum abietis_ (Caj. 1921) Kielland-Lund 1962, subassociation _myrtilletosum_. Subassociation is characterized by prevalence of dwarf shrubs *Empetrum hermaphroditum* Hagerup. and *Vaccinium myrtillus* L., and presence of *Cornus suecicus* L., *Linnaea borealis* L., *Lycopodium annotinum* L. in the field layer, and well-developed moss layer with *Pleurozium schreberi* (Sm.) Mitt., *Hylocomium splendens* (Hedw.) Br, Schimp et Gumb., and *Dicranum* spp.

MSF stand was ascribed to the same association, and subassociation. *Vaccinium myrtillus* and *Avenella flexuosa* (L.) Drej. prevail here, and characteristic species of the subassociation _dryopteridosum_: *Gymnocarpium dryopteris* (L.) Newm., *Brachythecium reflexum* (Web. et Mohr) Br., Schimp. et Gumb., *Plagiothecium laetum* Br., Schimp. et Gumb. grow here together with herbs of Alliance _Lactucion alpinae_ Nordh. 1936 - *Geranium sylvaticum* L., *Cicerbita alpina* (L.) Wallr.

Primary production.

Tabl. 2 Characteristics of forest stands investigated. All stands are mixed (*Picea obovata* and *Betula pubescens* Ehrh.), uneven-aged, natural stands.

Stand	Tree layer composition	Trees/ha	Age (yrs)		Chest-high diameter (cm)		Total phytomass (kg/ha)
			spruce	birch	spruce	birch	
FSF	7S3B	1026	145	60	21.3	8.7	853
MSF	8S2B	1280	160	45	32	9	964

Though primary production and fall out the MSF were lower, the element contents here were higher (Tabl. 3), that probably is connected with the elements input from the dusting of "Apatity" mining and processing factory, and tails. Structure of production and fall out were generally similar in both forest stands: tree layer was responsible for its major portion. But litter stock and composition have differences (Tabl. 4).

Tabl. 3 Aboveground primary production (kg/ha) and elements content (kg/ha) in FSF and MSF stands

Stand	Primary production (kg/ha)		Fall out per year (kg/ha)	
	total	elements content	total	elements content
FSF	5800	128.9	4860	105
MSF	4960	177.5	4190	122

Tabl. 4. Characteristics of the litter samples to the depth 5 cm in the FSF and MSF stand.

Stand	Stock (kg/ ha)	Moist-ure (%)	Ash cont-ent(%)	Mean nutrients content (%)	Nutrient content (kg/ha)			Nutrient content, total (kg/ha)
					P	Al	Fe	
FSF	28200	275	7.4	3.0	31	34	42	888
MSF	54500	242	27.6	7.8	725	403	240	4234

Ash content in litter in MSF, affected by aeolian dusting, was four times higher, mainly at the expense of P concentration, which was 23 times higher, than in the litter of FSF stand.
Though productivity and fall out MSF were lower, than in FSF, the litter stock was about twice as large (Tabl. 4). To elucidate the reason of this striking difference, litter transformation rate and course, and characteristics of litter leachates were analysed and compared. (Tabl. 5 and 6).

Tabl. 5 Rate and course of litter destruction in the MSF and FSF stands.

Stand	Fall destruction rate (%)	Litter destruction rate (%)	$C_{ha}+C_{fa}$ /soil sample	humification coefficient	C:N in litter	Prevailing elements	Degree of humification (%)
FSF	19	6.6	13.8	2.2	37	N,Si,Ca	10.2
MSF	28	5.8	18.8	5.9	27	Ca,N,P,Si,Al,Fe	16.1

Rate of fall destruction depends on the composition and hidrothermic conditions, and proved to be low for both forest stands. Prolonged period of biogenic activity of soils in the MSF and higher N content in the fall caused some increase of destruction rate. The fall which has been not destructed made adding portion to the litter stock. But litter formation depends on the fall destruction even in lower degree, than on the processes of litter destruction. Despite of higher rate of fall destruction in MSF, this stand stored about twice as large litter, than plain forest. This is accounted probably by processes of humification (and low C:N index provide support for this view), with prevailence of specific organic acids portion. Humification coefficient (2), which is counted as humus stored in the soil to the humus amount in the litterfall, in MSF is higher as twice than in FSF, carbon of fulvic and humic acids to soil sample is larger in MSF too. It indicates prevailing humification processes here, in MSF, which may be responsible as for lower rate of litter destruction here, as well for higher contents of N, Ca, Al, Fe, which get hold in the litter.

In this context, litter infiltrates composition is very informative for explanation of litter transformation processes. Volumes of litter leachates in both forest stands were comparable (Tabl.6) Owing to high ash content in the litter of MSF, portion of fulvic acids formed as a results of humification, are partly fixed in the litter. As a result pH of leachates in MSF is a little lower, than in FSF, and elements content is higher.

Tabl.6. Litter infiltrates characteristics for FSF and NSF stands.

Stand	V(mm)	pH	C content (mg/l)	N content (mg/l)	Other elements (Σ, mg/l)	C: Σ	Prevailing elements
FSF	284	4.1-4.9	31.7	1.8	13.8	2.3	Ca,S,K
MSF	260	4.5-6.3	31.7	2.7	30.2	1.0	K,Ca,S,Si

The ratio of C-content to total elements content explain, in what direction litter infiltrates affect the upper mineral soil horizon.
High ratio indicates, that litter infiltrates are very aggressive, and that results in the podzol formation (that is the case of FSF stand). Low C/other elements ratio suggests that elements accumulate in the illuvial soil horizon, and podzol formation is weak (tabl. 7).

Tabl. 7. Soil horizons A2 and B_{hfa} characteristics from FSF and NSF stands.

Stand	Thickness of soil horizon (cm)		Content in the B_{hfa}, %		
	A2	B_{hfa}	humus	Al	Fe
FSF	6	21	3.4	14.9	5.3
MSF	1	34	13.1	24.4	7.3

Conclusion

Litter of mountain spruce forest has larger amount of elements because of additional elements income owing to dusting from “Apatite” factory and owing to unique processes of litter transformation directed to its humification, with prevailing portion of fulvic acids, which bond the dusting products. As a result of high ash content in the litter, its infiltrates are less aggressive, that decreased process of podzolization in soils of MSF. As a result, here are formed specific illuvial-humic soils, which differ essentially from common podzolic soils of foothill spruce forest.

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